Commission of the European Communities

The European side-impact dummy 'Eurosid'

Proceedings of the seminar held in Brussels
11 December 1986

Report
EUR 10779 EN

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P R E F A C E

The Commission of the European Communities has since 1978 sponsored, in the framework of its study programme on the "Biomechanics of Impacts in Road Accidents", the development of an anthropomorphic test dummy suitable for determining the loads transmitted to car occupants in accidents involving a lateral impact. The aim of this initiative was to make available a suitable test tool for use in a future Community regulation relating to the assessment of the protective characteristics of cars by means of a full scale integrated test, in the frame of the EEC type-approval procedure for motor vehicles.

The development and validation programme has been carried out by major research organizations in France, R.F. of Germany, the Netherlands and the United Kingdom in collaboration with the European Experimental Vehicle Committee (EEVC). It has led to the definition and construction of a European Side Impact Dummy "EUROSID".

The objective of the Seminar was to present EUROSID to the interested parties in the national administrations, automobile and component industry, research and test organizations and automobile user organizations. Experts from the research organizations participating in the EUROSID development and validation programme have presented a detailed description of EUROSID and its components as well as explanations relating to its practical use.

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C O N T E N T S

OPENING ADDRESS

by Riccardo PERISSICH
Director for Coordination

Directorate-General Internal Market and Industrial Affairs

Commission of the European Communities

Ladies and Gentlemen,

Welcome to the European Communities headquarters and especially to this meeting. It is my pleasure, in the name of the Commission, to open this Seminar where we propose to introduce to you the results of a lot of research and development work, performed in laboratories in various countries, the results of which we now indicate in short with "EUROSID": the European Side Impact Dummy.

A few words of background and history.

The 1958 Treaty of Rome on the European Economic Community, in its article 100, provides for harmonized regulations (usually called Directives) in order to eliminate technical barriers to trade, e.g. those created by differing national requirements relating to the type-approval and registration of motor vehicles.

It was recognised that the Community, by the harmonization of these requirements, also has a task in improving the safety of road traffic and the protection of the environment.

For the Community, this task implies to keep its directives abreast with the technical state of the art which it accomplishes generally by adapting these Directives to the technical progress. In the field which is of interest today, i.e. protection of car occupants, the Commission sponsored a number of programmes like the Biomechanics Programme 1978-1982, reported upon at the March 1983 Seminar [1)], in order to gather the necessary technical data for its task. Our long term objective is to establish a new generation of safety standards implying a global assessment of the protective characteristics of passenger cars, based on per-

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1) "Biomechanics of impacts in road accidents", 21-22 March 1983, Report EUR 8938 EN.

formance criteria. This new generation should at a later stage at least complete, or even replace, the present set of design related component standards.

At the European Council, June 1985 in Milan, the Community decided to invest in a final effort to finalize the "Internal Market" by 1992 ; related activities are published in the so-called "White Paper". In the automobile sector, this programme includes the presentation of proposals relating to the afore-mentioned standards on the global assessment of the protective characteristics of cars in frontal and lateral collisions.

For this purpose, the development and finalization of the test device to be used to assess the safety performance provided by a car in a lateral crash, is needed. This item is specifically indicated in the Programme for the Road Safety Year 1986.

As the Commission did not possess, of course, the necessary expertise among its staff to deal with this very specific topic , we are very happy to have been assisted by the European Experimental Vehicles Committee (usually indicated by EEVC or CEVE in French) and the experts in its ad hoc Group on Dummy Development. During the years of work under EC-contracts in the Biomechanics and Validation Programmes, but also under private initiatives, supported by national governmental and private budgets, they have given essential and valuable support to this project of developing a suitable side impact dummy.

The recently received final reports of the validation work and the November 1986 meeting of EEVC concluded that the involved laboratories have been very successful indeed : as you could see outside the meeting room, EUROSID is present ! I expect that today speakers, who were involved in the development and testing work, can explain to you what they have achieved and what this dummy can do for us.

By "us" I mean of course the European Community as a whole : legislators, approval authorities, test houses, certainly also car manufacturers and, last but not least, the car users ; EUROSID should be a means to promote the development and building of even safer cars than those we have today.

But by "us" I also include many representatives of institutions from outside the Community : governments, manufacturers, scientists, etc. from all over the world honoured us to accept our invitation to attend and have shown their interest in the EUROSID-concept. It is my pleasure to address a special word of welcome to you, coming to Brussels all the way from countries like the United States of America, Canada, Japan and Sweden for example.

May I address the participants from the USA more directly : we all know that you, at the National Highway Traffic Safety Administration, prepared draft legislation to improve lateral protection and discussed it with your "counterparts", if I may say so, from the motor manufacturers from all over the world and with government representatives from Japan and Europe. It seems that, at that time many were not satisfied with some aspects of the proposals, including the dummy to be used, but I do hope that todays presentation contributes to resolve the dummy-question, and therefore represents a big step forward to common - that is world-wide - agreement.

Before concluding my introductory remarks, iI would like to thank, in the name of the Commission, those who were so kind not only to develop and test EUROSID, but also to prepare themselves for todays presentations to you, i.e. representatives of :

- the Transport and Road Research Laboratory -T.R.R.L.), United Kingdom
- Institut National de Recherche sur les Transports et leur Sécurité (INRETS), France
- TNO - Road Vehicle Research Institute (IW-TNO), The Netherlands and
- Bundes Anstalt für Strassenwesen (BASt), FR of Germany
- Association Peugeot-Renault (APR), France

and all those who assisted, inside and outside these Institutes, to allow us to arrange this meeting. This includes especially EEVC as a whole, through its Chairman, prof. Dr. B. FRIEDEL, and the Ad hoc Dummy Development Group through its Chairman, Mr. I.D. NEILSON, who was also so kind as to accept to act as Chairman of this Seminar.

May I now hand over the chair to you, Mr. NEILSON, and wish you all a successful day, which I hope will allow you, Mr. Neilson, to draw positive conclusions which will be useful for the Community services to prepare future legislation intended to improve safety of cars in side impact.

DESCRIPTION OF EUROSID

GENERAL INTRODUCTION

by I.D. NEILSON

Transport and Road Research Laboratory
(United Kingdom)

Ladies and Gentlemen,

It is my great pleasure to respond on behalf of all of us to Mr Riccardo Perissich of the European Commission and to thank him for the arrangements and the possibility of holding this Seminar today. We would particularly like to thank him for the very fine arrangements and for the very good facilities that we have here. There are many occasions when we wish to get together in our discussions between the various countries in Europe and it is always very encouraging to be able to come to Brussels to talk about our problems together.

As to a few detailed arrangements for today's meeting, I expect you have already discovered the interpretation arrangements on your headphones with the various switch numbers for the different languages: for French number 4, German number 3, Italian number 6, Netherlands number 7, Danish number 2 and English number 8.

As you can see from the blue Programme for the day this meeting has been planned essentially in three parts. We spend this morning on descriptions of the EUROSID dummy, how it came to be designed and on what basis it came to be designed. We have four presentations representing the four components which have been particularly developed for EUROSID. Then, in the afternoon, we start off by a series of three papers which deal with the performance of EUROSID as was shown in the Validation Programme which has been carried out during 1986 with financial support from the Commission. During the second half of the afternoon we have a Panel Discussion which will include the speakers and one or two others who have particular points to make and this is the opportunity for further discussion and for points of view to be made. It is intended, as it says right at the end of the Programme, that there will be discussions on each paper as they

are presented. The very slight change we are thinking of making in this arrangement is that we will take the first two papers together - the presentation on the pelvis and the abdomen - and then have a joint discussion on those two before the coffee break. Similarly, there will be the presentation on the thorax and shoulders, and on the neck, followed by a joint discussion for those two papers.

As to other arrangements for the day, you will see we have coffee breaks in the morning and afternoon. Coffee will be available just outside this auditorium. I do ask that delegates or representatives will be back in their seats at the times indicated after the breaks. I shall ask someone to give arrangements for obtaining lunch when we come to that time.

It is intended that at the end of this meeting today that we shall collect together the papers and the Commission has kindly agreed to issue proceedings which will comprise the papers themselves and an account of the discussions that we have had. This we hope will be issued fairly early in the New Year, in 1987, and the form in which it will be issued will be similar to the proceedings issued from the Biomechanics Seminar which was held, rather as this occasion is held, to mark the completion in that case of the Biomechanics Programme which was also sponsored by the Commission.

If you have not already done so, I hope you will carefully examine EUROSID who is outside the hall waiting for us to inspect him. It is good after all the work to see him there 'in the flesh', as you might say, and in his present form which we hope is reasonably complete.

Just to conclude my opening comments and arrangements, it may be worth giving a slight further brief history of the development of EUROSID until today.

For a long time the need has been seen for having side impact protection built into cars to a greater extent than is at present possible and it is one of those things that clearly needed legislation to bring about on a universal basis.

Quite a number of years ago now the EEVC Group was set up to look into this matter and duly reported - if I remember it was at the 9th ESV Conference in Kyoto - and it was pointed out that, of course, there was a considerable lack of data and information and so that no test methods could be proposed there were considerable difficulties in actually bringing such a test into being. It was of course for this reason that the Commission instituted their Biomechanics Programme which was in two parts as you will mostly remember: the major part was concerned with improving our understanding of the biomechanics of the human body in relation to lateral impact. There was about a quarter of the Programme however given over to the development of side impact dummies and, as Mr Perissich has already reminded us, that work went on during the Biomechanics Programme. There were three dummies developed on a preliminary basis: the Peugeot-Renault APROD, the MIRA dummy and the ONSER dummy, as it was called in those days. These three dummies were very dated at a late stage in the Validation Programme in comparison between themselves and in comparison with the American Sid dummy of that time.

I think the results of the work suggested that none of the dummies were entirely satisfactory. They were intended to explore different ways of dealing with the problem of a dummy which should be both good in terms of biofidelity and also useful in terms of being a test tool for measuring side impact situations. At the end of the Biomechanics Programme there was a slight difficulty in that funding was rather short at the time and new arrangements had to be made and this resulted in a combined dummy which we now know to be EUROSID being

developed which used the best components, or as we judged then the best components, from the previous dummies. But with the new arrangements it was necessary for organisations to take on new roles and so it came about that INRETS as ONSER is now called took responsibility for the pelvis, TNO carried on their work on the abdomen, TRRL took over the work on the thorax and the shoulders, and Peugeot-Renault started a further stage of development of the neck. During this time, as has been mentioned, there was an ad-hoc EEVC committee on this subject and it included the people who have been mentioned already but it also had the great advantage of support and advice from members of the European industry and on quite a number of occasions from NHTSA as well and we in EEVC have been very grateful for the very valuable advice we have received from all of those who helped us to come to decisions about which courses of action were preferable among the various possibilities open to ourselves in the development of EUROSID.

Well, I think as everyone knows, EUROSID appeared at the 10th ESV Conference at Oxford in July last year. This was an early EUROSID consisting of the various individual components being put together almost for the first time, and we nowadays refer to that EUROSID as being the component prototype. When something such as a dummy is in development it goes through many stages and it is difficult to label the different stages so that we can remember which version we are talking about and so we refer to that stage of EUROSID as being the component prototype because it was really just the assembling together of the individual components for the first time.

When that Conference was over it was quite clear that a validation of the work was very desirable and that this validation should take the form of a programme of testing and very fortunately the Commission provided extremely useful support, financial support and encouragement as well, for this Validation Programme. And 1986 has been taken up with the carrying through of the Validation Programme. This has

consisted of the tests which really form the data on which today's presentations are based. What was tested consisted of a series of four prototype EUROSIDs and these are labelled the first prototypes. So there were four first prototypes. These came into existence early in 1986 and have been used very extensively during this year. In fact, there have been well over 500 tests carried out between these four dummies. These tests have varied from relatively gentle impact situations to severe ones, from component certification type tests to tests of varying severity in the form of sled tests, full-scale tests in cars which have been struck either by the mobile deformable barrier or by other cars. These tests were largely carried through by the middle of 1986 and the data was organised and analysed subsequently and, as has been mentioned, was reported to the Commission a month or so ago. This meeting is of course to discuss the results and to give everyone the opportunity of seeing the dummy in its present form.

The last matter I think to be mentioned before we go on to the Programme proper, as you might say, is to say that of course we have now received orders for another series of prototypes and these will be labelled production prototypes. There is a batch already largely constructed which consist, I think, of eleven dummies in the production/prototype stage and I understand that a further batch of production prototypes will be constructed shortly afterwards in 1987.

As you will hear, the construction of EUROSID has been entrusted to, so to speak, a consortium of, in a sense, three organisations: the lead in arrangements and general organisation and presentation has been taken by TNO, general arrangements for production have been made and taken by OGLE, and certain of the components are also being produced by SEREME in France. If you look at the dummy outside you may feel that much of it looks remarkably familiar and that of course is because many of the components which are not specialist for side impact are of course very familiar American components from Hybrid II from Humanoid and so in a sense this is a truly international dummy.

Well, I think the time has come now to pass on to the Programme proper and we start with a presentation of the events which led up to the design and development of the pelvis and I introduce Monsieur Bouquet from I.N.R.E.T.S. in France who will tell us about this.

PRESENTATION RELATING TO THE COMPONENTS

A PELVIS FOR THE EUROPEAN SIDE IMPACT DUMMY

D. CESARI - R. BOUQUET - R. ZAC

INRETS - Laboratoire des Chocs et de Biomécanique

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ABSTRACT

During Phase IV of the EEC biomechanical programme, existing side impact dummies were evaluated and this work concluded that none of the dummies was acceptable. The European Experimental Vehicle Committee set up a working group to build a new side impact dummy to be used in a standard side impact test. The INRETS laboratory was in charge of the development of the pelvis. This paper includes the specifications for the pelvis, agreed upon by the EEVC working group dealing with this subject, anthropometric analysis to choose sizes and mass distributions, a description of the shape of the pelvic bone and the locations and the type of transducer (force and acceleration). The design of the hip joint and the use of deformable materials to simulate pelvic bone deformations are also discussed.

I - INTRODUCTION

In 1982, THE WORKING GROUP N° 6 OF THE EUROPEAN EXPERIMENTAL VEHICLE COMMITTEE (EEVC) agreed upon a full scale test procedure for side impacts (1)*. The report of this working group shows a need for an improved side impact dummy.

During the years 1980 through 1982 the European Economic Community (EEC) sponsored a biomechanical research programme (2) which included research dealing with side impact dummies.

In this programme the comparison of the four available side impact dummies, which were the DOT/SID (3), the APROD (4), the MIRA SID (5) and the ONSER SID (6) showed that none of them was acceptable at their present stage of development. For these reasons, the EEVC decided in 1983 to create an ad-hoc working group responsible for building a European Side Impact Dummy, which is called EUROSID.

This dummy is intended to be mainly used in the integrated side impact test with the EEVC mobile deformable barrier. The general specifications and the design requirements adopted by the EEVC side impact dummy ad-hoc group were reported by NEILSON (7) and our laboratory was responsible for the development of the pelvis and upper femur area of the EUROSID.

(*) Numbers in parentheses designate references at end of paper.

2 - MAIN SPECIFICATIONS FOR THE PELVIS OF THE EUROSID DUMMY

The EUROSID pelvis was designed to follow the specifications of the EEVC side impact dummy ad-hoc group and to integrate research results from the fields of biomechanics and of anthropometry.

The pelvis developed for the EUROSID has to attach to the legs of the Part 572 at the level of the upper extremities of the femur force transducer and to the torso at the lower extremity of the Part 572 lumbar spine ; it has to be compatible with the abdomen of the EUROSID developed by TNO.

The external shape of the pelvic bone has to be realistic. It must be representative of the shape of the human pelvis at the points directly involved in a side impact and at the interactions with the car seat, as well as at the iliac crests where the seat belt fits around the pelvis. Its design must consider the deformability of the pelvic bones as well as of the flesh.

The motion capability of the femur relative to the pelvis is considered of great importance and an abduction of 30° seems the value to be considered in the design of the hip joint.

Pelvic transverse force is considered as the injury related parameter to be recorded. However the EUROSID does allow measurement of pelvic acceleration at the same location as on the Part 572 dummy. The mass distribution between the bone and the flesh seems of great importance ; however the skeletal mass would take into account the mass of the abdominal contents located inside the pelvis. The flesh in the area of the side of the pelvis liable to be struck should be suitable to comply with the likely requirements and sufficiently durable that it will not deteriorate significantly after repeated impacts.

3 - DESIGN OF THE EUROSID PELVIS

The first part of the design is the selection of anthropometric data defining the sizes and the shapes of the several elements constituting the pelvis.

The geometry of the pelvic girdle was analyzed by Reynolds et al (8) and this study was followed by a plaster model of the 50th percentile male pelvis. This pelvic model was sent to several research laboratories by NHTSA and the shape of the EUROSID pelvic bones is based on this model. Figure 1 shows the EUROSID pelvic bone and the human pelvis model. The external shape and the important points such as the pubic symphysis, the H point, the center of junction between sacrum and lumbar spine are in the same locations on the EUROSID pelvis as on this human pelvis model.

The hip articulation of the EUROSID pelvis is intentionally different from the human one : to minimize the effect of leg position on pelvis loading, external forces are transmitted to the pelvis along an axis passing through the hip ball joint, as shown in figure 2. With this design

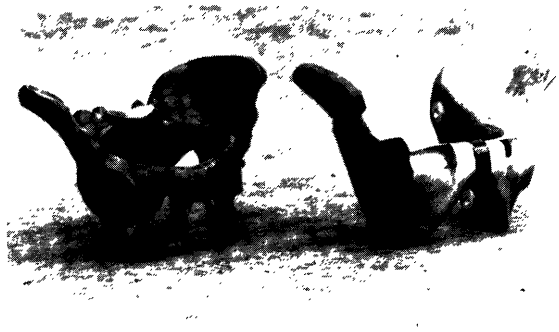


Fig 1 EUROSID pelvis bone and human pelvis model

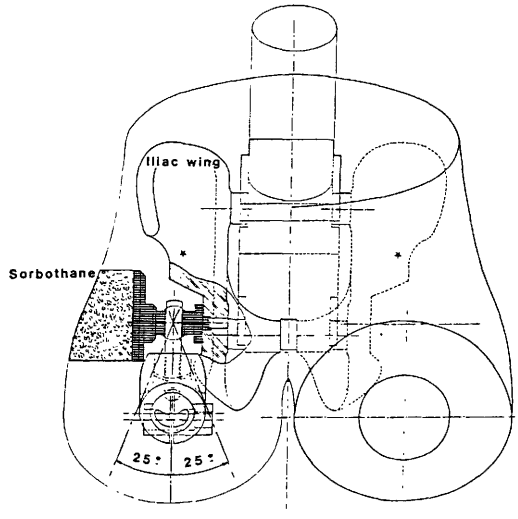


Fig2 EUROSID pelvis diagram

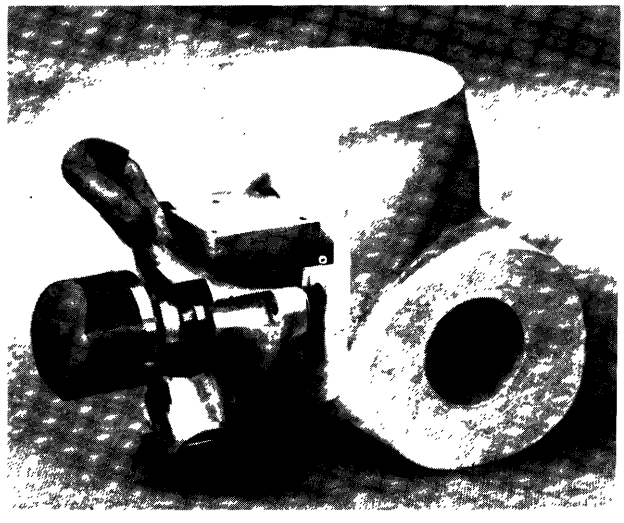


Fig 3 EUROSID pelvis Open view

the thigh position has no effect on the way in which an impact to the greater trochanter loads the pelvis, but an impact on the thigh loads the pelvis at the same point as on humans.

Previous tests with cadavers showed a much lower impact force than the same tests performed with dummies, the difference in response being mainly due to too low an energy absorbtion by the dummy's pelvis. To increase the energy absorbtion capability, the EUROSID pelvis has flesh, which is directly compressed by the impact, made from Sorbothane. This material is one of the two possible ones selected to simulate human flesh (9).

Figure 3 is an open view of the EUROSID pelvis showing the block of Sorbothane affixed to the hip plate. The Sorbothane is a polyurethane having a large hysteresis capability, which is able to absorb up to 80 % of the impact energy.

In moving from a standing position to a sitting one the human pelvis rotates. In a standing position the plane passing through the two iliac crests and the pubic symphysis is almost vertical. This plane is called pelvic reference plane. In a sitting position the pubic symphysis goes forward ; but the rotation angle is highly variable, however, the average seems to be about 30° (10) and this value was used in the design of the EUROSID pelvis. By comparison the pelvic reference plane of the Part 572 dummy makes an angle of 22 to 27° with the vertical when the dummy is sitting.

The EUROSID pelvis can be mounted on a Part 572 dummy. The interfaces are the lower extremity of the lumbar spine and the mid thigh at the upper extremity of the femur force transducers. The external shape of the EUROSID pelvis component is the same as the external shape of the Part 572 pelvis area.

The design of the hip joint allows an abduction angle of about 25° ; the same angle can be reached in an adduction motion. However the foam of the pelvis which contains the pelvis bone and the two thigh upper extremities is made with one piece so, the adduction and abduction angles will be limited by the deformation capability of the foam in this area.

At its present stage of development the weight of the pelvis is about 15.3 kg of which 12 kg is the metallic parts (skeleton) and 3.3 kg is the foam and the Sorbothane. As the mass of the metallic part has to simulate the mass of the skeleton and the mass of the abdominal contents included inside the pelvis, this mass distribution seems acceptable. This pelvis has to be used with the side impact upper abdomen developed by TNO and the weight of this abdomen is 3.9 kg, so the total weight pelvis lumbar spine and abdomen will be 21.0 kg.

According to the anthropometric study conducted by McConville (11) the total weight of the pelvis, the abdomen and the lumbar spine would be 19.45 kg of which 17.23 kg is the pelvis and the spine and 2.22 kg is the abdomen. These values are calculated from the values of body segment volumes multiplied by the density of each specific body segment and the results are in agreement with the values proposed by Robbins (12) in the study of seated posture of vehicle occupants. The results were also

corrected to take into account the desired dummy mass (75 kg). The human mass obtained by Robbins was 76.5 kg. All the data mass are listed in the table 3 of appendix.

The weight distribution of pelvic parts of EUROSID and of the human are listed in figure 4. The values included in these tables show that the weight of the TNO abdomen fitting the EUROSID is much higher than the weight of the human abdomen but the dummy sections and the human sections are not identical. A part of abdomen and lumbar spine mass should be included in the pelvic mass to better compare the total mass of the part "Pelvis + Abdomen". In this case, the difference is 1.45 kg but in the present stage of the study, this difference can be quite acceptable.

We can see in figure 5 the different parts of the EUROSID pelvis. The external shape attempts to represent accurately the way in which a human sits on a car seat. The pelvis is composed of two iliac wings made of cast aluminium alloy. Each iliac crest is covered with 4 mm of elastomer to decrease the shock effects. The two iliac crests are linked together forward by a force transducer. Rearward of the pelvis, the sacrum which has a hollow to receive accelerometers, is fixed on each lateral side to an iliac wing. The sacrum is also the base for the lumbar spine. A large Sorbothane cylinder is attached to a steel plate fixed on the iliac wing by an axis going through the ball joint. The Sorbothane compensates for the rigidity of the shell. The mechanical assembly is covered with a polyurethane foam which gives a dense skin over all its surface. A polyurethan film is also applied to the foam to increase its superficial tearing resistance.

4 - POSSIBLE MEASUREMENT WITH EUROSID PELVIS

The EUROSID pelvis is designed to measure pelvic compressive forces as well as pelvic acceleration. The compressive force is measured in the pubic symphysis area by a force transducer and on the iliac wing by a strain gauge. The pelvic acceleration is measured at the same location as on Part 572 dummy.

At the junction with the lumbar spine a 2.35 cm thick rigid block is screwed to the sacrum. This block could be replaced by a force transducer if in the future this seems necessary.

. Particular case of iliac wing

To know the lateral force applied to the iliac crest during an impact, it was necessary to decide upon measurement points. We chose to consider the iliac wing as a test specimen on which it would be possible to mount strain gauges. To define the correct area where we can have the greatest sensitivity of measurement, we have studied this problem by photoelasticity. A 3 mm depth of photoelastic resin was put on the iliac wing and we applied a force by steps on the point of the iliac crest the farthest from the median plane of the pelvis. During the test we used a polariscope by reflection and we could see color bands on the piece. When the force was stable, we were able to draw the color limits and thus to define the main point which give the concentration of constraints.

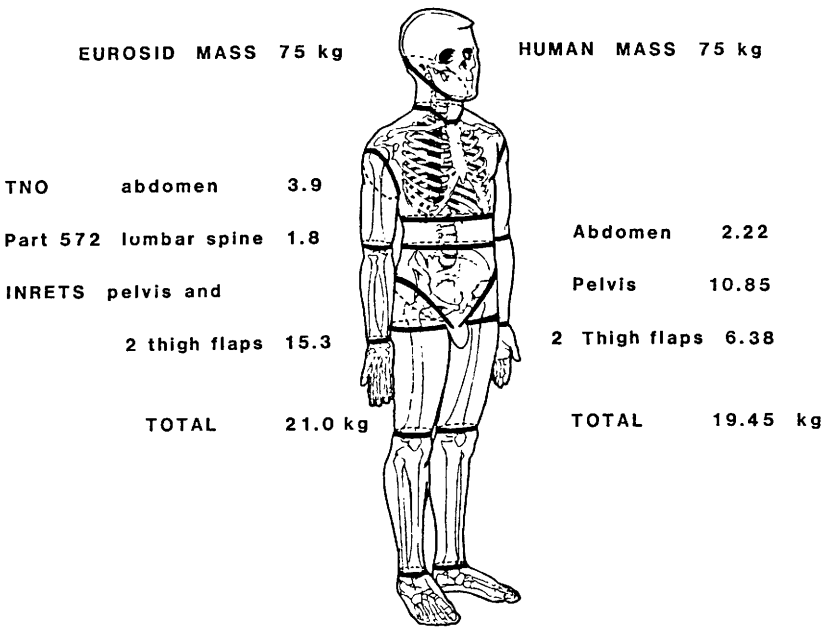
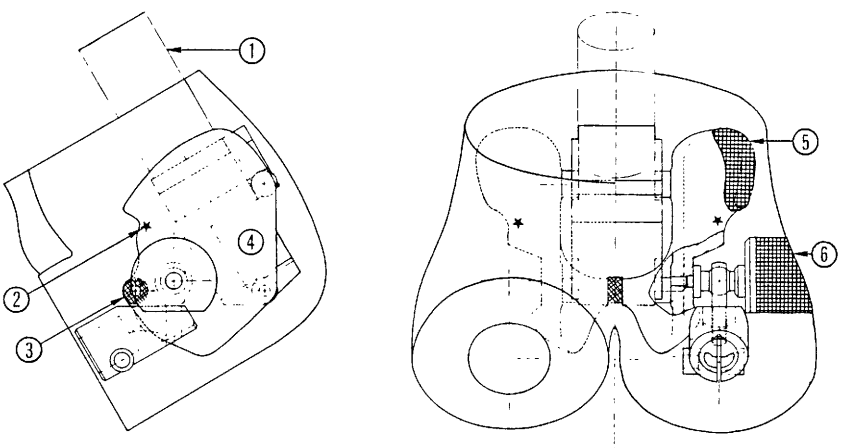


Fig 4 Total body segmentation scheme



(1) Lumbar spine
(2) Iliac wing strain gauge
(3) Pubic force transducers
(4) Pelvic acceleration transducers
(5) Iliac crest covered with polyurathane flesh
(6) Block of sorbothane

Fig 5 EUROSID pelvis diagram

To determine the principal directions of strain, we mounted 3 strain gauges at 45° on both main points. The results of the microdeformation measures permit calculating the principal directions which were drawn in the figure 6. Moreover from all the tests realized we can deduce the following information :

- the principal directions of the strain are similar for all the speeds with which the force was applied

- the area number 2 is more sensitive than the area 1

- the applied force versus the microdeformation gives a linear function

- we have mounted two strain gauges at 90° on the area number 2 of the two iliac wings of a complete EUROSID pelvis. Tests were performed in the conditions defined in the figure 7.

We have verified that the applied force versus the microdeformation gave a linear function on the two iliac wings but the right wing was less sensitive than the left wing. The linearity of the function was correct up to 10 kN.

. Pubic symphysis load cell

A study realized with cadavers (13) showed that the pubic rami fractures seem to be a typical injury of direct lateral impact in the sitting position.

The injuries recorded during autopsies of 22 cadavers are listed on table 1 and 2 of appendix. It's the reason why the pubic symphysis was choosen as the point to measure the load level.

The first tests performed with a load cell in the pubic symphysis showed a good correlation between external force applied against the great trochanter and internal force measured with the pubic load cell. This point was therefore very important and it was necessary to analyse the obtained measures in various impact conditions.

5 - RESULTS ANALYSIS OF CADAVER TESTS

All the tests were performed using a device especially designed to reproduce impacts similar to those observed in real accidents. The procedure we used has been described in a previous paper (14).

The impactor mass is 17.3 kg and the impacting system is a portion of a sphere (figure 8). The impact force and impact acceleration are measured on the mobile system through transducers.

During the test we recorded also pelvic acceleration.

The seat used gave the cadaver a posture identical to that of a car driver. The subject was unbelted and without lateral support.

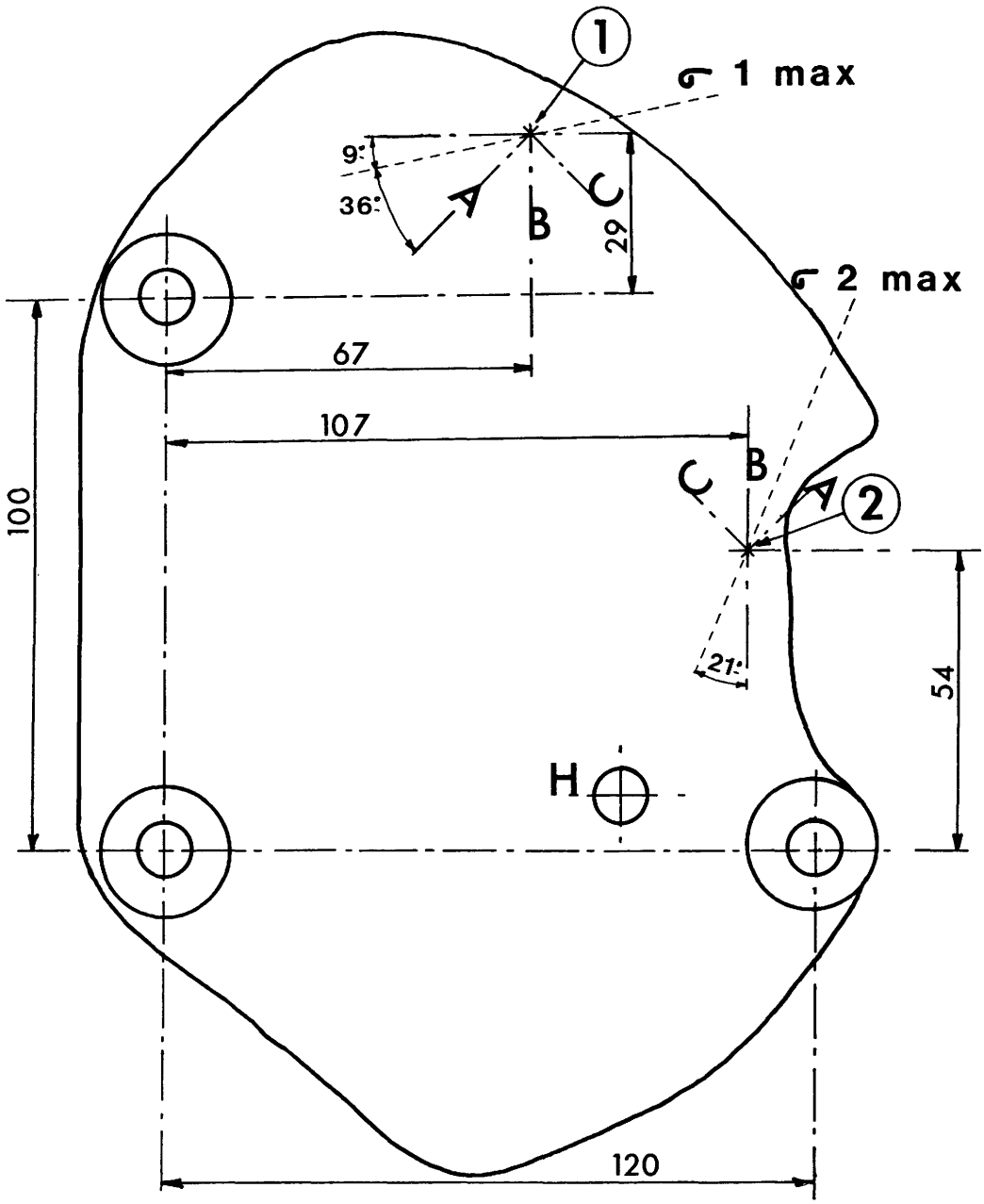


Fig 6 Iliac wing . 1 and 2 : Maximum strain areas

A,B,C- 3 strain gauges at 45°

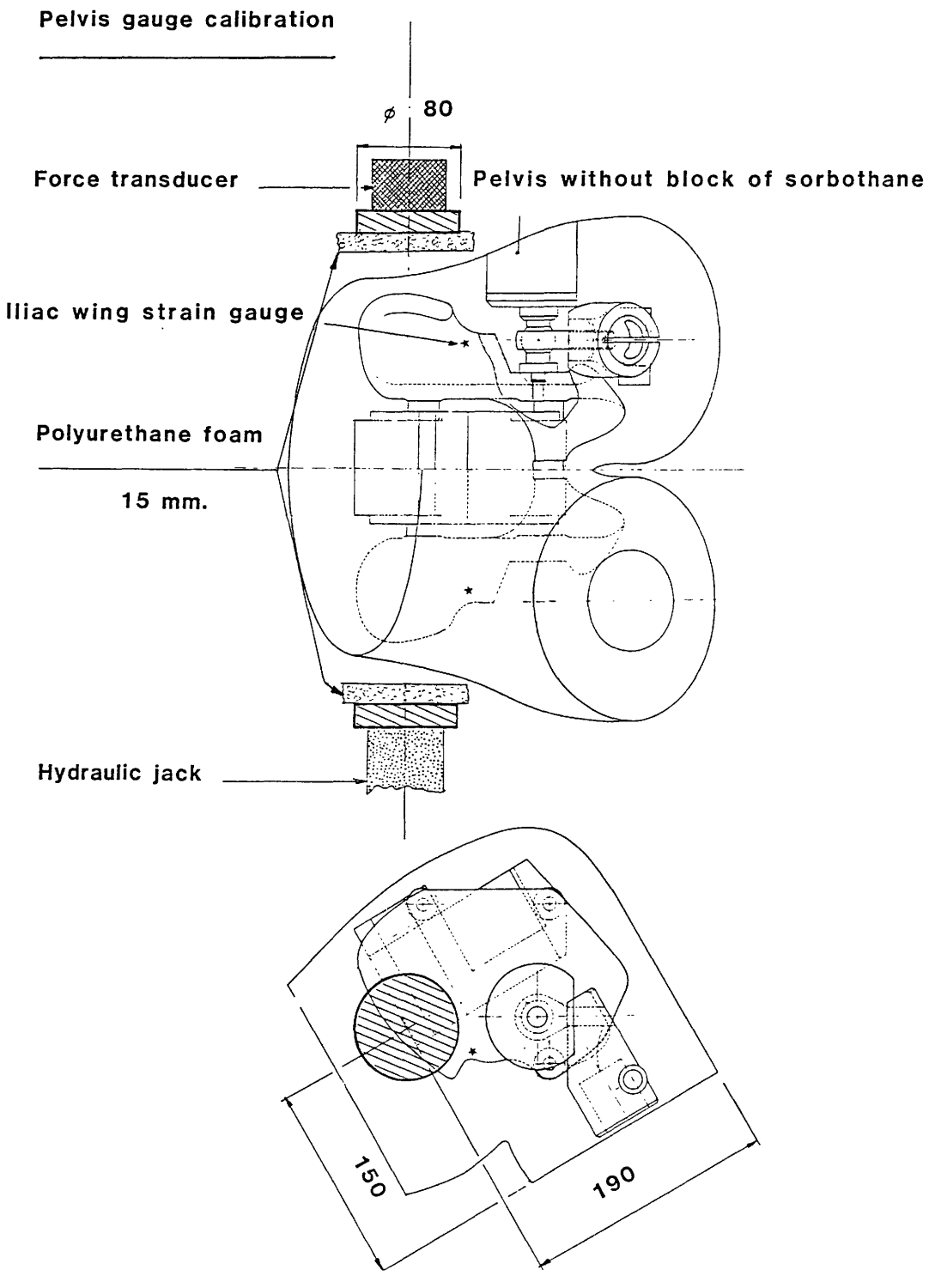


Fig 7 Pelvis gauge calibration

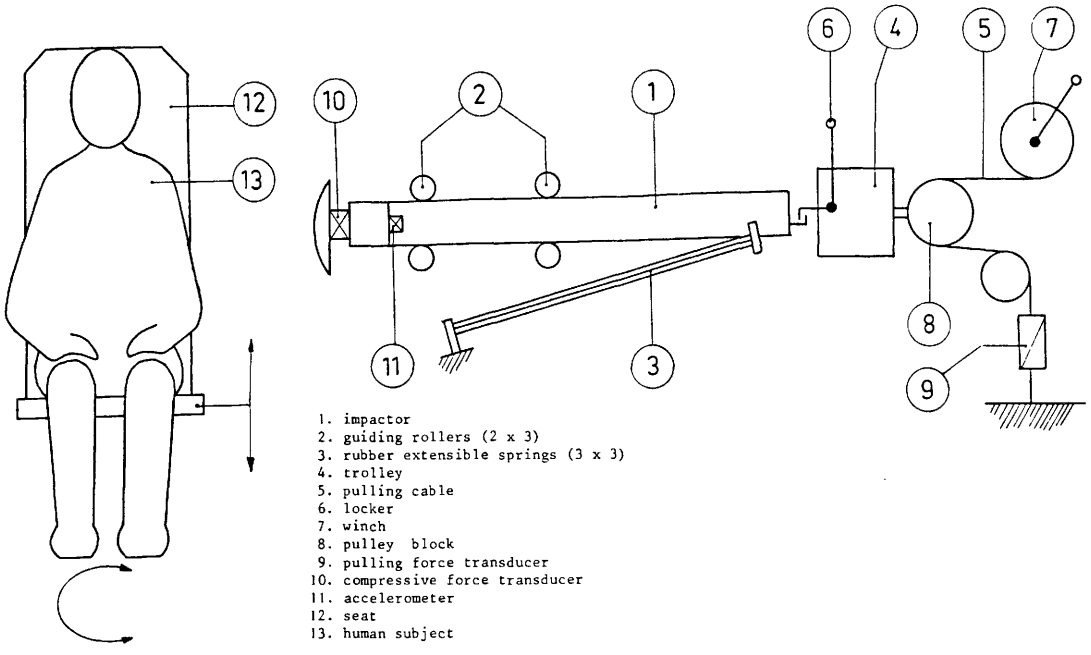


Fig 8 INRETS impactor

Age Range	Decreasing coefficient (YAMADA) (15)	Fracture force
71 years	0,815	10 KN
Average of INRETS tests		
20/39 years	1	12,27 KN
40/49 years	0,91	11,17 KN
50/59 years	0,89	10,92 KN
60/69 years	0,86	10,55 KN
70/79 years	0,79	9,69 KN

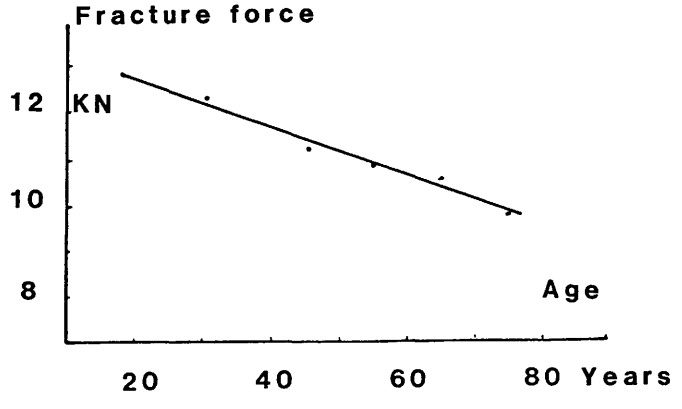


Fig 9 Human's pelvis tolerance in side impact

All the values recorded are listed in the appendix and the figures 1 and 2 of the appendix include all the data points.

All the cadavers tested in the INRETS laboratory were old humans so we cannot determine the pelvic resistance as a function of age. However the change of the bone resistance in function of the age is known for some bones.

If we make the hypothesis that the bone resistance of the pelvis follows the some rule as other bones, we can calculate a value of the pelvic tolerance for each age range. The average age of our study cadavers was 71 years and the mean fracture force wis 10 kN.

The fracture force decreases as a funtion of the age and the coefficients for each age range are listed in the following table and we can draw the curve "Fracture force versus age" (figure 9).

6 - COMPARISON BETWEEN CADAVER TESTS AND EUROSID TESTS

To draw the figure 10 we take the figure 3 of the appendix on which we draw the regression line obtained with the data points of seven EUROSID tests performed with the some impactor. In the regression line of cadaver data points we transfer the value found from the fracture forces (20 and 70 years). For the two points we find a speed of fracture and for each speed we can presume a force which should be measured in the EUROSID pubic force transducer.

In these conditions we can give the following results for the 20 year old human. The predicted fracture force for a 20 year old is about 12.8 KN. Looking at the reguession line for cadavers (fig. 10). The speed of fracture is about 14 m/s ??? and the fracture force measured on EUROSID is about 26 500 kN. For the 70 year old human, the average fracture force is 10 KN and the speed of fracture is about 11.2 m/s ??? the fracture force measured on EUROSID should be about 18 600 kN.

7 - DISCUSSION AND CONCLUSION

During the year 1985 the INRETS laboratory was responsible for the development of the EUROSID pelvis. The latest results of biomechanics were included in the pelvis study. Five identical prototypes were built and three of them were sent from the beginning of the year 1986 to the other laboratories which were involved in the validation programme : BAST, F.R. of Germany ; TNO, the Netherlands ; TRRL, United Kingdom.

The new pelvis for the European side impact dummy is completely different from the pelvis of other dummies except for the external shape of the flesh. Its design includes new solutions especially in the hip area and allows measurement of transvers compressive forces. The first tests performed with a dummy fitted with this pelvis show that the compressive force recorded on the pelvis is directly related to the impact speed.

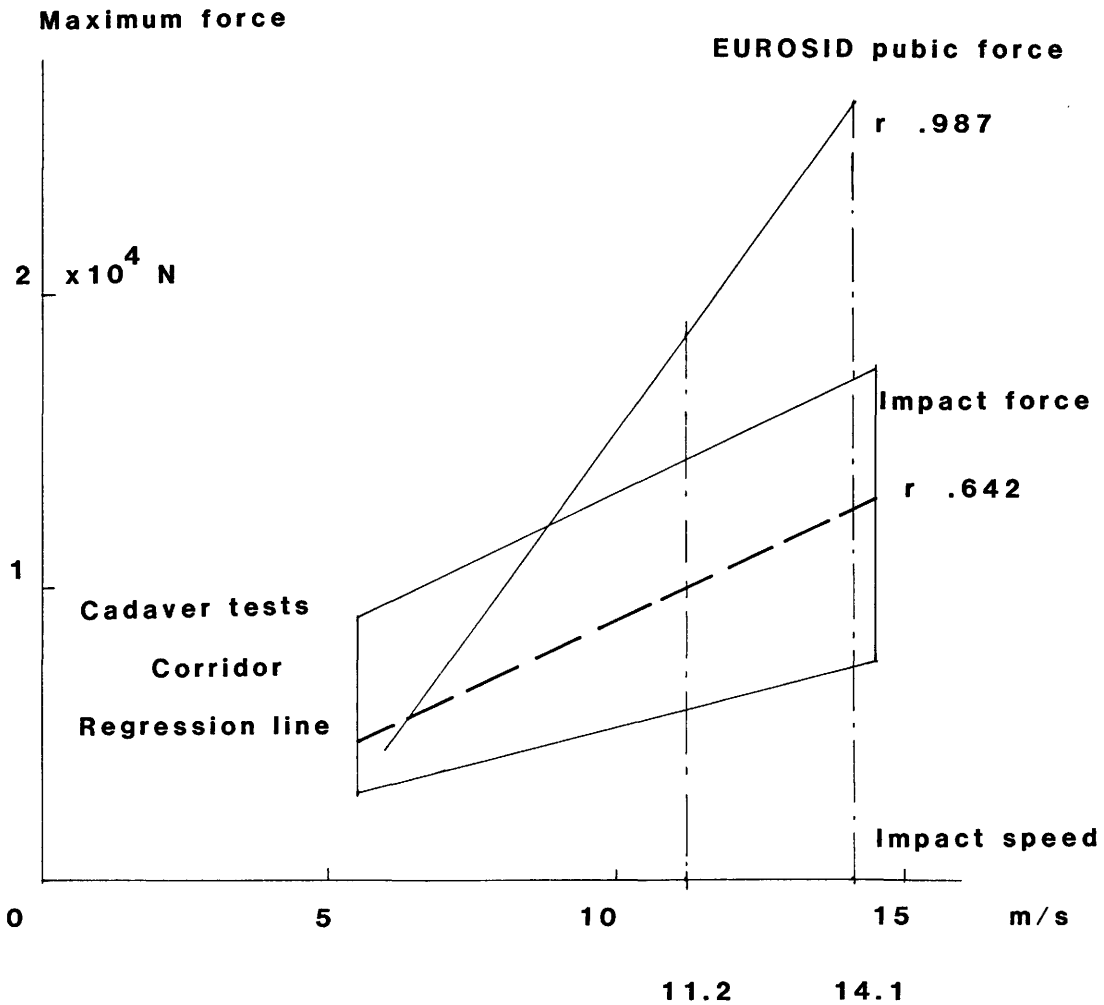


Fig 10 INRETS spherical impactor tests against cadavers and EUROSID pelvis

In the specific conditions of the spherical impactor tests, it is possible to define a human tolerance level and although the pelvis sensitivity of EUROSID is higher than the cadaveric one, it is also possible to define a pubic force value corresponding with a human tolerance level.

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APPENDIX

RESULTS CONCERNING THE INJURIES : the injuries sustained by the cadavers during the impactor tests were carefully recorded by an autopsy made after the tests. During this autopsy the pelvis was removed and the pelvic fractures carefully analysed. This procedure allows us to set up a complete list of pelvic injuries sustained by the cadavers during the tests. The injuries recorded during autopsies are listed on table 1.

TABLE 1

Test n°	AIS	Injuries
A4	3	Fracture of the right ilio + ischio pubic rami sacro iliac disjunction non complete fracture of sacrum
B3	3	Fracture of the right ischiopubic ramus Fracture of the right femoral neck and collapse of the femoral head
C4	3	Fracture of the right iliac wing Fracture of the right femoral shaft
D2	3	Fracture of the right ilio and ischio pubic rami, fracture of the right femoral neck, sacro iliac disjunction
E2	3	Fracture of ilio and ischio pubic rami Sacro iliac joint disjunction
H4	2	Right femoral shaft fracture
I5	2	Fracture of the right iliac wing
J3	3	Fracture of the right ilio and ischio-pubic rami. Pubic symphisis disjunction.
M3	2	Fracture of the right iliac wing
N7	3	Fracture of the right iliac wing. Fracture of the right ilio and ischio-pubic rami. Right sacro iliac disjunction.
O6	3	Fracture of the right ilio and ischio-pubic rami and right sacro iliac disjunction.
R5	2	Fracture of the sacrum

S4	3	Collapse of the head of the right femur through the acetabulum Fracture of the right and left ilio and ischio-pubic rami
T2	3	Fracture of the right acetabulum. Fracture of the right ilio and ischio-pubic rami
V2	3	Multiple fracture of the right ilio and ischio pubic rami. Fracture of the right femoral neck.
W2	2	Fracture of the right femoral shaft

TESTS WITH PADDING

X2	3	Fracture of the right and left ilio and ischio pubic rami. Bilateral sacro iliac disjunction.
Y2	2	Fracture of right ilio and ischio pubic rami
Z2	3	Fracture of the right ilio and ischio pubic rami. Right sacro iliac disjunction.

The distribution of these injuries recorded on cadavers are listed in table 2.

TABLE 2

Location	**Tests (19)**	
	without padding (16)	**with padding (3)**
Femoral shaft	3	
Femoral neck	3	
Acetabulum	2	
Iliac wing	5	
Pubic symphisis	1	
Sacro-iliac symph.	4	2
Sacrum	1	
One ramus	1	
Two rami	8	2
Three rami	0	
Four rami	1	1
Pelvic crush	1	

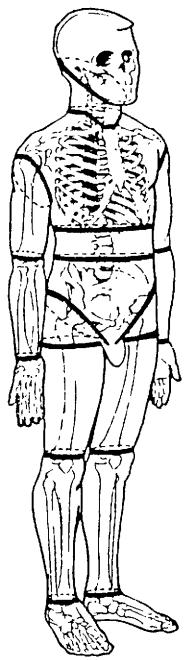

TABLE 3 : ESTIMATED SEGMENT MASSES AND VOLUMES

	V 1	D	V 2 = 0.9166 V1	M 1 = V 2 x D	M 2 = M 1 x 75/76.59
Segment	Predicted Volume (cm3)	Density (g/cm3)	Scaled Volume (cm3)	Estimated Mass (g)	Corrected Mass (g)
Head	4 337	1 071	3 975	4 257	4 170
Neck	1 012	1 023	928	949	930
Thorax	24 909	1 023	22 832	23 357	22 870
Abdomen	2 450	1 010	2 246	2 268	2 220
Pelvis	11 964	1 010	10 966	11 076	10 850
Right Upper Arm	1 854	1 058	1 699	1 798	1 760
Left Upper Arm	1 854	1 058	1 699	1 798	1 760
Right Lower Arm	2 120	1 099	1 943	2 135	2 090
Left Lower Arm	2 120	1 099	1 943	2 135	2 090
Right Upper Leg	9 029	1 045	8 276	8 648	8 470
Left Upper Leg	9 029	1 045	8 276	8 648	8 470
Right Lower Leg	3 760	1 085	3 446	3 739	3 660
Left Lower Leg	3 760	1 085	3 446	3 739	3 660
Right Foot	1 028	1 085	942	1 022	1 000
Left Foot	1 028	1 085	942	1 022	1 000
TOTAL	80 254	---	73 559	76 591	75 000
Right and left flaps of thighs	6 800	1 045	7 106	6 513	6 380
	J.T Mc Conville et. al. (11)	Clauser et. al or Dempster	Robbins et. al. (12)		

	CADAVERS					SPHERICAL IMPACTOR				
TESTS	SEX	AGE	HEIGHT (cm)	WEIGHT (Kg)	PELVIS ACCELERATION (g)	SPEED Km/h	SPEED (m/s)	ENERGY (J)	Max. mesured force (N)	Max. load against the pelvis (N)
A 1	F	70	167	58		21.0	5.83	309	3 600	4 170
A 2						26	7.22	474	5 000	5 800
A 3						30	8.33	631	6 000	6 960
A 4						41	11.39	1 179	9 600	11 140
B 1	F	84	154	70		21	5.83	309	4 400	5 100
B 2						30	8.33	631	5 400	6 260
B 3						35	9.72	859	7 000	8 120
C 1	H	69	173	78		25.6	7.11	460	4 850	5 620
C 2						32	8.89	718	8 730	10 120
C 3						39.4	10.94	1 089	8 730	10 120
C 4						47.5	13.19	1 583	11 900	13 780
D 1	F	63	160	52	50	25	7.11	437	4 000	4 410
D 2					59	30.8	8.56	633	4 750	5 230
E 1	F	72	156	60	54	25.2	7.00	424	4 750	5 230
E 2					38	31.1	8.64	646	5 000	5 510

	CADAVERS					SPHERICAL IMPACTOR					
TESTS	SEX	AGE	HEIGHT (cm)	WEIGHT (Kg)	PELVIS ACCELERATION (g)	SPEED Km/h	SPEED (m/s)	ENERGY (J)	Max. mesured force (N)	Max. load against the pelvis (N)
H 1	H	69	175	86	40	25.5	7.08	434	6 000	6 610
H 2					48	30.2	8.39	609	9 750	10 740
H 3					54	34.6	9.61	799	10 250	11 290
H 4					H.S	38.2	10.61	974	11 250	12 400
I 1	H	65	181	63	70	25.5	7.08	434	9 250	10 190
I.2					64	30.3	8.41	613	10 500	11 570
I 3					72	35.5	9.86	842	10 500	11 570
I 4					100	39.8	11.05	1 058	11 500	12 670
I 5					110	45.1	12.52	1 358	12 000	13 200
J 1	H	75	177	63	57	25.5	7.08	434	7 000	7 710
J 2					50	30.6	8.50	625	6 000	6 610
J 3					82	35.6	9.89	846	7 500	8 260
K 3	H	75	171	55	44	25	6.94	417	5 000	5 510
K 4					48	30.8	8.55	633	6 500	7 160
K 5					60	35.3	9.81	832	7 500	8 260

	CADAVERS					SPHERICAL IMPACTOR				
TESTS	SEX	AGE	HEIGHT (cm)	WEIGHT (Kg)	PELVIS ACCELERATION (g)	SPEED Km/h	SPEED (m/s)	ENERGY (J)	Max. mesured force (N)	Max. load against the pelvis (N)
L 1	M	71	165	85	78	29.7	8.25	588	8 000	8 820
L 2					86	35	9.72	818	10 000	11 020
L 3					122	39.6	11.00	1 046	12 000	13 220
L 4					144	44.6	12.39	1 327	14 000	15 430
N 5	M	54	184	86	64	33	9.17	728	7 750	8 540
N 6					66	37.1	10.47	950	9 000	9 920
N 7					95	41.1	11.42	1 129	9 500	10 470
O 4	M	70	160	79	52	32.9	9.14	723	5 120	5 650
O 5					61	37.8	10.50	955	5 500	6 061
O 6					59	42.2	11.72	1 190	6 060	6 680
P 5	M	65	164	60	40	29.1	8.08	566	4 560	5 020
P 6					48	33.6	9.33	754	5 060	5 580
P 7					43	37.7	10.47	950	5 000	5 510
P 8					48	41.3	11.47	1 140	5 500	6 060

	CADAVERS					SPHERICAL IMPACTOR				
TESTS	SEX	AGE	HEIGHT (cm)	WEIGHT (Kg)	PELVIS ACCELERATION (g)	SPEED Km/h	SPEED (m/s)	ENERGY (J)	Max. mesured force (N)	Max. load against the pelvis (N)
R 1	H	80	180	92	77	36.5	10.14	890	8 500	9 366
R 2					83	39.6	11.00	1 048	9 625	10 606
R 3					91	43.4	12.06	1 259	9 875	10 880
R 4					95	47.1	13.08	1 482	10 625	11 708
R 5					95	50.6	14.06	1 711	11 000	12 120
S 2	H	79	164	64	68	36.1	10.03	871	6 375	7 025
S 3					57	40.7	11.31	1 107	6 000	6 611
S 4					68	44.4	12.33	1 317	6 375	7 025
V 2	H	61	162	50		27.7	7.69	512	5 172	5 699
W 2	H	85	170	68	68	30.1	8.36	605	6 740	7 427
AC 1	H	71	174	63	72.9	25.6	7.11	437	5 888	6 488
AC 2					59.4	29.7	8.25	589	5 723	6 306
AC 3					82.2	35	9.72	817	7 755	8 545
Mean		71.00	168.70	68.44						
Standard Deviation		7.96	8.78	12.84						

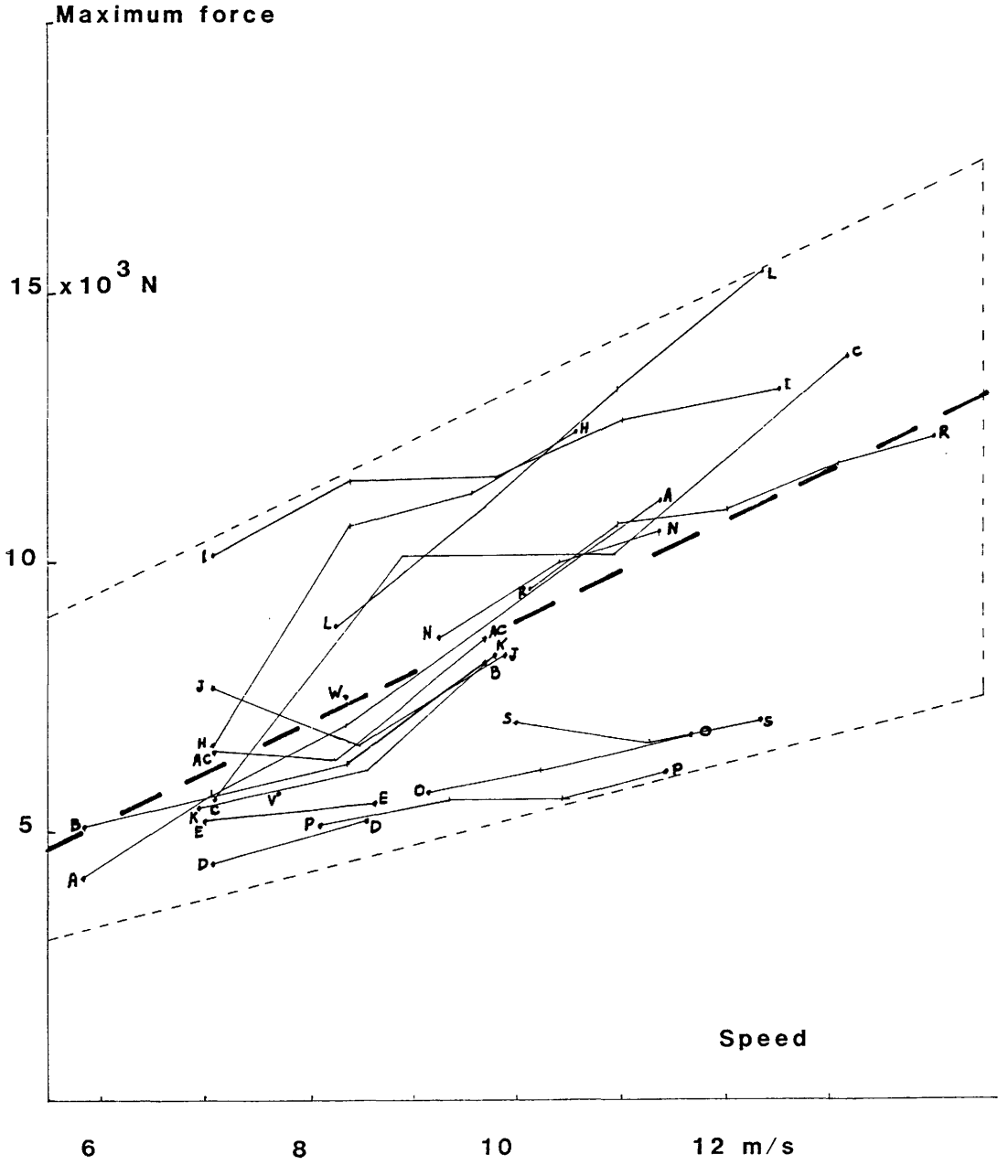

Figure 1

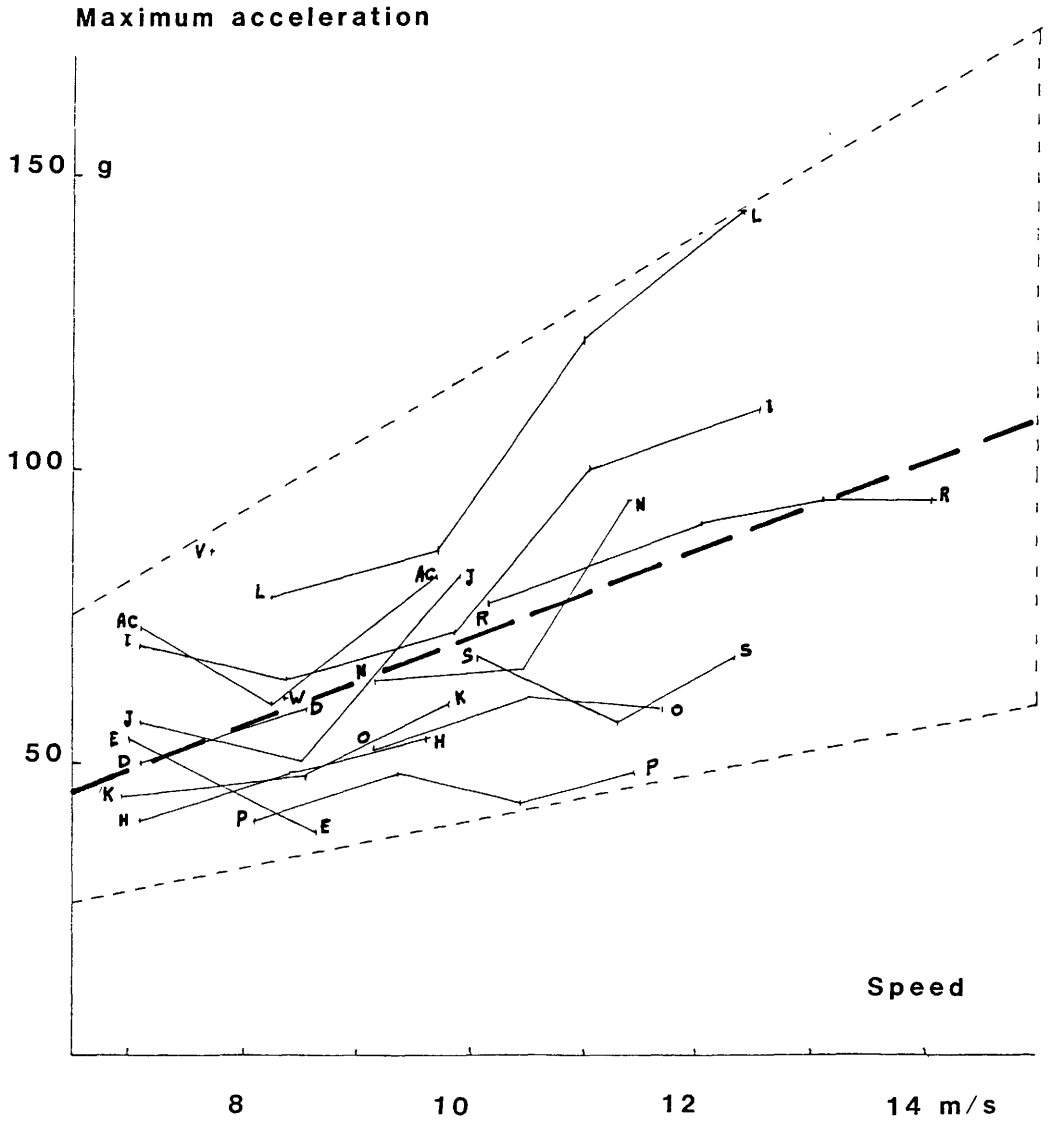

Figure 2

ABDOMEN SECTION OF THE EUROPEAN SIDE IMPACT DUMMY

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ABSTRACT

An injury-detecting abdomen section for the European Side Impact Dummy (EUROSID) has been developed by the TNO Road-Vehicles Research Institute. The design is based on built-in tolerance limits with a yes/no detection system for side impact testing. This abdomen section consists of a rigid penetration stop around the lumbar spine surrounded by a mass carrying flexible foam layer. In compression switches between foam and penetration stop are activated whenever force and penetration limits are exceeded. Biomechanical performance and tolerance limits were based on cadaver tests. Prototypes of the abdomen section were evaluated in 1982 and 1986 in EEC research programmes and improved afterwards.

A SIDE IMPACT DUMMY has been designed and constructed by a group of European research laboratories working together under the auspices of EEVC. This so-called EUROSID-dummy enables the measuring of potential risk to the head, thorax, abdomen and pelvis in side impacts. The design is based on accident investigation, biomechanical studies and the experience gained from the development and evaluation of three side impact dummies carried out in the EEC Biomechanics Programme 1978-1982 [1]*). The design base and design principle as well as the evolution of the abdomen section are presented in this paper. Also, an evaluation of the biofidelity is included.

CADAVER DROP TESTS

The base for the abdomen design was a force versus deflection corridor and tolerance limits obtained from cadaver drop tests, performed by Association Peugeot-Renault [2]. Unembalmed cadavers were perfused and dropped laterally on a rigid hardwood simulated armrest of 7 cm width (Fig. 1). The drop height was one or two metres. The impacts were all centred on the liver area. Accident studies show that severe liver injuries are the most frequent abdominal injuries observed in lateral collisions [2].

The relation between maximum normalized force on the armrest (body weight 'normalized' to 75 kg) and abdominal injuries (liver injuries associated with rib fractures) was analysed and for AIS 3, a tolerance level of 4500 N could be defined (Fig. 2). No obvious relation was found between abdominal AIS and penetration of the armrest into the abdomen. However, it appeared that under a value of 28% relative penetration (with respect to the abdominal half-thickness) there is little risk of injury occurrence. This penetration corresponds with 39 mm for 50th percentile dummies.

*) numbers in parentheses designate references at the end of paper.

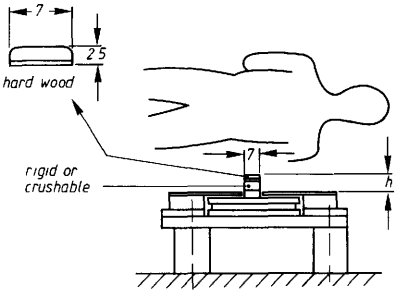

Fig. 1. Configuration of the abdominal lateral drop tests.

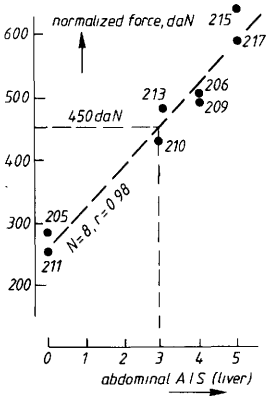

Fig. 2. Maximum normalized force versus abdominal AIS obtained from APR cadaver drop tests.

The force versus penetration response of the cadavers was found to be velocity-dependent. Because the velocity change of an occupant in a laterally struck car is closer to two than to one-metre drop tests, the two-metre drop tests were selected to define a performance corridor. Figure 3 shows the corridor as well as the tolerance limits proposed by APR.

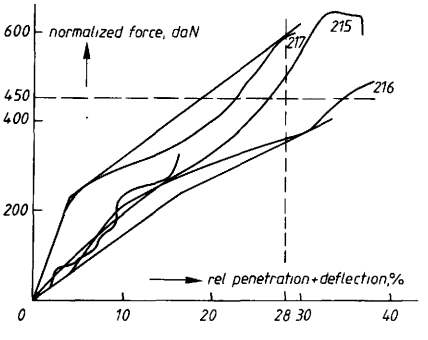

Fig. 3. Performance corridor and tolerance limits proposed by APR.

DESIGN PRINCIPLE

An abdomen section of a side impact dummy should interact in a humanlike manner with any structural component of a tested car in a side impact in order to assure correct kinematics of the complete dummy. So, it should act as a correct loading device for the car components and show a correct response to this loading. Furthermore, the abdomen section must measure injury parameters or detect exceedance of a set of human tolerance limits. Another requirement was to construct an abdomen that would allow easy interfacing with existing, Part 572 derived, side impact dummies (e.g. APROD) and would have an easy-to-use and easy-to-maintain measuring system.

The TNO abdomen design is based on the cadaver tests and requirements discussed in the preceeding section. To avoid a complicated instrumentation system it was decided by Maltha and Stalnaker [3] to built-in the injury tolerance limits and to detect them by a simple yes/no transducer system. A flexible material for the abdomen had to be selected which would give a dynamical force deflection response inside the cadaver corridor up to the critical deflection limit of 39 mm. This limit was built-in by choosing the correct thickness for the abdominal 'flesh' (closed cell foam).
Mathematical model simulations were performed to find the correct foam characteristics [3]. Mass had to be added to the outside layer of the foam at impact side (which may be chosen left or right) to obtain a dynamical response in agreement with the cadaver corridor. In order to maintain the flexibility of the 'flesh', a curved slab of solid rubber filled with lead-pellets was used (see Fig. 4).

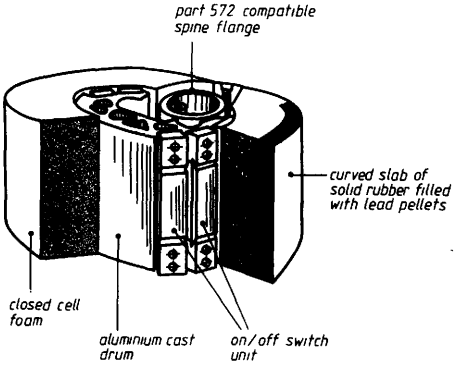

Fig. 4. Early prototype of TNO abdomen section (partly cut open to show principle).

The foam layer covers a rigid metal drum, which is attached to the lumbar spine - thorax box interface of the dummy. The drum is positioned around the flexible lumbar spine of the dummy. At the impact side three vertical switch units are located between the flexible material and the drum (Fig. 4). The switch units are identical and located at 30 degrees from each other to account for oblique impacts. Each switch unit consists of rather a stiff steel leaf spring with an underlying tape type contact switch.

When an intruding object (e.g. an armrest) has enough energy and stroke to penetrate more than 39 mm, the flexible material bottoms out against the leaf springs. If the force on the spring builds-up, bending increases. As soon as the pre-set force level is reached, the tape switch closes and gives an electrical signal indicating that the initial penetration and force limits are exceeded. The space between leaf spring and tape switch, and therefore the force limit, is adjustable. In the present abdomen prototypes it is normally set to correspond with an externally applied force of 4500 N, which is the proposed tolerance limit for AIS 3 (see Fig. 2). At the non-impacted side three 'dummy' units are located, which can be interchanged with the switch units for impacts from the opposite direction.

EVOLUTION OF THE DESIGN

The dynamic response of the abdomen design described in the previous section and shown in Figure 4, was verified by a series of pendulum impacts carried out in 1982 within the framework of the lateral dummy comparison testing of the EEC Biomechanics Programme Phase IV [4]. The design was tested in the APROD 82 and DOT/SID side impact dummy prototypes. The response of the abdomen appeared to be just below the lower boundary of the cadaver corridor. Furthermore, it was concluded that the rubber/lead slab should be integrated in the foam layer and that the switch units could be simplified.

Based on the results of this earlier evaluation programme the EEVC Ad-Hoc Group on the Development of a Side Impact Dummy drew up new specifications for an European Side Impact Dummy. The abdomen was required to have a correct interfacing with the EUROSID pelvis and thorax sections. The modified design is illustrated in Figure 5 (the design principle was maintained). Four similar abdomen sections ('first prototype') were built for the 1986 EUROSID Evaluation Programme and tested in pendulum impacts, sled and car tests.

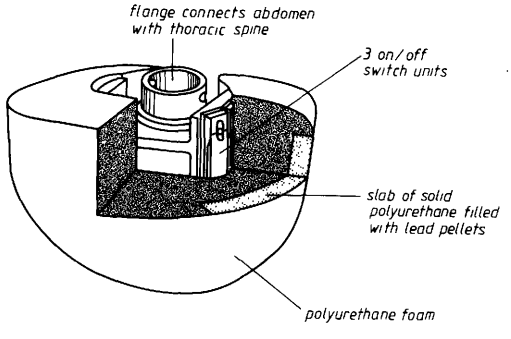

Fig. 5. First prototype of EUROSID abdomen section.

The biofidelity of this design has been evaluated by means of standard pendulum tests. The pendulum velocity of 6.3 m/s is equivalent to the cadaver drop height of 2 metres. The Part 572 calibration pendulum is provided with a 7 cm high hardwood armrest, identical to those used in the cadaver drop tests. The total pendulum mass was 24.3 kg. Figure 6 shows the resulting force versus deflection characteristic together with the cadaver performance corridor. The abdomen response has been corrected for the thickness of the wet-suit, which covers the chest and abdomen of the EUROSID. The impact force and abdomen deflection have been calculated from the pendulum acceleration (CFC 180). It follows that the dynamic response of the abdomen is well within the performance corridor. Figure 6 also includes the switch contact force, obtained from the switch time histories, together with a 5% tolerance area around the force and penetration limits.

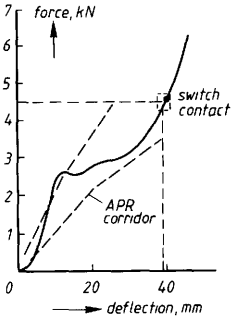

Fig. 6. Dynamic response of EUROSID abdomen (first prototype) obtained from pendulum impacts.

Mertz [5] recently reviewed the APR cadaver drop tests. He proposes a force versus time corridor rather than a force versus deflection corridor as abdomen performance requirement. Figure 7 shows the resulting corridor, obtained from 2-metre drop tests on a rigid armrest. A typical result of the 6.3 m/s pendulum impact is included in this figure. The force and time values of this pendulum impact have been normalized, according to methods proposed by Mertz [6], to obtain an impactor mass of 16.4 kg (mean effective impact mass of cadavers in drop tests). It follows that the dummy abdomen response is reasonably well within this more recently developed performance corridor.

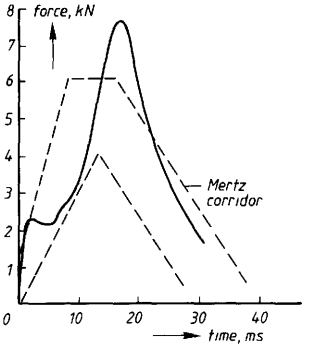

Fig. 7. Force versus time performance corridor proposed by Mertz and normalized dynamic response of EUROSID abdomen (first prototype) obtained from pendulum impacts.

The present abdomen design is also evaluated by the reconstruction of two real accidents. The first real accident (which showed an AIS 4 abdominal injury) was also reconstructed with human cadavers some years ago. In contrast with the real accident, no abdominal injuries were found in these tests. In the second real accident no abdominal injuries were observed. INRETS [7] reconstructed both real accidents twice. No abdominal switch contact is observed in both tests of both series of the EUROSID Evaluation Programme.

The repeatability of the current design appears to be adequate in pendulum tests. The coefficient of variation of the test results seems to be well within acceptable limits [8].

From the 1986 EUROSID Evaluation Programme it was concluded that some minor improvements in the abdomen design are necessary or desirable:
- rubber/lead slab at left hand side as well as right hand side of the abdomen for impacts from both directions;
- improvement of the foam fixation to the metal drum;
- avoidance of interference of abdominal flesh with the lower rib which otherwise disturbs the rib response;
- the edges of the switch units should be more rounded to avoid tears in the abdominal flesh.

These improvements, which will be incorporated in the next version ('production prototype') of the EUROSID abdomen section (Fig. 8), are not expected to affect biofidelity.

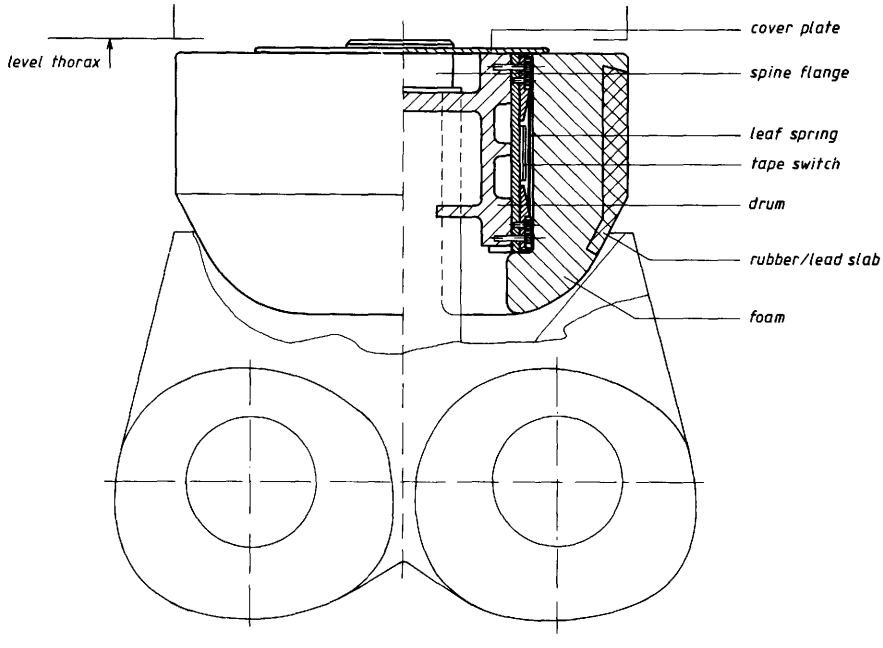

Fig. 8. Production prototype of EUROSID abdomen section.

DISCUSSION

The abdomen section is designed to detect those injuries that occur from a blunt penetration in the 12 cm space between the dummy's lower ribs and the iliac wing of the pelvis. This abdominal space in a 50th percentile human is approximately 4.5 cm. Therefore, in real accidents a large part of the abdominal injuries is being associated with rib and pelvis fractures. The shape of the iliac wings of the EUROSID-pelvis is realistic, while the thorax section includes only those ribs which protect the lungs and heart (head of the 11th rib to costal end of 6th rib). Besides, the ribs are positioned perpendicularly to the thoracic spine instead of downwards. So, the dummy abdomen section has to cover a larger area with respect to injury detection. Measurements of the force applied to the iliac wing and deflection of the lower rib of the EUROSID could also indicate certain 'abdominal' injuries, while penetration of a relatively small protruding object will be detected by the abdomen section.

The mass of the EUROSID abdomen is approximately 5 kg (including lumbar spine), which is almost twice the mass of the Part 572 abdomen. The EUROSID mass will be increased by about 1 kg in the next version of the design ('production prototype'), due to the extra rubber/lead slab. This difference is partly compensated by the lower mass of the EUROSID thorax.

A summary of the abdomen certification procedure is provided in reference [10].

The EUROSID is developed for side impact regulation testing in normally equipped test houses. Therefore, an easy-to-use and easy-to-maintain dummy measuring system is preferred. However, research and car development testing often requires more information than regulation testing. Furthermore, new data bases will become available and new performance requirements and injury criteria will be developed (see e.g. [9]). That's why the development of a more sophisticated side impact dummy (or even omni-directional dummy) should continue and cooperation between Europe and the USA is recommended.

CONCLUSIONS

1. Based on cadaver drop tests performed by the Association Peugeot-Renault an abdomen section for the European Side Impact dummy has been developed.

2. The original design developed in 1981 has been modified several times; however, without changing the design principle.

3. The abdomen section is designed for oblique impacts up to 30 degrees from the lateral direction.

4. An adjustable force tolerance limit and a fixed penetration tolerance limit are built-in and exceeding of the limits is detected by a simple yes/no transducer system.

5. The dynamic response of the abdomen in pendulum impacts appears to be in good agreement with performance requirements derived from cadaver drop tests.

6. The EUROSID Evaluation Programme showed that the repeatability of the current design is satisfactory and that some minor improvements in the design are desirable.

ACKNOWLEDGEMENTS

The development and evaluation of the abdomen section is sponsored by the EEC and by the Dutch government within the framework of the National Road Safety Programme. Comments and advice are obtained from the members of the EEVC Ad-Hoc Group on the Development of a Side Impact Dummy.

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The Thorax of the EUROSID Dummy

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ABSTRACT

This paper describes the design and development of the EUROSID thorax. It describes the design of the chest, which was based on the concept of the APROD chest, and the development of a new shoulder. The degree to which the performance of these parts matches cadaver results is shown. The repeatability, reproducibility, durability and certification are not described here as these aspects are the subject of other papers. This paper shows that a thorax has been produced, following the specification laid down by the EEVC Ad-Hoc Group on Dummies, that can measure chest deflection, the injury parameter preferred by the Ad-Hoc Group. It can also measure the more recently proposed criteria such as the Viscous Injury Criteria.

INTRODUCTION

It will be recalled that the basis for the design of EUROSID was the three prototype side impact dummies produced as a result of the EEC Biomechanics Programme of 1978-82 and the results of the comparability study of these three dummies.(1) The EEVC Ad-Hoc Group on Dummies produced a specification (2) for the desirable features of a side impact dummy, which acted as guidelines for the development of the three prototypes and the Ad-Hoc Group used this and the results of the comparative testing of the dummies to agree on the best features which could be incorporated in a unified European Side Impact Dummy. The various components of this dummy were developed by different institutes in Europe under the guidance of the Ad-Hoc Group, and TRRL agreed to develop the chest, in consultation with the Peugeot-Renault Association and TNO. TRRL also agreed to see if a shoulder design could be produced that would meet the specification.

It was agreed within the Ad-Hoc Group that the preferred injury criterion for the chest would be based on lateral chest deflection and that the design would be based on that of APROD (3) but modified such that there would be three independent sections instead of two and the design would try to minimise the likelihood of the piston assembly binding or jamming.

SHOULDER DESIGN

The Ad-Hoc Group did not consider that injury to the clavicle was particularly frequent nor was it serious enough to warrant an injury criterion. However, interaction between the vehicle interior and the shoulder could influence test results and if the shoulder were unrealistically rigid, vehicle design solutions could result which would be ineffective for humans.

The design requirements for the shoulder come from the EEVC list of desirable features for both the shoulder and the arm. Essentially these require that, when struck laterally, the shoulder deflects clear of the chest by forward and/or upward movements and that the arm will not interfere with impact to the thorax. The reasons for this latter requirement are that tests within the EEC Biomechanics programme demonstrated that the thorax is much less likely to be injured from lateral impact if the arm is interposed between the impacting object and the chest than if the chest is struck directly. As cars are designed for use by a wide range of occupant sizes and sitting positions, it is unlikely that the occupant's arm will always be between his chest and the vehicle side. Therefore it is desired to test the vehicle in the worst case condition where the arm is not between the chest and the intruding vehicle side. Also the presence of an arm partially shielding the thorax would be likely to lead to variable results.

The detailed performance requirements are based on tests performed by the Peugeot-Renault Association in which cadavers' shoulders were struck laterally with an impactor and some volunteer tests at TRRL in which the maximum lateral displacement of the shoulder under a relatively small force was measured.

The centre of rotation of the clavicle has to be rearward of the point of contact at the shoulder extreme to encourage forward movement from a lateral impact. But no single position could be found that would allow the upper arm to rotate forward without interfering with the upper rib. The solution was to use a cam so that once the shoulder had started to rotate the centre of rotation moved forward, allowing the arm to clear the chest. (Figure 1).

A design of arm where the 'skeleton' was kept away from the struck side of the arm and where the flesh of the upper part was made from Sorbothane enabled the force level to be kept down to the same order as that observed in the cadaver tests, and the deflection of the shoulder under 200 Newtons was 190mm, comfortably exceeding the minimum value of 55mm found in the TRRL volunteer tests. Figure 2 shows the impactor force curves obtained during the EUROSID Evaluation tests, together with the performance corridors proposed by Dr Mertz from the normalised cadaver data.

CHEST DESIGN

The design principles of the EUROSID chest were based on the APROD design; that is, ribs connected at the back to the spine box through a piston running in a cylinder. The APROD has a central cylinder with pistons at each end of the ribs. There is a central rubber spring in the cylinder between the ends of the pistons. With this design, the APROD chest is sensitive to impact from either side. However it also means that the bearing length for the piston within the cylinder is very short so that side forces at the rib end of the piston can generate very high loads in the bearings. For the EUROSID chest, this bearing length was considerably increased by having only one piston attached to one end of the rib and a much longer cylinder attached to the spine box and to the other end of the rib. So that the dummy can be made to be sensitive to impact from either side, the rib, cylinder and piston are made as a removable module that can be inverted onto the spine box for impact to the other side. It was

decided to make three identical rib-cylinder-piston modules for the chest. This enables this unit to be serviced and certified separately from the whole dummy, a feature which is convenient for test houses.

The biomechanical basis for the design of the chest has come from three main sources; Cadaver drop tests performed by the Peugeot-Renault Association, (3) Cadaver impacts performed by UMTRI for NHTSA (4) and rigid wall sled tests performed at the University of Heidelberg and elsewhere for NHTSA.(5) The parameters chosen for correlation with the dummy performance were chest deflection, impact force and rib and spine acceleration. Unfortunately, in none of the cadaver tests were all these parameters measured.

A one dimensional lumped mass model of the rib module was used to simulate the cadaver tests in an attempt to deduce the appropriate values for rib mass and spring stiffness required to match the cadaver data bases. It soon became apparent that the rib acceleration was highly dependent on the properties of the flesh as well as the effective rib mass and was particularly complicated by the test conditions where the arm was present between the chest and the impacting object. Thereafter this parameter was felt to be less useful than the others.

It was found to be impossible to obtain a combination of mass and stiffness that could simulate all the cadaver responses. The addition of a damping component in parallel to the piston and coupled to the impacted side of the rib helped but still no unique set of values could be found. Figure 3 shows the model used in comparison with the final design of the rib-piston-damper module. It is not possible to match the dynamic performance of an object as complex as the human chest by a lumped mass model under all possible dynamic conditions. Consequently a compromise set of spring, mass and damper characteristics were chosen which were within the range of values found to be necessary to simulate the cadaver test results, commensurate with the practical requirements to build a dummy that would not break or deform permanently under routine testing. More emphasis was given to the results of tests which were closer to the conditions under which the dummy would be used, namely the 15 mile per hour rigid wall test.

The chosen values were K1, primary rib dynamic stiffness, 33 kN/m, K2, the damper connecting spring, 66 kN/m and the damper function $F = 150V^{1.65}$ N. The effective dynamic mass of the rib was about one half of a kilogram.

Figure 4 shows a drawing of the shoulder and chest assembly. This was the design of the thorax that was used in the EUROSID Evaluation programme. The rib is made from a single strip of steel, 2½ millimetres thick with 10mm of flesh attached to the outside. The flesh in the struck area is Sorbothane while that on the remainder of the rib is polyurethane foam to reduce the effective mass of the rib. Behind the piston inside the cylinder is an encapsulated spring. A range of springs can be used in this piston and the appropriate one is chosen to maintain the correct dynamic stiffness of the rib-piston module. The specially produced damper is connected to the rib in parallel to the piston via a spring to reduce the very high forces that would otherwise be generated on first impact.

The lateral displacement of the thorax can be measured by an optical device attached to the cylinder which detects a 4 bit Gray code attached to the piston. Although the EEVC Ad-Hoc Group considered that the rib deflection was the most appropriate parameter for injury detection, provision has been made for the attachment of the accelerometers to the ribs behind the struck surface, and to the top of the spine so that sensitivity repeatability and biofidelity of these parameters could be established.

The EUROSID thorax is capable also of measuring more recently proposed injury criteria such as the viscous injury criterion proposed by Dr Viano.(6) This is the maximum of the product of the instantaneous velocity of compression and the percentage chest compression at that point. Table 1 shows the viscous injury response for the rigid and padded wall tests, where, in this case the compression was calculated as the percentage of the half thorax laterally.

TABLE 1.

Viscous Injury Response in Sled Tests.

Test Condition	Viscous Response, (V*C) max (m/s)
15 mile/h Rigid Wall	0.78
20 mile/h Rigid Wall	1.72
15 mile/h APR Pad	0.53
Limit proposed by Viano (7) for frontal impact	1.0

Langdon(7) of TRRL has proposed two parameters in addition to compression; rib velocity change within the first millisecond of its movement which is related to compression wave injuries such as lung contusion, and, as an alternative to the viscous injury criterion, the force on the damper which, it is suggested is related to the shear wave injuries such as laceration or rupture of internal organs.

All these parameters can be measured on the EUROSID thorax.

Figure 5 shows the results of impactor tests performed in a manner similar to the cadaver tests performed by UMTRI in the United States. The range of results are shown together with a mean curve and superimposed is the performance corridors proposed by Dr Mertz, chairman of the ISO Working Group on Dummies, based on the UMTRI cadaver tests. As the compromise chest stiffness chosen was greater than that necessary to simulate the data, the impactor force generated in these tests was higher than the performance corridor, although the period was about right.

Figure 6 shows the force-deflection curve for the 15 mile per hour padded wall test together with the performance corridor derived from the cadaver drop tests performed by the Peugeot-Renault Association. The padding used here was the APR padding. For the tests against the rigid wall, the first part of the force curve rises above the corridor.

Figure 7 shows the thoracic wall force results for the 15 mile per hour rigid wall test. It should be noted that the cadaver tests under this condition were performed with the upper arms beside the thorax, between the rib cage and the impact plate. In the EUROSID tests, the arms were set so that the hands rested on the knees of the dummy with the arms straight. Also shown is the performance corridor proposed by Mertz.(8) It can be seen that the force is of the right order but the curve does pass outside the corridor.

Figure 8 shows the wall force for the 20 mile per hour rigid wall test and the proposed corridors. Again the levels are about right but the curve goes outside the corridor. Figure 9 shows the wall force for the 15 mile per hour padded wall test using an APR padding block, together with the performance corridor for a 14 mile per hour impact with this padding proposed by Krause of the Ford Motor Company.(9) Bearing in mind the slight difference in impact speed, the peak force is in reasonable agreement with the proposed corridor.

It was observed in the rigid wall tests that, unlike the impactor tests, the shoulder did not immediately rotate forward but generated a relatively stiff structure between the upper arm and the spine for a short period before rotating. This affected both the spine acceleration and the thoracic wall force. This was also observed in some car tests although this may be less important as there is not usually a rigid structure immediately opposite the shoulder. However, it can lead to the upper arm becoming trapped between the interior of the car and the chest.

Possible methods of reducing this tendency are being considered including setting the angle of the upper arm to a fixed value of 40 degrees ahead of the torso line and the use of arms with a plastic skeleton instead of steel.

Rigid wall tests have been performed to compare these solutions. Figure 10 shows the thoracic wall force generated in a 15 mile per hour test with the existing arm 40 degrees forward together with the Mertz corridor. The double peak is characteristic of the delayed shoulder movement.

Figure 11 shows the result of the same tests using the arm with the plastic 'skeleton'. The double peak is reduced and the peak force lies within the performance corridor.

Figure 12 shows the wall force produced in this test but with the plastic skeleton arm parallel to the chest. A reasonably smooth response was obtained although the peak force was higher than the proposed corridor.

Figure 13 shows the lateral spine acceleration for the test using the arm with a steel skeleton. Also shown is the plus and minus one standard deviation values either side of the mean peak value for the cadaver results presented by Eppinger, Marcus and Morgan in their 1984 SAE paper. (10). Again the double spike is apparent.

Figure 14 shows the result for the same test but using the arm with a plastic 'skeleton'. The double spike has disappeared although the peak value is more than one standard deviation below the mean cadaver value.

Figure 15 shows the spine acceleration for the same arm but placed alongside the thorax. Again the curve is basically unimodel.

TABLE 2.
Thoracic Impulse in the 15 mile/h Rigid Wall Tests.

Arm	Thoracic Impulse (N-S)
Metal skeleton, 40° Fwd.	194
Plastic skeleton, 40° Fwd.	218
Plastic skeleton, beside chest	248
NHTSA Cadaver Tests (11)	250

Table 2 shows the thoracic impulse measured in these tests in comparison with the reported cadaver mean result. The impulse values for the tests with the arms ahead of the thorax are probably reduced because most of the arm will have contacted the rigid wall away from the force measuring plate.

Now that the EUROSID Dummy is complete, studies can be made relating cadaver data and accident-injury information to dummy responses in order to establish appropriate performance criteria. A preliminary review of the results of some of the EUROSID Validation Study tests together with published cadaver and accident-injury data suggests that a tentative limit to rib deflection, as measured by the EUROSID transucers, might be 25-35mm in order to avoid chest injuries of severity greater than AIS3.

CONCLUSIONS

This review of the EUROSID thorax has shown that a design of shoulder and chest has been produced that show reasonable biofidelity as indicated by the results presented. The performance can be altered if desired by changing the springs and dampers. Modifications have been suggested which should improve the performance of the shoulder in rigid wall tests and, probably, also in vehicle tests.

Figure 16 shows the overall design of the thorax of EUROSID which was the design that was used in the Evaluation study, the results for which appear in the later papers.

ACKNOWLEDGEMENTS

The invaluable assistance of Ogle Design in the design and production of the EUROSID thorax is gratefully acknowledged, as is the help given by MIRA and Middlesex Polytechnic in some of the tests performed on the dummy.

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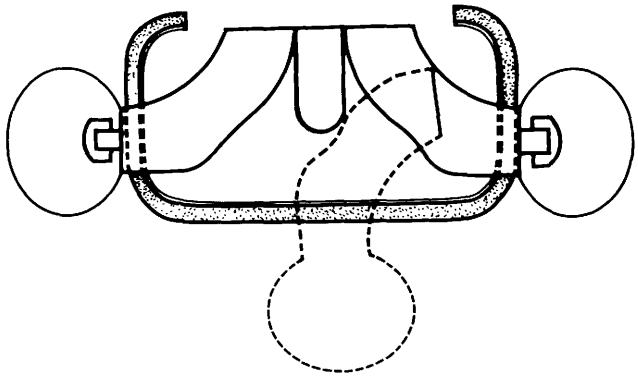

Fig.1 Diagram of Shoulder Cam (Top view)

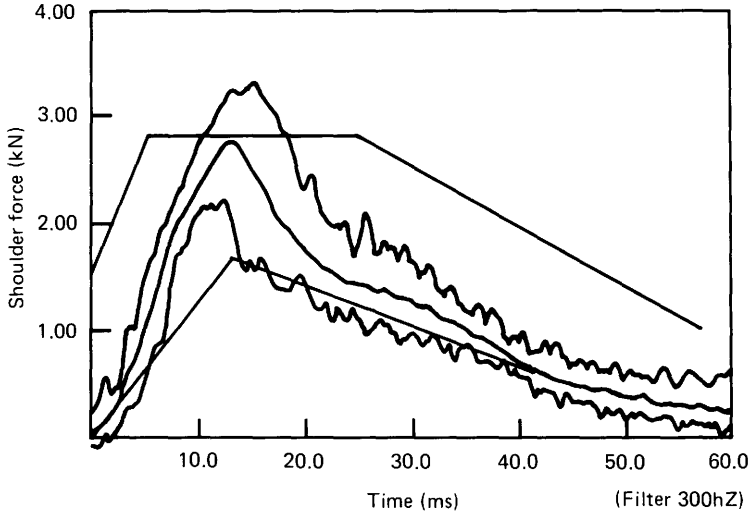

Fig.2 Shoulder force produced by a 23.4kg impactor at 4.3m/s

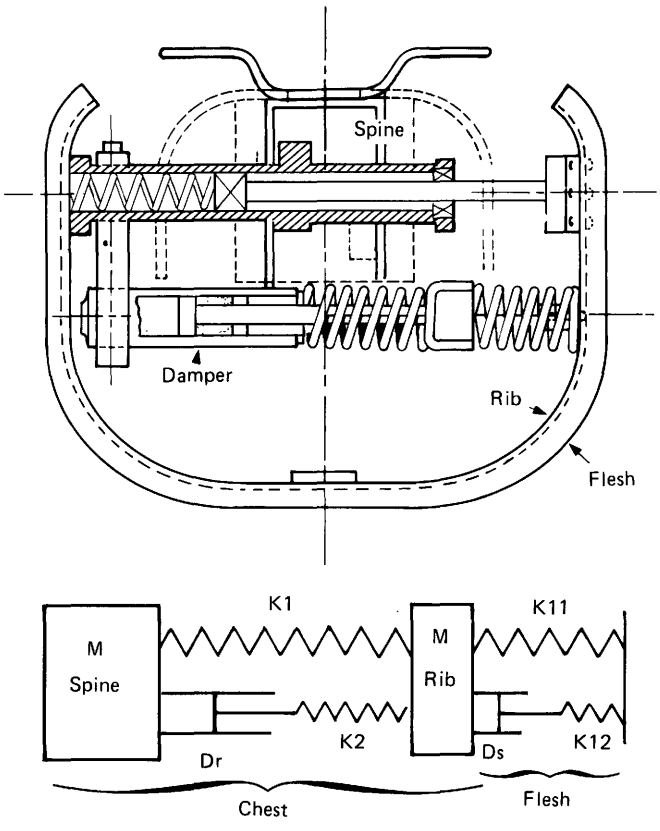

Fig.3 Diagram of Rib-Piston Module and the Mathematical Model of the Thorax

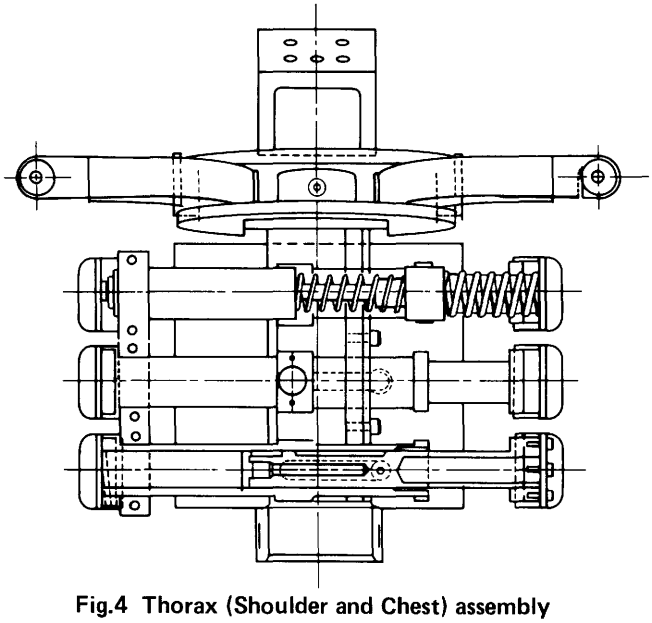

Fig.4 Thorax (Shoulder and Chest) assembly

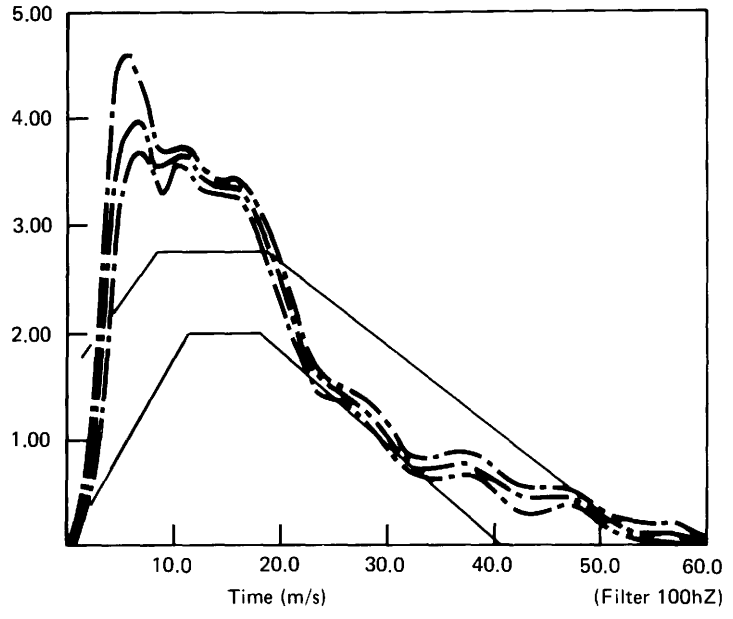

Fig.5 Force on Thorax produced by a 23.4kg impactor at 4.3m/s

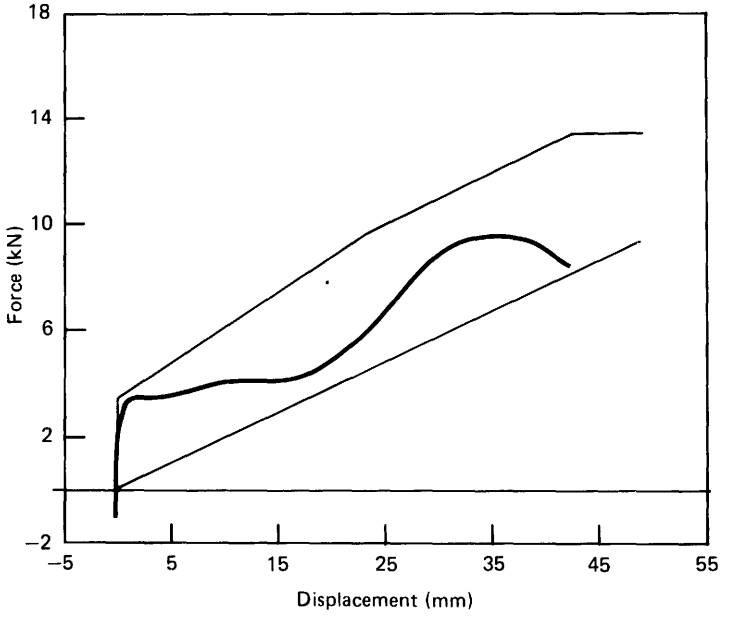

Fig.6 Thorax force-displacement curve for padded wall test and performance corridor based on APR cadaver tests

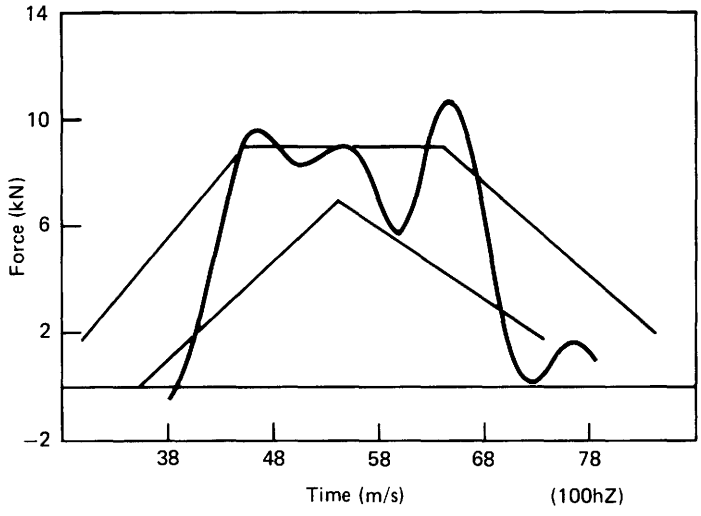

Fig.7 Thoracic wall force, 15 mile/h (6.7m/s) rigid wall test and performance corridor (9Ref.8)

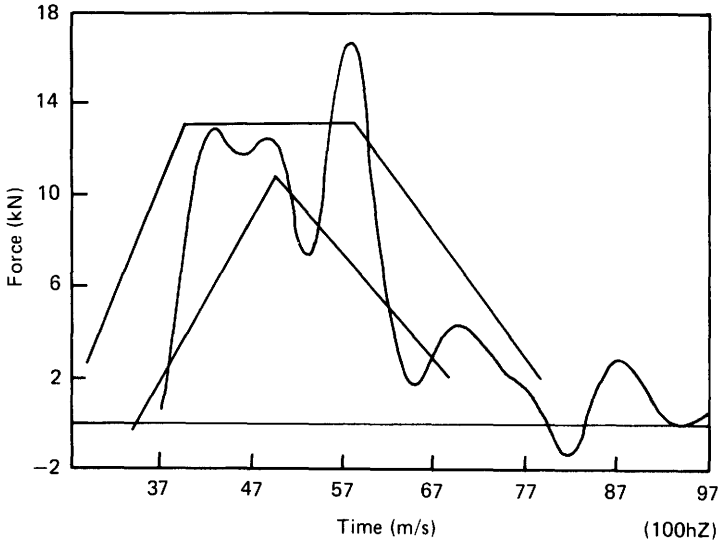

Fig.8 Thoracic wall force, 20mile/h (8.9m/s) rigid wall test and performance corridor (Ref.8)

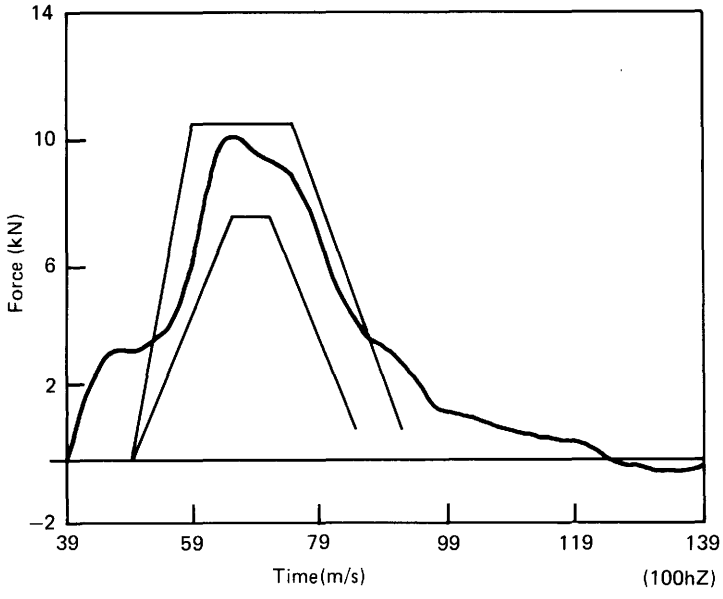

Fig.9 Thoracic wall force, 15mile/h (6.7m/s) padded wall test and performance corridor (Ref.9)

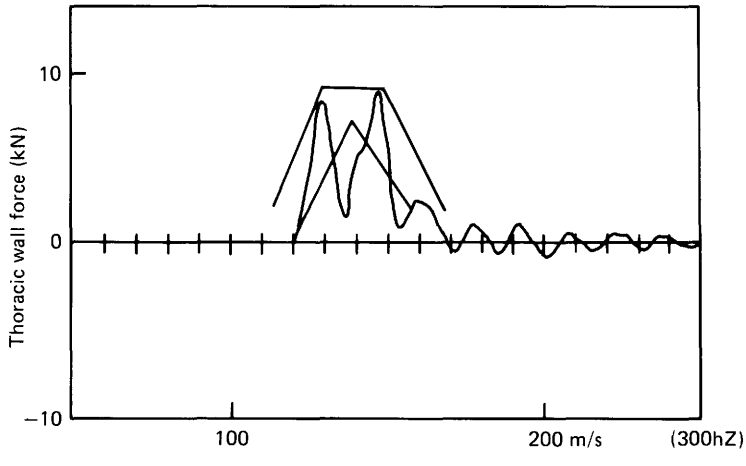

Fig.10 15mile/h Rigid wall test. Thoracic wall force Arm (steel skeleton) 40° forward

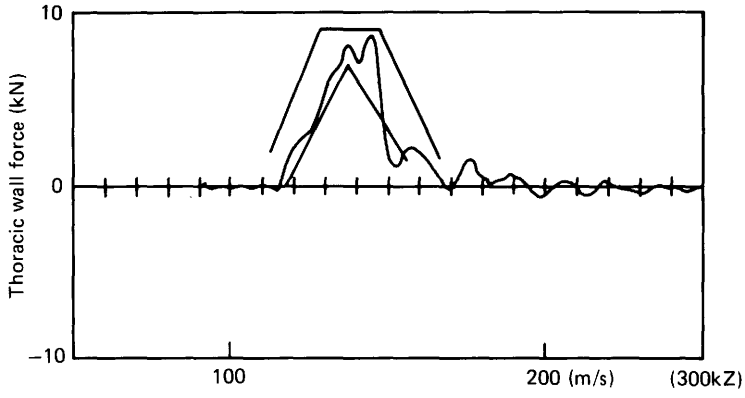

Fig.11 15mile/h Rigid wall test. Thoracic wall force Arm (plastic skeleton) 40° forward

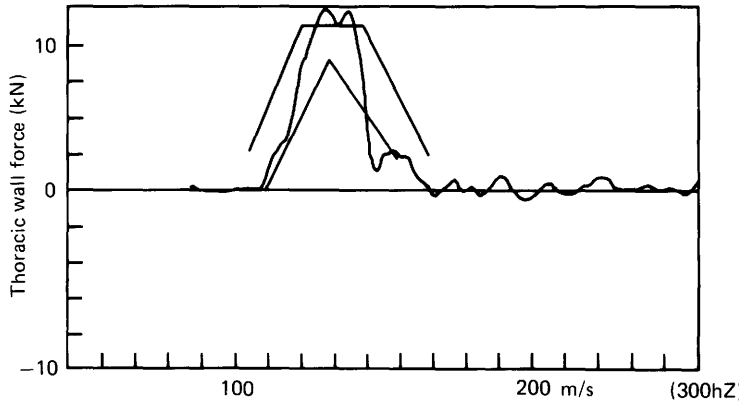

Fig.12 15mile/h Rigid wall test. Thoracic wall force Arm (plastic skeleton) parallel to chest

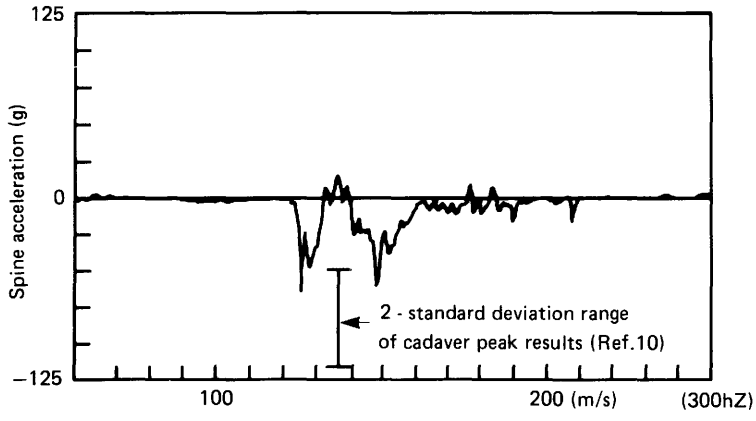

Fig.13 15mile/h Rigid wall test. Spine acceleration Arm (steel skeleton) 40° forward

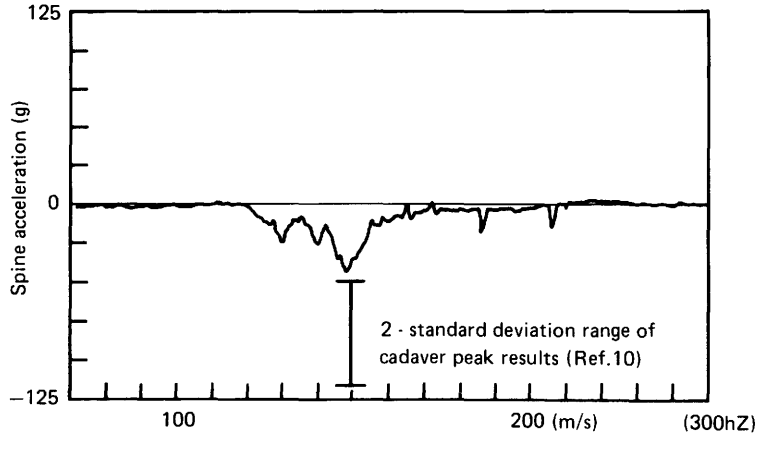

Fig.14 15mile/h Rigid wall test. Spine acceleration Arm (plastic skeleton) 40° forward

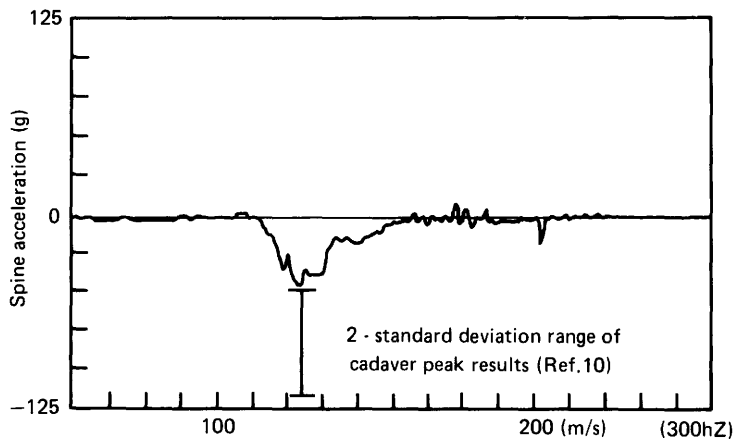

Fig.15 15mile/h Rigid wall test. Spine acceleration Arm (plastic skeleton) parallel to chest

Fig.16 EUROSID first prototype showing shoulder and chest design

Presentation related to the NECK COMPONENT

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ABSTRACT

The scope of this paper is to present APR contribution to the EUROSID EVALUATION PROGRAMME. The APR test matrix included twenty neck pendulum repeatability tests and six neck biofidelity tests. Since the repeatability of the neck will be dealt with in the presentation related to the whole dummy repeatability, a short summary about the neck characteristics is proposed. A major part of this communication concerns the data base used for the EUROSID neck development, the mechanical design as well as the performance of this segment, in terms of biofidelity, when the whole dummy is subjected to +Gy sled tests. A comparison between EUROSID and human responses is proposed on the basis of neck requirements as recently formulated by the ISO/SC12/WG5. Results indicate that the biofidelity of the EUROSID neck is on the whole satisfactory. The cadaver/EUROSID comparison, proposed at the end of this paper, suggests reliable behaviour of the neck, in spite of a lack of sufficient cadaver data in more severe test conditions.

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INTRODUCTION

A first attempt to develop a dummy neck with reliable responses in lateral direction was made by the Association PEUGEOT-RENAULT in 1982.

This first version was designed to be used on the APROD dummy (1)* (2)and built on the basis of human data obtained from low severity sled tests (2)(3)(4). The evaluation of the biofidelity of this neck was performed within the framework of the EEC Comparison Testing Programme (5).

Following the conclusion of this programme, APR redesigned a new neck prototype according to the data base mentioned above as well as to new data derived from high severity sled tests (6). This prototype was chosen for the EUROPEAN SIDE IMPACT DUMMY -EUROSID- and presented together with the abdomen, pelvis and thorax components by the Chairman of the EEVC Ad-Hoc dummy group in the 1985 ESV Conference (7).

An extensive evaluation testing programme of the EUROSID dummy, sponsored by the EUROPEAN ECONOMIC COMMUNITY, was defined and carried out in 1986 by TNO (THE NETHERLANDS), TRRL (U.K.), INRETS (FRANCE), BAST (GERMANY) and APR (FRANCE) in collaboration with the EEVC.

1. EUROSID NECK DESCRIPTION

The EUROSID neck comprises three parts :

- a neck/torso interface piece,
- a head/neck interface piece,
- a central section made of rubber that links the two interfaces to one another.

The various neck sections are illustrated in Figure 1. Each interface is composed of two plates ; an exterior one and an intermediary one bound to the central part. These plates are linked by means of a screwed half-sphere, which constitutes a point of rotation.

In order to modulate respectively relative head-neck and neck torso movements, two types of buffers are interposed between the plates as shown in section CC in Figure 1.

The triangular section buffers and the central neck part are all part of the same system ; they are made up of a special 70-shores rubber. The circular section buffers are made up of a 70-shores natural rubber. An illustration of the neck-torso interface in its final position is proposed in Figure 2.

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* Numbers in brackets refer to the bibliography at the end of the paper

The several neck components were designed in order to reproduce head neck kinematics observed with volunteer as well as with cadaver tests, i.e to allow the following head displacements :

- a pure translation in the plane of impact (in the first part of the motion) ;
- a rotational movement composed by a lateral flexion and a torsion.

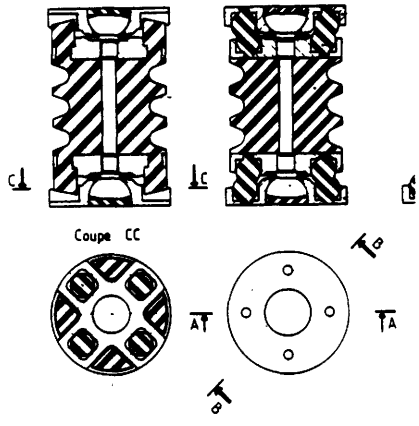


Figure 1 : EUROSID NECK DESIGN

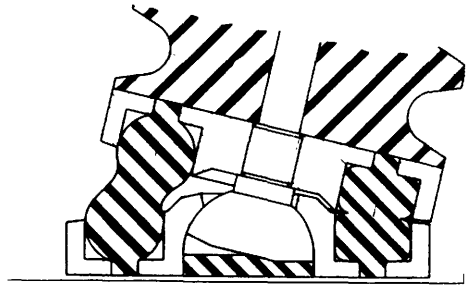


Figure 2 : NECK-TORSO INTERFACE

Photographs illustrating the neck design as well as its several components are included in the end of this paper (see Appendix).

With a view to evaluating the whole system's mechanical behaviour, two rigid wall sled tests were performed with the neck attached to the APROD dummy (10).

In these tests, the dummy was subjected to an impact velocity of 8.7 m/s without deterioration of the neck parts.

Following a first analysis of the neck biofidelity, again with the APROD dummy (6), two prototypes with a 70-shores and 75-shores hardness respectively were produced for evaluation in the framework of the EEVC Testing Programme of EUROSID.

2. SUMMARY OF APR CONTRIBUTION TO EUROSID EVALUATION

The APR contribution to the EUROSID dummy evaluation programme comprised neck repeatability as well as biofidelity tests.

Repeatability tests were conducted under the PART 572 specifications, while biofidelity tests were performed according to conditions summarized in Table 1.

Two groups of biofidelity tests were carried out in accordance with the available biomechanical test references in lateral direction. These are +Gy sled tests as conducted by Dr EWING (NAMRL) with the use of volunteers (2) and APR cadaver tests performed at a higher G-level of sled deceleration (6).

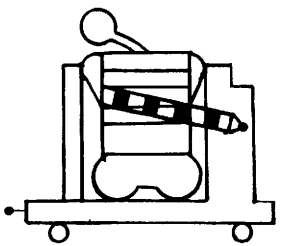
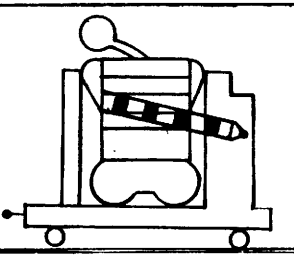
3. NECK REPEATABILITY TESTS

Twenty tests were carried out with the head-neck assembly fixed in lateral mode to the PART 572 neck certification pendulum. The neck was mounted on the pendulum without brackets.

Results, including head acceleration and kinematics relative to the pendulum, show a high degree of repeatability (11). The maximum coefficient of variation (SD/mean value) obtained was 7 % with most results having much lower ratios.

Table 1 :

SUMMARY OF NECK BIOFIDELITY TESTS

OBJECTIVES	TYPE OF TESTS	HUMAN REFERENCE DATA BASE	INPUT DATA	MEASUREMENTS	CONFIGURATION
BIOFIDELITY OF THE EUROSID NECK	2 lateral sled tests involving the whole dummy	Volunteer tests conducted by Ewing - NBDL New Orleans (2)	Peak sled velocity : 6 m/s Peak sled acceleration : 7G	ACCELERATIONS : - sled - Head - T 1 KINEMATICS : Head and T 1 relative to the sled	
	4 lateral sled tests involving the whole dummy	Cadaver tests conducted by APR - Nanterre France (5),(6)	Peak sled velocity : 6 m/s or 8 m/s Peak sled acceleration : 13G	ACCELERATIONS : - sled - Head KINEMATICS : Head and T 1 relative to the sled	

4. NECK-SLED BIOFIDELITY TESTS

4.1. INTRODUCTION

Six sled tests involving the whole dummy were performed in order to evaluate EUROSID neck biofidelity in lateral impact. The human reference data base comprises the results from volunteer tests conducted by the NAMRL staff (2) as well as those from APR tests performed with the use of cadavers (5)(6). Volunteer and cadaver data allow the biofidelity of the neck segment to be evaluated respectively under low and high impact violence.

The EUROSID dummy was subjected to two tests according to the first data base conditions and four tests with respect to APR data. Two types of neck material were tested, i.e a 70-shores and 75-shores hardness respectively for both impact conditions.

Results from these tests as well as the test set-up, instrumentation and filtering are presented in the following.

4.2. TEST SET-UP, INSTRUMENTATION AND FILTERING

4.2.1. Dummy Positioning

A sled, similar to the one used by APR or EWING and Al. (2)(5), on which a rigid seat was fixed in an upright position, was used. The seat was attached to the sled in a sideward position.

In order to limit the translation of the dummy, a wooden side board was fixed vertically to the seat, in such a way that the top of the side board was on a level with the dummy's right shoulder.

The dummy was placed on the seat in the upright sitting position and adjusted in such a way that its mid-sagittal plane was vertical and perpendicular to the impact plane (perpendicular to the direction of the sled displacement), as shown in Figure 3.

The dummy was restrained by shoulder straps in order to limit the motion of its upper torso. In addition, the dummy's restraint system comprised a lap belt, a pelvis strap and a nylon belt around its chest. The X-anatomical axis of the dummy's head was horizontal (see also Figure 3).

4.2.2. Sled Deceleration Profile

The EUROSID dummy, positioned as mentioned above, was subjected to 6 tests where the peak sled deceleration and initial velocity were as follows :

- 7 G and 6 m/s for tests EURO 1 and EURO 2 respectively,
- 13 G and 6 m/s for tests EURO 3 and EURO 4 respectively,
- 13 G and 8 m/s for tests EURO 5 and EURO 6 respectively.

The sled deceleration profile for each type of sled conditions should be within a corridor defined from the reference data base.

4.2.3. Dummy Instrumentation

The dummy was instrumented as follows :

- 1 triaxial accelerometer mounted at the head c.g level,
- 2 triaxial accelerometers mounted at T1 and T4 levels respectively,
- 3 sphere-shaped aluminium targets fixed onto the head and T1 respectively, as shown in Figure 4.

In addition, an accelerometer was mounted to the sled structure for the measurement of sled deceleration. The channel filter classes were the following :

- head acceleration : 1000,
- thorax acceleration (T1 and T4) : 180,
- seat and sled acceleration : 180.

4.3. THE SETTING-UP PROCEDURE FOR HEAD AND T1 MOTION ANALYSIS

Cinematographic coverage of tests was provided by five high speed cameras, fixed in the laboratory, with a filming frequency of 500 frames per second.

A setting-up procedure for cameras calibration was performed in order to allow three-dimensional head and T1 kinematics relative to the sled to be obtained from film analysis.

Figure 5 shows a cube-shaped mount used for this calibration.

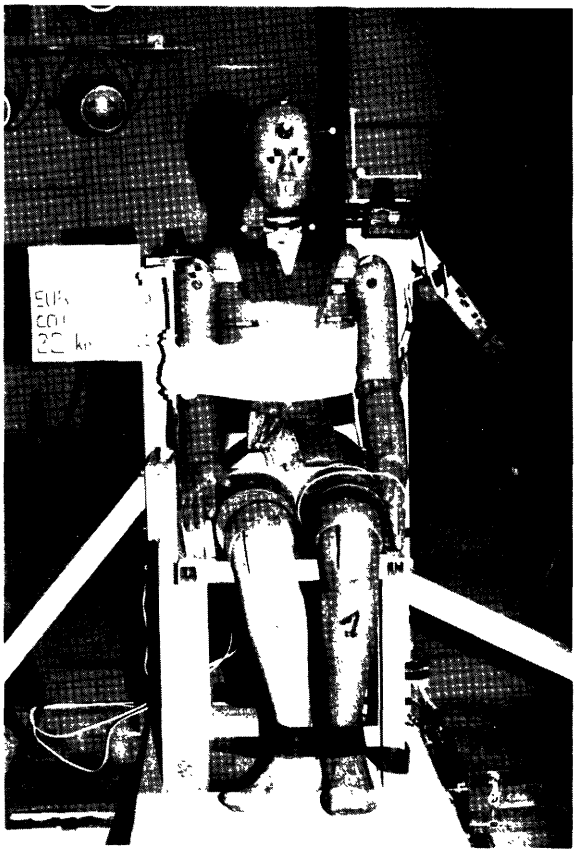


Figure 3 : Test set-up used for neck biofidelity tests

Figure 4 : Head instrumentation used for neck biofidelity tests

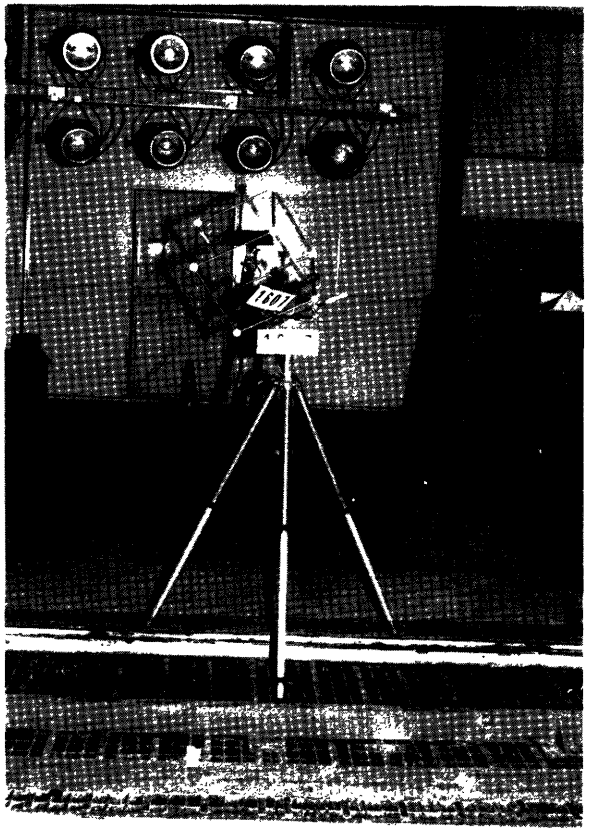


Figure 5 : Setting-up procedure used for camera's calibration

4.4. RESULTS

In this section, EUROSID neck performance is compared with data from volunteer and cadaver tests. The volunteer data are those proposed by MERTZ (9) as lateral neck bending response requirements, on the basis of WISMANS and SPENNY results (12)(13) concerning test number LX 2302.

The cadaver data are those proposed by TARRIERE (14) and discussed during the ISO/WG5 Session of June 1986. Two sled tests with EUROSID were selected for this comparison as their results appeared to be the closest to those from references mentioned above. They are EURO 2 and EURO 3 tests (11).

EUROSID/Volunteer Neck Response Comparison

To allow the EUROSID and volunteer input conditions to be compared, the EURO 2 sled acceleration-time history is plotted in Figure 6 together with a corridor defined by MERTZ (9). Except for the rising portion of the corridor where small deviations are observed, the EURO 2 sled acceleration curve lies within the required envelope.

In Table 2, are summarized both volunteer and EURO 2 test results. The sled velocity change and the peak sled acceleration of EURO 2 test are close to those from volunteer tests. This indicates that the duplication of LX 2302 test with EUROSID is satisfactory in terms of input conditions.

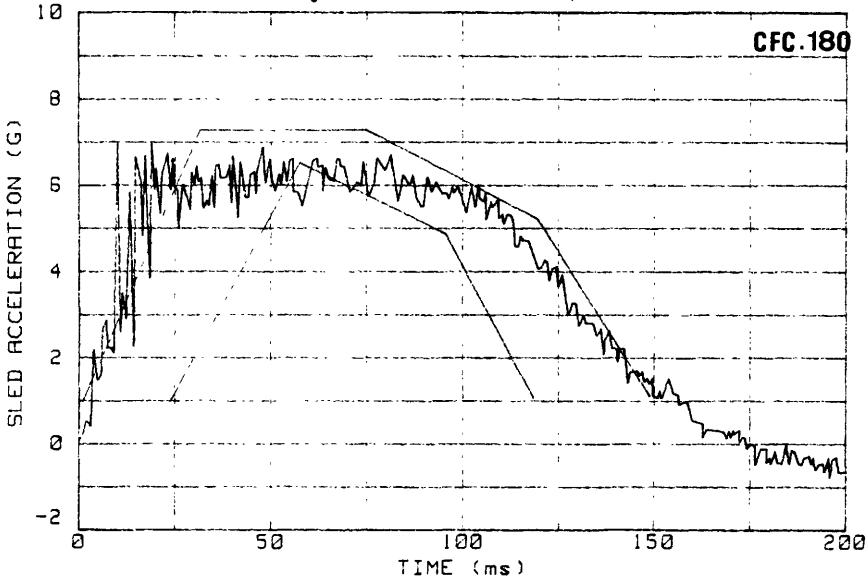


Figure 6 : SLED ACCELERATION-TIME HISTORY FROM EURO 2 TEST COMPARED WITH ACCELERATION-TIME CORRIDOR AS DEFINED BY MERTZ (9)

The T1-peak lateral accelerations for the two tests are also given in Table 2. Maximum and minimum differences are 6.9 G and 1.5 G. In addition, the analysis of the EURO 2 T1 lateral acceleration-time history shows that this curve reflects a general characteristic common to volunteer tests, i.e a first high peak followed by others of lesser magnitude.

Discrepancies between both tests in terms of head c.g lateral acceleration are very small since the minimum difference is of 1 G.

As far as head and T1 kinematics are concerned, two EUROSID data are very close to the required responses ; for instance the maximum lateral displacement of head c.g and the head flexion angle (see also Table 2).

PARAMETERS	VOLUNTEER RESPONSES TEST LX2302	EUROSID RESPONSES TEST EURO 2
PEAK SLED DECELERATION G	7	7,3
SLED VELOCITY CHANGE m/s	6,4	6,19
PEAK LATERAL ACCELERATION OF T1 - LEVEL G	17,3 ± 2,7	13,1
PEAK LATERAL ACCELERATION OF THE HEAD C.G G	12,5 ± 2,5	9
MAX. LATERAL DISPLACEMENT OF T1 RELATIVE TO THE SLED mm	69 ± 7	45
MAX LATERAL DISPLACEMENT OF HEAD C G RELATIVE TO THE SLED mm	153 ± 15	164
MAX. VERTICAL DISPLACEMENT OF HEAD C G RELATIVE TO THE SLED mm	80 ± 8	89
MAX HEAD FLEXION ANGLE degrees	50 ± 5	54
MAX HEAD TWIST ANGLE degrees	30 ± 5	22

Table 2 : EUROSID NECK RESPONSES COMPARED WITH THOSE FROM ONE VOLUNTEER TEST

The T1 maximum lateral displacement for the EURO 2 test appears to be 27 % less than the minimum corresponding volunteer parameter.

Large differences appear, however, in terms of maximum vertical displacement of the head c.g and the maximum head twist angle.

In Figures 7 and 8 are presented head kinematics relative to the sled and the T1 origin in the impact plane respectively. These data are provided by a computer programme allowing head linear and angular displacements to be obtained in three dimensions.

In order to complete this comparison, head kinematics time-histories related to T1 from both tests have to be compared. This question requires however a certain harmonization between APR graphical outputs and those from the bibliography (13), and will be discussed in another paper.

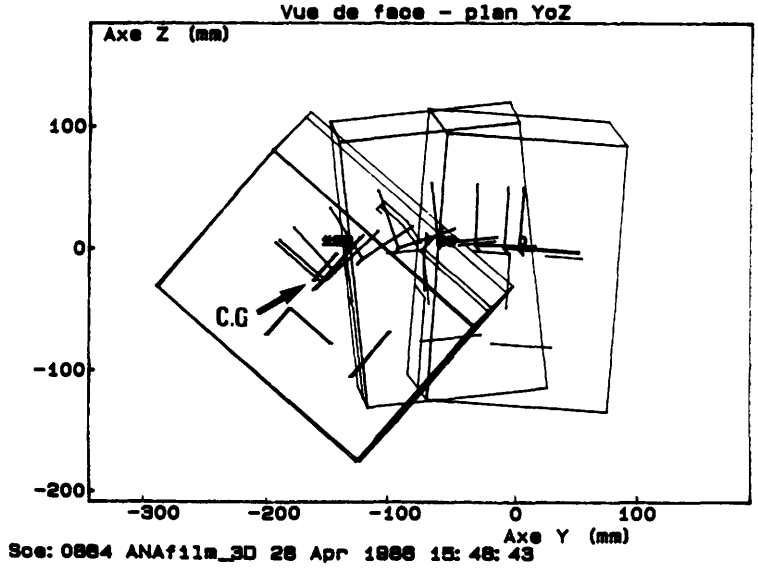


Figure 7 : HEAD KINEMATICS RELATIVE TO THE SLED OBTAINED FROM A LOW G-LEVEL NECK BIOFIDELITY TEST NB EURO 2

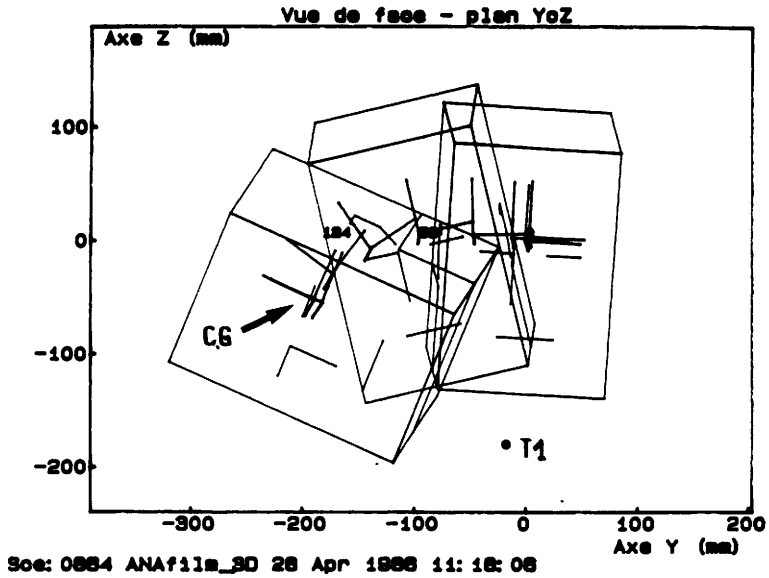


Figure 8 : HEAD KINEMATICS RELATIVE TO T1
OBTAINED FROM A LOW G-LEVEL NECK BIOFIDELITY TEST
NB EURO 2

EUROSID/Cadaver Neck Response Comparison

Four sled tests involving the whole dummy were performed according to the test set-up already described. These are EURO 3, EURO 4, EURO 5 and EURO 6, where input conditions are more severe than in the previously discussed tests.

The first couple of tests was conducted with peak sled deceleration and velocity change of 13 G and 6 m/s respectively, whereas input conditions for the second couple were 13 G and 8 m/s. Two types of neck material hardness were used, i.e 70 and 75 shores. The first one was used for EURO 3 and EURO 5 tests and the second for EURO 4 and EURO 6 tests.

The peak sled deceleration reached a magnitude of 13.8 G, 14.7 G, 13.6 G and 14 G respectively (for tests EURO 3 up to EURO 6). The maximum sled velocity change was 6 m/s, 6 m/s, 8.38 m/s and 8.19 m/s respectively.

As indicated previously, the EURO 3 test results will be compared to those from one APR cadaver test i.e MS 249 (6)(14). The results of EURO 3 and MS 249 tests are given in Table 3.

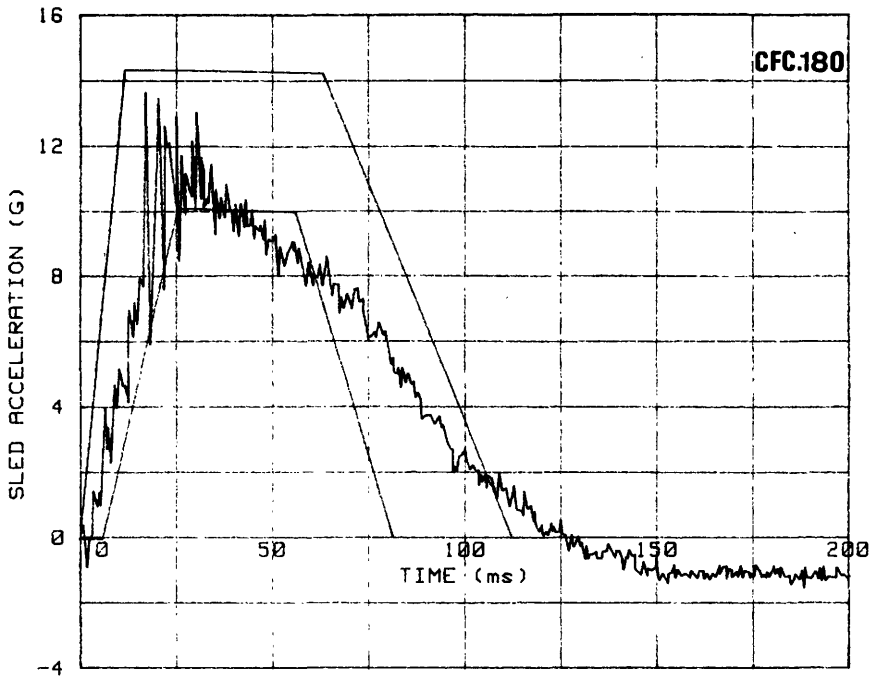


Figure 9 : SLED ACCELERATION-TIME HISTORY
FROM EURO 3 TEST COMPARED WITH
ACCELERATION TIME CADAVER CORRIDOR

In terms of input conditions, both tests appear to be similar. The peak sled deceleration and velocity show differences of 1.6 G and 0.08 m/s. Furthermore, the sled acceleration-time histories from test EURO 3 lie within the required acceleration-time corridor shown in Figure 9.

The cadaver and the EURO 3 responses in terms of T1 peak lateral acceleration give a very small difference (0.2 G).

Generally speaking, the EUROSID neck in test EURO 3, reproduces well the type of head kinematics observed with the cadaver test. The head in EURO 3 test describes a pure translation, followed by a three-dimensional movement composed by a lateral flexion and a torsion.

Maximum head c.g displacements in lateral and vertical directions were 191 mm and 60 mm respectively. Head lateral flexion and torsion reached a magnitude of 72 degrees and 48 degrees respectively.

PARAMETERS	CADAVER RESPONSES TEST MS249	EUROSID RESPONSES TEST EURO 3
PEAK SLED DECELERATION G	12,2	13,8
SLED VELOCITY CHANGE m/s	6,08	6,0
PEAK LATERAL ACCELERATION OF T1 - LEVEL G	20	19,8
PEAK LATERAL ACCELERATION OF THE HEAD C.G G	36	9,6
MAX. LATERAL DISPLACEMENT OF T1 RELATIVE TO THE SLED mm	67	52,5
MAX. LATERAL DISPLACEMENT OF HEAD C.G RELATIVE TO THE SLED mm	294	191
MAX. VERTICAL DISPLACEMENT OF HEAD C G RELATIVE TO THE SLED mm	79	60
MAX HEAD FLEXION ANGLE degrees	78	72
MAX HEAD TWIST ANGLE degrees	42	48

Table 3 : EUROSID NECK RESPONSES COMPARED WITH THOSE FROM APR CADAVER TEST

As indicated in reference 14, data from MS 249 test cannot be considered as a basis for a dummy neck evaluation in severe test conditions. This is due to the fact that neck injuries were observed with MS 249 cadaver. However, data in Table 3 suggest a satisfactory behaviour of the neck in terms of sensitivity.

Neck responses observed in EURO 3 test show higher magnitudes than those obtained from EURO 2 test, which was performed at a lower sled deceleration. This observation concerns head linear and angular displacements, T1-lateral displacement and acceleration respectively. A large difference appears between MS 249 and EURO 3 tests in terms of lateral acceleration of the head c.g, with peak values of 36 G and 9.6 G respectively. This could be explained by neck injuries, i.e cervical fractures observed with MS 249 subject (6)(14).

Conclusions concerning the whole neck biofidelity will be given when the data base, in severe test conditions, is completed.

5. DISCUSSION

In the framework of the EEVC evaluation programme of the EUROSID dummy, APR has performed twenty neck repeatability tests and six sled tests for the neck biofidelity evaluation. For the two types of tests configurations, additional runs were carried out in order to ensure that the required input conditions were respected.

When subjected to pendulum tests under the PART 572 neck calibration procedure, the EUROSID neck, shows a satisfactory repeatability. The maximum coefficient of variation relating to head responses obtained from these tests was 7 per cent, with most results having much lower ratios (11).

As far as the neck behaviour is concerned, a small semi-permanent bending of this segment was observed after ten pendulum tests. A reset procedure, comprising head orientation adjustment relative to the pendulum, was applied to the neck allowing the repeatability of input conditions to be guaranteed (11).

During the EUROSID test programme, it was realised that the whole dummy must not be carried around by supporting it through a hook in the head ; since there is no cable inside the neck, this could destroy the segment.

On the basis of the neck repeatability results, a certification procedure was defined and the corresponding tests were already carried out. The aim of this procedure is similar to the PART 572 one but with the following differences :

- the head assembly is mounted on the PART 572 pendulum in lateral mode, without neck bracket ;
- the pendulum impact velocity is 3.4 $\pm$ 1 m/s.

A detailed description of this procedure as well as a first indication of the required data for the neck certification feature in reference (15). The complete procedure will be available in the near future when the processing of tests already mentioned will be completed.

The biofidelity of the EUROSID neck was evaluated, in the framework of EUROSID programme, on the basis of volunteer as well as cadaver data obtained respectively at low and high violence sled tests. The EUROSID dummy was subjected to two tests according to volunteer data base and four tests with respect to APR cadaver tests. In both configurations, two types of neck material hardness were used for evaluation, i.e 70 and 75 shores. The analysis of results showed that the 70 shores version gives a better reliability than the 75 shores one.

The comparison between EUROSID and volunteer responses was done taking into account neck bending response requirements, as proposed by M. MERTZ, Chairman of the ISO/SC12/WG5 (9).

The parameters considered for this comparison comprise sled acceleration and velocity, T1 and head c.g lateral acceleration, T1 and head c.g lateral displacement, head c.g vertical displacement and finally head rotation magnitudes (flexion and torsion) with respect to the sled.

Results show that input conditions of EUROSID tests are very close to those of volunteer test. Expressed in percents*, differences for the sled acceleration, velocity and T1 lateral acceleration are 4 %, 3 % and 10 % respectively. These data show that the duplication of volunteer test (Nb LX 2302) with EUROSID was satisfactory.

As far as head kinematics is concerned, the lateral head c.g displacement and the head flexion angle of EUROSID are close to those of the volunteers.

The peak magnitude of the head c.g lateral acceleration of EUROSID test is close enough to the corresponding requirement, the difference with the volunteer test being of 1 G.

Large discrepancies between EUROSID and volunteer tests are observed for the head c.g vertical displacement and the head twist angle with differences of 59 % and 51 % respectively.

Generally speaking, the biofidelity of the EUROSID neck at a low G-level appears from this comparison to be satisfactory. An improvement of the neck design in order to increase the head twist angle and the head c.g vertical displacement is however desirable. Such improvement depends, in fact, upon the neck biofidelity performance at a higher violence.

This aspect of the EUROSID neck characteristics was discussed partially in this paper. The results suggest the following remarks.

1) The test set-up used for EUROSID neck biofidelity evaluation at a high G-level of sled deceleration was satisfactory since input conditions, i.e the sled velocity change, the peak sled deceleration and the maximum T1-lateral acceleration respectively obtained with EUROSID are very close to those of the cadaver test.

2) No direct comparison between EUROSID and the cadaver in terms of peak head responses, was performed since the cadaver parameters were influenced by cervical injuries. However, head angular and linear displacements obtained from the EUROSID test show a certain sensitivity, with higher magnitudes than those observed in a low EUROSID G-level test.

To complete the data base and thus allow a whole neck biofidelity evaluation to be performed, two cadaver tests at a 13 G-level of sled deceleration will be conducted by APR at the beginning of 1987.

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* (EUROSID response - volunteer response)/volunteer response

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APPENDIX

Figure 1 : THE EUROSID NECK DESIGN

Figure 2 : EUROSID NECK COMPONENTS

Figure 3 : THE NECK-THORAX INTERFACE ASSEMBLY

Figure 4 : THE HEAD-NECK INTERFACE ASSEMBLY

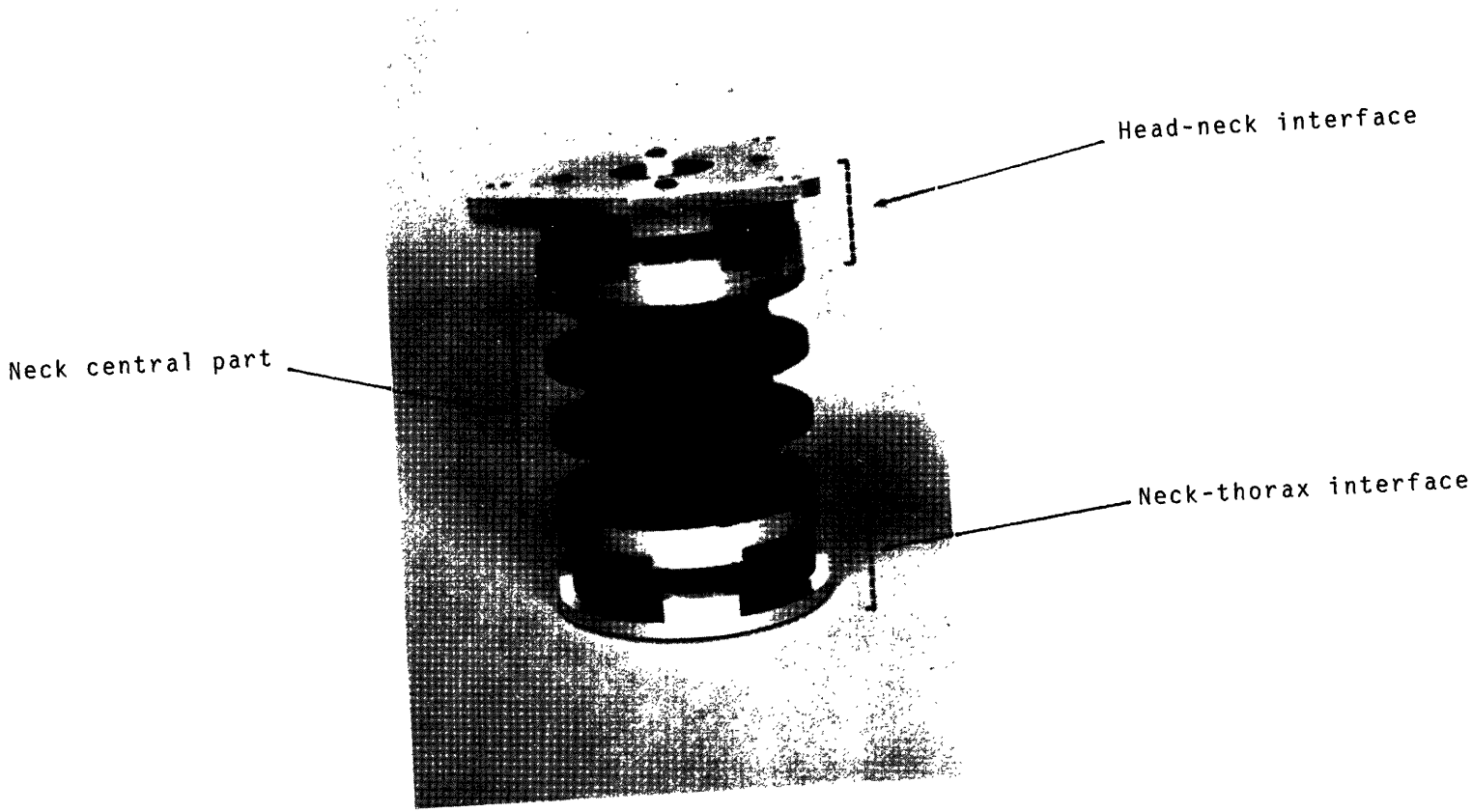

Figure 1 : THE EUROSID NECK DESIGN

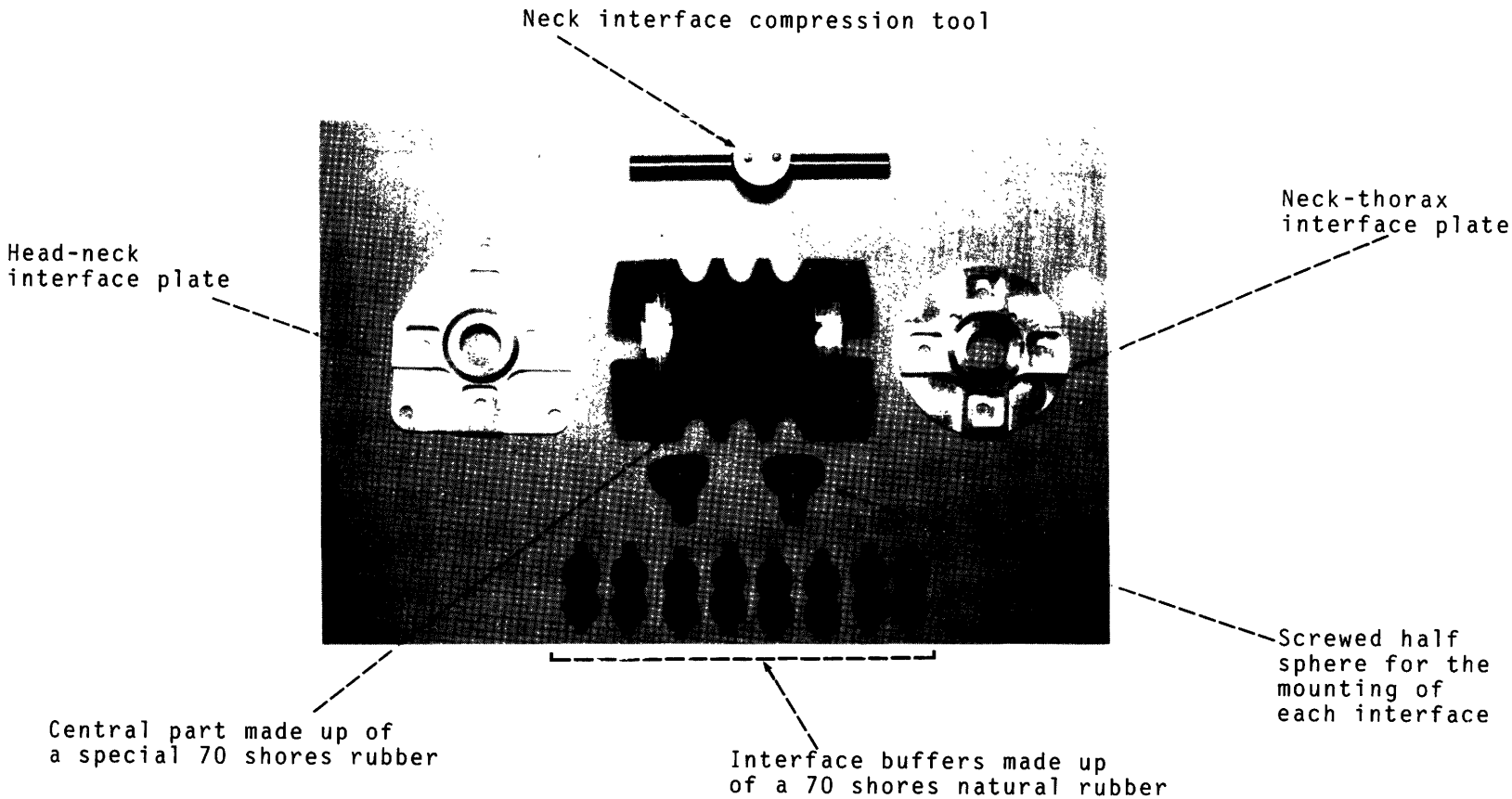

Figure 2 : EUROSID NECK COMPONENTS

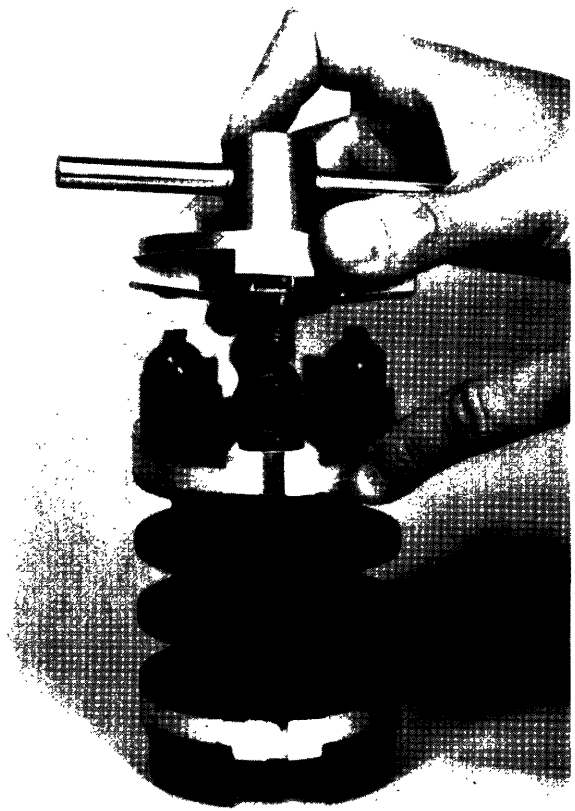

Figure 3 :

THE NECK-THORAX INTERFACE ASSEMBLY

Figure 4 :

THE HEAD-NECK INTERFACE ASSEMBLY

D. CESARI

INRETS - LCB

SENSITIVITY OF EUROSID

ABSTRACT

The EUROSID was evaluated in a wide programme including a large number of tests performed in a different tests conditions. In such a programme the evaluation of EUROSID sensitivity was a large part. This chapter reports on the analysis of tests conducted by the five research institutions which were involved in the EUROSID validation programme, i.e. BAST, INRETS, Peugeot-Renault Association, TNO and TRRL. For each body area, the influence of the variation of several parameters such as impact speed, impact location, impact angle, test temperature ... in the dummy response. This analysis shows that the EUROSID is almost not sensitive to the variation of parameters which are not related to impact severity, whereas it is sensitive to the change of parameters linked to crash severity.

1 - INTRODUCTION

The EUROSID dummy is designed to be used in a standard test procedure to perform the evaluation of side impact protection of cars in which it will be tested. For such a use a dummy is mainly a measurement tool.

It has to have a high biofidelity ; this is included in the process to finalize its design ; it has to be durable, repeatable, and sensitive to changes in certain input parameters, but not sensitive to changes in others.

The sensitivity is very important, as we have to be certain that the dummy is able to discriminate good cars from worse in terms of occupants protection in side impact.

The evaluation programme of EUROSID was very extensive. In principle most of tests were conducted in two laboratories under identical conditions. In order to make clearer the findings of the sensitivity evaluation, tests results of only one laboratory were used for each sensitivity evaluation ; however it was verified that the results found are generally similar to those of the tests conducted in the second laboratory.

The EUROSID is designed to perform specific measurements on the head, the thorax, the abdomen and the pelvis. The head is an Hybrid III head and so its sensitivity was not evaluated in the validation programme of EUROSID (1).

The sensitivity of the three other body segments is evaluated ; the neck is also included in the sensitivity evaluation, because its behaviour can affect the value of head injury parameter.

2 - HOW TO DEFINE THE DUMMY SENSITIVITY

As a measurement device a dummy must be sensitive to some parameters variation, and insensitive to the variation of others ; this seems a paradox.

In a general way, the dummy must be sensitive to changes of parameters linked to the injury mechanisms involved in these conditions in the same way in which they change for humans, but not sensitive to the variation of external parameters completely independent of the behaviour of the car being tested.

Studies on injury mechanisms in side impact have demonstrated that the injury severity of impacted side occupant is related to the velocity of the car side panel at the instant it hits the occupant (2), so a side impact dummy has to be sensitive to the speed of the impacting object.

The sensitivity of a dummy is a comparison between output and input parameters variations.

3 - SENSITIVITY OF EUROSID NECK

The EUROSID dummy is fitted with a new neck which has been developed taking into account the results of cadaver and volunteer tests (3).

The tests of the EUROSID validation programme which can be used to verify the neck sensitivity are sled tests. These tests were performed under three conditions, as indicated in table 1, two tests being performed under each condition. APR conducted these sled tests.

	Speed	Deceleration Peak
Type 1	6 m/s	7 g
Type 2	6 m/s	13 g
Type 3	8 m/s	13 g

Table 1 - Conditions of neck tests

It is then possible to evaluate the EUROSID sensitivity as a function of the impact speed (comparison between type 2 and type 3 - tests) and as a function of sled deceleration (comparison between type 1 and type 2).

The EUROSID neck is not designed to perform measurements itself ; however the neck behaviour has a direct effect on head motion and consequently on head impact severity. The parameters to be considered for sensitivity evaluation are then linked to the amplitude of head motion.

Three main parameters can be considered : the flexion angle between head and thorax, the head lateral displacement and then the head twist angle.

Figure 1 shows the variation of these three parameters as a function of impact speed and sled peak deceleration variations.

In the two cases it is possible to make the same kind of observations : the twist angle is much more sensitive to the changes of impact speed and sled deceleration than the other parameters.

The values of flexion angle and head lateral displacement are high, even for low severity tests, and the maximum value that they can reach is limited either by the geometry (for lateral displacement) or by the orientation of forces applied to the head.

The neck twist angle sensitivity is high ; this results from taking into account biofidelity specifications in its design.

4 - SENSITIVITY OF THE EUROSID THORAX

TNO, TRRL and INRETS for sled tests were in charge to conduct sensitivity tests of the thorax.

According to tests performed it is possible to evaluate the thorax sensitivity as a function of impact speed, impacting mass, impact direction, distribution of impact and temperature variation. The tests used for thoracic sensitivity evaluation are pendulum tests.

Several measurements were made during these tests : they are mainly thoracic deflection at the three rib levels and thoracic acceleration on ribs and on the spine. The criterion retained on EUROSID for the evaluation of thoracic injury risk is the thoracic deflection ; so it is important to focus the analysis of thorax sensitivity on the values of thoracic deflection as a function of changes in input parameters.

4.1 - Sensitivity as a function of impact speed

Pendulum tests were performed at impact speed of 1.5 m/s ; 2.5 m/s ; 3.5 m/s ; 4.3 m/s and 5 m/s, two tests being performed at each speed. The other impact characteristics were kept constant during the tests (impactor mass : 23.4 kg, impact angle : 90°, impact centered on the 2nd rib, room temperature : 20° C)

In these tests three ribs are loaded simultaneously, so for each test it is possible to consider the deflection of the three ribs together.

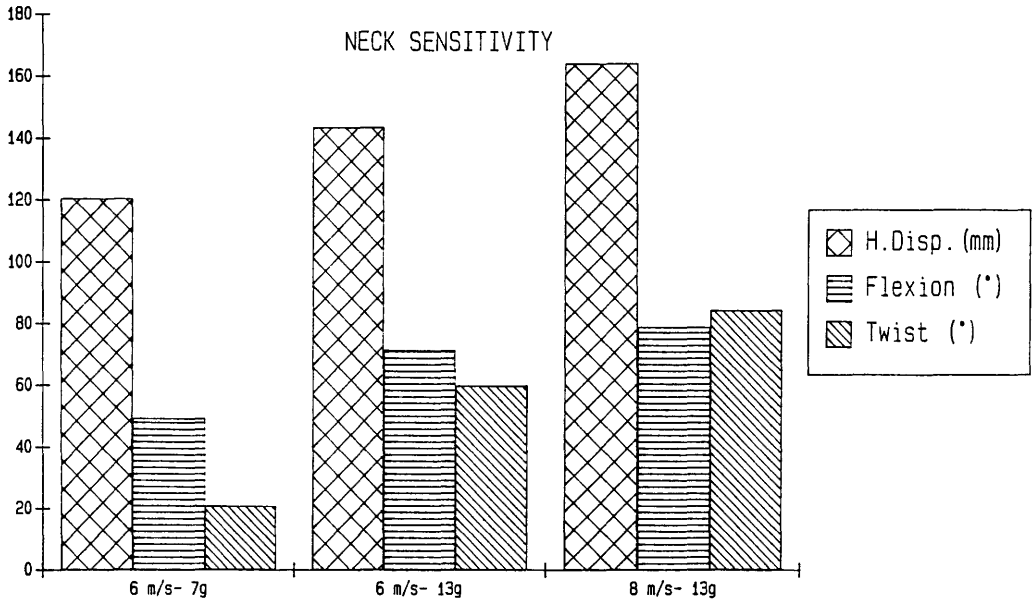

Fig. 1 : Neck sensitivity to impact speed and impact deceleration variations

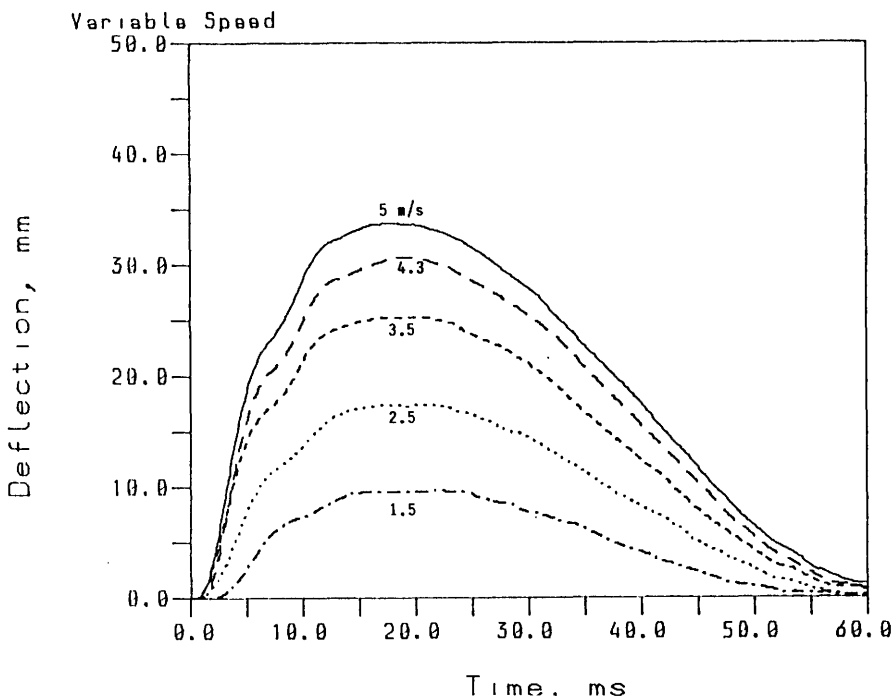

Fig. 2 : Time histories of rib deflection for five pendulum impact speeds

Figure 2 shows the plots of thoracic deflection versus time for the 5 impact speeds (10 tests, 30 measurement points). This figure indicates that the impact durations, and the shape of time/deflection curves are independent of the impact speed. However, the maximum value reached by the thoracic deflection is related to the impact speed ; it indicates also that the speed variation during the first part of the thoracic deformation is increased when the speed varies from 1.5 m/s to 3.5 m/s and then remains constant when the speed increases further.

The values of maximum thoracic deflection as a function of impact speed are reported on figure 3. This figure shows an almost linear correlation between deflection peak and impact speed. Only the deflection recorded during the tests performed at the highest speed (5 m/s) seems to be slightly lower than the value predicted by a linear relationship. When the impact speed is multiplied by two, the thoracic peak deflection is more than the doubled : this indicates a good sensitivity of the thorax to impact speed variation.

These findings are confirmed by the results of sled tests. In these tests the EUROSID is seated on a sled which is decelerated ; it moves in the direction of deceleration and hits a rigid flat and vertical panel at a speed almost equal to the impact speed of the test. Such tests were performed at impact speed of 4.7 m/s, 5.6 m/s, 7.0 m/s and 8.9 m/s. In these tests there is an increasing of the rib deflection in connection with impact speed ; however the middle and lower ribs are deflected of about the same amount, but the upper rib sustains a higher deflection, as it is indicated on table 2.

Speed (ms)	4.7	5.6	7.0	8.9
Upper rib	220	257	380	508
Middle rib	65	120	232	323
Lower rib	52	122	210	376
Average	116	167	265	376

Table 2 : Deflection in mm obtained in sled tests

4.2 - Sensitivity of EUROSID thorax as a function of impactor mass

Pendulum tests were performed on EUROSID thorax with several impactor mass values. Three values were chosen 12 kg ; 23.4 kg ; 30 kg. Two tests were performed for each mass values ; the impact speed was 4.3 m/s, the other impact parameters were kept constant for these tests and the same as those of the thorax impact speed sensitivity tests.

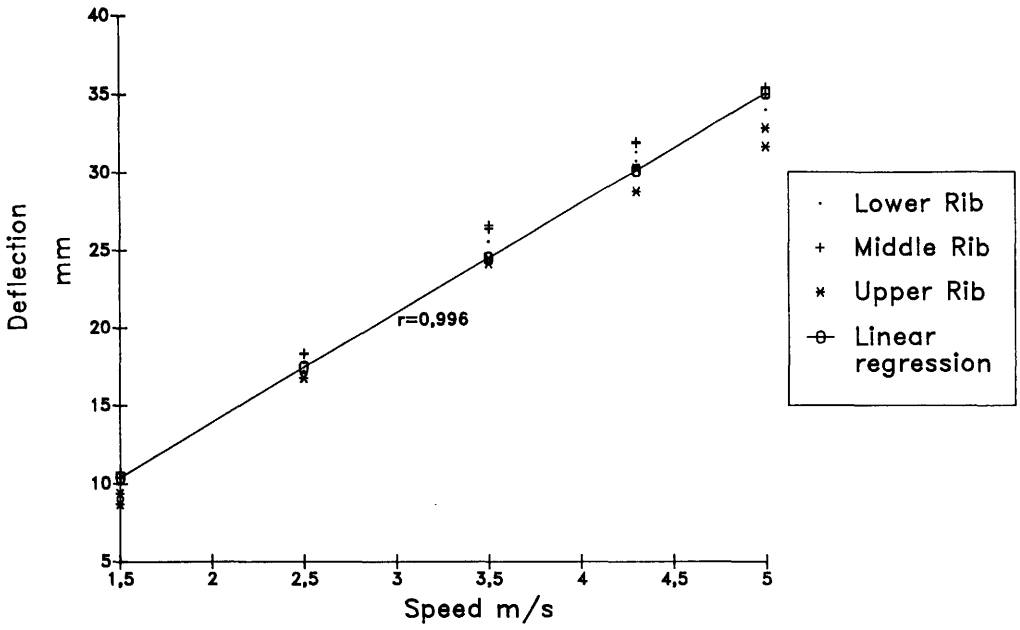

Fig. 3 : Thoracic deflection as a function of impact speed

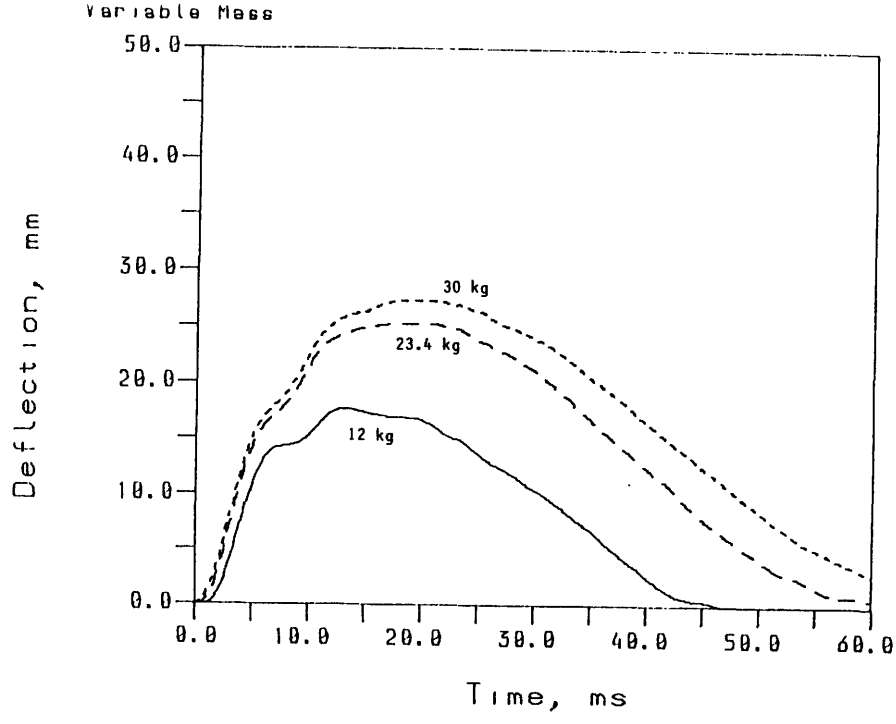

Fig. 4 : Time histories of rib deflection for three pendulum masses

On figure 4 is plotted the rib average deflection versus time for the three values of impactor weight.

The maximum of deflection increases with the mass value, but also the duration of the impact is higher in tests with a heavier impactor figure 5 shows the relation between peak deflection of the three ribs and impactor weight. It is clear the thoracic deflection increases as the pendulum weight becomes heavier, but when the weight is multiplied by two, the deflection increases about 50 %, and if we consider the differences between tests with the two highest impactor masses (23.4 kg and 30 kg) the deflection increases four times less than the impactor weight.

This analysis indicates that the EUROSID thorax is sensitive to changes of impacting weight but two to four times less than it is sensitive to speed variation. When impactor mass and velocity are combined to give kinetic energy, a good correlation is found between peak deflection and impact energy.

4.3 - Thoracic sensitivity of EUROSID to impact angle

The EUROSID dummy is designed to be used in a car, seated on the impacted side, to be hit with an angle of 90° by a mobile deformable barrier. In such a test forces applied to the dummy are mainly horizontal and perpendicular to its symmetry plane ; however the loads are transmitted to the dummy by the side panel (door pillar...) during its deformation and then the dummy loads are not necessarily exactly perpendicular.

Tests were performed in which the pendulum hits the dummy with an angle of 70°, 80°, 90°, 100° and 110°. Angles below 90° correspond to a pendulum trajectory coming from the front.

On figure 6 is plotted the average rib deflection versus time for impact angle from 70° to 110° with a step of 10°.

This figure shows clearly that the impacts with 100° and 110° angle give results identical to 90° impact tests, but in tests with an impact of 70° and 80° the flexion peak is lower, the duration is shorter, and to some extent, the shape is different.

The peak deflection versus impact angle, as plotted on figure 7 indicates these differences between forward and rearward lateral impacts.

As the deflection measurement of EUROSID thorax is made only in one axis a decrease in the deflection might be expected when the impact direction is not perpendicular, such a decrease would imply that the thorax is less susceptible to injury for impacts which are not exactly perpendicular.

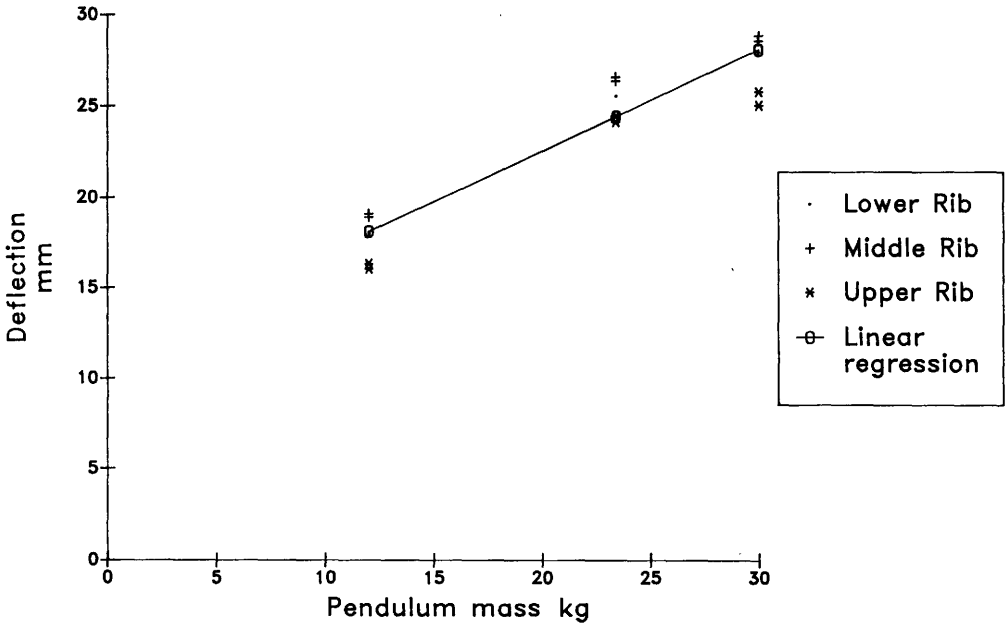

Fig. 5 : Thoracic deflection as un function of pendulum mass

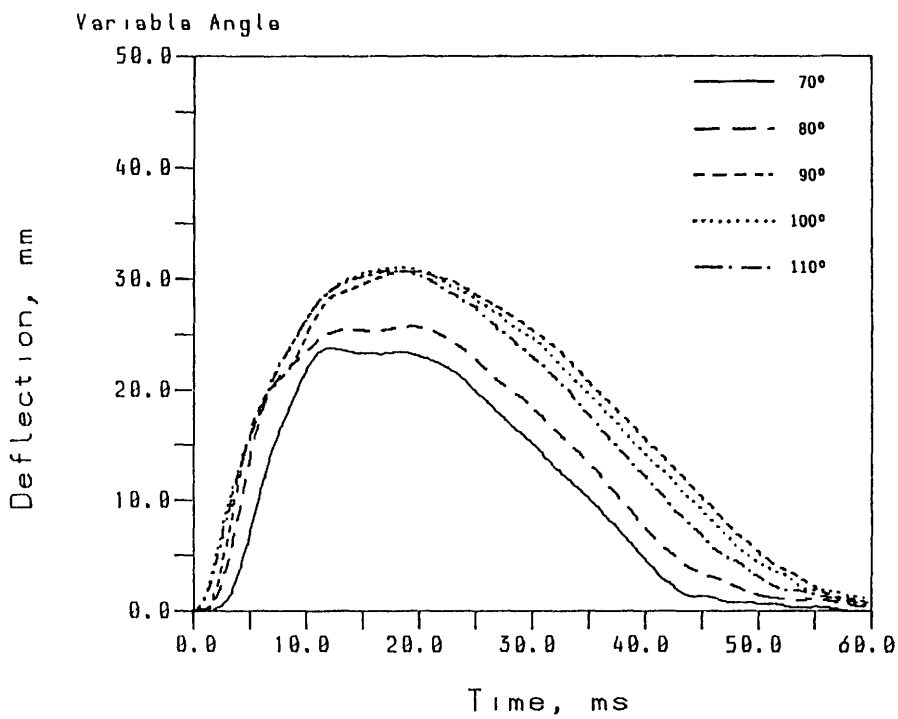

Fig. 6 : Time histories of rib deflection for five impact angles (70° to 110°)

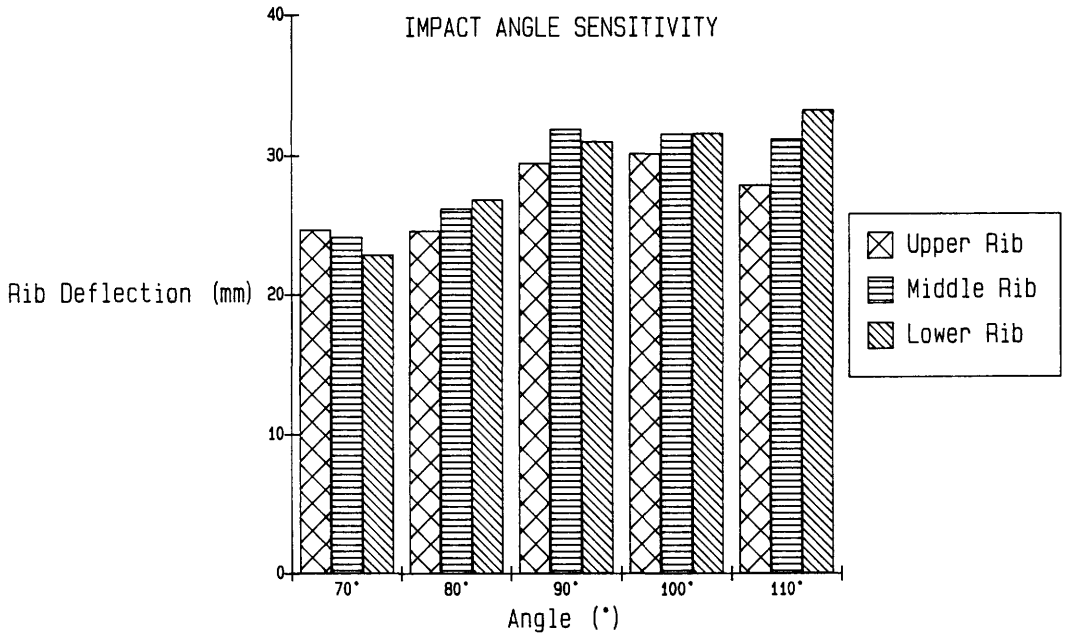

Fig. 7 : Comparison of peak rib deflection for the five impact angles

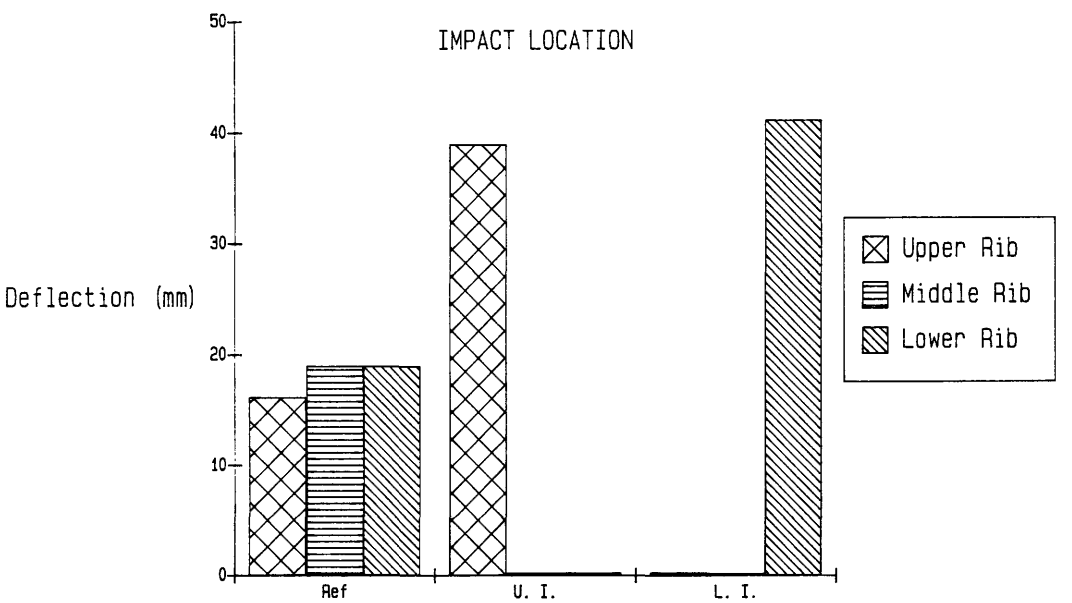

Fig. 8 : Comparison of rib deflection for localized and distributed impacts on the thorax

For symmetrical behaviour for forward and rearward lateral impacts, the relation between angle and deflection would be.

Deflection = Deflection 90° x Sin (impact angle)

It is noticeable that the 70° and 80° impacts give a deflection value lower than these theoretical values whereas the 100° and 110° tests give a higher value.

4.4 - Sensitivity of EUROSID thorax to impact location

The EUROSID thorax is made of three identical rib levels which are not together by a sternum.

Normally during a full-scale side impact test the three ribs would be loaded simultaneausly ; however a localized deformation of the car side could load only one or two of the ribs.

To evaluate this the thorax EUROSID sensitivity tests were performed using a pendulum with a 45 mm high front face. During the test the pendulum hits either the upper rib (2 tests) or the lower ribs (also two tests). The other impact parameters were identical.

Analysis of tests results shows that the deflection of the rib which is directly impacted is much higher than the deflection occuring when the three ribs are loaded together (figure 8) ; the duration of the deflection is also longer when only one rib is involved by the impact, but the shapes of the first part of the plots are identical.

4.5 - Thoracic sensitivity of EUROSID to temperature variation

Standard tests must be performed with a room temperature around 20° C, but it would be advantageous for the dummy to be usable over a range of temperature.

Tests were performed with room temperature equal to 15° C, 20° C and 25° C. The other parameters being identical in all the tests.

The values of average thoracic deflection are plotted on figure 9.

This figure shows closely similar results for 15° C, 20° C, and 25° C tests and this lets us confirm that the EUROSID thorax is not sensitive to temperature variation in the range of 15-25° Celsius.

5 - SENSITIVITY OF THE ABDOMEN

TNO and TRRL were in charge to conduct tests necessary for the evaluation of the thoracic sensitivity.

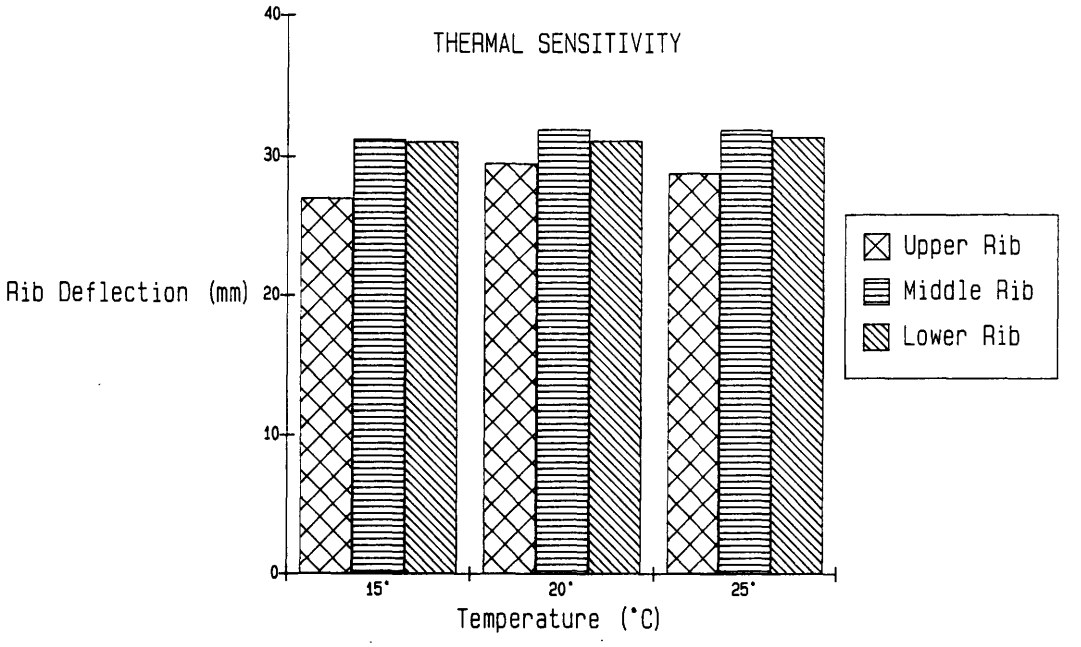

Fig. 9 : Sensitivity of the thorax to temperature

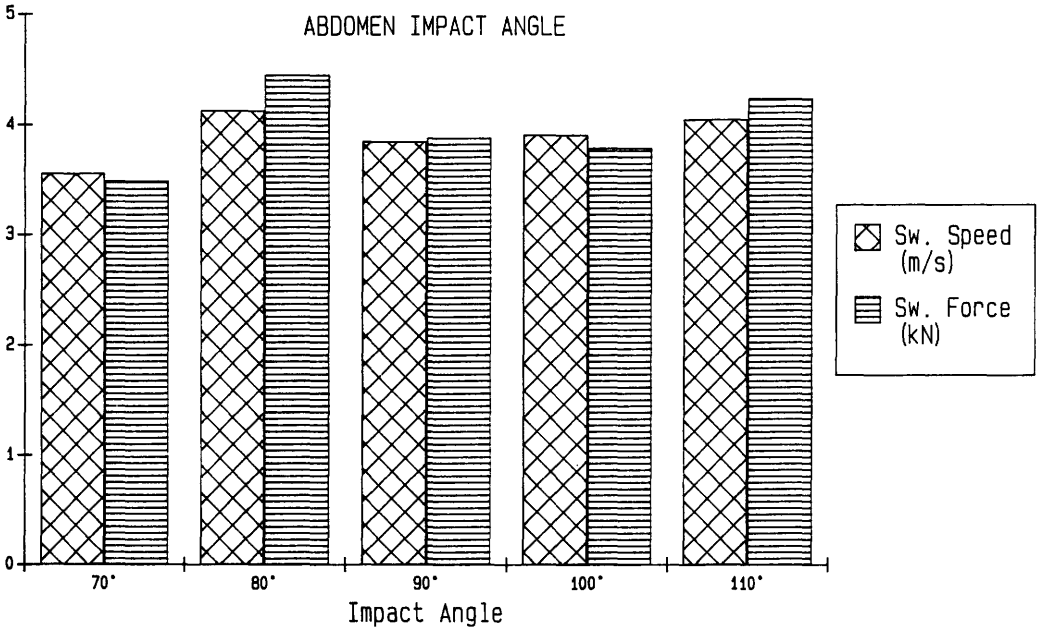

Fig. 10 : Abdominal switching speed and switching force as a function of impact angle

The EUROSID dummy is fitted with an abdomen specially designed to indicate a risk of abdominal injuries. This abdomen includes three switches located on one side which can be activated at a specific crush corresponding to a chosen force value. The dynamic characteristies of the abdomen are based on cadaver tests results.

As the EUROSID abdomen gives an output which is yes or no, the evaluation of its sensitivity can be made only by checking the test parameters values at which the switch contact occurs for different test conditions.

The most suitable reference parameters are the impact velocity and the switching impactor force.

The comparison of values of these two parameters can be made according to the angle of impact (70° to 110°, step 10°) impactor shape (4 different shapes) and impactor mass (18 kg, 23.4 kg, 28 kg).

5.1 - Abdomen sensitivity to angle of impact

Pendulum tests were performed on EUROSID abdomen ; the midsaggital plane of the dummy was oriented successively at 70°, 80°, 90°, 100°, 110°, 0° being the plane of the pendulum trajectory.

Figure 10 shows the values of the impact speed required to activate the abdominal switch for each of the 5 angle values.

This figure indicates a low sensitivity of the abdomen to impact angle : the impact speed necessary to activate one of the three switches stays within + 7.5 % of the value obtained at 90°.

It is also noticeable that the speed necessary to activate one of the switches can be either lower or higher than for 90° impacts : when an impact is exactly centered on a swith the speed necessary to activate it usually seems to be lower.

The same observation can be made for the switching impact force, but its variation is more important (+ 15 %, - 10 % of the 90° value). Both parameters (impact speed and impact force) vary in the same direction compared to the 90° values.

5.2 - Sensitivity of abdomen to impactor shape

The abdomen was tested with four impactor faces. All the probes were 150 mm width ; two of them were rectangles, (one 45 mm high and the other 70 mm). The third one was a 60° triangular prism impact on one edge and the last an horizontal semi-cylinder with a 35 mm diameter.

Compared to the standard impactor (70 x 150 mm rectangle) the small rectangle and the cylinder need a lower impact speed to activate the one of the abdominal switches. A lower surface of contact between the probe

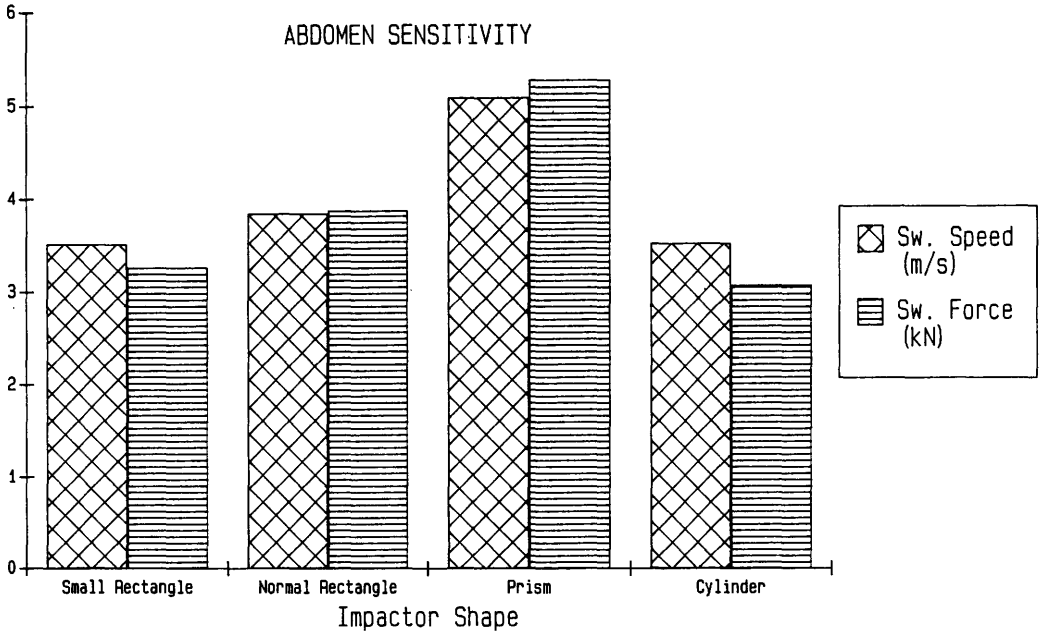

Fig. 11 : Effect of impactor shape on abdominal switching speed and switching force

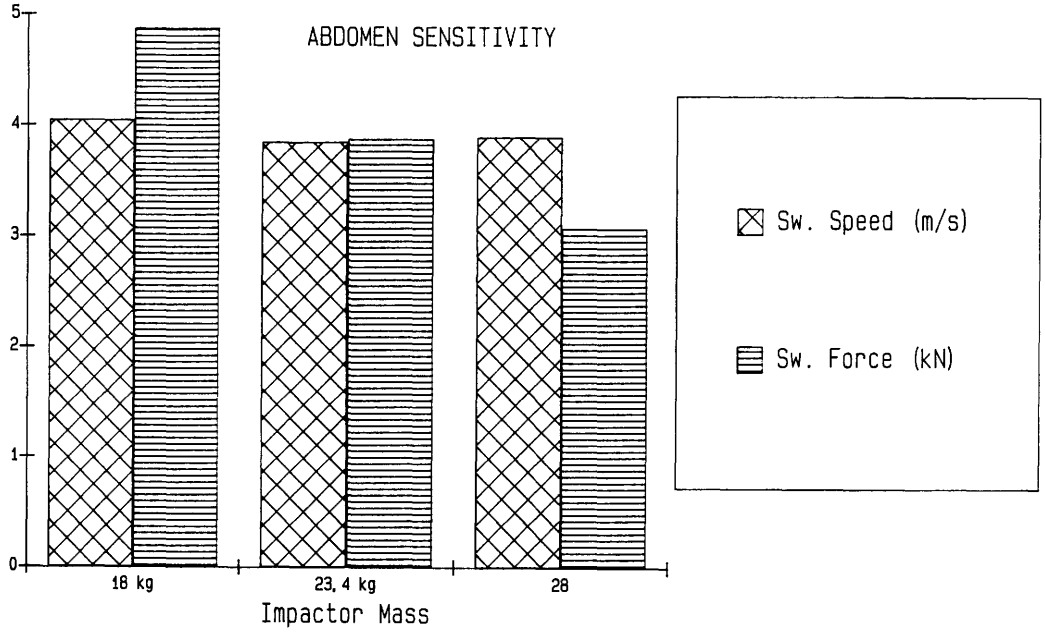

Fig. 12 : Sensitivity of the abdomen to impactor mass

and the abdomen explains these lower values ; the sharp prismatic probe needs an impact speed 32 % higher than the standard one to activate the abdominal switch (figure 11).

The same observations are made on the switching impactor force, but with a higher difference for the tests with the small rectangle and the cylindric impact inface compared to the standard one.

In a slightly different test programme where the impact velocity was the same for all impact forces a second laboratory observed a lower switching force with the prism face.

5.3 - Sensitivity of the abdomen to impactor mass

Beside the standard tests which were made with a 23.4 kg, impactor tests were performed with a 18 kg and a 28 kg impactor mass. The variation in impact speed required for switching by the different masses is five times lower than the variation in impactor mass itself ; this confirms a low sensitivity of the abdomen to impactor mass, even when the mass is increased compared to standard tests (figure 12).

In contrast the impactor force at switching varies by the same percentage as the impactor mass variation.

6 - SENSITIVITY OF EUROSID PELVIS

INRETS, TNO and TRRL for sled and temperature tests were in charge to conduct tests necessary for the evaluation of the thoracic sensitivity.

In the frame of the validation programme of EUROSID, the same types of tests were performed on the pelvis and on the thorax. The main parameters recorded during these tests were the compression force of the pelvis at the pubic symphysis (pubic force) and the transverse acceleration of the sacrum (pelvic acceleration).

6.1 - Pelvis sensitivity as a function af impact speed

These pelvis sensitivity tests were performed by impacting the pelvis on the greater trochanter. Two types of tests were performed : pendulum tests with Part 572 pendulum at impact speed of 4.4 m/s ; 5.0 m/s ; 6.2 m/s and impactor tests with a 17.3 kg impactor with impact speed of 6.2 m/s ; 8,5 m/s and 10.5 m/s.

The tests being performed in different conditions (different probe shape, different impactor weight...) it is not possible to agglomerate the results ; however it is possible to compare them.

Analysis of pelvic force versus time plots shows identical shapes but increasing with the impact speed, as indicated on figure 13. The same observation can be found in traces obtained from impactor tests (figure 14).

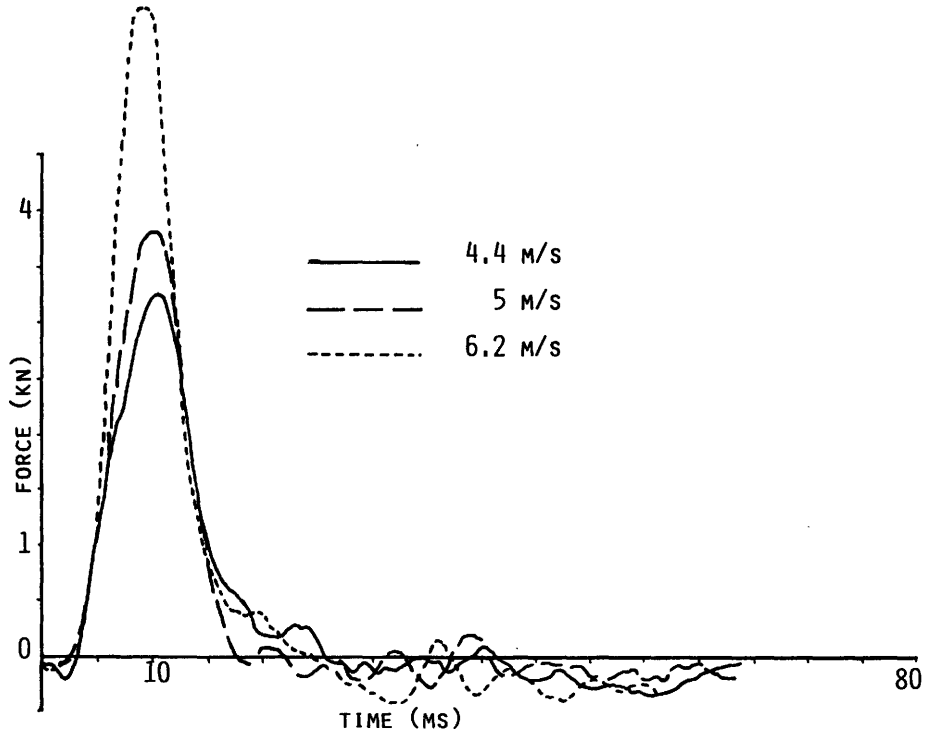

Fig. 13 : Time histories of pubic force in pendulum tests for three impact speeds

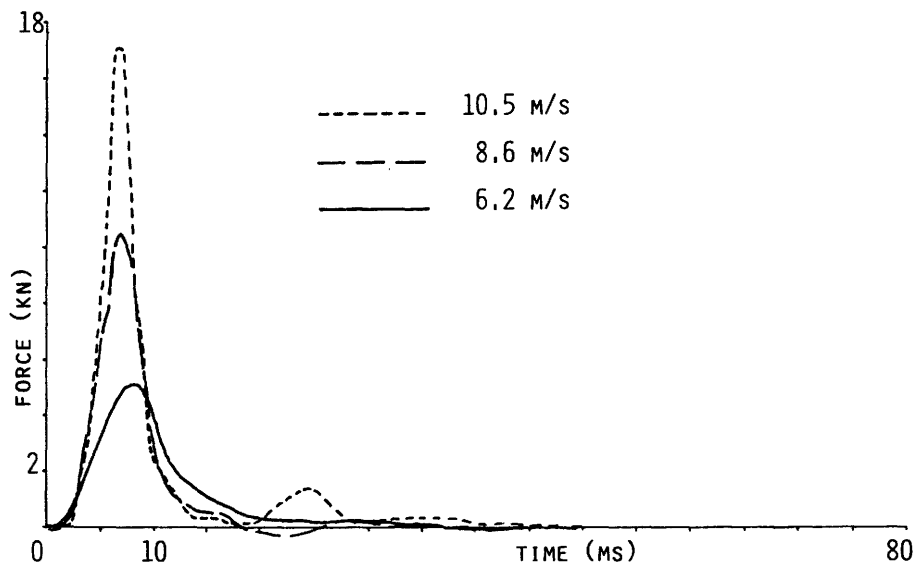

Fig. 14 : Time histories of pubic force in impactor tests for three impact speeds

Looking at the peak values of pubic force for these two test series shows a great sensitivity of the EUROSID pelvis to changes of impact speed : from 4.4 m/s to 6.2 m/s impact speed (+ 41 %) gives a pubic force increase from 3.26 KN to 6.0 KN (+ 84 %) and in impactor tests a speed increasing from 6.2 m/s to 10.5 m/s (+ 69 %) induces a pubic force increase from 5.18 KN to 17.13 KN (+ 230 %).

Sled tests in which a dummy hits its side against a flat rigid surface permits the evaluation of the pelvis sensitivity. Sled tests were performed at 4.7 m/s ; 5.6 m/s ; 7.0 m/s and 8.9 m/s impact speeds. When the speed increases from 4.7 m/s to 8.9 m/s (+ 68 %) the pubic force increases from 6.1 KN to 20.4 KN (+ 223 %)

The same types of observations can be made if we consider the pelvic acceleration, but with a lower sensitivity in pendulum and impactor tests, and a higher sensitivity in sled tests.

		Sensitivity factor
Pendulum	P. Force	2.05
	P. Accel.	2.00
Impactor	P. Force	3.33
	P. Accel.	2.87
Sled	P. Force	3.28
	P. Accel.	3.70

Table 3 : Pelvis sensitivity factor for speed variation.

6.2 - Pelvic sensitivity as a function of impacting mass

Most of the sensitivity tests were performed with a part 572 pendulum (23.4 kg). Tests with a lower mass (19 kg) and a higher (31 kg) were also performed at 4.3 m/s impact speed.

It is then possible to compare the effects of pendulum mass, the other parameters being kept identical.

Comparison of pubic force versus time plots shows a slope at the beginning and the end of the variation independent of the pendulum mass ; however tests performed with the heaviest mass correspond to a higher and sharper peak, as indicated on fig. 15.

Analysis of peak values shows that the pubic force increases slowly with the impacting mass (Fig. 16).

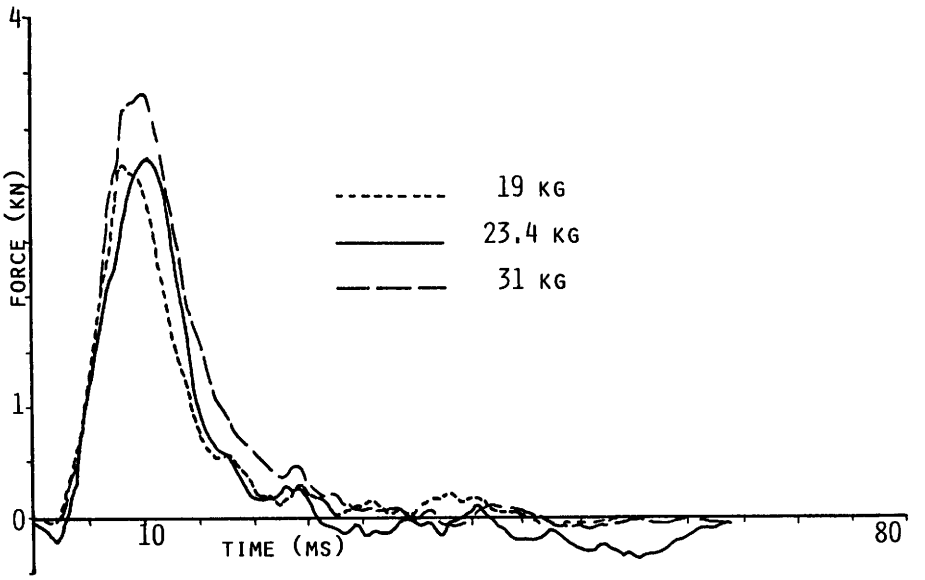

Fig. 15 : Time histories of pubic force for three values of pendulum mass

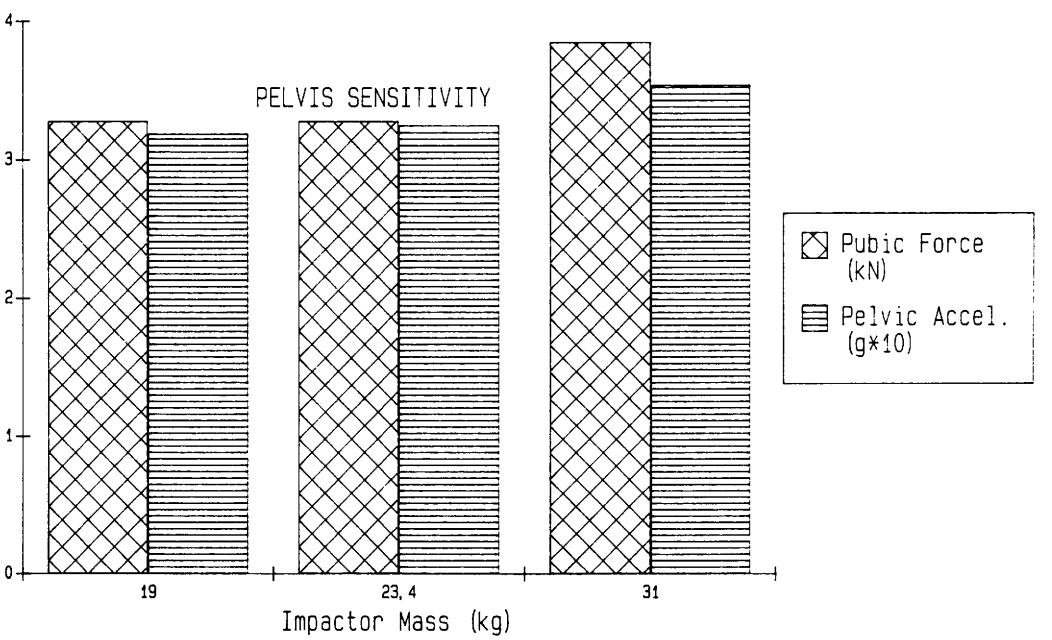

Fig. 16 : Pelvis sensitivity to mass variation

	Sensitivity factor
Pubic force	0.27
Pelvis accel.	0.22

Table 4 : Pelvis sensitivity factor to impacting mass

When the impacting mass increases from 19 kg to 31 kg (+ 63 %), the pubic force varies from 3 385 N to 3 880 N (+ 15 %) and the pelvic acceleration goes from 31.8 g to 35.2 g (+ 10.7 %).

6.3 - Pelvis sensitivity to impact angle

As with the thorax, the EUROSID pelvis was tested with impact angles different from 90°. The values between the pendulum trajectory and the symmetrical plane of the dummy were : 70° and 110°.

Figure 17 shows the surperposition of pubic impact force versus time for pendulum trajectories equal to 70°, 90°, and 110°. This figure indicates that the curves are similar, but the maximum of pubic load is higher in 90° tests than in 70° or 110° tests.

Comparison of maximum values indicates a decrease of about 7.5 % for 110° impacts and 13 % for 70° impacts compared to 90° ones (figure 18).

The values determined by trigonometric calculation would predict a decrease of 6%.

If we consider the pelvic acceleration angled impacts show also a decrease of peak transverse acceleration by 19 % for 70° impacts and by 9 % for 110° impacts.

6.4 - Pelvis/sensitivity to contact area

Beside the tests made with the part 572 pendulum of diameter 152 mm, two tests were performed with a 45 mm square contact area ; these tests were performed at an impact speed of 4.4 m/s.

	Part 572	45 mm Square	difference
Pubic force	3.26 KN	3.42 KN	+ 5 %
Pelvis accel.	32.15 g	23.3 g	- 30 %

Table 5 : Influence of contact area

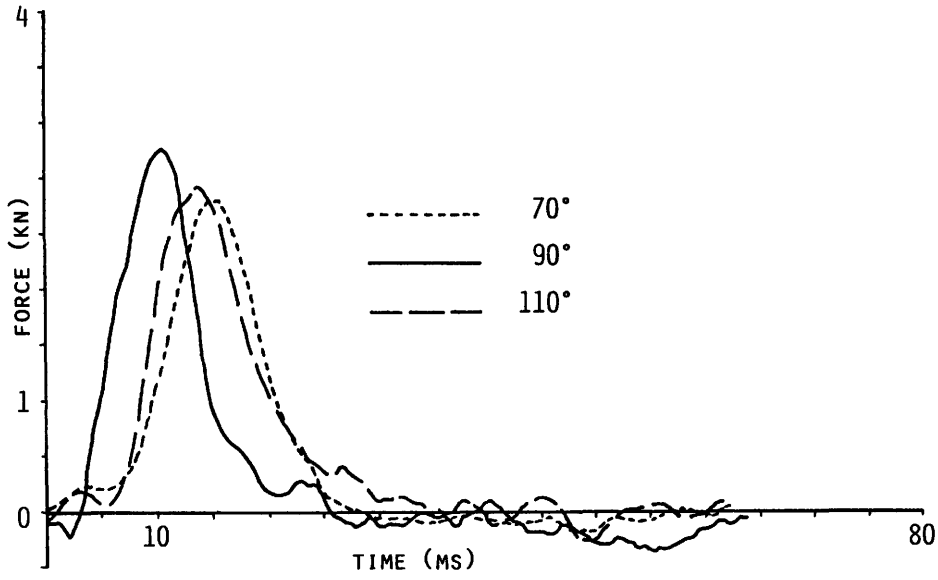

Fig. 17 : Time histories of pubic force for three impact angles

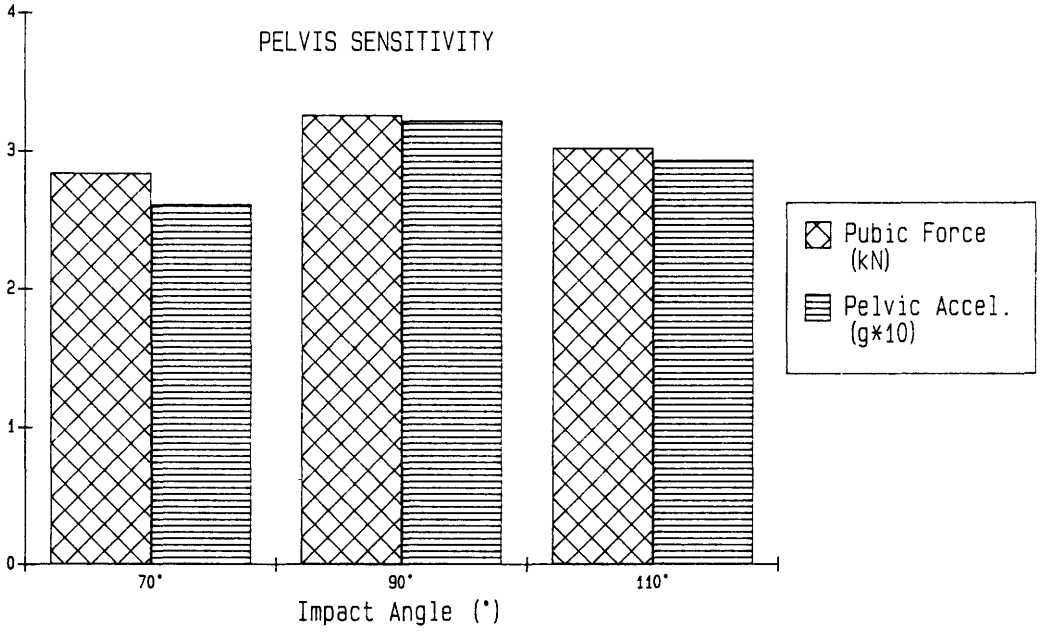

Fig. 18 : Sensitivity of the pelvis to impact angle

Comparison of pubic force and pelvic acceleration shows opposite variation : a localized impact increases the compression force of the pelvis, whereas it decreases greatly the pelvic acceleration : the explanation of these apparently contradictory results can be found if we consider that a localized impact would penetrate more which increases the value of the force transmitted to the pelvis, and because of the increased crush, it lowers the acceleration sustained by the pelvis.

6.5 - Sensitivity of pelvis to temperature

The same procedure as for the thorax was used to check the sensitivity of EUROSID pelvis to temperature variation. Pendulum tests were performed at 4.2 m/s with a standard Part 572 pendulum centered on the great trochanter in the following thermal conditions : stabilized room temperature equal to 15° C, 20° C, 25° C.

Figure 19 shows the traces of the pubic force versus time for these three conditions, and allows to make the following remarks :

- The shape of the plots is not modified by temperature effects within the range tested.

- Tests at 25° C give almost identical results than tests at 20° C.

- Tests at 15° C correspond to a 14 % higher pubic force compared to 20° C results.

However as the car to be tested is stationary and because of the lights used for high speed movies, the room temperature would be rather higher than below 20° C.

7 - EUROSID SENSITIVITY BASED ON THE RESULTS OF BARRIER TO CAR TESTS

The validation programme of EUROSID included several full scale tests. Some of them were accident reconstructions conducted by INRETS ; the others were mobile deformable barrier-to-car tests performed by BAST and TNO. The last ones can help to evaluate the sensitivity of EUROSID : these tests were conducted under EEVC configuration (4) but at different speed : 45 km/h (1 test) 50 km/h (2 tests) 55 km/h (1 test) : these tests enable us to verify the influence of the barrier impact speed on the EUROSID output. Two tests in which the barrier is in a crabbed mode were also to conducted : in these tests the impact speed was 54 km/h, which corresponds 50 km/h perpendicular component of the speed these tests results can be compared to those of the tests performed at 50 km/h in a pure 90° situation. All these tests were performed with the same struck car model.

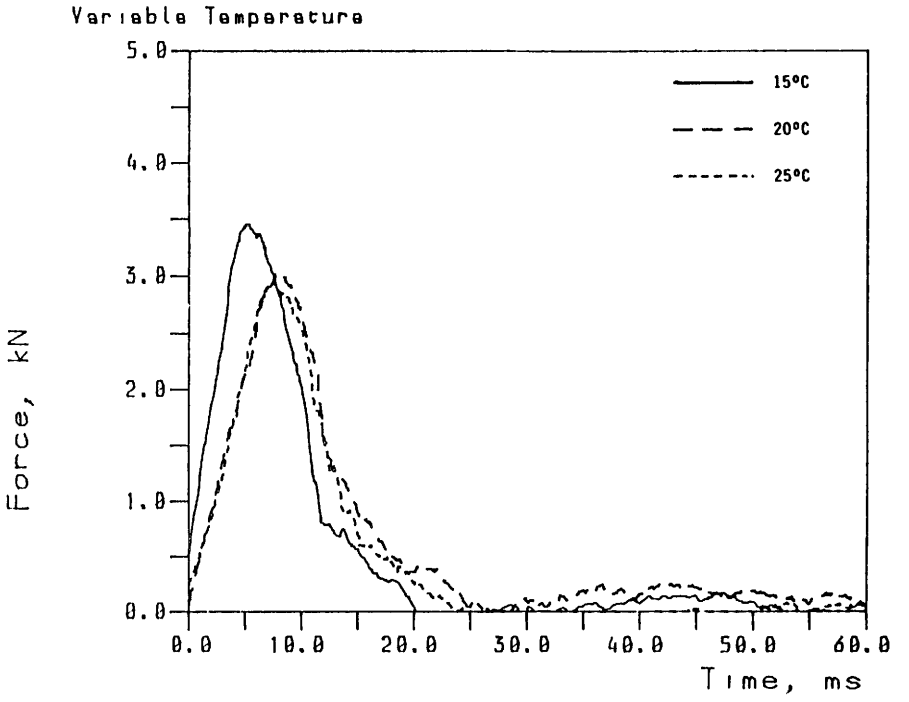

Fig. 19 : Time histories of pubic force for trhee values of room temperature

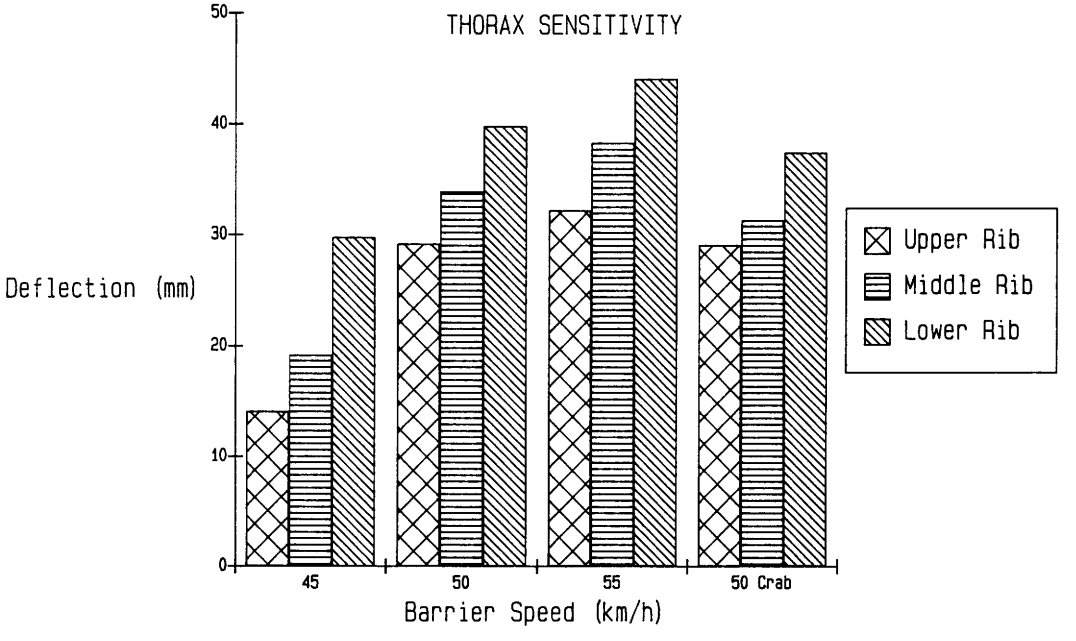

Fig. 20 : Thoracic deflection in MDB tests at different speeds, and for crabbed configuration

7.1 - Sensitivity of EUROSID to impact speed

The EUROSID sensitivity in full scale barrier to car tests can be mainly evaluated taking into account the injury parameters of the thorax and of the pelvis.

Figure 20 shows the values of maximum thoracic deflection according to impact speed. The value of thoracic deflection increases from top to bottom rib : for 50 km/h tests the deflection of the third (bottom) rib is 36 % higher than the deflection of the top rib. The value of the rib deflection increases clearly with the speed : when the impact speed is increased from 45 to 55 km/h (22 %) the average thoracic deflection goes up from 21 mm to 38 mm (81.6 %) ; if we consider the most deflection rib -which is the bottom one- the deflection is increased by 38 % for the same range of impact speed.

In the same tests the compression force of the pelvis was measured as well as the pelvic (sacrum) acceleration.

Table 6 gives the values of pubic force (peak and 3 ms values) and pelvic transversal acceleration (peak and 3 ms values).

Impact Speed	Pubic Force (KN)		Pelvic Accel. (g)	
	Peak	3 ms	Peak	3ms
45 km/h	4.7	4.4	80.5	73.7
50 km/h	5.1	4.7	82.9	74.3
55 km/h	6.2	5.6	97.5	90.8

Table 6 : pelvic injury parameters in MDB tests.

For all these parameters, their value increases clearly with the impact speed, and there is very few differences in terms of sensitivity in the range of impact speed of 45 to 55 km/h their value increases approximately 1.5 time more than the speed. This indicates a high sensitivity of the pelvis to speed variation, but not so high than the findings of pendulum sensitivity tests.

7.2 - Sensitivity of EUROSID to test configuration

The EEVC side impact procedure is based on a full scale barrier to car test, the barrier and its trajectory being perpendicular to the struck car at the time of the impact ; however it has been suggested that the test procedure is modified in order to have the barrier in a crabbed mode during the test. Two tests were performed in this configuration in the EUROSID evaluation programme.

As indicated on figure 20 , the crabbed mode gives lower thoracic deflection than the pure 90° impact, even if the perpendicular component of the speed is the same in the two configurations. This difference is found on the three levels of ribs.

The average decrease in thoracic deflection is 5.7 % of the value found in pure 90° tests, and reaches 6.7 % for the bottom rib, which is the most deflected one.

Table 7 includes the values of pubic force and pelvic acceleration (peak and 3 ms values) for 90° and crabbed configurations, The comparison of values shows a decrease of all the parameters in crabbed mode compared to the pure 90° impact.

	Pubic Force (KN)		Pelvic Accel. (g)	
	Peak	3 ms	Peak	3 ms
90°	5.2	4.7	85.2	77.6
Crabbed	4.2	3.6	75.4	67.0

Table 7 : Comparison of pelvis injury parameters in 90° and crabbed tests.

In a general way the crabbed test which was expected to be more severe than the pure 90° impact gave lower loading on the dummy.

8 - DISCUSSION AND CONCLUSIONS

Analysis of more than 150 tests conducted by the five contractors of the EUROSID validation programme allows to find the main characteristics of the EUROSID sensitivity.

The EUROSID dummy is highly sensitive to the variation of impact speed ; this is found as well in impactor and pendulum tests, as in sled tests and in full scale barrier to car tests.

The EUROSID dummy has a low sensitivity to impacting mass variation : the ouput parameter varies 2.5 to 3 times less than the impacting mass.

The EUROSID dummy has a low sensitivity to angle of impact within plus or minus 20° ; however angles below 90° correspond to a lower response than the angles higher than 90°.

The EUROSID is sensitive to the contact area of the impact : a lower contact surface area increases the value of the injury parameters. This is especially true for the thorax and the pelvis.

The EUROSID dummy is almost not sensitive temperature variation within the range of 15°-25° C. Only low temperature increases the value of the pubic force.

All the analysises confirm an almost good behaviour of the EUROSID in terms of sensitivity : the dummy is highly sensitive to the parameter directly related to injury mechanisms.

It has a low or very low sensitivity to external parameters (temperature, angle...).

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REPEATABILITY AND REPRODUCIBILITY OF THE EUROPEAN SIDE IMPACT DUMMY

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ABSTRACT

Five European laboratories, INRETS, BASt, APR, TRRL and TNO, have performed an extensive evaluation programme for the European Side Impact Dummy (EUROSID). Approximately 500 tests were conducted with four dummies. Among other aspects the repeatability and reproducibility of these four EUROSIDs are evaluated by means of impactor tests, sled tests and Moving Deformable Barrier tests. The repeatability of the dummy can be considered acceptable. The results of the reproducibility tests are promising; however, no obvious conclusions could be obtained from these tests at the end of the programme, because some dummy components had already been damaged due to the large number of (sometimes excessive) previous tests.

AN EXTENSIVE EVALUATION PROGRAMME for the European Side Impact Dummy (EUROSID) has been undertaken by INRETS, BASt, TNO, APR and TRRL. Four dummies were built and the laboratories agreed upon a test programme on these dummies. A major topic in the evaluation programme was the repeatability of response of the dummy to similar impacts. Impactor tests were performed on each relevant body part (i.e. shoulder, chest, abdomen and pelvis), as well as pendulum tests with the head/neck system. The repeatability of the complete dummy was evaluated in sled and MDB tests. The repeatability in response between different dummies ('reproducibility') was also checked by sled tests. This paper summarizes the most important findings obtained from this test programme.

NECK REPEATABILITY TESTS

Introduction

Twenty neck pendulum tests were performed by TNO and APR in close agreement with the Standard Part 572 neck calibration procedure. The test set-up and results of the TNO tests [1]*) will be presented here and compared with those of APR [2].

*) numbers in parentheses designate references at the end of paper.

Test set-up

The head and neck (without bracket) are attached in a lateral mode to the Part 572 neck pendulum. An aluminium rod with two plastic spheres (total mass 35 grammes) is screwed into the existing hole on top of the Hybrid-III head, in order to measure from a high speed film the head motion in the impact plane, as well as to measure the trajectory of the 'projected' centre of gravity (see Fig. 1). The head is equipped with a triaxial accelerometer. The Standard Part 572 calibration velocity is applied to the pendulum, while the prescribed pendulum acceleration is approximated (see 'Test results').

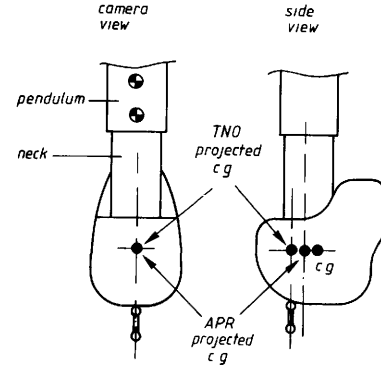


Fig. 1. Test set-up neck pendulum tests; definition of 'projected' centre of gravity.

Test results

In the TNO tests the 5 g's and 20 g's time limits of this standard input were fulfilled. However, the maximum pendulum acceleration requirement (20-24 g's) was not fulfilled. In the APR tests this acceleration was only slightly higher than the required limit. However, the time duration requirements were not fulfilled. Therefore the input on the head-neck system was different in the TNO and APR tests (see Fig. 2).

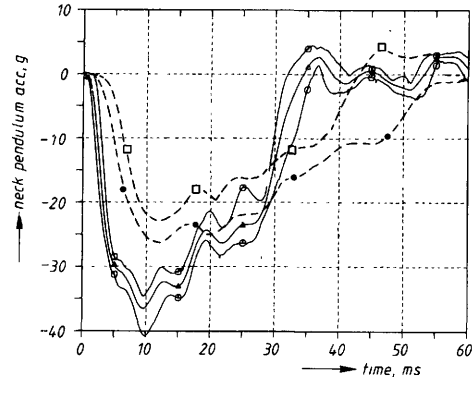


Fig. 2. Pendulum acceleration versus time corridor (o-o) including mean results (Δ-Δ), obtained from TNO neck repeatability test, compared with the APR corridor (●-□).

Table 1 summarizes the most important test results in terms of mean value, standard deviation and coefficient of variation. The maximum head accelerations as well as the maximum lateral head c.g. displacement, are considerable higher in the TNO tests. This is caused by the difference in pendulum acceleration, the slight difference in definition of 'projected' centre of gravity as well as by the different high-speed camera set-up. Figure 3 shows the head c.g. trajectory corridor with respect to the pendulum obtained from the APR repeatability tests. Figures 4 up to and including 6 show the acceleration versus time histories of the head obtained from the TNO tests.

Table 1. Results of neck pendulum repeatability tests.

Test input/results		TNO			APR		
		mean	SD	CV	mean	SD	CV
pendulum impact speed	(m/s)	6.81	0.05	0.7%	7.06	0.01	0.1%
max. pendulum acc.	(g)	35.9	0.9	2.5%	25.1	0.9	3.6%
max. long. head acc.	(g)	16.7	0.7	4.2%	7.5	0.5	6.7%
max. lat. head acc.	(g)	23.6	0.7	3.0%	15.0	0.8	5.3%
max. vert. head acc.	(g)	35.9	1.3	3.6%	26.5	1.9	7.2%
max. lat. proj. c.g. displ.	(mm)	159.2	3.2	2.0%	110.4	2.9	2.6%
max. vert. proj. c.g. displ.	(mm)	135.0	7.0	5.2%	139.6	2.8	2.0%
max. head flexion	(degr.)	112.4	2.1	1.9%	108.7	5.7	5.2%

Only small differences are observed in the results between TNO and APR with respect to the maximum vertical head c.g. displacement and the maximum head flexion angle. The coefficient of variation is 1.9% to 5.2% in the TNO tests and 2.0% to 7.2% in the APR tests. The standard deviation of the results obtained from film analysis is influenced by the accuracy of this analysis.

TNO performed 25 and APR 28 neck pendulum tests without mechanical failure. However, it was noted in these test series (with a severe input) that the rubber parts of the neck need some time to recover after each test.

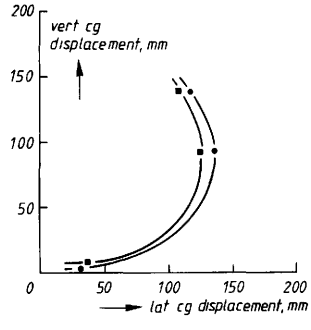


Fig. 3. Head c.g. trajectory corridor with respect to the pendulum obtained from APR neck repeatability tests.

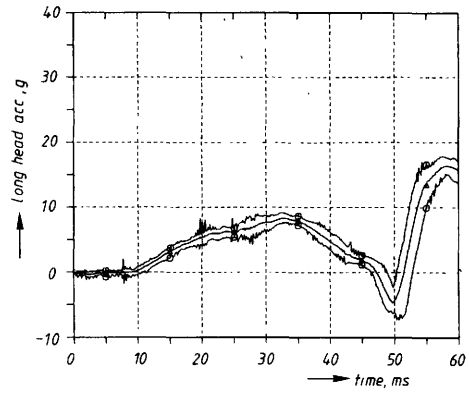


Fig. 4. Longitudinal head acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO neck repeatability tests.

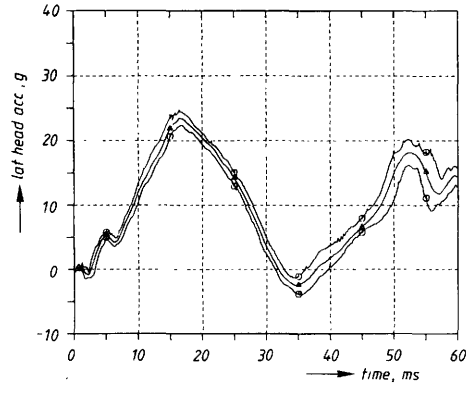


Fig. 5. Lateral head acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO neck repeatability tests.

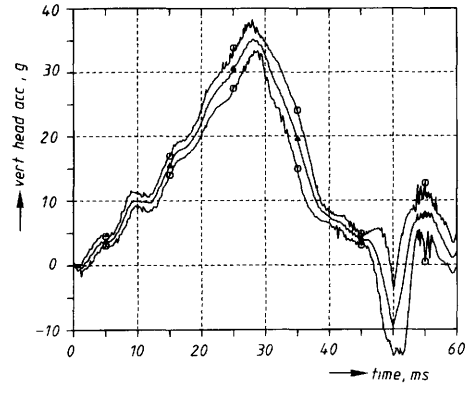


Fig. 6. Vertical head acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO neck repeatability tests.

IMPACTOR REPEATABILITY TESTS ON SHOULDER, CHEST, ABDOMEN AND PELVIS

Introduction

Twenty identical impactor tests were performed on each body part in order to evaluate the repeatability of the EUROSID. The test set-up and results of the TNO tests [1] will be presented and compared with those of TRRL [3] and INRETS [4].

Test set-up

The dummy is placed in an upright position on a flat, rigid, horizontal surface with no back support. The dummy is positioned such that the ribs are horizontal. Both legs are placed in a forward, parallel position, perpendicular to the body and supported at the heels. Three different arm positions are specified (see Fig. 7):
- hands tied together and positioned above the head in chest tests;
- upper arm forward 20 degrees to the vertical, forearm horizontal and straight ahead in shoulder tests;
- arms extended horizontally forward in abdomen and pelvis tests.

The arms were supported by light-weight rods at the wrist in the positions with the arms forward. The dummy did not wear additional clothes besides the wet-suit.

The Standard Part 572 calibration pendulum of 23.4 kg mass, suspended by 4 wires fixed to the laboratory ceiling, is used as an impactor by TNO and INRETS. The shoulder, chest and pelvis tests are performed with this flat impactor face (152 mm diameter). In the abdomen tests another impactor face is used: a rectangular shaped hardwood face with a height of 70 mm (150 mm width in TNO tests; 70 mm width in INRETS tests). This simulated armrest is fixed to the pendulum, resulting in a pendulum mass of 24.3 kg in the TNO tests and 23.7 kg in the INRETS tests. An impactor guided by linear bearings is used in the TRRL tests. The dimensions and mass are identical to that of the Part 572 pendulum.

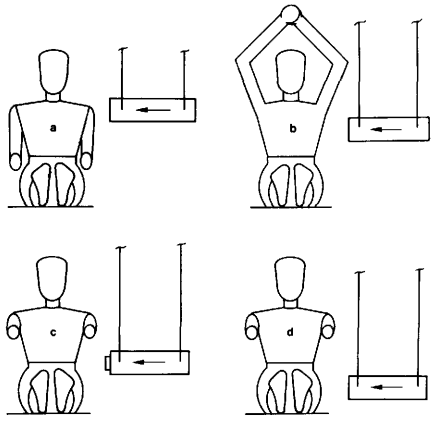


Fig. 7. Test set-up impactor tests; shoulder repeatability tests (a), chest repeatability tests (b), abdomen repeatability tests (c) and pelvis repeatability tests (d).

The impactor speed for the repeatability impacts is 4.3 m/s in the shoulder, chest and pelvis tests, and 6.3 m/s in the abdomen tests. The central longitudinal axis of the impactor is centred perpendicular to the mid-sagittal plane of the dummy (90 degrees impact) and aligned with:
- the pivot centre of the shoulder clavicle joint in the shoulder tests;
- the midsection of the middle rib in the chest tests;
- the midsection of the middle leaf spring in the abdomen tests;
- the centre of the great trochanter representation in the pelvis tests.

The dummy is instrumented with accelerometers in the pelvis and chest (spine and three ribs). Furthermore, the special EUROSID instrumentation is available: three rib deflection units in the chest, three on/off switches in the abdomen and three force transducers in the pelvis (pubic symphysis and two iliac wings). The pendulum is instrumented with an accelerometer to calculate the impact force. In some of the test series the results are shifted in time to obtain initial slope alignment.

For all tests the temperature is maintained at 20 $\pm$ 1 °C.

Shoulder test results

The results of the shoulder repeatability tests performed by TRRL and TNO are summarized in Table 2. The maximum force and deflection appear to be somewhat higher in the TNO tests. This could be caused by the differences in impactor (non-guided or guided) and by the different Channel Filter Classes (600 against 180).

The coefficient of variation is 5.2% to 6.9% in the TNO tests and 6.8% to 8.3% in the TRRL tests. Figure 8 shows the force versus time corridor obtained from the TNO shoulder repeatability tests.

No mechanical failure is observed in both test series.

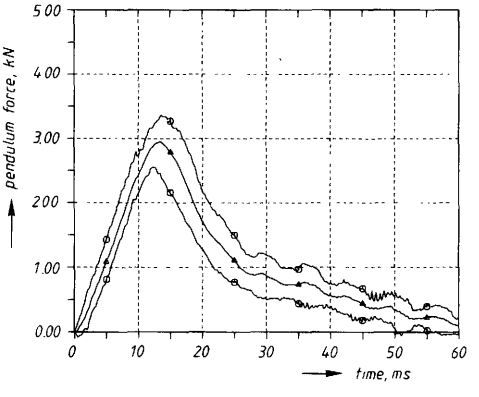


Fig. 8. Pendulum force versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO shoulder repeatability tests.

Table 2. Results of shoulder repeatability tests.

Test input/results		TRRL*			TNO		
		mean	SD	CV	mean	SD	CV
impactor speed	(m/s)	4.30	0.05**	--	4.28	0.03	0.7%
max. impactor force	(kN)	2.65	0.18	6.8%	2.98	0.21	6.9%
max. lateral deflection	(mm)	65.8	10.8	8.3%	84.6	4.4	5.2%

* results of 5 tests out of 20
** range around mean value.

Chest test results

The results of the chest repeatability tests performed by TRRL and TNO are summarized in Table 3. The maximum deflections of the three ribs are almost similar in the TRRL tests, whereas in the TNO tests they are increasing from upper to lower rib. This is probably caused by the difference in impactor-guidance. The coefficient of variation of the maximum rib deflections is much lower in the guided impactor tests of TRRL (1.3% to 3.4% against 2.2% to 5.2%). This is also observed in the results of the rib accelerations. However, differences in Channel Filter Class (1000 for TNO against 180 for TRRL) also have a strong influence on this result. The coefficient of variation of the maximum lateral spine acceleration and maximum impactor force are relatively high.

Figures 9 up to and including 12 show the middle rib deflection versus time corridor, the middle rib acceleration versus time corridor, the lateral spine acceleration versus time corridor and the pendulum force versus time corridor respectively, obtained from the TNO chest repeatability tests.

No damage or mechanical failure is observed in the TNO and TRRL test series.

Table 3. Results of chest repeatability tests.

Test input/results		TRRL			TNO		
		mean	SD	CV	mean	SD	CV
impactor speed	(m/s)	4.31	0.03	0.7%	4.32	0.03	0.7%
max. impactor force	(kN)	--	--	--	5.76	0.71	12.3%
max. upper rib defl.	(mm)	29.3	1.0	3.4%	23.3	1.2	5.2%
max. middle rib defl.	(mm)	30.3	0.4	1.3%	31.2	0.7	2.2%
max. lower rib defl.	(mm)	29.6	0.8	2.7%	34.9	0.9	2.6%
max. upper rib acc.	(g)	198.9	7.3	3.7%	297.3	22.0	7.4%
max. middle rib acc.	(g)	216.8	2.3	1.1%	431.5	42.3	9.8%
max. lower rib acc.	(g)	184.5	5.2	2.8%	373.4	42.9	11.5%
max. lat. spine acc.	(g)	--	--	--	25.5	3.7	14.5%

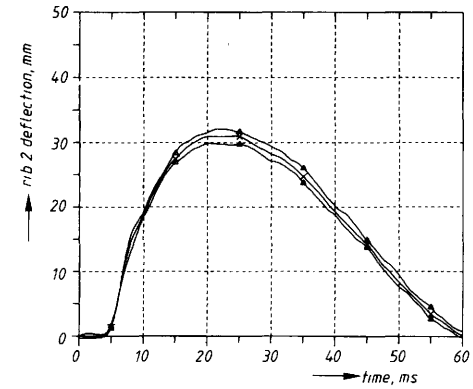


Fig. 9. Middle rib deflection versus time corridor (Δ-Δ), including mean result (x-x), obtained from TNO chest repeatability tests (slope alignment applied).

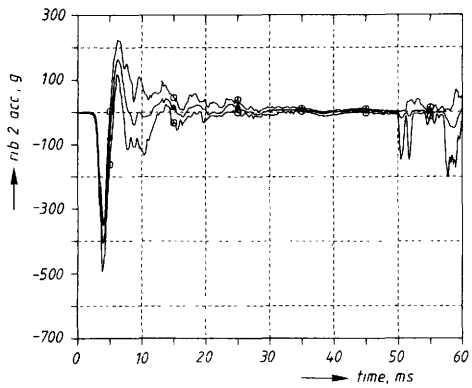


Fig. 10. Middle rib acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO chest repeatability tests (slope alignment applied).

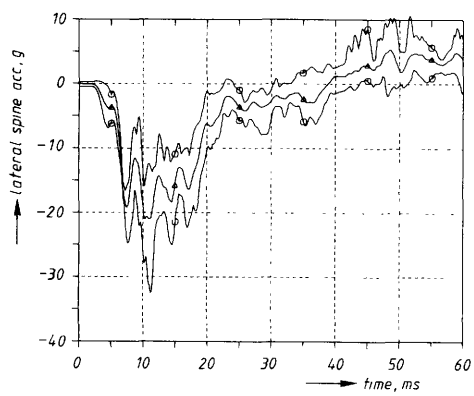


Fig. 11. Lateral spine acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO chest repeatability tests (slope alignment applied).

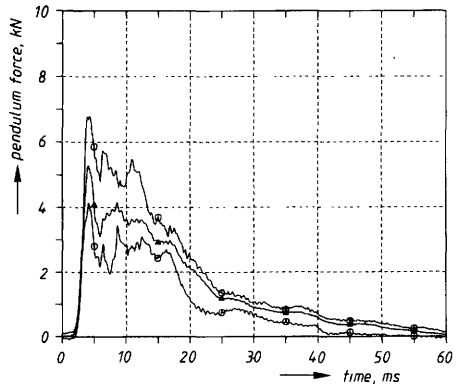


Fig. 12. Pendulum force versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO chest repeatability tests (slope alignment applied).

Abdomen test results

The results of the abdomen repeatability tests performed by TNO and INRETS are summarized in Table 4.

Table 4. Results of abdomen repeatability tests.

Test input/results		INRETS*			TNO		
		mean	SD	CV	mean	SD	CV
impactor speed	(m/s)	6.30	0.05	0.8%	6.33	0.02	0.3%
max. impactor force	(kN)	11.42	0.39	3.4%	10.39	0.31	3.0%
switch contact force	(kN)	4.98	0.39	7.8%	4.55**	0.08	1.8%

* only 14 tests due to damage of abdomen
** values assessed from smoothed curves.

The coefficient of variation of the maximum impactor force is similar in both test series (3.0% respectively 3.4%), whereas it differs considerable with respect to the switch contact force (7.8% in the INRETS tests against 1.8% in the TNO tests). The switch contact force is defined as the pendulum force at the time of switch contact. The switch contact forces had to be assessed (by defining a smoothed curve), due to oscillations in the pendulum acceleration time histories of the TNO tests. Therefore they are not very reliable. Figure 13 shows the pendulum force versus time corridor obtained from the TNO abdomen repeatability tests.

A smaller impactor face is used in the INRETS tests, which probably caused damage to the abdominal foam after test no. 14 (the rubber/lead slab came off the foam-layer).

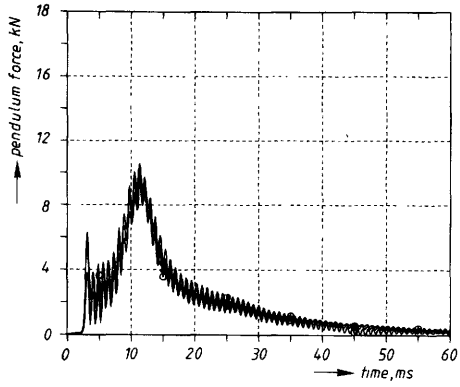


Fig. 13. Pendulum force versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO abdomen repeatability tests (slope alignment applied).

Pelvis test results

The results of the pelvis repeatability tests performed by INRETS and TNO are summarized in Table 5. The maximum impactor force and pubic symphysis force are somewhat higher in the INRETS tests, which is probably caused by the somewhat higher impactor speed [4]. The coefficient of variation varies from 1.2% to 6.6% in the TNO tests and from 2.0% to 3.3% in the INRETS tests. Figure 14 up to and including 16 show the pendulum force versus time corridor, the lateral pelvis acceleration versus time corridor and the pubic symphysis force versus time corridor respectively, obtained from the TNO pelvis repeatability tests. The ilium force is almost zero in these tests and therefore the results are not presented here.

Some tears in the skin and foam of the pelvis were observed during the evaluation programme.

Table 5. Results of pelvis repeatability tests.

Test input/results	INRETS			TNO		
	mean	SD	CV	mean	SD	CV
impactor speed (m/s)	4.39	0.05	1.1%	4.30	0.01	0.2%
max. impactor force (kN)	9.10	0.18	2.0%	7.28	0.09	1.2%
max. pubic symph. force (kN)	3.03	0.10	3.3%	2.11	0.14	6.6%
max. lat. pelvis acc. (g)	30.5	0.9	3.0%	30.7	1.4	4.6%

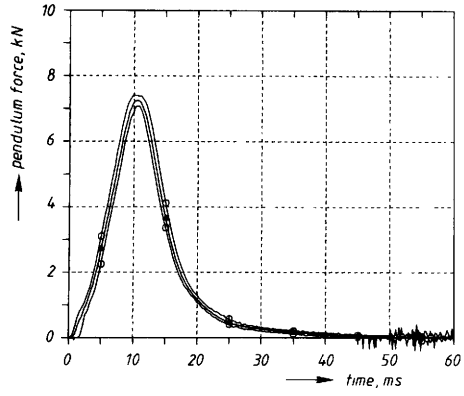


Fig. 14. Pendulum force versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO pelvis repeatability tests.

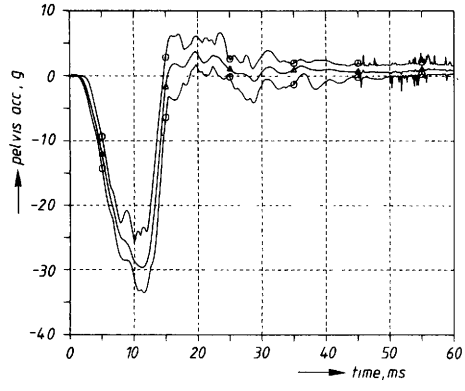


Fig. 15. Lateral pelvis acceleration versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO pelvis repeatability tests.

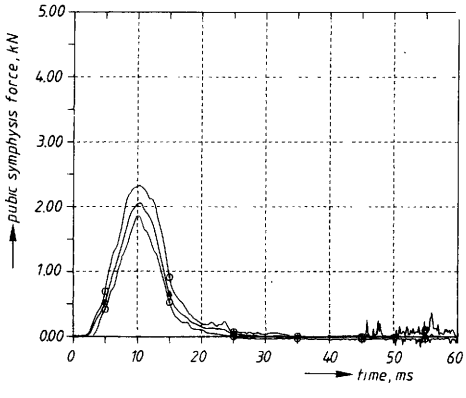


Fig. 16. Pubic symphysis force versus time corridor (o-o), including mean result (Δ-Δ), obtained from TNO pelvis repeatability tests.

SLED AND MDB REPEATABILITY TESTS

Introduction

The repeatability of the complete dummy can be evaluated by analysing the results of series of three sled tests performed by INRETS [4] and the results of three Moving Deformable Barrier tests performed by the BASt [5]. The test set-up and results are presented in this section.

Sled test set-up

INRETS has performed two series of three padded wall sled tests in the Heidelberg configuration [4]. PVC-foam blocks and APR-padding, which are fixed to the two force plates (position slightly different from Heidelberg-sled), are impacted by the chest and pelvis of the EUROSID (see Fig. 17). The left shoulder in these tests (impact side) is moved forward by taping the left wrist to the right arm. The sled impact speed is 6.6 to 6.7 m/s.

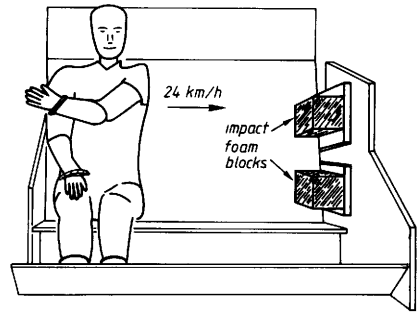


Fig. 17. Test set-up INRETS padded wall sled tests.

Sled test results

Figure 18 up to and including 24 show the results of the three sled tests with APR-padding. The lower rib deflection was almost zero and is not presented here. The repeatability of the shape of these curves can be considered acceptable. Similar results were obtained from the sled tests with the PVC-foam blocks.

A minor damage to the chest was observed in the INRETS tests. Direct severe impacts on the shoulder can cause mechanical failures.

Fig. 18. Upper rib deflection versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

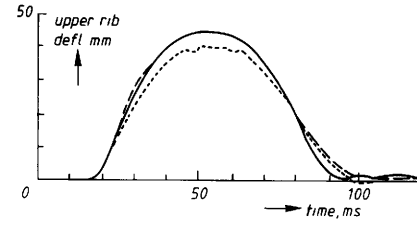


Fig. 19. Middle rib deflection versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

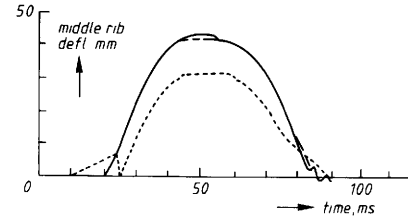


Fig. 20. Upper, middle and lower rib acceleration versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

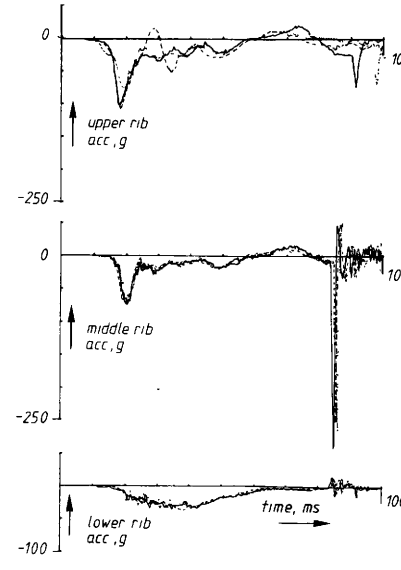


Fig. 21. Lateral chest acceleration versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

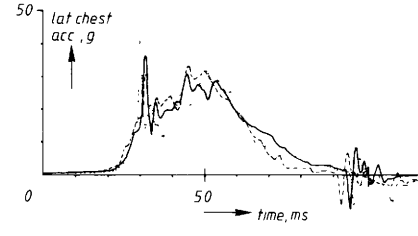


Fig. 22. Iliac wing force versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

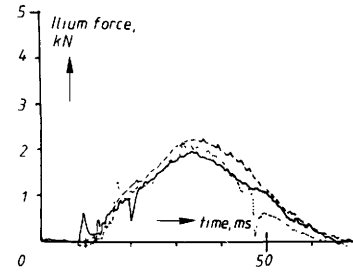


Fig. 23. Pubic symphysis force versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.

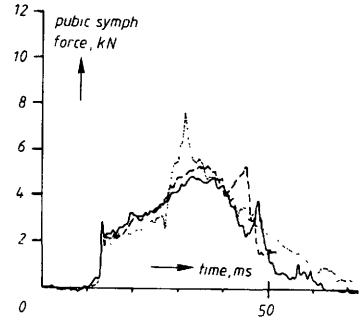
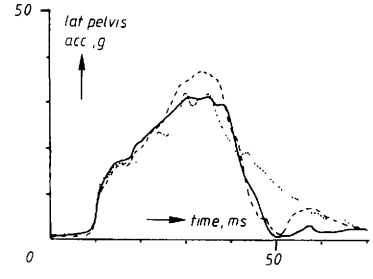


Fig. 24. Lateral pelvis acceleration versus time histories obtained from three padded wall (APR-padding) sled tests performed by INRETS.



MDB test set-up

The BASt has performed three Moving Deformable Barrier (MDB) tests [5]. The impact speed of the MDB, with an EEVC-IV impactor face [6], is 50 km/h and the impact angle is 90 degrees (see Fig. 25). The EUROSID dummy is seated in a driving position with the hands on the steering wheel. In test no. 2 the seat was very soft due to the age of the car and therefore the dummy sat somewhat lower with respect to the vehicle (Volkswagen Golf).

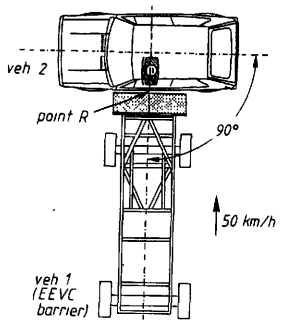


Fig. 25. Test set-up BASt Moving Deformable Barrier tests.

MDB test results

Fig. 26 up to and including 32 show the results of three MDB tests performed by the BASt. The results appear to be very repeatable, except the (middle) rib acceleration time histories which are (probably) influenced by the damping of the upper arm. The lateral flexion angle of the head relative to the upper torso varies from 91 to 95 degrees in these tests. No abdominal switch contact occurred in these tests.

No serious damage was observed in these tests.

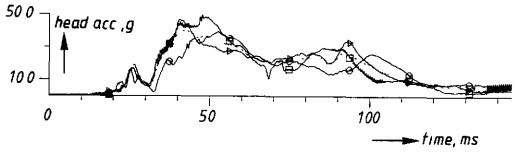


Fig. 26. Resultant head acceleration versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

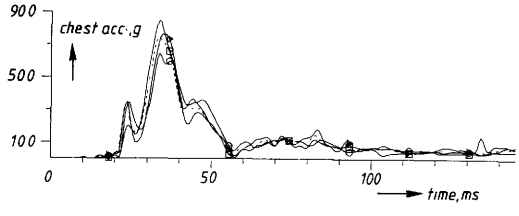


Fig. 27. Resultant chest acceleration versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

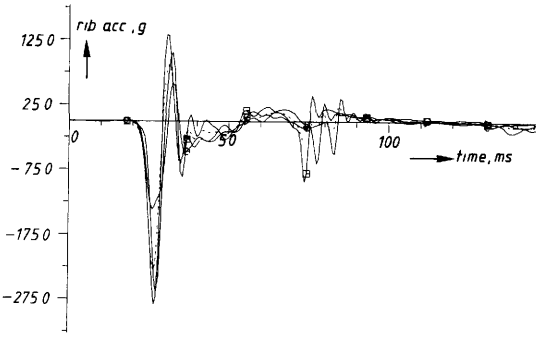


Fig. 28. Middle rib acceleration versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

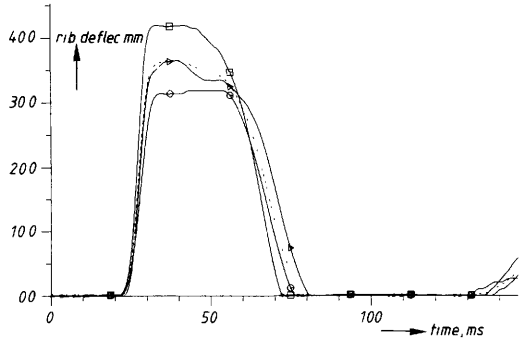


Fig. 29. Middle rib deflection versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

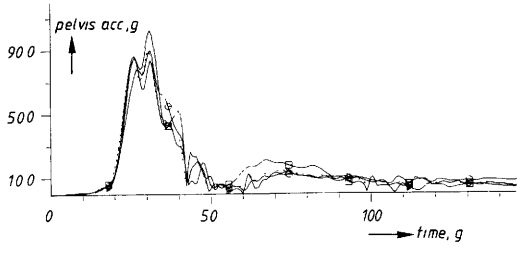


Fig. 30. Resultant pelvis acceleration versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

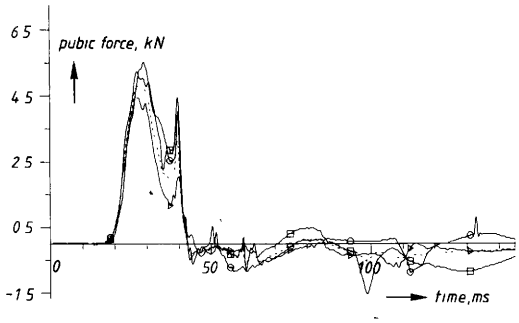


Fig. 31. Pubic symphysis force versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

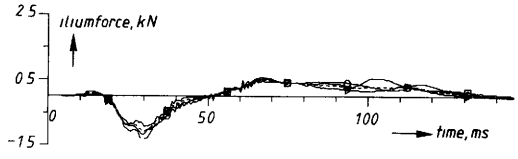


Fig. 32. Left ilium force versus time histories, including mean result (----), obtained from three MDB tests performed by BASt.

REPRODUCIBILITY TESTS

Introduction

In order to evaluate the reproducibility of the dummy TRRL has performed three rigid wall sled tests with each of the four dummies [3]. The test set-up and results are presented in this section.

Test set-up

In the TRRL tests the impact wall of the Heidelberg-sled is modified slightly; the chest force plate is extended 30 mm towards to the dummy (to avoid tilting of the dummy resulting from large differences in chest and pelvis flexibility). The top side of the chest force plate is lowered into a position typical of modern cars to avoid direct shoulder impact. Furthermore, the arms of the dummy are set straight and the hands are placed on the knees. TRRL has performed three rigid wall sled tests (impact speed 7.0 m/s) with each of the four dummies [3].

Test results

The overall coefficient of variation (CV) of the 12 sled tests is presented in this section. The CV of the maximum rib deflections and acceleration varies over the three ribs from 8.0% to 15.3% and from 12.1% to 33.0% respectively. The CV of the maximum pubic and ilium force is 10.9% and 50.3% respectively, while that of the maximum lateral pelvis acceleration is 10.3%.

The four EUROSID dummies were tested by TRRL at the end of the evaluation programme and some dummy components were already damaged at that stage (e.g. tears in flesh-simulating material). The four dummies had been subjected to various previous tests (only MDB tests; or impactor and MDB tests; or impactor and sled tests; or impactor, sled and car-to-car tests). This could cause high CV values when the repeatability between the four prototypes was evaluated. The results of the lower rib seemed to be disturbed sometimes by interference with the abdominal flesh. No abdominal switch contact was observed in these tests. The coefficient of variation of the maximum iliac wing force is very high, probably due to the rigid impact (only a small amount of 'flesh' over the iliac wing).

The coefficient of variation of the thoracic wall force in these 12 sled tests appears to be good (6.4%), showing a repeatable loading behaviour of the dummy. However, there was a significant difference (at the 5 percent level) between the pelvic wall forces generated by the four dummies, but this may well have been due to the different amount of pelvic flesh damage suffered by the dummies.

DISCUSSION

The repeatability and reproducibility of response is a major consideration when the performance of a dummy is evaluated. The repeatability of the EUROSID is checked by means of series of pendulum side impacts performed by different laboratories on all relevant body parts of the dummy. The ratio between standard deviation and mean value ('coefficient of variation') of the peak results of these tests varies as follows:

- 1.9% to 7.2% for the neck;
- 5.2% to 8.3% for the shoulder;
- 1.1% to 14.5% for the chest;
- 1.8% to 7.8% for the abdomen;
- 1.2% to 6.6% for the pelvis.

The relatively high coefficient of variation (CV) for the chest is caused by the variations in maximum lateral spine acceleration. In the chest pendulum impacts performed within the framework of the EEC Biomechanics Programme Phase IV [7], the spine accelerations of the four evaluated side impact dummies also gave the highest CV-value (from 6.0% for the INRETS dummy to 24% for the MIRA dummy). During the repeatability (and reproducibility) test programme the dummy and instrumentation are not calibrated, but are only inspected visually for damage. This aspect as well as the repeatability of the dummy set-up have a strong influence on the repeatability of the dummy response.

In a paper by Donnelly et al. [8] concerning the repeatability and reproducibility of the NHTSA Side Impact Dummy a coefficient of variation of 6% or less is considered to be good; a CV of 8% or less is considered acceptable. The repeatability of the various body parts of the four EUROSID 'first prototypes' could be considered acceptable in this respect. The repeatability of a dummy should not be evaluated by the amplitude response ('peak values') only, but also by the time response to similar impacts. The time response corridors obtained from the pendulum repeatability tests and presented in this paper in general show a good repeatability of the EUROSID.

Repeatability of the test set-up is much more difficult in sled and MDB tests than in impactor tests. However, the results of these tests performed by INRETS and BASt show an acceptable repeatability of the complete dummy. It should be noted that the position of the arm (out-of-the-way or 'protection' of chest) could strongly influence the repeatability of the dummy in full-scale side impact testing. Evaluation of a proposed seating position for the EUROSID [9] will be necessary in this respect.

The repeatability in response between the four dummies ('reproducibility') was also checked by means of sled tests. They were performed at the end of a large test programme in which the four dummies had been subjected to different amounts of potentially damaging impacts. Also, the dummies were individually assembled from separate components by the four laboratories. Furthermore, the calibration procedures of the components had not been fully developed yet. Differences were found in the peak value response of the four 'first-prototype' dummies. However, the shape of the response curves were consistent for the four dummies. In this respect the results of the reproducibility tests are promising. Further evaluation of this aspect should be conducted with the next version of EUROSID.

CONCLUSIONS

1. More than 200 pendulum/impactor repeatability tests have been performed on the neck, shoulder, chest, abdomen and pelvis of the four first prototype EUROSID's.

2. The repeatability of the EUROSID with respect to amplitude and time response in the impactor/pendulum tests can be considered acceptable to good.

3. The repeatability of the EUROSID in (six) padded wall sled tests and (three) Moving Deformable Barrier tests appears to be acceptable.

4. Damage or mechanical failure of some dummy components is observed during the evaluation programme.

5. Based on the results of the evaluation programme some design changes of these 'first prototypes' have been proposed to improve the durability and repeatability of the EUROSID.

ACKNOWLEDGEMENTS

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CERTIFICATION AND SETTING-UP OF EUROSID

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Abstract

Each test dummy must be calibrated or certified, as every other measuring device, before being used in crash tests. The certification procedure is a set of tests on dummy components and on the whole dummy which have to be carried out to confirm that the dummy is correctly adjusted and the response of defined impacts lie within specified limits. As such a special certification procedure for the EUROSID has to be developed. This procedure described here is based on the calibration experience of institutes which developed and built the proto-type dummy parts.
Furtheron the assembly of the EUROSID and the instrumentation is described. A seating procedure for the EUROSID into the testcar is proposed and discussed.

Introduction

Before assembling the dummy, the head, neck, shoulder, thorax, abdomen and pelvis have to be first visually checked. Then certification is performed on these parts, some parts requiring removal from the dummy and others not.

The following is a summary of the certification procedures.

- A certification procedure for the head has not been developed at this time, but suggestions are made based on earlier work.
- The certification of the neck consists of a test similar to the Part 572 pendulum test except that the head is mounted sideways. The neck bending and head rotation is measured.
- The shoulder certification is based on a simple standard pendulum impactor test.
- The thorax certification consists of a full range of tests on each rib module where damper, springs and the complete module is tested with impactor drop tests.
- The abdomen certification is done by two impactor tests with an "armrest impactor": one low energy test where the contact switch should not close and one high energy impact test where contact is made.
- The pelvis certification consists of calibrating the strain gauge force transducers on each iliac wing with a hydraulic jack, and a pendulum test on the side of the pelvis of the assembled dummy using a Part 572 pendulum.

* This paper was prepared with the help of the colleges Mr. Janssen (TNO), Mr. Roberts (TRRL), Mr. Cesari (INRETS), Mr. Bendjellal (APR), who were responsible for the drafting of the certification procedures for the individual dummy components.

All certification data given below may change slightly for the production proto-type dummies because the given data were evaluated from the preproduction prototypes used in the "EUROSID Validation Program."[1] For each of the following certification procedures it is required that testing be done between the temperatures of 18 and 22 degrees Celsius.

Certification of the EUROSID Head

The EUROSID head is a commercially available spare of the Hybrid III dummy. A defined head certification procedure, for instance a drop test on the side of the dummy head checking that the measured impact response is within a defined range, has not yet been developed because this was not an aim of the "EUROSID Validation Program." However, in the phase IV of the "Biomechanics Program"[2] head drop tests with different dummy heads were carried out and from this a certification procedure could be easily devised. The condition in this program was a free-fall head drop test from a height of 0.5 m onto a flat rigid surface, the side of the head impacting at an angle of 25 deg. A typical response of the Hybrid III head was a head deceleration of about 260 g.

Certification of the EUROSID Neck

The first check of the dummy neck should be focused on the "line of sight" of the dummy. If the head centerplane is not in the midsaggital plane of the dummy - e.g. the neck is permanent bent or twisted - the circular section buffers must be replaced. Then the upper and lower nut of the neck must be tightend so that the length of the neck from the upper plate to the lower plate is in the range of 134 mm - 136 mm. The now following EUROSID neck certification will be done with the standard Part 572 pendulum calibration equipment. The head is laterally installed on the pendulum; (Figure 1).

The neck should be mounted, without bracket, on a rigid aluminium plate (thickness: 9 mm) fixed to the pendulum. The distance between the head c.g. and the sensitive axis of the pendulum accelerometer should be 345 mm. The head midsaggital plane should be vertical and should coincide with a plane passing through the pendulum lateral centerline.

The pendulum should be released and be allowed to freely fall from a height to achieve a velocity of 3.4 m/s $\pm$ 0,1 m/s.

The pendulum is decelerated by an impact on a fixed aluminum honeycomb and the neck is laterally bent. The deceleration time-history of the pendulum should correspond to the deceleration-time pulse specified in Figure 2. The maximum pendulum deceleration should not exceed 33 g and not be lower than 27 g.

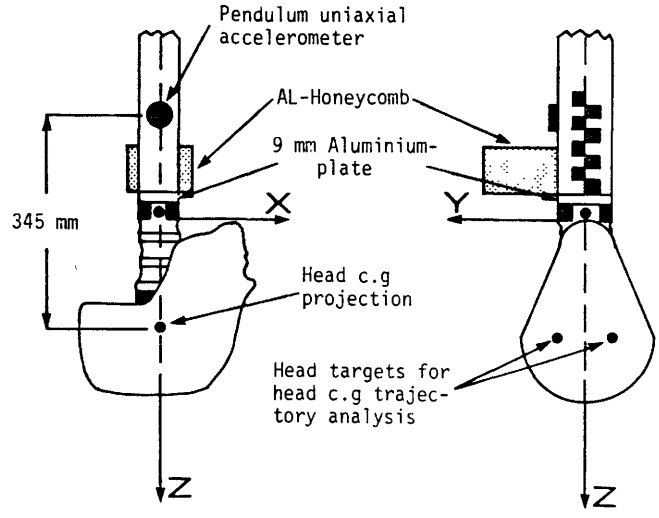

Figure 1: Neck Certification Test Set-Up

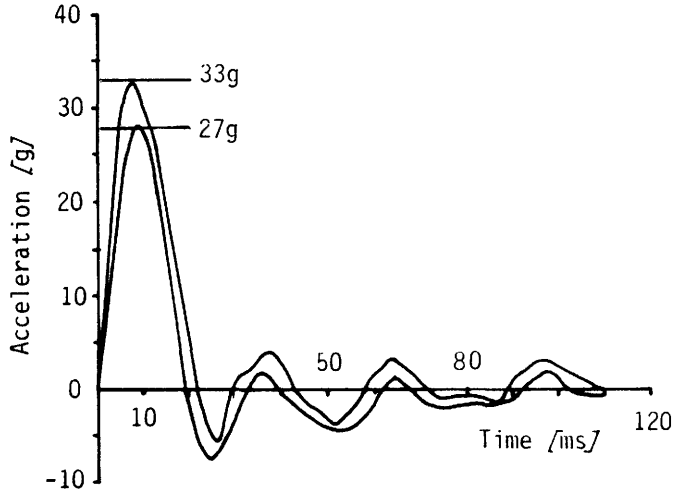

Figure 2: Pendulum acceleration-time corridor

The head should be equipped with a 3-axis accelerometer mounted on its c.g. A uniaxial accelerometer should be used for the measurement of the pendulum acceleration. Its location will be in accordance with the PART 572 specifications. The head and pendulum accelerations should be processed using a 1000 CFC and a 60 CFC respectively.

The head c.g. displacements and the head flexion angle relative to the pendulum should be measured by appropriate device or method. For the neck certification the following specifications are given:

- The maximum head resultant acceleration should be 19.8 ± 1 g and should occur between 14.5 und 17.0 ms.
- The maximum head flexion angle relative to the pendulum should be 65.8 ± 1 degrees and should occur between 72 and 80 ms.
- Specifications concerning head c.g. displacements in horizontal and vertical direction will be specified when the corresponding results will be available.

The neck has to be changed if the given certification values can not be achieved.

Certification of the EUROSID Shoulder

The shoulder of the EUROSID is certified in a simple Part 572 type of impact test. The face (ø150 mm) and mass (23.4kg) of the impactor is the same as the Part 572 impactor. The impactor must be suspended from a rigid support by four wires with the centre line of the impactor at least 3 m below the rigid support. The included angle of the wires must not be greater than 20 degrees. (A linearly guided impactor will result in higher force levels since the arm slides across the face of the impactor during the impact.) The face of the impactor should be lightly dusted with french chalk prior to each certification impact.

The dummy should be sat on a flat horizontal rigid surface with the anterior posterior axis of the dummy perpendicular to the direction of impact. The dummy legs should be horizontal and the thorax vertical. To maintain this position the dummy may need to be propped up. If this is the case the props must not prevent the dummy falling sideways in the direction of the impact. The dummy should be positioned so that the axis of the impactor is common with the axis of the upper arm pivot. The struck arm should be simply supported at the wrist with the upper arm at an angle of 40 degrees forward of the vertical and the forearm horizontal. The hand of the unstruck arm should be placed on the dummy's lap.

The impactor should freely swing onto the shoulder of the dummy. The impact velocity of the impactor shall be between 4.2 and 4.4 m/s. The peak deceleration of the impactor shall be between 9 and 14 g (filtered to Channel Class 180). If the shoulder fails to meet the specification the mechanics of the shoulder should be inspected and cleaned. The condition of the upper arm flesh should be inspected for obvious damage and the shoulder return force should be reset. To reset the shoulder return force the arm should first be removed.
The force required to move the cam forward, when applied within 5 mm of the outer edge of the clavicle, should be between 20 and 25N in the forward a-p direction. To adjust the return force the length of the elastic cord should be adjusted at the rear of the neck. If the shoulder still fails certification the upper arm should be changed.

Certification of the EUROSID Thorax

The EUROSID thorax consists of three identical rib modules. Figure 3 shows the main components of this rib module: the spring-damper system, the piston-cylinder assembly with the deflection measuring transducers and rib, all components fixed in a rigid spine box.

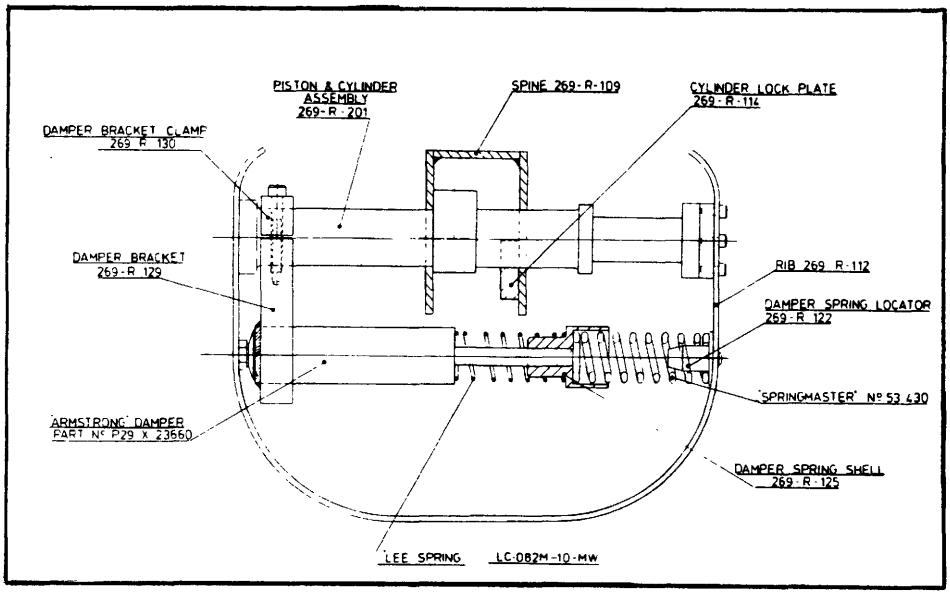

Figure 3: Rib module of the EUROSID

Each rib is individually certified in three separate sets of tests. The first test is designed to certify the complete module. The other two tests are designed to certify the two main components of the module, the damper and the primary rib stiffness.

All the module certification tests can be carried out on a simple falling mass impact rig. A simple drop rig is shown below in Figure 4 and 5.

Two impactors are required for certification. The main impactor is based on the Part 572 impactor face but with a mass of 7.78 kg. The second impactor is used to certify the damper and damper springs, it is a shaped impactor with a mass of 1 kg. The main requirement for the drop rig is that there should be a free drop height for the impactor of 5 m and that the impactors should be guided throughout the impact.

Full rib module certification is the first certification test that should be carried out. If full rib module certification fails, the damper should first be removed and be tested for the presence of air in with the oil. If necessary the damper should be bled, and the length of stroke (50 mm) be checked. If the damper passes certification without alteration the primary rib stiffness should be checked. Having confirmed certification of the damper and rib the module should be reassembled and newly tested as a full module.

Certification of the Rib Module

The certification of the full rib module is a simple series of impacts, using the Part 572 type impactor. The rib should first be removed from the spine unit and mounted vertically in the test rig with the struck side of the rib uppermost. Figure 4 shows the mounted rib module on the drop test rig.

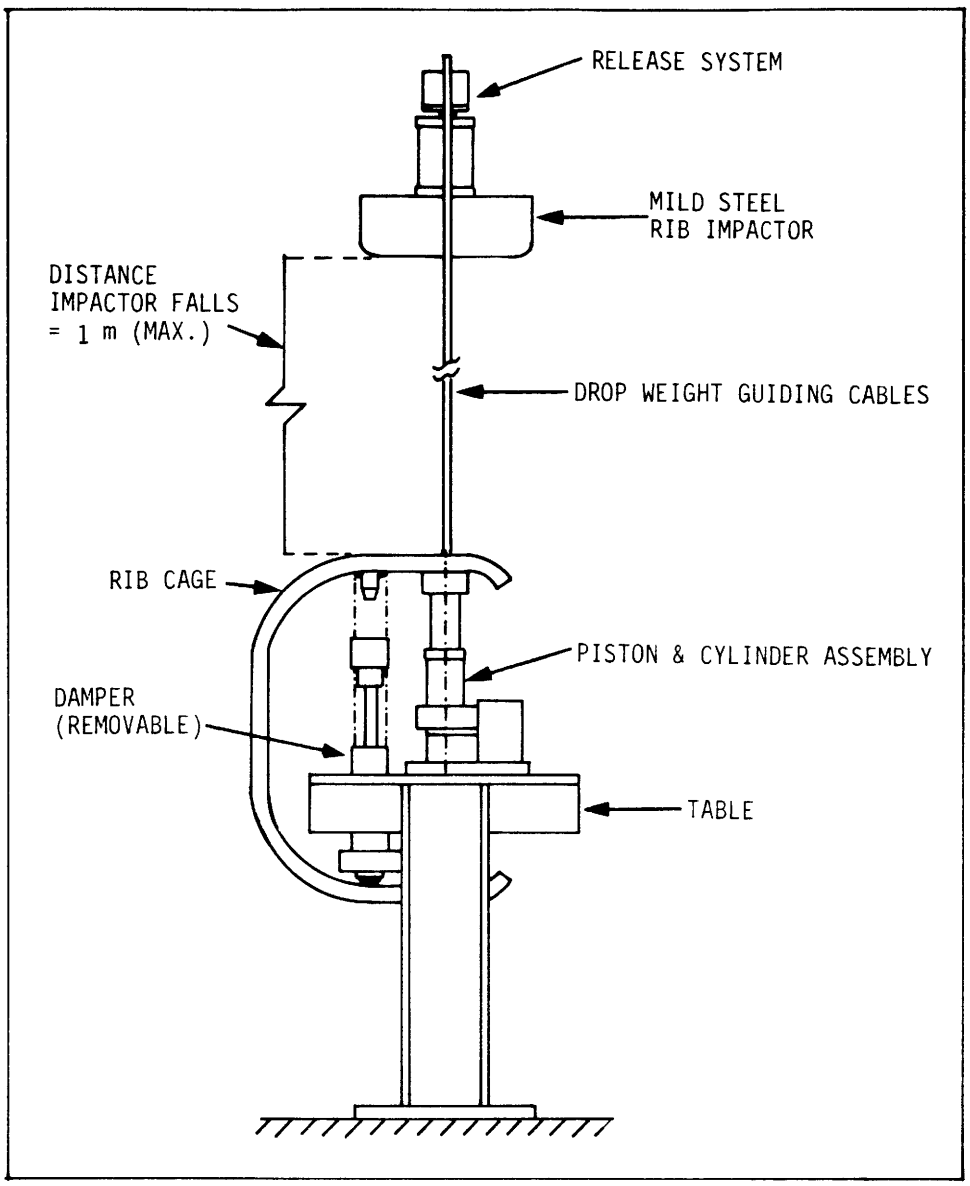

Figure 4: Rib certification rig with complete rib module.

The impactor should be released from a series of prescribed heights and allowed to fall free onto the rib module. The mass falls on the axis of the piston. These data can be recorded immediately from the thorax transducer instrumentation unit. The certification corridor is given in Table 1 If the rib module deflection fails to lie within this corridor, the rib and damper should be put throughout the other certification tests.

Impact Velocity (m/s)	Drop Height (mm)	Minimum Displacement (mm)	Maximum Displacement (mm)
1.0	51	10.0	14.0
1.5	115	16.5	20.5
2.0	204	23.5	27.5
2.5	319	30.0	34.0
3.0	459	36.0	40.0
3.5	625	41.5	45.5
4.0	816	46.0	51.0

Table 1: Certification Corridor for Full Rib Module

Certification of the Damper

The certification of the damper is based on the peak displacement of the damper during a series of impacts. The damper is fitted with both the damper return spring and the damper spring for these tests. The compressed length of the damper return spring should first be set to 70 mm. The test set-up is shown in Figure 5. The drop heights and the certification corridor is given in Table 2. If a single test fails to meet the corridor the test can be repeated. If a damper fails certification it should first be bled and if it fails a second time it should be exchanged.

Impact Velocity (m/s)	Drop Height (mm)	Minimum Displacement (mm)	Maximum Displacement (mm)
3.13	500	13.64	15.83
4.43	1000	18.69	21.10
5.42	1500	22.24	24.89
6.26	2000	25.06	27.91
7.00	2500	27.38	30.39
7.67	3000	29.39	32.49
8.29	3500	31.10	34.29
8.86	4000	32.61	35.81
9.39	4500	33.93	37.10
9.90	5000	35.14	38.22

Table 2: Certification Corridor for Damper and Damper Spring

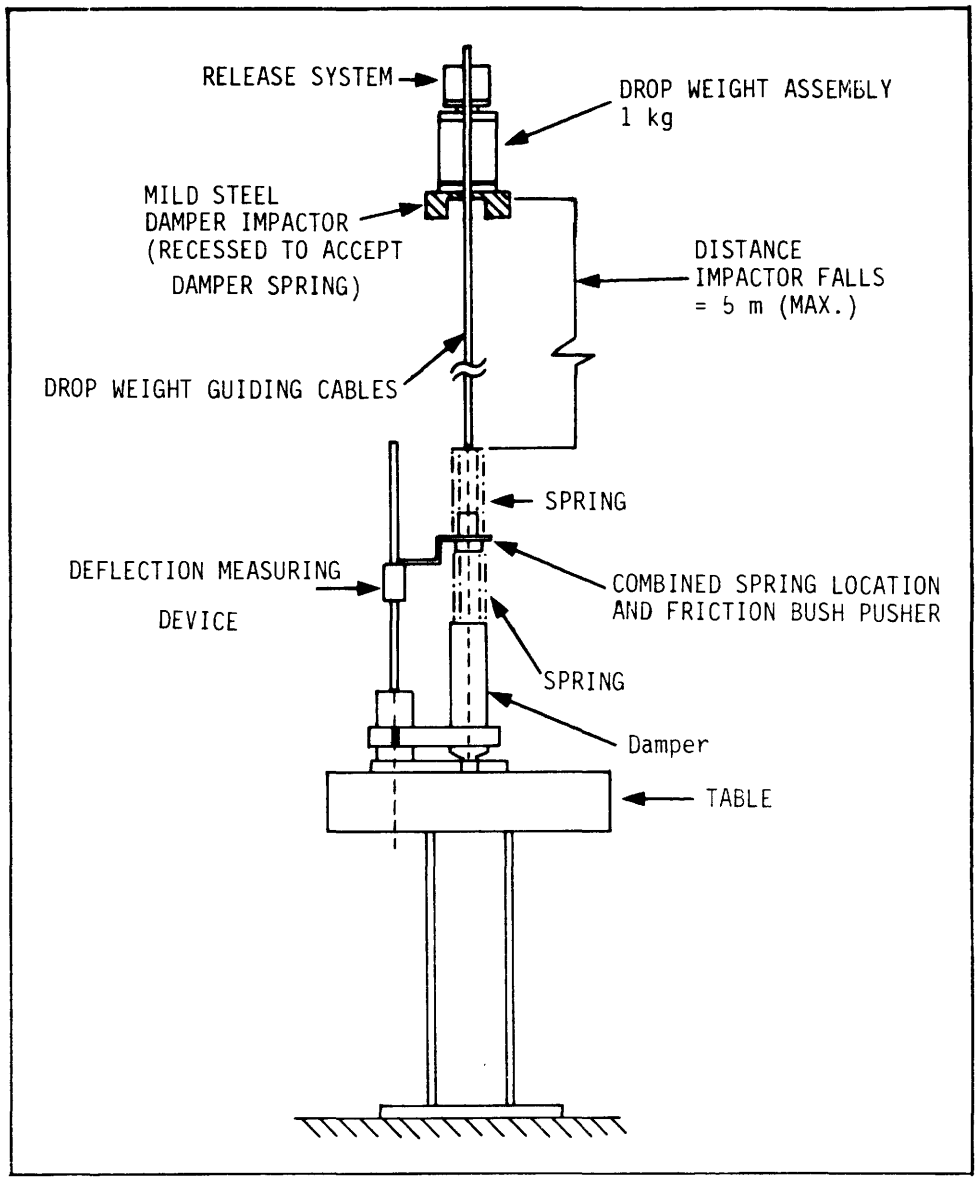

Figure 5: Rib Certification Rig with Damper-Spring Unit

Certification of the Primary Rib Stiffness

The test arrangement for primary rib stiffness is similar to that shown in Figure 4 except the damper unit is removed. The rib certification is based on rib deflection which can be measured by the EUROSID thorax displacement measuring transducer. The drop heights and the certification corridor is given in Table 3.

At each drop height the displacement can be recorded from the peak hold display of the transducer processor. If the rib fails certification any permanent deformation should first be looked for. The rib should have at least 10 mm of precompression at assembly; if it does not the rib should be discarded. If at least 10 mm of precompression is present and the rib still fails certification the spring held within the cylinder should be changed for either a stiffer or weaker one, which ever is appropriate.

Impact Velocity (m/s)	Drop Height (mm)	Minimum Displacement (mm)	Maximum Displacement (mm)
1.0	51	14.5	18.0
1.5	115	23.5	26.5
2.0	204	32.0	35.5
2.5	319	41.0	44.5

Table 3: Certification Corridor for Primary Rib Stiffness

Certification of the EUROSID Abdomen

This calibration should be done with the abdomen installed in the dummy.

First the foam covering of the abdomen and the contact leaf springs has to be removed from the drum to preset the abdomen contact leaf springs. The space between the spring and tape switch, which affects the force, can be reset to a defined value by unscrewing the inner socket screws and shifting the wedge-shaped blocks. The space between the spring and switch should be 0.75 $\pm$ 0.05 mm, as measured by a feeler gauge. Next the dummy spine is bent backwards and the foam covering is placed around the abdomen drum. Care should be taken not to displace the leaf springs.

The dummy should be placed in an upright seated position on a flat, rigid, low friction, horizontal surface with no back support. The dummy must be positioned such that the ribs are horizontal. Both legs are placed in a forward, parallel position, perpendicular to the body. The arms are extended horizontally forwards and are supported by light-weight rods at the wrist. The impacting device is a pendulum suspended by wires. It is centered perpendicular to the midsaggital plane of the dummy (Fig. 6). The impactor mass should be 23.4 kg (Standard Part 572 pendulum) plus 1 kg for the "armrest" impactor-face described below. The impact velocities should be 6.3 $\pm$ 0.2 m/s and 4.2 $\pm$ 0.2 m/s. The front of

impactor must be equipped with a (hardwood) simulated armrest of 7 cm height (Fig. 6). The center of the impacting armrest lies on the central longitudinal axis of the impactor, which should be carefully aligned with the center of the leaf springs in the abdomen. The armrest should allow a free penetration in the abdomen of at least 60 mm.

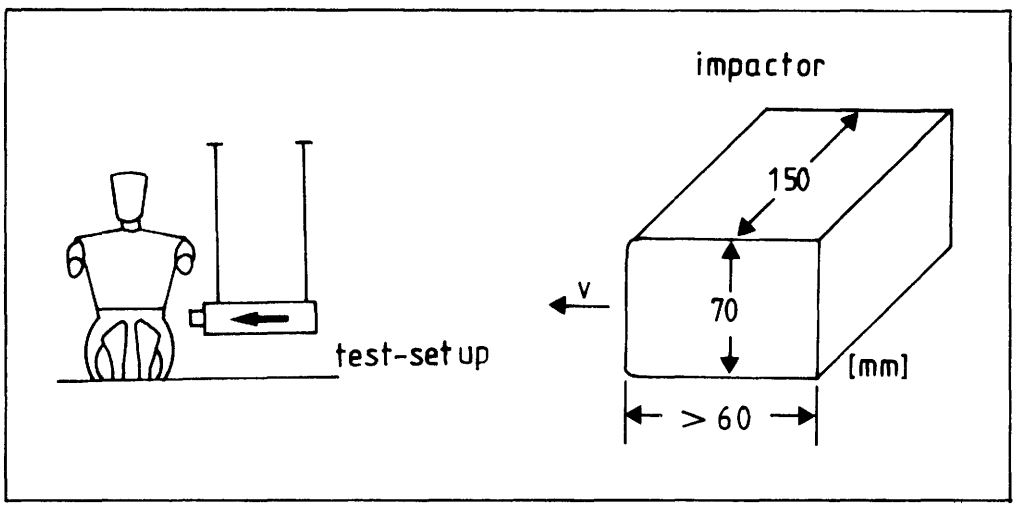

Figure 6: Test Set-Up and Impactor Face for EUROSID Abdomen Certification

The impact acceleration should be measured directly by measuring the deceleration of the impactor. The acceleration signal should be filtered to Channel Class 180. In the high velocity impact (6.3 m/s), switch contact should occur; if not, check the preset value. In the low velocity impact (4.1 m/s) no switch contact should occur. If contact occurs check the preset value and check the abdominal components visually for failures. The pendulum deceleration-time histories of both tests should be within defined corridors which have not yet been determined and will therefore be published later. If the calibration results are not within the corridors, the abdomen foam covering should be replaced.

Certification of the EUROSID Pelvis

The EUROSID pelvis is instrumented with a load cell at the pubic symphysis, a pair of strain gauges for the force measurement on each iliac wing and optionally a 3-axis accelerometer at the c.g. of the pelvis.

Calibration of the Strain Gauges

Before the certification of the dummy pelvis as a whole, the transducers must be individually calibrated. This requires that the load cell of the sacrum be removed from the pelvis and then the pelvis assembly (less the load cell) be mounted in a test fixture. A hydraulic jack provides the force for strain gauge calibration when the pelvis is held as shown in Fig. 7. The drawings for the support can be provided by INRETS.

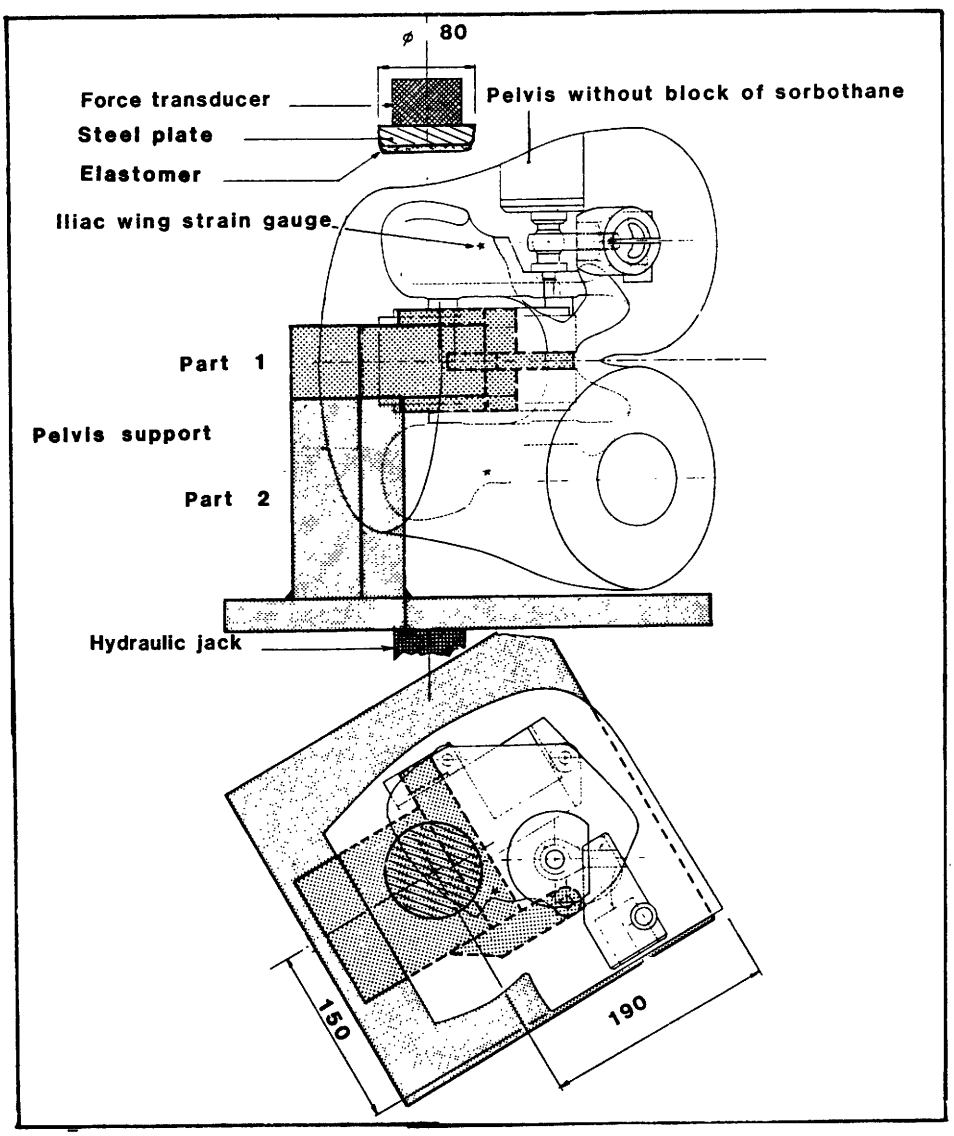

Figure 7: Pelvis Strain Gauge Calibration Test Set-Up

The pair of strain gauges on each iliac wing (all gauges R=350Ω) are electrically connected in a half Wheatstone bridge and usually operate with a 10 Volt input. The maximum load that can be measured reliably is 10 kN. The hydraulic jack face (ø 80 mm) is covered with a 5 mm thick piece of elastomer. The force is applied on the side of the pelvis, 190 mm from the bottom surface and 150 mm from the front.

During strain gauge calibration a voltage output results from a pressure input. A force transducer in the jack measures the compressive force which should be at maximum 6 - 7 kN. The output is normally linear, but because of tolerances in production of the pelvis shell and accuracy of strain gauge installation, the slope varies. A recalibration of the strain gauges must be done if in an impact test a load value of 10 kN is exceeded. Normally a permanent deformation occures at 12 kN and ruptures (or tears) occur at about 18 kN. After strain gauge calibration the load cell is assembled in the sacrum again, the pelvis is mounted on the lumber spine and the Hybrid II legs are mounted on the pelvis.

Calibration of Load Cell

For certification of the main pelvic loading through the equivalent of greater trochanter, the dummy is placed on a flat horizontal surface with extended arms and legs; the arms may be partially supported. The plane of the ribs should be horizontal. Between dummy and table two foils of 2 mm thick teflon are placed so that there is a defined friction between dummy and table. The dummy should have a free side motion on the foils of about 50 cm.

The standard Part 572 impact pendulum is used with 23.4 kg mass and 150 mm face diameter. The centreline of the pendulum should pass through the middle of the Sorbathane block, which is placed in front of the femur neck bolt. This location is identical to the H-point of the dummy.

The velocity of the pendulum must be between 4.22 m/s and 4.31 m/s while the impactor force (acceleration of impactor multiplied by the mass of the pendulum) is required to be in the range of 8000 N $\pm$ 2 %. The lateral acceleration measured in the dummy pelvis should be 35 g $\pm$ 3 % and the load cell in the pubis symphysis should indicate a load of 4000 N $\pm$ 6 %. If these values can not be reached the pelvis must be checked and/or plevis flesh renewed.

EUROSID Assembly After Certification

The EUROSID head is fixed on top of the neck with 4 screws, while the neck is fixed on the neck bracket on top of the thorax also with 4 screws. The certified rib modules are fitted onto the spine with the sternum spacer in place. The shoulder cap, a foam moulding, is attached to the cam block by Velcro strips. The torso is fitted onto the abdomen with 2 screws. The lumbar spine is screwed on the pelvis, the former being fixed onto the abdomen. Finally arms and legs must be attached onto the torso. All adjustable dummy joints are adjusted to hold between 1 and 2 g's. This amount just barely restrains the weight of the individual limb when it is extended horizontally.

The principle item of dummy clothing is a rubber suit with short sleeves and no legs. The suit is zipped up at the front. Some practical advice -- because there is no steel cable inside the dummy neck, transport of the dummy by hanging from the head is not advised. A screw location for lifting is provided at the base of the neck. The legs must also be supported when lifting the dummy.

EUROSID Instrumentation

The dummy is equipped to accept a triaxial accelerometer in the head. Provisions has been made to mount accelerometers in the chest and pelvis also,if required. The three rib deflection transducers are standard equipment. These transducers are optical devices employing a 4 bit gray code and are connected with a special unit that records the maximum deflection directly. There is additional provision for mounting uniaxial accelerometers on each of the three ribs. Holes are provided for mounting on the inside of each rib close to the point of impact. The abdomen has three contact switches on the impacted side which indicate force overloads. The pelvis has strain gauges on each iliac wing and a force transducer in the pubic symphysis. Table 4 shows the Channel Classes used for filtering the different signals.

Instrumentation	Channel Frequency Class
- Head: triaxial accel. c. of g.	1000
- Chest: deflection transducer 3 x	180
/¯triaxial accel. c. of g.	180_7
/¯rib accel. 3 x	180_7
- Abdomen: on/off switch 3 x	1000
- Pelvis: force transducer (pubic symph.)	600
strain gauge (iliac wing) 2 x	600
/¯triaxial accel. c. of g.	180_7

Table 4: Filter Frequencies for the Different Measuring Channels

EUROSID Seating Procedure

The certified and assembled dummy is normally clothed in form-fitting cotton stretch underwear and the feet are equipped with the usual shoes before the dummy is brought into the test car.

There are two major intentions for the seating procedure. The first is to define the positions of the head, chest, abdomen and pelvis relative to the car side structure by fore and aft seat adjustment and seat back angle to achieve a standard dummy/car-side-structure geometry. The second intention is to position the upper arms relative to the torso center line such that there is consistent exposure of the thorax to the intruding car structure and that there is no damping or distribution of loads by the arm in the area of the ribs.

Therefore the car seat is adjusted (e.g. 50 mm in front of the R-point) and seat back inclined (e.g. 25 deg.) as the first step. Steering wheel and all further adjustments are positioned at their midtravel positions, except the head restraint which is normally positioned with its top surface at the height of the c.g. of the dummy's head.

Next the dummy is seated, normally in the driver's position. The plane of symmetry of the dummy shall coincide with vertical median plane of the seat. The restraint systems shall be adapted to fit the dummy in accordance with the manfacturer's instructions. A shoulder belt should be placed across the upper chest in a normal wearing position leaving the shoulder joint free for motion. The arm positioning procedure is specific for side impact dummies equipped with arms such as the EUROSID. (The American SID, however, has torso integrated arms.) It is proposed that the angle between upper arm and torso centre line on each side shall be 40 $\pm$ 5 deg., and the angle between forearm and upper arm on each side shall be 135 $\pm$ 15 deg. (Fig. 8)

The hand position at the steering wheel is proposed to be in quarter-to-three position. If the quarter-to-three position can not be achieved and if the steering wheel is adjustable, locate the steering wheel such that the quarter-to-three position is achieved and the arm angles remain within the above specified ranges. Further, if arm angles and steering wheel adjustment do not allow the quarter-to-three position, the left hand can be positioned between 7 and 11 o'clock and the right hand between 1 and 5 o'clock while the arm angles may be located in the above specified range and the steering wheel adjusted anywhere along its travel if adjustable. In all cases described, the symmetry of the arms shall be maintained about the dummy midsaggital plane.

If the above described arm positioning and steering wheel adjustment do not allow the specified hand position, it is proposed that the steering wheel be placed at its midposition and arm angles positioned at 40 and 135 deg. for upper arm and forearm respectively and the hands be located on the steering wheel where possible regardless of the requirement just given.

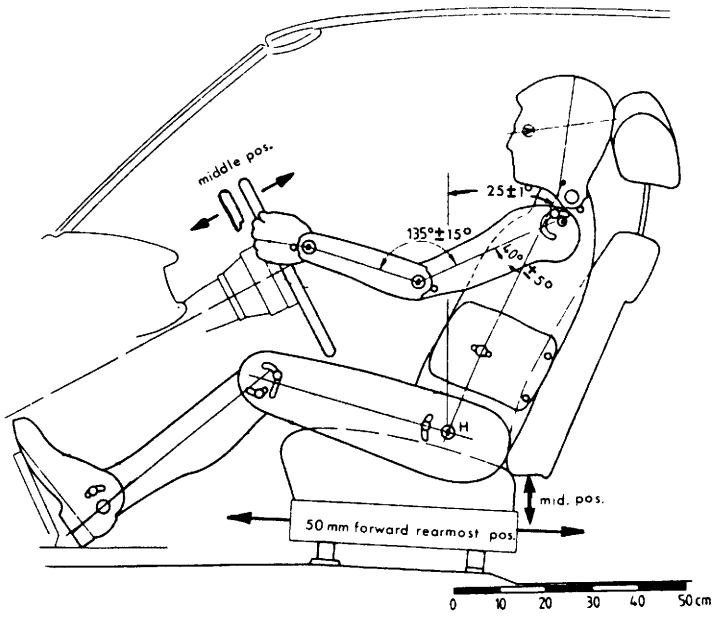

Figure 8: EUROSID positioned in Test Vehicle.

Summary

A complete set of certification tests have been developed for the EUROSID. A few numerical specifications are missing at the time of publication. Some minor changes in the procedure or specifications may be necessary for the Production Prototype dummies (the second batch). The dummy set-up is described and nearly all the certification procedures are illustrated by drawings. A favourable seating procedure for the dummy in the test car is proposed.

Literature

/1/ EUROSID Validation Program:
ECE Contract No. 85/7790/025
Final Reports of TRRL, BASt, INRETS, TNO

/2/ Biomechanics Program:
Proc.: Biomechanics of Impacts in Road Accidents
Brussels 21-23 March 83

Full Scale Tests with the EUROSID

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Bundesanstalt für Straßenwesen (BASt)

Full scale tests with the EUROSID have been carried out until now by INRETS, TNO and BASt. The results of these tests are summarized here.

Full scale tests carried out by INRETS

INRETS has reconstructed two real accidents, each twice, as selected for the "Joint Biomechnical Research Program KOB" [1]. The first accident was a side impact between two Peugeot 504's at an impact angle of approximately 70 deg. and an impact speed of about 75 km/h. Table 1. relates the injury parameters of the real accident with those of the EUROSID tests.

	REAL ACCIDENT	FIRST TEST	SECOND TEST
Thorax	6 rib fractures (ASI 3)	Deflection : 22.9/16.1/18.8 mm	Deflection : 22.7/20.6/18.8 mm
Abdomen*	AIS 4	No switch contact	No switch contact
Pelvis *	AIS 3	Pubic force : 7110 N Iliac force 6200 N	Pubic force : 10930 N Iliac force 5790 N

Table 1: EUROSID Injury Parameters -
First Accident Reconstruction
Two Peugeot 504's, 75 km/h, 70 deg.

* No injuries in the three accident reconstructions with cadavers were observed (see [1])

In the second accident a Peugeot 304 struck a Renault R15 from the side with an impact speed of about 57 km/h and an impact angle of 75 deg. The results of this test are summarized in Table 2.

The conclusions of INRETS were as follows [2]:

- The Reconstruction of real accidents showed the ability of the EUROSID to predict injury risk in side impact.
- A few slight transformations can be introduced to improve the durability without change in the behaviour of the dummy.
- The EUROSID dummy is suitable for use in procedures for testing the lateral protection of car occupants.

	REAL ACCIDENT	FIRST TEST	SECOND TEST
Thorax	13 rib fractures + Flail chest ASI 4	Deflection : 47.5/52.1/51.2 mm	Deflection : ?/?/46.3 mm
Abdomen	No injury	No switch contact	No switch contact
Pelvis	No injury	Pubic force : 8370 N Iliac wing force 3050 N	Pubic force : 8400 N Iliac wing force 1850 N

Table 2: EUROSID Injury Parameters - Second Accident Reconstruction Peugeot 304, Renault R15, 57 km/h, 75 deg.

Full scale tests carried out by TNO

TNO has performed two tests with a movable deformable EEVC barrier (MDB) at 90 deg. and 50 km/h impact speed into a 4-door mid-size car. In one test a permanent rib deflection of the lower rib occured. The results of the EUROSID measuring values are shown in Table 3.

EUROSID Measurements		test 1	test 2
- head:			
. max. result. accel.	(g)	127.3	94.1
. 3 ms max. accel.	(g)	57.3	55.4
. HIC		298	189
. max. lateral accel.	(g)	119.9	85.9
. contact time	(ms)	50	46
- chest:			
. max. result. spine accel.	(g)	65.8	67.7
. 3 ms max. spine accel.	(g)	55.2	61.2
. SI		272	273
. max. lateral spine accel.	(g)	64.2	65.9
. max. lat. upper rib accel.	(g)	289.4	317.9
. max. lat. middle rib accel.	(g)	364.7	344.4
. max. lat. lower rib accel.	(g)	189.2	276.7
. max. upper rib deflection	(mm)	23.0	29.5
. max. middle rib deflection	(mm)	30.3	34.6
. max. lower rib deflection	(mm)	26.3	34.0
. contact time	(ms)	18	16
- abdomen switches		-	-
- pelvis:			
. max. result. accel.	(g)	98.1	88.6
. 3 ms max. accel.	(g)	85.7	84.6
. max. lateral accel.	(g)	96.1	88.2
. max. pubic symph. force	(kN)	4.99	2.69
. max. ilium force	(kN)	2.22	1.38
. contact time	(ms)	16	18

Table 3: Results of MDB crash tests by TNO

The conclusions of TNO were as follows [3]:

The overall behaviour of the EUROSID was satisfactory. The repeatability of the 3 ms maxima of head, chest and pelvis, as well as the SI, was good in the MDB crash tests. The rib accelerations were almost identical (except for the damaged lower rib).The maximum rib deflections showed higher values in the second test than in the first, while maximum pelvis forces were greater for the first test. From previous studies it is known that small changes in dynamic behaviour of the intruding door can cause these effects.

Full scale tests carried out by BASt

The suitability of the EUROSID was tested by the BASt in 7 full scale vehicle tests with different test configurations and velocities. The test vehicle was a VW Golf I and the colliding body a movable deformable barrier (EEVC IV face), which struck the test vehicle at right angles (EEVC proposal) and also in the crabbed direction of travel (NHTSA proposal).

An important value for the assessment of the behaviour of the EUROSID is the rib deflection. Table 4 shows the results of rib deflection under the different test conditions. Further results of these tests are incorporated in the papers "sensitivity" and "repeatability" of EUROSID.

Test No / rib	ESID 1	ESID 2*	ESID 3	ESID 4	ESID 5	ESID 6	ESID 7
	90°, 45 km/h	90°, 50 km/h	90°, 50 km/h	90°, 50 km/h	90°, 55 km/h	crabbed 54 km/h	crabbed 54 km/h
upper rib	14,1	45,3	29,7	28,7	32,2	27,6	30,6
middle rib	19,2	41,8	31,7	36,1	38,3	29,0	33,5
lower rib	29,8	32,3	38,3	41,2	44,1	34,6	40,1
Σ	63,1	119,4	99,7	106,0	114,7	90,2	104,2
mean per rib	21,0	36,1			38,2	32,4	

Table 4: Maximum Rib Deflection Values for the EUROSID

* lower seating position of the dummy (old and too soft seat in the testcar)

The dummy was tested in full scale tests at velocities up to 55 km/h. The tests could be conducted without causing extensive damage to the dummy. The few damages of the BASt tests were:

- jamming of the springs (easily releasable)
- tearing of the pelvis flesh
- breaking of the helicoil out of the plastic shoulder.

One suggestion for easier handling by TNO and BASt was that the two box supply unit for the opto-electronic transducers could be combined and placed in the test vehicle. The output from this device would be connected in series with all other outputs and be transmitted out of the car by the commonly used PCM system.

The BASt`s test results suggest that the repeatability of the EUROSID results was satisfactory. The dummy was able to make a sufficient distinction between lateral collisions of varying degrees of severity. It can be concluded that the EUROSID is suitable for use in procedures for testing the lateral protection of vehicles [4].

Summary

Thirteen full scale tests were carried out using EUROSID. Detailed reports have been submitted to the European Commission. From these it can be concluded that:

- The dummy has shown in the full scale tests in the scope of the "EUROSID Validation Program" that handling is as easy as for other dummies.

- Violent side impact tests could be conducted resulting in only minor damage to some dummy components.

- Slight modifications for improvement can be introduced which should rectify current problems and be satisfactory without the need for any renewed validation of the dummy.

Literature

[1] BASt: Joint Biomechanical Research Project, KOB Heft 34, Köln 1982

[2] Cesari, D.; Bouquet, R.: Validation Program for EUROSID, INRETS Final Report for EEC, Contract 85/7790/025, Arcueil 1986

[3] Janssen, E.G.: EUROSID Evaluation, TNO Test Program, Final Report for EEC, Contract 85/7790/025, Delft 1986

[4] Glaeser, K.-P.: Side Impact Tests with EUROSID, BASt, Final Report for EEC, Contract 85/7790/025, Bergisch Gladbach 1986

PANEL DISCUSSION ON PRACTICAL CONSIDERATIONS

Availability and costs

Problems of deciding tolerance levels

Chairman : I.D. Neilson
(T.R.R.L., United Kingdom)

Panel Members :

F. Bendjellal (A.P.R., France)
R. Bouquet (I.N.R.E.T.S., France)
D. Cesari (I.N.R.E.T.S., France)
B. Friedel (BASt., F.R. Germany)
H. Henssler (Commission of the European Communities)
K.P. Glaeser (BASt., F.R. Germany)
J. Wismans (I.W.-T.N.O., The Nehterlands)
R. Lowne -T.R.R.L., United Kingdom)
C. Tarrière (A.P.R., France)
P.D. van der Koogh (I.W.-T.N.O., The Netherlands)

PANEL DISCUSSION

E U R O S I D S E M I N A R

Chairman :

This session consists of a panel discussion and we have put together various different aspects of the dummy which could well be mentioned at this part of the Seminar. First of all, I should perhaps mention that the panel consists of those of us who are sitting along this end of the room and I should introduce them.

First of all, of course, you know most of them in any case, but perhaps to explain why they are here this afternoon. We have the authors and presenters of the papers whom we have already heard today. Beyond that, on the end, Prof. Friedel who is from BASt. He is here because he is Chairman of EEVC (European Experimental Vehicles Committee) and he has been in overall charge of the activities behind the scenes for the organization of the EUROSID development and for many other things as well.

Next on the line is Mr Van der Koogh from TNO. He is particularly concerned with the fact that EUROSID is now in production as a dummy by the group of organizations : TNO, OGLE and SEREME. Mr Van der Koogh will have a few things to say about matters related to the availability of the dummy.

We have Mr Henssler here on my left who, as you know, is here from the EC-Commission. In fact I think he has been associated with almost every development at the Commission in connection with vehicles for many years. He has, so to speak, fathered the Com-

mission's interest in the side impact test procedure and in the subsequent developments of the EUROSID dummy and the Mobile deformable barrier face.

Next is Dr. Tarrière, whom we all know from Association Peugeot-Renault. He has taken a very large part in the early days in the developments leading up to EUROSID and there are two particular points he would like to make to us later on in this Session.

Apart from those of us on this table, we have been very glad to welcome representatives from NHTSA, as indeed we have done during the EEVC ad hoc meetings on this topic. Today we have Mr Kanianthra with us and I think he has a few words to say later on. But first, I think we should have our panel discussion. I have had a few questions put to us, and then we can go onto a general open question session.

First of all, Mr Wasko of M.V.M.A. Would you like to put your question to the audience ?

Mr Wasko :

Thank you Mr Chairman. One of the major questions we have is : we have conducted a series of sixteen full vehicle tests last year using 1985 model year Ford vehicles and we had expected the EUROSID dummy to be available shortly. We have a set of vehicles waiting for the EUROSID dummy so we can duplicate the tests with the NHTSA side impact dummy and we would like to start these as soon as possible. One thing that would help us would be to have the calibration procedures for the dummy as soon as possible. If the dummies come in March, and the calibration procedure arrives at the same time, I'm afraid our testing would not get started until May or possibly June. I would like to start testing as soon as possible so therefore if calibration procedures are available, even if in preliminary form, they would be greatly appreciated.

The second question is about the calibration procedures. Will there be some recommendation as to how often each of the components within the dummy should be calibrated ? It may be the rib section has to be calibrated more often than the pelvis area. We do not know and we would welcome any advice in this area. Thank you.

Chairman :

Well, as to the question of copies of the calibration procedures, we are producing these in written form at the moment. They are not finally complete, but I imagine that we can send you preliminary copies quite soon. They have been prepared in the course of the preparation for this Session. Mr Glaeser, I think, has been putting them together. Do you have any comments here ?

Mr Glaeser :

As I said in my little speech, there are one or two individual points which still have to be determined exactly in these procedures, but essentially we have more or less determined the overall procedures. One or two points might still change when the next dummy series comes up.

I do not think the calibration itself is particularly difficult, we always calibrate with the dummy sitting upright on the table. The heights of pelvis and thorax differ sometimes.

Only the ribs are a difficult procedure. There is a test impact drop procedure on the rib module and then there are the other tests which also have to be carried out to check the spring, damper and the primary rib stiffness. Those other tests only have to be carried out if the main test has failed.

Chairman :

The second part of the question is : How often should these certification or calibration tests be carried out ?

Mr Cesari says that it is as often as you have the enthusiasm to do it, maybe before and after each test ! But in practice it is rather less. I think it is appropriate to ask the designers of the various major components as to their particular answers for their components.
First of all Mr. Bendjellal.

Mr Bendjellal :

Yes Chairman, as regards the neck, I'm not sure about the necessary frequency of calibration but all I can say is that if during an ordinary test of the neck you notice any sort of irreversible bend in the neck or something, then you need to go into a calibration procedure again, to look into the behaviour pattern of the neck. As a maximum number, perhaps after 20 tests or something like that, a calibration may be required. Really everything depends on the tests that you are carrying out, and also on the state of the neck after the tests.

If you see that there is some damage to the neck, then you want to replace it with another one. If the head seems not to be acting properly in an overall test, then you may need to calibrate again. Before doing that you should at least change or replace the buffers in the head/neck interfaces and if replacing those buffers doesn't do the job then you will have to change the central section, indeed the whole neck. Thank you.

Chairman :

Turning then to the thorax, a comment from Mr Lowne.

Mr Lowne :

I think Mr Chairman that experience will tell us how frequently we need to recalibrate or re-certify these body components and if the organizations having the production prototype dummies are able to certify them between each major test, it will give everybody an idea how quickly they will need to be certified. When we performed the

dummy reproducibility test at TRRL, we received the dummy at the end of the validation programme. In some cases they had been subjected to well over a hundred tests and only two of the rib modules needed to be modified to bring them back into certification (specification). So, it seems to me, from those results, that maybe the thorax will go for several tests before requiring to be re-certified. Thank you.

Chairman :

Mr Cesari, for the pelvis.

Mr Cesari :

Yes, this is a question which is really difficult to give a fixed answer to, bearing in mind the limited experience we have so far, but for the pelvis, and I think Mr Glaeser said this also, when the impact is more than 10 ms/h I think it would be sensible to calibrate. As for the pelvis itself, there are two types of tests, one for calibrating the strain gauges for measuring the electric impulses released which are then measured in a gauge close to the iliac wing and I think this should be done periodically but not too often because there is no reason for this to change dramatically. The second calibration test involves the response of the pubic symphesis to acceleration and that could be done a bit more often, because it's linked to the dynamic response of the pelvis and if you find that this calibration is not giving satisfactory results in the range shown, then you can intervene. For example you may find there is some problem in the interfaces in the interior of the pelvis. I do not think it is necessary then to test too often, the tests for calibration show this. In spite of that, you may find that there are a number of changing circumstances, and with a pelvis itself you may need to test more often.

Chairman :

Thank you.

Well I think in summary we can say that there are not selected times for repeats of certification but that this depends on the usual good engineering practice of a laboratory, looking out for any obvious failures, looking out for cases where there has been a high loading of the component and being careful not to exceed anything that the developments suggests is a prudent number of tests. In point of fact there is littler evidence of great changes in certification levels in the validation programme to date.

Turning to our next questionner, this in Mr Kanianthra.

Mr Kanianthra :

The NHTSA is very much interested in finding out your plans in developing the associated injury criteria related to measuring with this device, and second part of the question is : Is thoracic deflection likely to exceed any criteria the experts in biomechanics may be considering for injury levels ? One may want to limit it too.

Chairman :

I think this is a question for Mr Lowne.

Mr Lowne :

As far as the thorax is concerned, the relationship between the results measured on the deflection transducers and injury are concerned, the relationship will be determined from accident information and from tests performed on cadavers. There is already information from the Heidelberg tests, from the tests performed by the Peugeot-Renault Association drop tests. We can relate these to the results on similar tests with the dummy and, using this we can

deduce some performance criteria. We also intend to use accident data and accident reconstruction to relate these results to what happens to people actually injured on the road.

I can't actually comment on whether the chest deflection of the dummy is likely to be able to exceed any criteria proposed in the future, but I think that for legislative use it will be good enough.

Mr Kanianthra :

Do you have a time schedule for when these injury criteria may become available ?

Chairman :

Well, we are working on it hard at the moment and it is a little difficult to say. I think this is a progressive matter : as we go on with 1987, I think our ideas will become more and more definite. It can't be predicted with any certainty. I think some of them will be pretty clear by the middle of 1987. We have preliminary ideas for most of them at the moment.
Any other comments on that point ?

Mr Tarrière :

In general (this is the same for all injury criteria, either for the thorax or the head or the abdomen or the pelvis) it cannot be done if you don't have the dummy at your disposal and if you don't know how it behaves in relation to the behaviour of a human body. Statistics on tolerance relate to the human body, but for these to be transposed into a performance (criteria) statistics on the dummy, you have to be certain that the dummy itself resembles a human body very closely. If there are any differences, in any sector, then you have to know to what extent it is different from the human body ; so we cannot expect to get any clear answers today on that. Today is really a roundup of our assessment of the dummy. I think if you

look at it point by point, as people have already said, for each section there are going to be studies in this line and I think the responses should come in a not too distant future.

Mr Chairman, I would like to use this opportunity to answer Mr Schmidt question on zones of the body other than the four main ones we talked about today. I think it is clear that the dummy has been developed to predict and respond to risks of injury in the main four areas of the head, thorax, pelvis and abdomen, and also the neck. The neck trails behind these four sectors in the context of the risk in real life accident ; so the answer is quite clear, we are not proposing protection criteria for the neck ; that is not one of our priorities. Nevertheless the neck is very important because the behaviour of the thorax, the shoulders and the neck govern the dynamic response of the head against the lateral wall and it's in that context, and with that basic idea in mind, that we have given the neck a high priority, not in isolation but as a way of helping us to increase the accuracy of our predictions of risks to the head. Obviously, this is open to question. The figures on assessing priorities have been discussed at great length, they have taken a year, within the group of ISO/TC.22 SC12 GT 6 and we have used information from Germany, America, the U.K., France and others and all this information has been put together and priorities have been drawn up. It was decided above all that the neck should not be given increased priority in the prediction of injury risks, and as Mr Bendjellal said this morning, it could be discussed again if we see different developments in the future and if we find that the neck becomes more important than is at present thought. So, those are my comments on injury criteria. I think, as he dummy is at the moment, for the four main body areas, it would be a long time before we will be able to introduce new criteria which will be acceptable by the international community.

Chairman :

Thank you. I think there is one obvious coment to be made on the selection of injury criteria. There are two aspects of it : there is the question of response of the actual human body and the level of impact at which the human body suffers a certain level of injury and then separately from that there is the question of the match between the dummy and the human body. There may need to be some sort of factor between the injury criteria loading which is thought to be appropriate to the human body and that thought to be appropriate for the dummy. In several cases, we probably have a good idea what is this relationship between the human body and EUROSID and if there are problems, I think they are more in the nature of what is really the appropriate level for the human. Some of these criteria are for injuries or they relate to injuries which in the past we have not considered, but now it is clearly the time that we should. There is a great deal of information around the world, a lot of it doesn't exactly answer our questions but comes close to it and as Chairman, I've been very interested to see the vast amount of biomechanical data that has been used and to note that it, of course, originated from all around the world, particularly from the United States as well as from Europe. Perhaps if we pass now to our third questionner, Mr Koch from Volvo.

Mr. Koch :

My question concerns the response of the dummy at higher speeds. We have seen today that a lot of tests were carried out at the interval of 4 to 8 m/s. But the fact is that many accidents occur at higher speed, say 15 m/s corresponding to roughly 50 km/h. Is the dummy still a durable and reliable tool at that level of violence ?

Chairman :

Thank you. There have been a small number, but an important number of tests carried out with complete cars and the EUROSID dummy in them, at approximately the side impact test conditions that have

been under discussion, possibly 50 km/h. Many of these have been carried out by BASt. So, perhaps, if I turn to Mr Glaeser again, he might wish to comment on this.

Mr. Glaeser :

I'd like to say, Mr Chairman, that we've done one test at 55 km/h, but I think some centers have tested it at 70 km/h but at a right angle ; we have not done this test, we used another angle. Using the test at 55 km/h, there was no substantial damage to the dummy, but maybe some other speaker may be able to help.

Mr Cesari :

Yes, I would be able to.

First of all, you cannot have a direct comparison between a pendulum test and an impact test, or in other words between a laboratory test and with a MDB and a real car. You talk about 50 km/h, but when the dummy actually hits the wall, in a true side impact, the speed is much lower, about half or even two thirds of three-quarters lower, then in laboratory tests on a dummy, particularly in bench tests, we have found certain criteria (parameters), either acceleration or impact which were much lower than those which we found using the MDB and even lower than those which we found in reconstructions of accidents at 70 km/h. We have subjected the dummy to thorough tests at speeds at which (it) would in fact be used in a real situation.

Chairman :

Any others on the panel who would like to comment ?

Our response to that question means that we can now move to general questions from the floor.

Anyone who would like to put a question ?

Mr Wasko :

Mr Chairman, two questions relating back to the calibration again; most of the calibration, from what I understand today, is based on the part 572 calibration but the thorax requires some unique equipment. Will that equipment, the drawings and the description, be made available before the dummies and secondly before TNO has offered or will offer a "class" in March for technicians on calibrating and using the dummies in Delft in the Netherlands. I have asked our member companies if they have an interest in this and several have said yes and we are wondering if the Consortium or TNO might consider holding a class in the United States. Thank you.

Chairman :

I think, first of all, we need a reply on the question of certification and the thorax. Mr Roberts, I think you have probably been most concerned with this, in fact you have developed the procedure. Would you like to give a little more indication about its complexity?

Mr Roberts :

There are TRRL schematic drawings of the calibration equipment for the rib modules themselves. They have to be updated at the moment because of slight changes in the transducer heads which will be coming out with the next generation of dummies, but once those have been modified, there is no reason at all why they can't be released. So yes, drawings can be made available. Thank you.

Chairman :

Now that our question have turned to this matter, it might be very appropriate if I asked Mr Van der Koogh to tell us a little bit about the availability and the future for EUROSID in terms of actually obtaining the dummies.

Mr van der Koogh :

Thankyou. I would indeed like to take the opportunity to clarify a few points on the production of the dummy.

As you know, earlier this year, the EEVC decided that the EUROSID dummy would be proposed as a dummy to be used in the EEC type approval procedure for side impact protection. This, of course, would mean that the dummy would have to be availaible. During the meeting in Wolfsburg in April of this year, there were three parties who showed an interest in involvment in this production ; OGLE, SEREME and TNO, and at the time the EEC representatives recommended a cooperation between those three parties. This seemed to be a good idea and following talks between the three this led to the forming of a Consortium, so to speak, a cooperation agreement and a preliminary production plan for the first series of prototypes. These would have to be sold to a selected number of laboratories which were designated by the EEC. In August of this year a mailing and offers were sent to these laboratories which resulted in 11 orders for EUROSID dummies, which will be supplied in March of 1987. Roughly speaking, the division of tasks between the three members of the consortium is that OGLE and SEREME are responsible for the production and the assembly of the dummy and TNO will take care of central coordination, marketing and sales.

In our talks with the two partners, the price of the dummy was set at 54,500 Ecus which includes all special transducers and conditioning electronics, an allowance for preparing users documentation, some client support and an allowance for minor improvements on the dummies design.

It is expected that after today's Seminar, other interested laboratories may be able to buy a dummy from us.

Of course, ladies and gentlemen, TNO, OGLE and SEREME will do their utmost to supply their clients with a good product and will take care of quality, service, spare parts, training courses and retrofit sets, if necessary. To clarify the point of the training courses, Mr Chairman, the first will be in March 1987, on the 11th and the 12th. An interest was expressed for a course in the United States. I think that if there is enough interest for that and enough participants, then certainly an arrangement can be made to do so.

Now, another point I think that needs clarification is the following : T.N.O. itself, of course, will be one of the users of the dummy since it is involved in both research and compliance testing and this is, we think, an advantage since in this way, knowledge on the performance of these dummies in actual practice will be available at first hand. It is also an advantage in terms of assessing and evaluating feedback data from other users. On the other hand, there are dangers in a situation like that, since TNO then is playing two roles, that of user and that of seller. We try to be in a clear position by separating both roles within our organization. A special task force has been formed that is responsible for the selling and servicing of EUROSID and this task force is completely independent from all other activities. It has a special status within the organization and very clearly defined responsibilities. In this way, the TNO laboratory, so to speak, is just another user of EUROSID and will be treated as any other user. And, of course, since this EUROSID dummy is an official European dummy, all decisions on modifications of the dummy are taken by the EEC through its committees and that is not a thing that we as TNO can do. So I hope, ladies and gentlemen, that this is a very clear situation. We have the same sort of set up for our compliance testing department and found that it works excellently.

On the other hand of course, this form of organization also implies that our researchers are completely free to criticize EUROSID, like all other users are and as far as I know them, they will probably be amongst the first to do so.

There is one general other point I'd like to make, Mr Chairman, if I may ; I think in order to compliment the EEVC on their vision to take the initiative and do something about side-impact protection. We have been working with a great number of partners in this project. There has been said quite a lot about that this morning, but all considered, I think that a considerable achievement has been made within a very reasonable span of time and I'd like to congratulate all those who were involved in the EUROSID project or rather series of projects.

For us, TNO, the development work on the EUROSID in this inter-european setting, and in cooperation with so may other European laboratories has been a very positive experience and I think it would be perhaps a pity if this did not get an adequate follow-up.

Chairman:

Thank you very much.

There are several other aspects to bring up this afternoon and one of them is to mention our cooperation with NHTSA. There has been a long running cooperation and the latest part of that is that the Commission of the EC especially arranged that one of the first four EUROSID dummies should be sent to NHTSA for them to get some preliminary experience and we are glad to have Mr Kanianthra with us today. I think he may just have a few words he would to say on how he sees the situation from his side of the Atlantic.

Mr Kanianthra :

Thank you Mr Chairman. We have very much appreciated this opportunity to be here to discuss and participate in this discussion. We are all here very much interested in the side impact protection and EUROSID is certainly a very interesting device from our perspectives, especially because we are very very anxious to protect occupants in side impact accidents, but one of the things which concerns us is the immediacy of the problem and how quickly can we solve or remedy the problem from our point de view.

I know that development of any device takes time and especially within your organization because of the involvment of different governments it becomes more difficult, but certainly you must be congratulated on your achievement, so far. We will certainly watch with interest the progress and we are very happy that you choose to supply one of the dummies to us. Our current plans are to test both in pendulum and sled environment the dummy we get and these tests will be completed by the end of February. By March we should have the results analyzed and we would welcome any opportunity for a forum where these results can be presented. We leave it up to you to suggest any such forum for that purpose. Our own plan for evaluation is to compare the EUROSID and our side-impact dummy. The two do not have the same criteria to measure but, as we understand it, we can measure accelerations and we are planning to make acceleration measurement comparisons between the two dummies. When we receive the two dummies we have ordered from TNO, we will be conducting further tests, both in vehicle tests a well as pendulum and sled tests. These things are still being planned and we are awaiting the delivery of the dummies before finalizing the tests. Thank you.

Chairman :

We had thought it would be a good idea to perhaps ask Doctor Tarrière if he had anything further he wished to say to us on the question of deciding on tolerance levels, but maybe you have already expressed your thoughts on this matter.

Doct. Tarrière :

Yes, I think I said this earlier on, when I said that it would be a bit premature to say at the present point. A chapter is being written in this story but I think statistics from the present phase can also be used for this purpose.

Clearly, all these statistics for assessing EUROSID in the same condition as those of a human body, and you have seen that a number of these tests have been carried out, and you have had the results shown to you today. This is a important and factual basis from which to extrapolate conclusions on transposing the characteristics of a human body to EUROSID. Tests and the KOB programme, conditions which were reconstituted in the INRETS tests, all this has served as an example as well as things that we have seen on cadavers, on human bodies and on the dummy. Maybe that is not enough. It may mean that new tests have to be done, but certainly that is a help and, with your permission, Mr Chairman, I'd like to underline two things. Mr Kanianthra, in accepting this dummy, has made us a very interesting offer. He said that his group is studying and assessing EUROSID and he said at the same time something that may represent a new initiative, that is the organizing of a meeting in which we can study all the tests and all the results, whichever organization has undertaken them. In other words, all the organizations who have ordered dummies should get together with a view to using them and reporting their tests. I think this would be a very feasible meeting and we could indeed organize it now because it would help us to look at this information in a cohesive manner.

Another important point I want to make is that if EUROSID is assessed by each individual organization, using their own system, their own procedures, then when you come to bring all this information together, you may find that it is distorted, that the jigsaw doesn't fit together, and the different groups and the different organizations should be able to use the same references, the same biofidelity references based on the human body. Maybe people have already made this clear today but I want to underline it once more that these references are available at the moment ; they have been accepted internationally and the incorporation of these figures which is being done by Mr Mertz, of the ISO/TC 22/ SC 12/ GT 5 Group. He has grouped all this information together with a view to having a better idea of the importance of EUROSID. He has taken all information from a number of experts all over the world and these results are going to be discussed next week in the SC 12 meeting in London and it would be excellent if all those groups who have taken part in the development of EUROSID could as far as possible bear in mind these references, not necessarily to overhaul their whole operations, that would be far too much, but certainly to use them within the existing frame-works.
They should apply them for a given period of perhaps about six months with a view to getting a more cohesive summary of the behaviour of the dummy.

As regards bio-fidelity, I think that would be useful to shed some more light on this discussion, and I think we all want to get one unique dummy for international use. I think that would be an advantage and I think it is by applying these procedures and by collective decision making as a result of pooling all our inter- · national results, that important steps forward could be taken.

Mr Kanianthra addressed remarks to the Chair, to the head table when he said that initiatives must be taken. Well, I think that he's certainly right, if we are to make any progress. Thank you.

Chairman :

We have moved from the past, from the history to the present and on the future. We ourselves have two organizations to which we look for helping us to make our progress. There is first of all the Commission of the EC and also, for those of us who are concerned with, the EEVC, and I wonder if it might be helpful if I may ask you, Mr Henssler, to explain a little bit more of the Commission's views and how they see matters for the future.

Mr Henssler :

Thank you very much, Chairman.

First of all, I would like to remind the audience that today we are rounding off a development which in 1978 has been started in the European Biomechanics programme. Since this time we have used more than a million Ecus in public funds for the development of EUROSID. It should not be forgotten that the EC contribution was just 40 %, so the total amount is much larger than that. I think that we are now at a point where we have to pass on our results to the legislators. Now it is their task to work out legal provision on this basis. Of course, it appears always desirable that such a promising development as Eurosid should be further improved as instrument of the future research. But we must always bear in mind that we developed this instrument to enable us to deal with the problem of type-approval of motor vehicles, at European level, under side impact conditions, not just for the sake of research itself.

There are always three basic considerations behind any legal provision : administrative definitions and provisions ; the factual test instrument and then the criteria for performance or protection and I think that we could define and determine Eurosid, as it is at the moment, as a test instrument for regulatory purposes.

We are looking now at the specific provisions of a European side impact regulation. The administrative part has already been dealt with in the Economic Commission for Europe of the UN. They have made certain progress there, so what we have to do now is to define the technical instrument necessary to carry out the tests of a relevant type approval procedure. We need this test instrument and its specifications, all the more, because we have also, as Mr. Tarrière has already pointed out, to establish the protection criteria. We already do have ideas, of course, which are emerging from the biomechanical programme and have been discussed in other bodies too. But we can only fix them exactly now, and to do that, of course, we need the feed-back coming from the dummy tests. Therefore we must be as soon as possible sure that this dummy, as it stands at the moment, will be the instrument to base such legislation on. That leads me on to an appeal for EEVC which monitored the scientific development of the whole EC programme, to determine the specifications for the dummy now and to give them to us. In that way, we as the European regulatory body can then take those specifications and build them into a first draft for EC provisions on side-impact testing.

Just a brief comment on the procedure as well : for about a year now, we have the Erga Safety Group, the Global Approach Group, looking at passenger safety. That group dealt with short-term provisions first of all, about individual specific regulations but then in its more long term mandate it also includes the development of provisions for these global tests as one of its tasks. That group is waiting now for the specifications to come through on the basis of this dummy for side-impacts, so that it can work that into its proposals. One thing is clear, a decision on that regulation will take some time, optimistically you might say 1988 but given the political and economic impact of such provisions, you can't expect them to be adopted overnight and then it needs a bit of time before it can come into force. I think we should start our work as soon as possible. Thank you.

Chairman :

Thank you very much for those helpful indications. I don't know, Professor Friedel, if there is anything finally you could tell us.

Prof. Friedel :

Thank you very much Chairman. There is an area which should be given a great priority in finding a solution. Over the years their (EEVC) work has streched to two areas that is to say the definition of test conditions and barriers, I will not go into that, that is one element, and the second one is work which Mr Neilson has carried out within the EEVC ad hoc Group on the side impact dummy and that is essentially what you have been hearing about today. Member States discussed EUROSID and discussed the results of the assessment study which the EEC was kind enough to co-finance. This was in the last meeting in November and they saw that the dummy is now suitable to be used in a test stage by the people who have an interest in getting to know this particular instrument. We always felt that EUROSID was developed for legislative provisions eventually and in our governmental Committee we have always had close links with the Commission of EC and also with the Economic Commission for Europe in Geneva. We thought it was very important not simply to develop a tool for research when we wanted something which could be used and have an influence on legislation. We should make every effort to try to increase progress in this area of side impact protection. The way we see further development will be that first of all the draft of the ERGA group to the Commission must be completed. We will have to fill in the blanks which were in the first draft and on the dummy and the specifications. We will do that as quickly as possible so that we could start the procedures for discussions and so on. Certainly the role of TNO is an important one. The task of TNO is to look at the production and sales of such dummies to train people to use them. The EEVC ad hoc group has been in existence for many years, so the feeling was that it should finish this work in 1987. The EEVC want to round if off in that way. Thank you.

Chairman :

Mr Henssler

Mr Henssler :

Thank you very much Chairman. I am very grateful to Prof. Friedel for that information and the wish for future cooperation which he has expressed as regards the specification list which will be made available to us very soon. This appears to be the correct way to continue our work and I'm glad to see that the ad hoc Group on the dummy development is going to continue, because now it's going to be used as a platform to bring together all the different experiences which will be made with the pre-production prototypes. As Mr Kanianthra has just mentioned, from that I think that the American experience should also come into this ad hoc Group so that the whole thing can be drawn together and in that way perhaps corrections can be made, if necessary, to the specification list. We can of course always introduce minor changes. Thank you.

Mr Meekel :

Thank you Mr Chairman. I am also very glad to have heard what Mr Friedel said on the follow up of this day. I have understood that within a few months we can expect the final drawings and specifications of the dummy which can be used in the ERGA-Safety meetings. That means that in that group, we can follow up in drafting a text for a Directive which has to be established later on. But in the meantime, relationships with NHTSA exist and discussions are still going on. As has been said already this afternoon, there is also a possibility for a harmonized procedure on side-impact testing. In May this year there was a public hearing in Washington on the proposed rule-making by NHTSA in the USA. I don't know what has happened after that. Is it possible that we can have some information from our colleagues from NHTSA ? What has happened between that meeting and today ?

Chairman :

This is a fair question to put to Mr Backaitis or Mr. Kanianthra.

Mr Kanianthra :

I'll offer that to Mr Backaitis.

Mr Backaitis :

Frankly nothing has been decided, but definetely it has not been killed.

Chairman :

I think there still is room for discussion and hopefully the co-operation which has existed for some time now between both sides of the Atlantic, will continue.

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CHAIRMAN'S SUMMARY

by I.D. Neilson, T.R.R.L., United Kingdom

Ladies and Gentlemen,

I think the time has come for me as Chairman to summarise this days meeting. I don't want to go over all the ground that we have just been discussing, which is the question of where do we go from now, but just briefly to summarise the meeting as regards what it has said about EUROSID. Much more carefully considered conclusions will be produced with the proceedings which we are very glad to have published for us in the future by the Commission and this will act as the definitive conclusions from the meeting which hopefully will be contained in that. But, just for the present, there are a few points to be made.

I think clearly a fair degree of cooperation has been achieved and it has been effective in the sense that EUROSID exists if not in this room out in the lobby and this is an improvement on the situation at the public hearing in May 1986 in Washington when everyone was saying 'Well, where is this EUROSID? We've never seen it. We've never seen any results from it!' Well, we are now attempting to rectify this. So EUROSID exists. There are many aspects of its performance which we have attempted to present to you this afternoon and really once again it is a question of reading the proceedings when they finally arrive to see what we were trying to get at.

We have had some comment on biofidelity of the dummy. I think it is clear that great attempts have been made to produce a dummy which is representative of the human being with respect to the response to lateral impact or the many different responses to the different parts of the lateral impact. We have seen the difficulty of producing, on the one hand, a dummy which is fully representative of the human and, on the other hand, is practically suitable as a measuring device and there is a need for a suitable set of decisions as to how far we go to meet these two often opposed requirements.

This perhaps most clearly shows in questions of sensitivity. If you slightly alter the conditions of impact to a dummy, how do you want the response to differ? Do you want it to do the same as the human being, which may have quite large changes with small changes in impact conditions, or, do you want it to be suitable for a legislative test procedure where possibly you want zero sensitivity and the same output for a given input even if the given input is from a slightly different set of conditions, a slightly different angle or slightly different temperature, or something like that?

We have seen this afternoon that repeatability of EUROSID has generally speaking been very good considered component by component. The problems begin to arise when we put the whole lot together and I think there are two situations there. There is the fact that of course there were a few modifications which were clearly needed which were apparent from the Validation Programme and these modifications have been put in hand and will be incorporated in the next twelve dummies so that should improve repeatability in some very obvious respects. And we hope that when that has been done we will have a fairly good dummy from the point of view of repeatability.

In a rather similar sort of way we have looked at the reproducibility: the question of all the different dummies being similar in their responses. The actual results we achieved in the Validation Programme were not, perhaps, quite as good as we would have hoped, but the four dummies, the poor things, were rather exhausted by the time we subjected them to the tests and some of the results were perhaps due to again slight changes in their characteristics during the very extensive test programme which was slightly beyond the possibilities of certification to put right without new components. One thing I think that did become clear from the test programme was that as regards durability, generally speaking, the durability of this dummy does seem to have been really very good. The question that was

raised was 'Well, was the severity of test quite up to the maximum severity of test that a dummy of this sort will have to satisfy?' We like to think that it has been tested pretty nearly to the maximum level, if not completely so, and hopefully the indications are good.

The question of certification was raised and the question of setting up the dummy for a test procedure. We have described the certification set-up procedures as they exist at the moment. Further work is going on and I think will continue to go on until a legislative directive or whatever it happens to be is finally agreed. But nevertheless there is enough known about certification for the new dummies to go into a test programme with a reasonable degree of certification procedure ready before they start. It is mainly a matter of communicating this to interested parties.

Well, I could talk for a long time but I don't think anyone would really wish me to do so. It does say on the Programme that we hope to have Mr Garvey to make a few final remarks and here he is I think coming along to complete this evenings performance.

CLOSING REMARKS

by T. GARVEY, Commission of the European Communities

Gentlemen,

At this late stage in the evening I'm not going to keep you very long. I want to make a series of three groups of remarks around one theme and that is the word "harmony" which has been mentioned on at least two or three occasions since I came into the room.

First of all why am I here? One of my responsibilities in the Commission is the achievement of internal market according to the White Paper by 1992 for a fairly wide range of industries including the automobile sector and, whereas harmony is a lovely word gives you nice vibrations and so on, harmonization on the other hand has tended to be a word which has not been too popular with the media, certainly in some countries. But harmonize we must in areas where internal market barriers could be justified under Article 36 of the Treaty on health and safety grounds. Good regulations are necessarily always a balance between social factors and economic factors but the one thing they do need is the best scientific input that we can provide. Clearly, at a certain time too you have to marry political requirements and urgencies with scientific perfectionism and so on. At a certain stage you have to say 'go'. But this venture has I suppose harmonious objectives in that the whole objective is noble and that is the protection of life. Also the second one which is in harmony with the first because there is no contradiction between the protection of the citizens in Europe and an equally high level of protection throughout the market and not different rules and regulations in each country. The second thing I'd like to say about harmony is of course that what you have been talking about today, and what you have witnessed today, is clearly the result of a harmony of coming together, a cooperation on quite a significant European scale and I think that is not to be lost sight of. Any new piece of equipment of course, like the cars that I suppose you are ultimately involved in, needs a running-in period - a 'rodage' as they say in French - and clearly the experience of the first users

will be extremely important both in relation to ultimate design improvement and to the input of the work of the EEVC dummy development group.

The final thing I want to say about harmony is a wider connotation. This regulatory activity with which we are involved, and which you have been talking about today, has of course consequences wider than the Community. I want to emphasise those finally. Our regulatory activity within the Community has an impact on the consequences in our dealings with the rest of the world. I'll first of all mention the activities of the ECE in Geneva which has already started preparatory work we understand on the side impact regulation. We have always had the best of relations with this body and look forward to close and profitable collaboration from both of us in this area in the future. The second thing is to draw your attention to the positive response which you will have noted, somewhat 'nuancé', in response to the last question of the National Highway Traffic Safety Administration to collaborate with the Community in this matter. I hope that following the results of the presentation today and taken together with the results of their own tests with one of the EUROSID prototypes this dummy concept may be considered by the NHTSA as appropriate for their side impact test procedure. Because, it seems to me, that there is one thing that we must not miss in trying to remove the barriers from within this Community. We should not do it in such a way that we end up by erecting barriers between ourselves and our main trading partners, whether that be Japan whether that be the United States. And that's the last harmonization theme I wanted to strike. That we are dealing with a global problem, that technology which is global and markets which are global and we should look at it in that kind of harmonious way and in the work which is done and within the Community to get rid of the divisions between ourselves we shouldn't erect divisions with our main trading partners.

I won't take any more of your time except to say, with the very greatest of pleasure and sincerity, a word of thanks to all of those who were involved: the researchers who have carried out the different projects that have come together in this, the authors and the panellists here today, the interpreters, the technicians and you the audience with your questions and your interest and last, but by no means least, Dr. Neilson, for your participation, sir, as Chairman guiding us through this Programme and, indeed, keeping us most efficiently on schedule. Thank you all for your participation.

I hope to echo what was said that we will be in a position to publish the formal proceedings of the Seminar as soon as possible and, having said that, all that remains for me to say is to invite your company, to invite you to continue your contacts and discussions on a more informal and personal basis over a glass in the room next door. Thank you very much.

THE EUROPEAN SIDE IMPACT DUMMY

- A BRIEF SUMMARY -

This brief summary presents the history of EUROSID, the construction, the measurements and calibration, as well as the organisation of the future production and sales of EUROSID.

History EUROSID

1978-1981	EEC Biomechanics Programme sponsors development of prototypes and components of Side Impact Dummies
1981-1982	EEC Biomechanics Programme coordinates and sponsors extensive comparison testing of three European and one United States Side Impact Dummy prototypes
1983	EEC Biomechanics Seminar, Brussels, concludes that none of the existing prototypes is suitable for use in legislation testprocedures
1983	France, England and the Netherlands voluntarily start cooperation to develop a unified European Side Impact Dummy (the 'EUROSID')
1983-1986	Extensive development of EUROSID components under guidance of the EEVC Main Committee and Ad Hoc Dummy Development Committee
1986	EEC sponsors European evaluation programmes of four EUROSID prototypes
1986	TNO, OGLE and SEREME join forces to manufacture and sell the EUROSID

Construction

- **head** – metal casting with special flesh cover allows assessment of head injuries from direct contact with the interior
- **neck** – composition of metal disks and rubber elements with special joints to head and thorax ensures correct biokinetic motion of the head (SEREME/APR)
- **thorax** – 3 separate identical ribs covered with flesh-simulating plastic. Each rib attached to a system of piston, springs and damper. System insures correct biomechanical deflection and measures injury under distributed as well as localized loads (OGLE/TRRL)
- **shoulder** – special shoulder construction allows arm and shoulder to move aside realistically and exposes the ribs to direct impacts (OGLE/TRRL)
- **arms** – special design with realistic joints and flesh simulation (OGLE/TRRL)
- **abdomen** – metal casting covered by mass carrying plastic flesh simulation. Measures injury from abdominal overload (TNO)
- **spine** – solid rubber cylinder and steel cable
- **pelvis** – metal castings of pelvic bones in 2 sections covered by foam and with special flesh simulation to measure injury from loads through iliac wing and hip joint (SEREME/INRETS)
- **legs** – metal skeleton with flesh simulation and joints allowing realistic motion

Whenever modifications prove necessary the manufacturers will incorporate these in such a way that the dummy can be kept up-to-date by the purchase of some retrofit parts.

Measurements and calibration

Measurements:

- **head** – three-axial accelerometer in centre of gravity (transducers not included)
- **neck** – none
- **thorax**
  - three-axial accelerometer in centre of gravity (transducers not included)
  - 3 opto electronic rib displacement transducers (transducers and conditioning electronics included)
  - 3 optional uniaxial rib accelerometers (transducers not included)
- **abdomen** – 3 adjustable load threshold on/off switches (transducers included)
- **pelvis**
  - three-axial accelerometer in centre of gravity (transducer not included)
  - 2 straingauges on iliac wings (transducers included)
  - 1 load cell in pubic joint (transducer included)

Number of measurement channels:

- total of 18 channels + 3 optional channels
  - 12 accelerometers
  - 3 opto electronic displacement transducers
  - 3 on/off switches
  - 2 straingauges
  - 1 load washer

Calibration:

- dummy will be delivered adjusted, tested and calibrated
- recalibration procedures for users are currently under development

Left/right measurements:

- dummy is convertible from Left Hand Drive to Right Hand Drive

Production and sales

Cooperation TNO, OGLE and SEREME
to produce and sell the EUROSID dummies;
tasks divided as follows:

TNO

- **general coordination**
- **marketing and sales**
- **after sales service**
- **training course**
- **production of abdomen section**

OGLE

- **production of thorax/shoulder/arm section**
- **purchase and quality control of other components**
- **assembly and quality control of complete dummy**
- **drawings and documentation (together with TNO)**

SEREME

- **production of pelvis- and neck sections**

THE EUROPEAN SIDE IMPACT DUMMY "EUROSID"

Brussels - December 11, 1986

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The purpose of this seminar was to present this testing device, which is to be used in the future regulations on safety of car occupants, to the interested circles and parties (national administrations, test-houses, automobile industry, international bodies and research institutes and laboratories involved in activities on that matter, etc.).

Equally the seminar served as a platform to discuss the findings of the EEC-sponsored contract studies with those of the work on similar projects carried out in other parts of the world, especially in the USA.

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