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Experience of Using EUROSID-1 in Car Side Impacts

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EXPERIENCE OF USING EUROSID-1 IN CAR SIDE IMPACTS

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Report of the European Experimental Vehicles Committee - Working Group 9

Abstract

A database on EUROSID-1 performances in 31 full scale side impact tests is set up. Specific attention is given to the dummy results in relation to protection performance criteria. Mainly tests according to the proposed European side impact regulation with passenger cars are studied. Other tests included in the database are tests according to the American procedure, reconstructions of tests performed with cadavers ("FAT-tests") and several tests according to the European procedure with special vehicles.

Analysis of the database, considered representative for almost 20% of European cars on the current market, show that EUROSID-1 is sensitive to car design. Differences in thorax and abdomen response of this dummy are obvious between 2/3-door vehicles and 4/5-door vehicles. Differences in dummy responses on the basis of vehicle test weight are less obvious, however it appears that dummy responses decrease with increasing vehicle test weight.

The design of EUROSID-1 corresponds with injury assessment needs in side impact car testing. As far as sensitivity is concerned, EUROSID-1 is considered an appropriate anthropomorphic test device for approval and research purposes to improve side occupant protection.

Introduction

An anthropomorphic test device has to comply with several guidelines before it can be used in a test environment. For side impact dummies, quantitative guidelines have been developed (and some are still under consideration) for biofidelity, repeatability, reproduceability, measurement capability and calibration. Sensitivity, handling and durability are more qualitative characteristics of crash dummies, but also highly determine whether a dummy is suitable for car safety evaluation [1][1].

EUROSID-1, the production version of the European Side Impact Dummy and successor of the production prototype EUROSID, was released in April 1990. Since then,

[1] Numbers in parentheses designate references at end of paper

about 18 months have passed and hundreds of tests with this dummy have been conducted. The biofidelity and in some cases repeatability and reproduceability of this dummy, have been assessed in several research programmes comprising numerous sled, drop and impactor tests [2,3,4]. During the past 12 months or so, also quite a large number of full scale tests (FST's) with EUROSID-1 have been conducted. Objectives of these FST's vary: determining the status of and improving current passenger cars to proposed regulations, comparison of side impact dummies between each other and comparison of EUROSID-1 with cadaver responses.

The objective of this paper is to show EUROSID-1 responses in a number of full scale side impact tests with passenger cars. From these responses an impression is given of what can be expected from EUROSID-1 under these test conditions. The results are further studied as to what can be expected from current and proposed side impact regulations.

Results of FST's are gathered in a database set up by the TNO Crash-Safety Research Centre. Dummy responses collected merely concern performance criteria defined in side impact regulations. Discussion is held concerning sensitivity of EUROSID-1 during the FST's, performance of current car designs and possible effects resulting from side impact regulation.

EUROSID-1 measurement capability

The European Side Impact Dummy EUROSID-1 is designed for the evaluation of vehicle occupant protection under lateral impact. The dummy represents a 50th percentile male subject, weights 72 kg and has no lower arms. The specifications for this dummy have been developed by TRRL (UK), INRETS (F), APR (F), BASt (G) and TNO (NL) in co-operation with the EEVC Working Group on the Development of a Side Impact Dummy. EUROSID-1 is produced by Ogle Design Limited (UK) and the TNO Crash-Safety Research Centre (NL).

Figure 1 illustrates the position of the instrumentation for EUROSID-1. Measurement capabilities are available for the head (triaxial acceleration at centre of gravity), thorax (upper spine triaxial acceleration, lower spine lateral acceleration, lateral rib acceleration and lateral rib displacement for each of the three ribs), abdomen (three forces) and pelvis (triaxial pelvis acceleration and lateral pubic symphysis force). With this instrumentation the EUROSID-1 comprises 20 channels [5].

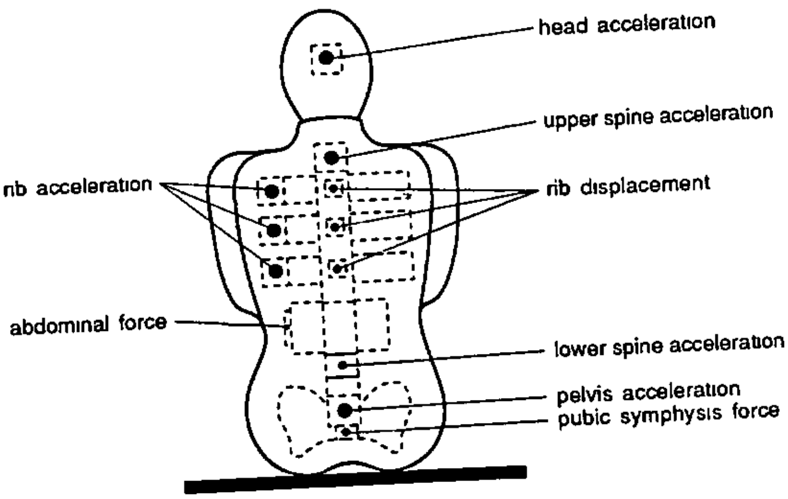

Figure 1: EUROSID-1 instrumentation for left hand side impacts (convertible to right hand side impact).

Side impact procedures

Legislative bodies in the United States of America and Europe are very active in preparing safety regulations for vehicle occupant protection in side impact. Regulations, although still under consideration, are very well elaborated. In the USA, the National Highway Traffic Safety Administration (NHTSA) is responsible for preparing a safety standard for occupant protection in side impact, released as Federal Motor Vehicle Safety Standard 214 "Side Impact Protection" (refered to as FMVSS 214) [6]. In Europe, the European Experimental Vehicles Committee (EEVC) has proposed a side impact procedure to the European Community (EC). This procedure was further elaborated by ECE/GRSP (Economic Commission for Europe/Working Party on the Construction of Vehicles) (refered to as EEVC-procedure) [7].

The database set up, comprises FST's according to both the proposed European and the American procedure. Furthermore tests are included in the database being reconstructions of cadaver tests performed at the University of Heidelberg under commission of the Forschungsvereinigung Automobiltechnik e.V. (FAT) [8]. Below a short description is given only of the EEVC-procedure and FMVSS 214 because results and discussions presented in this paper will concentrate on tests performed according to these two procedures.

FMVSS - test set-up

The American procedure FMVSS 214 describes a side impact on a passenger car with a movable deformable barrier (MDB). The MDB, weighting 3000 pounds (ca. 1360 kg), impacts the stationary vehicle laterally at a velocity of 33.5 mph (53.9 km/h). The wheels of the barrier are positioned at an angle of 27 degrees (this procedure is also refered to as "crabbed"). The barrier front is constructed of aluminium honeycomb, representing a deformable vehicle front including its bumper. FMVSS 214 specifies the US.SID as the dummy to be used to assess dynamic performance. Recently, the Working Group on Anthropomorphic Test Devices of the International Organisation for Standardization (ISO/TC22/SC12/WG5) considered BIOSID and EUROSID-1 acceptable dummies to be specified in the ISO full scale side impact test procedure [9]. This has also led to rulemaking activities at NHTSA for these two dummies to be included in FMVSS 214.

Figure 2a shows the principle of the FMVSS 214 test set-up. Dummy performance criteria specified in this regulation are given in Table 1.

EEVC - test set-up

The European Side Impact Procedure also describes a passenger car to be laterally impacted by a MDB. The wheels of the "European barrier" are, however, not positioned at an angle. Impact velocity should be 50 km/h. The barrier is constructed of a trolley equipped with a deformable foam front representing the crushable zone of an average European passenger car including its bumper. Total mass of the barrier is 950 kg. The European procedure specifies EUROSID-1 as the dummy to be used.

Figure 2b shows the principle of the EEVC-procedure test set-up. Dummy performance criteria specified in this regulation are given in Table 1.

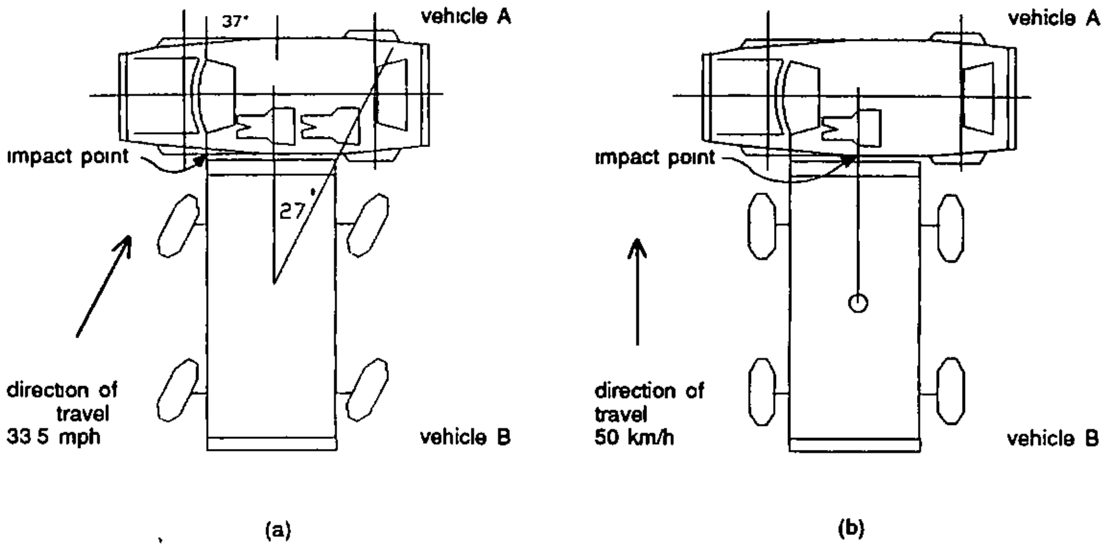

Figure 2: Principles of the test set-up for FMVSS 214 (a) and EEVC-procedure (b).

Dynamic performance criteria

The dynamic performance criteria for the dummy given in the European and American side impact regulation differ. FMVSS 214 specifies only acceleration requirements for the dummy's thorax and pelvis. The EEVC-procedure specifies various requirements for the head, thorax, abdomen and pelvis. Other performance criteria than those assessed by the dummy, such as door opening after the test, are not further discussed here. Table 1 provides an overview of dummy performance criteria for FMVSS 214 and the EEVC-procedure.

Table 1: Dummy performance criteria for FMVSS 214 and EEVC-procedure.

Dummy Body Part	Regulation/Dummy FMVSS 214/US.SID		EEVC-proc./EUROSID-1	
Head	-		HPC	≤ 1000 (s)[1]
Thorax	TTI	≤ 90 (G)[2]		
		≤ 85 (G)[2]		
			V*C	≤ 1.0 (m/s)[3]
			D	≤ 42 (mm)[4]
Abdomen	-		F_{tot}	≤ 2.5 (kN)[5]
Pelvis	$a_{lat,max}$	≤ 130 (G)[6]		
			F_{ps}	≤ 10 (kN)[7]

[1]: HPC = Head Protection Criterion;
[2]: TTI = Thoracic Trauma Index, 90 G applies to 2-door vehicles, 85 G applies to 4-door vehicles;
[3]: V*C = Viscous Criterion, applies to all 3 ribs of EUROSID-1;
[4]: D = lateral rib Displacement, applies to all 3 ribs of EUROSID-1;
[5]: F_{tot} = peak value of the sum of 3 abdominal forces of EUROSID-1;
[6]: $a_{lat,max}$ = peak lateral acceleration of the pelvis;
[7]: F_{ps} = peak pubic symphysis force.

The database

The database contains results of 31 FST's with EUROSID-1, conducted from Januari 1991 through August 1991. The data are provided by TRRL (UK), BASt (G), INRETS (F) and TNO (NL). All tests included are MDB-type tests on passenger cars. In all tests the dummy (driver or passenger position) was seated at the struck side. Table 2 provides an overview of the most important characteristics of the database discussed in this paper.

Table 2: Characteristics of the database on EUROSID-1 in full scale MDB tests.

* All tests were conducted with EUROSID-1				
* Total number of tests:				31
- No. EEVC tests:			26	
- No. EEVC tests with European passenger cars:		***22***		
- No. dummies in driver position.	***22***			
- No. dummies in passenger position	***12***			
- No. EEVC tests with "special" cars:		4		
- No. FMVSS tests:			***3***	
- No. dummies in driver position:	***3***			
- No. dummies in passenger position:	***3***			
- No. "FAT-tests"			2	

* All dummies were seated on struck side of the vehicle.
* Of the 22 EEVC tests with European passenger cars, 9 were right-hand-side and 13 left-hand-side impacts.
* Of the 22 EEVC tests with European passenger cars 7 tests were conducted on vehicles having a test weight below or equal to 1200 kg, 7 tests on vehicles having a test weight of more than 1200 kg but not more than 1450 kg and 8 tests on vehicles having a test weight above 1450 kg.
* Of the 22 EEVC tests with European passenger cars 5 vehicles had 2 or 3 doors and 17 vehicles had 4 or 5 doors.

Specific attention will be given in this paper to the tests according to the EEVC-procedure and to the tests according to FMVSS 214 (bold-faced italics in Table 2). The data are further analysed for differences between different vehicle weight classes (note: test weight is used here to devide the data) and between 2/3-door and 4/5-door vehicles. Also differences between EUROSID-1 in driver and passenger position are studied.

Results

Detailed results are presented in the Annexes at the end of this paper. The Annexes contain the dummy part, the parameter measured or calculated from measurements, the minimum, maximum and average value of the parameter, the number of tests (No.T) from which the average value is calculated and the number of tests in which a specific parameter fails the criterion (No.F). For all parameters presented the appropriate filter classes are applied according to [6] and [7].

Figure 3 shows the principle of the graphical presentation of the test results. Maximum, minimum and average dummy responses are expressed as percentage of the performance criteria. If a dummy response exceeds 100% it fails the requirement. Absolute values of the response criteria are given in Table 1.

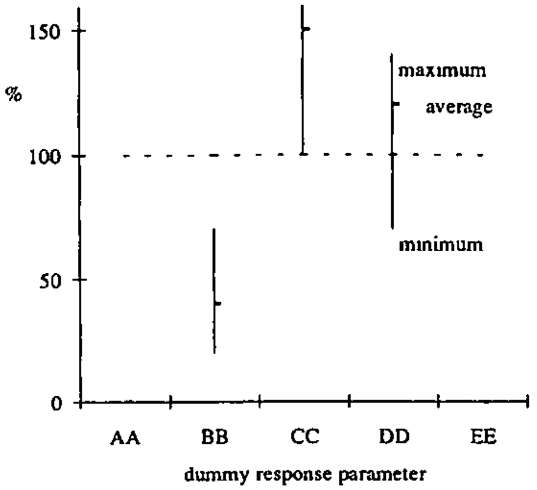

Figure 3: Example: dummy response as percentage of performance requirement.

EEVC tests: European passenger cars (22 tests)

Figures 4 and 5 show EUROSID-1 responses in tests conducted according to the EEVC-procedure with European passenger cars for driver (22 tests) and passenger (12 tests) position respectively. Presented are Head Protection Criterion (HPC), Viscous Criterion for all three ribs (VC1, VC2, VC3), lateral rib displacement for all three ribs (D1, D2, D3), total abdominal force (F_a) and pelvis pubic symphysis force (F_{ps}). Tables 3 and 4 give the absolute values of the data shown in Figures 4 and 5 respectively. Annex 1 contains detailed data on this set of tests.

For EUROSID-1 in driver position, values of dummy responses are observed both well above and below the performance criteria, except for HPC and F_{ps}: head and pelvis responses stay well below their requirement. VC values range from ca. 30% to ca. 200% of the performance criterion (1.0 m/s) for all three ribs. Rib displacements (D) range from ca. 50% to ca. 130% of the performance criterion (42 mm), also for all three ribs. Abdominal force (F_a) ranges from ca. 30% to ca. 160% of the performance criterion (2.5 kN). Average results for thorax (VC and D) and abdomen (F_a) approximate the criteria. Maximum values for HPC and F_{ps} lie more than 30% below the performance criteria.

The EEVC-procedure does not require a EUROSID-1 in passenger position for car approval. Nevertheless in 12 tests a passenger dummy is applied. In these 12 tests, all responses of EUROSID-1 in passenger position stay well below the criteria, except for the abdominal force which exceeds the criterion (2.5 kN) in 1 test. For this reason, dummy responses for EUROSID-1 in passenger position in tests according to the EEVC-procedure will not further be analysed.

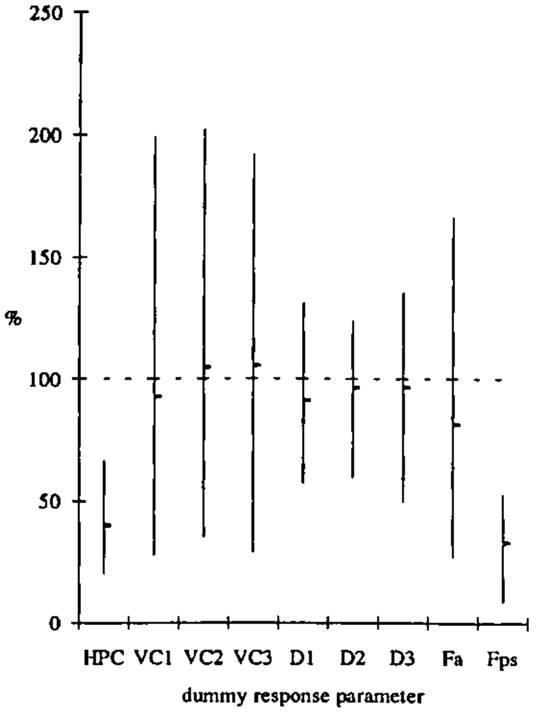

Figure 4: Results of tests according to EEVC-procedure: European passenger cars, driver position.

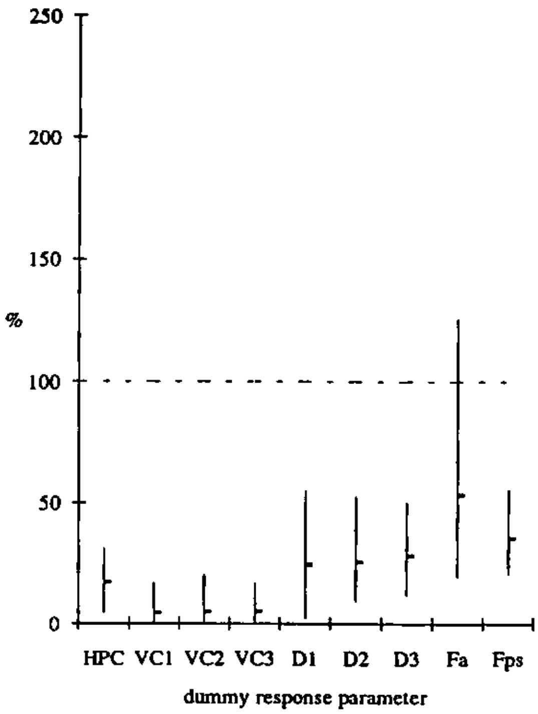

Figure 5: Results of tests according to EEVC-procedure: European passenger cars, passenger position.

Table 3: Range and average of EUROSID-1 responses in EEVC tests with European passenger cars, driver position.

parameter	range	average
HPC	202 - 664	398
VC1	0.28 - 1.99	0.93
VC2	0.35 - 2.02	1.05
VC3	0.29 - 1.92	1.05
D1	24 - 55	38
D2	25 - 52	41
D3	21 - 57	41
F_a	0.7 - 4.2	2.0
F_{ps}	0.9 - 5.3	3.3

Table 4: Range and average of EUROSID-1 responses in EEVC tests with European passenger cars, passenger position.

parameter	range	average
HPC	48 - 311	170
VC1	0.00 - 0.17	0.04
VC2	0.00 - 0.20	0.05
VC3	0.01 - 0.17	0.05
D1	1 - 23	10
D2	4 - 22	11
D3	5 - 21	12
F_a	0.5 - 3.1	1.3
F_{ps}	2.1 - 5.6	3.6

FMVSS tests: American passenger cars (3 tests)

Figures 6 and 7 show EUROSID-1 responses in tests conducted according to FMVSS 214 with American passenger cars for driver (3 tests) and passenger (3 tests) position respectively. Presented are Thoracic Trauma Index (TTI) for all three ribs and peak lateral pelvis acceleration ($a_{lat,max}$) as percentage of the performance critera. Tables 5 and 6 give the absolute values of the data shown in Figures 6 and 7 respectively.

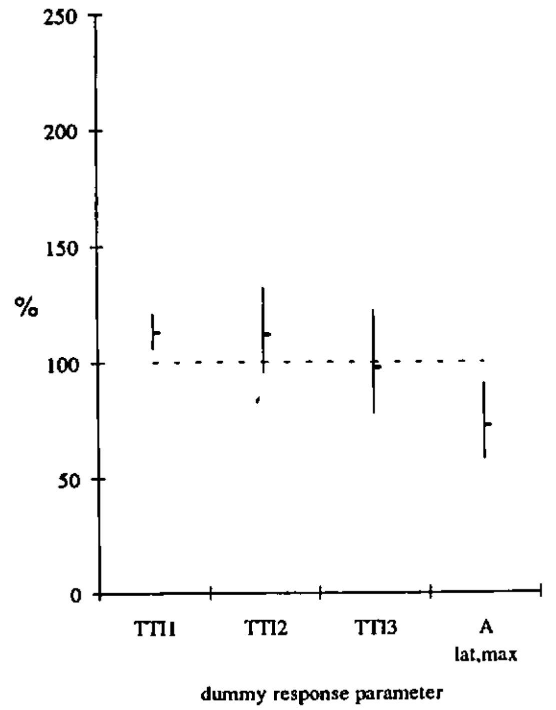

Figure 6: Results of tests according to FMVSS 214: American passenger cars, driver position.

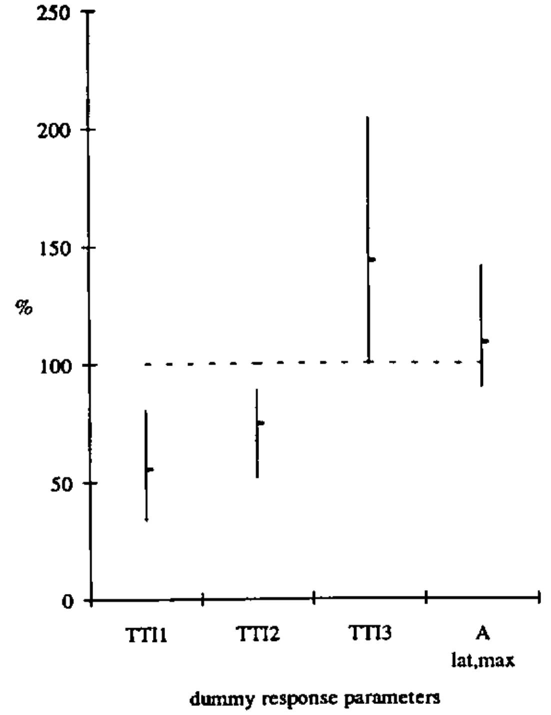

Figure 7: Results of tests according to FMVSS 214: American passenger cars, passenger position.

Table 5: Range and average of EUROSID-1 responses in FMVSS tests with American passenger cars, driver position.

parameter	range	average
TTI1	95 - 109	102
TTI2	86 - 119	101
TTI3	71 - 110	88
$a_{lat,max}$	75 - 118	94

Table 6: Range and average of EUROSID-1 responses in FMVSS tests with American passenger cars, passenger position.

parameter	range	average
TTI1	30 - 73	50
TTI2	46 - 80	67
TTI3	90 - 184	129
$a_{lat,max}$	117 - 184	141

Results of the tests according to FMVSS 214 presented here form part of a research programme of the EEVC Working Group on the Development of a Side Impact Dummy. Objective of this study is to compare US.SID and EUROSID-1 responses in the same tests. Sled tests as well as FST's are or will be performed on EUROSID-1 up till the end of 1991. The results of the FST's according to FMVSS 214 will only be discussed to a limited extend, in order not to anticipate on results of the complete research programme yet to come. Furthermore the number of tests according to FMVSS 214 included in the database is low. Results shown in Figures 6 and 7 and Tables 5 and 6 thus are only limited representative of what can be expected of EUROSID-1 in tests according to FMVSS 214.

Annex 2 contains details of the dummy responses for the 3 tests with American passenger cars according to FMVSS 214. Average results for EUROSID-1 in driver position lie at or just above (ca. 10%) the performance criterion for TTI (85G) and ca. 25% below the criterion for pelvis acceleration. Average results for EUROSID-1 in passenger position lie well below (more than 25%) the performance criterion for upper and middle rib TTI but exceeds the performance criterion for lower rib TTI by more than 40%. The average result for EUROSID-1 in passenger position lie close to the performance criterion for peak lateral pelvis acceleration, however this average lies well above that found for EUROSID-1 in driver position.

EEVC tests: weight classes (7-7-8 tests)

Responses of EUROSID-1 in tests according to the EEVC-procedure are further analysed for differences in responses on the basis of differences in vehicle test weight (M). This test weight includes the dummy c.q. dummies, instrumentation, vehicle mounted camera's and additional weights. For this the set of 22 tests is devided into 3 sections/weight classes:

- vehicles with M ≤ 1200 kg (7 tests),
- vehicles with 1200 < M ≤ 1450 kg (7 tests), and
- vehicles with M > 1450 kg (8 tests).

Figures 8, 9 and 10 show the dummy responses as percentage of performance criteria for the three sections mentioned above. Tables 7, 8 and 9 give the absolute values of the data presented in Figures 8, 9 and 10 respectively. Annex 3 contains detailed data of the sections mentioned above.

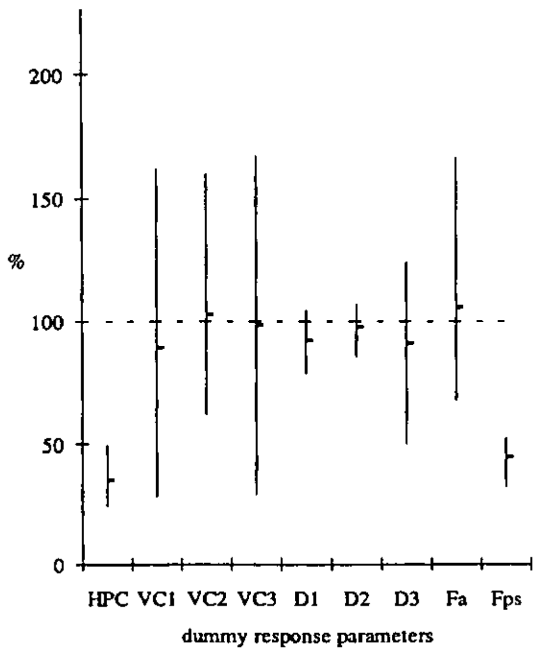

Figure 8: Results of tests according to EEVC-procedure: M ≤ 1200 kg, driver position.

Table 7: Range and average of EUROSID-1 responses in EEVC tests: M ≤ 1200 kg, driver position.

parameter	range	average
HPC	243 - 496	348
VC1	0.28 - 1.62	0.89
VC2	0.62 - 1.60	1.03
VC3	0.29 - 1.67	0.98
D1	33 - 44	39
D2	36 - 45	41
D3	21 - 52	38
F_a	1.7 - 4.2	2.6
F_{ps}	3.2 - 5.3	4.4

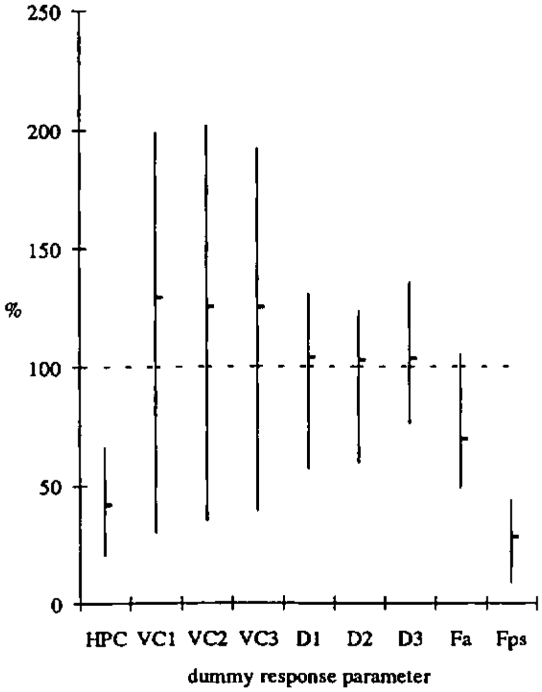

Figure 9: Results of tests according to EEVC-procedure: 1200 < M ≤ 1450 kg, driver position.

Table 8: Range and average of EUROSID-1 responses in EEVC tests: 1200 < M ≤ 1450 kg, driver position.

parameter	range	average
HPC	202 - 664	418
VC1	0.30 - 1.99	1.29
VC2	0.35 - 2.02	1.25
VC3	0.39 - 1.92	1.25
D1	24 - 55	44
D2	25 - 52	43
D3	32 - 57	43
F_a	1.2 - 2.6	1.7
F_{ps}	0.9 - 4.4	2.8

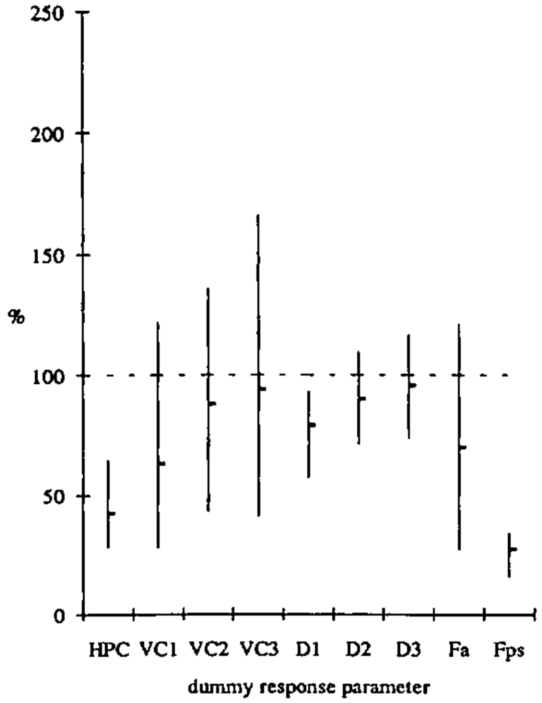

Figure 10: Results of tests according to EEVC-procedure: M > 1450 kg, driver position.

Table 9: Range and average of EUROSID-1 responses in EEVC tests: M > 1450 kg, driver position.

parameter	range	average
HPC	278 - 648	422
VC1	0.28 - 1.22	0.64
VC2	0.43 - 1.36	0 88
VC3	0.41 - 1.66	0.94
D1	24 - 39	33
D2	30 - 46	38
D3	31 - 49	40
F_a	0.7 - 3.0	1.8
F_{ps}	1.6 - 3.4	2.7

Average abdominal force is highest for the lowest vehicle test weight class. F_a is similar between the higher two weight classes. Values found for HPC and F_{ps} are all well below performance criteria (see also Figure 4) and will not be further discussed.

Average VC values for tests with vehicles having a test weight of 1200 kg or less, approximate the performance criterion for all three ribs of EUROSID-1. For vehicles with a test weight between 1200 and 1450 kg average VC values exceed the criterion by ca. 25%, again for all three ribs. Tests with vehicles having a test weight above 1450 kg show an average VC ca. 10% to 40% below the criterion. The same trend can be seen for rib displacements: average rib displacements are largest for vehicles weighting 1200 to 1450 kg and are slightly above the performance criterion; rib displacements for vehicles weighting more than 1450 kg show the lowest average values (ca. 5% to 20% below criterion) while vehicles with a weight below 1200 kg show average rib displacements slightly below the criterion.

EEVC tests: number-of-doors classes (5-17 tests)

From earlier experience in side impact testing, it is known that the position of the B-pillar highly affects dummy responses in FST's. B-pillar position and thus the number of doors is considered an important parameter in car safety design. For further analysis of the dummy responses in the database, the total set of 22 tests according to the EEVC-procedure is devided in 2 sections:

- vehicles with 2 or 3 doors (5 tests), and
- vehicles with 4 or 5 doors (17 tests).

Figures 11 and 12 show EUROSID-1 responses as percentage of performance criteria for the two sections mentioned above. Tables 10 and 11 give the absolute values of the data presented in Figures 11 and 12 respectively. Detailed data are contained in Annex 4.

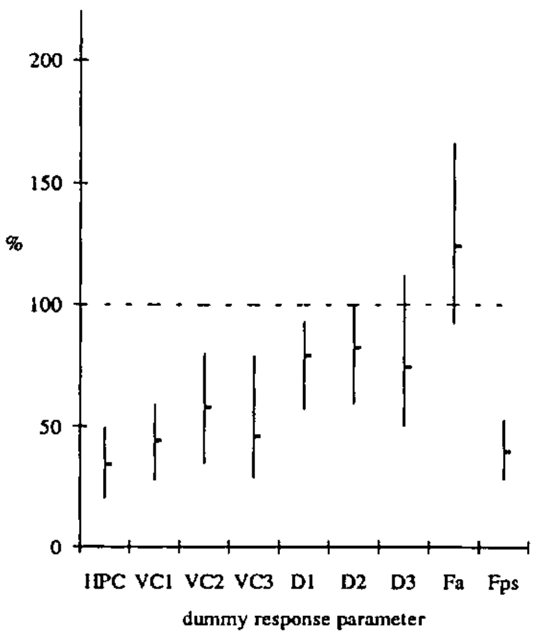

Figure 11: Results of tests according to EEVC-procedure: 2/3 doors, driver position.

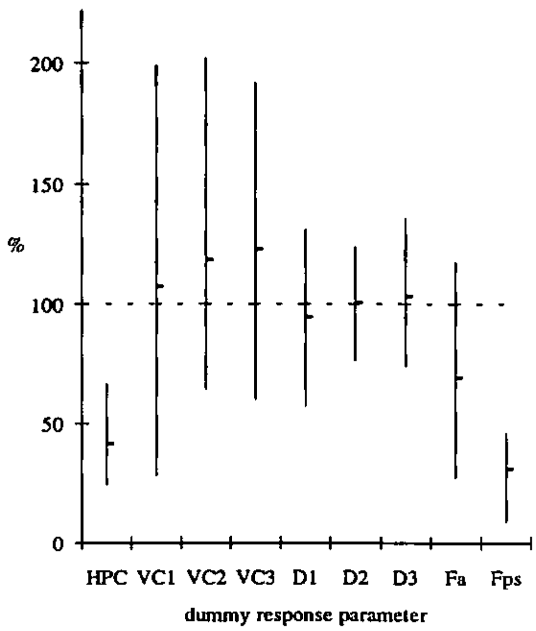

Figure 12: Results of tests according to EEVC-procedure: 4/5 doors, driver position.

Table 10: Range and average of EUROSID-1 responses in EEVC tests: 2/3-doors, driver position.

parameter	range	average
HPC	202 - 496	342
VC1	0.28 - 0.59	0.44
VC2	0.35 - 0.80	0.58
VC3	0.29 - 0.79	0.46
D1	24 - 39	33
D2	25 - 42	35
D3	21 - 47	31
F_a	2.3 - 4.2	3.1
F_{ps}	2.8 - 5 3	4 0

Table 11: Range and average of EUROSID-1 responses in EEVC tests: 4/5-doors, driver position.

parameter	range	average
HPC	243 - 664	414
VC1	0.28 - 1.99	1.07
VC2	0.64 - 2.02	1.18
VC3	0.60 - 1.92	1.23
D1	24 - 55	40
D2	32 - 52	42
D3	31 - 57	43
F_a	0.7 - 2.9	1.7
F_{ps}	0.9 - 4.6	3.1

Average as well as maximum VC values are below the performance criterion for 2/3-door vehicles for all three ribs of EUROSID-1, while average VC values exceed the performance criterion for 4/5-door vehicles for all three ribs. Average rib displacements are below the performance criterion for all three ribs of EUROSID-1 for 2/3-door vehicles, while average rib displacements approximate the performance criterion for 4/5-door vehicles. In general: 2/3-door vehicles show lower EUROSID-1 thorax responses in tests according to the EEVC-procedure compared to 4/5-door vehicles.

The average abdominal force for 2/3-door vehicles exceeds the performance criterion by ca. 25%. Average abdominal force for 4/5-door vehicles is well below the criterion (ca. 30%). Average pubic symphysis force is higher for 2/3-door vehicles compared to 4/5-door vehicles but for both types of vehicles the pubic force stays well below the performance criterion. In general: 2/3-door vehicles show higher EUROSID-1 abdomen and pelvis responses in tests according to the EEVC-procedure compared to 4/5-door vehicles.

Discussion and conclusions

The general objective of this study was to present responses of the EUROSID-1 found in a number of full scale side impact tests with passenger cars in order to show what can be expected of this dummy as a research and approval tool. Furthermore the data are used to show possible effects of side impact regulation on current car design. For this a database is set-up comprising 31 tests according to three procedures. The database includes tests conducted at four laboratories during Januari 1991 through August 1991. Presented in detail are results obtained with EUROSID-1 in 22 tests according to the EEVC-procedure and in 3 tests according to FMVSS 214.

Responses of EUROSID-1, in tests according to the EEVC-procedure as well as according to FMVSS 214, show a reasonable spread around the performance criteria. This implies that EUROSID-1 is sensitive to car design. Comparison of dummy responses in tests according to the EEVC-procedure for different vehicle weights did not show great differences, although it appears that for increasing vehicle test weight dummy responses decrease. Differences between 2/3-door and 4/5-door cars are more obvious. Thorax responses of EUROSID-1 in driver position are considerably lower for 2/3-door cars compared to 4/5-door cars. On the other hand abdomen and to a lesser extend pelvis responses are higher for 2/3-door cars compared to 4/5-door cars. Usually the B-pillar is positioned further backwards relative to the dummy for 2/3-door cars compared to 4/5-door cars. Furthermore the B-pillar construction will be stiffer in 2/3-door cars compared to 4/5-door cars. These two features may account for a large part of the differences observed in dummy responses between 2/3-door vehicles and 4/5-door vehicles.

Differences in the test set-ups used in the EEVC-procedure and FMVSS 214 are indicated by different performances of the dummy in passenger position relative to the performance criteria. Barrier stiffness and impact position in FMVSS 214 are such that (rear) passengers on the struck side will be more involved in the impact than compared to the EEVC-procedure and higher dummy responses are likely.

In no test according to the EEVC-procedure head responses of the EUROSID-1 exceeds the performance criterion. This affirms the general opinion that during the proposed full scale side impact test no head contact with the car interior occurs. Within EEVC consideration is given to a separate head to car interior impact tests as a possible addition to car safety evaluation. Accident studies have shown that head contact may occur in side collisions. The initiative of EEVC of preparing an additional procedure for head impact for side impact occupant protection is supported by the results presented in this paper.

Analysis of thorax responses of EUROSID-1 in tests according to the EEVC-procedure (driver position) show that in 14 tests VC exceeded 1.0 m/s. In 12 of these 14 cases this concerns 2 or 3 ribs. Thus in a majority of the tests according to the EEVC-procedure in which the VC criterion was exceeded, more than 1 rib showed a VC exceeding 1.0 m/s. This implies that three thoracic ribs suffice to assess the risk of injury to this body part. The design of EUROSID-1's thorax thus is considered satisfactory.

Further analysis of abdominal force responses of EUROSID-1 in tests according to the EEVC-procedure in driver position, show that maximum force readings are largest for the rear transducer in ca. 65% of the tests and for the middle trandsducer in ca. 35% of the tests. In no test the front transducer gave the highest response for the driver. Reason for this is the non-lateral intrusion of the door. Highest car deformation is usually seen at or very close to the B-pillar which lies somewhat to the backside of the dummy.

Pubic symphysis loads all lie well below the performance criterion of 10 kN. This tolerance level of 10 kN was determined by reconstruction of impactor tests on cadavers with the production prototype EUROSID [10]. The production prototype EUROSID incorporated an aluminium pelvis construction. EUROSID-1, however, incorporates plastic iliac wings and is less stiff than the production prototype EUROSID. Thus lower pubic symphysis loads are likely for EUROSID-1 compared to the production prototype in the same tests. Nevertheless the low pubic symphysis loads observed in the tests affirm the fact that in side collisions very few serious pelvic injuries occur.

Data included in the database merely concern tests with European passenger cars according to a recently developed procedure. Research laboratories and car manufacturers are concerned op to now with the performance of current car designs. No tests are included in the database with modified/improved vehicles and thus the results of this study represent part of the current status of European passenger cars as far as side impact is concerned. The database presented in this paper represents almost 20% of the cars sold in Europe in

1990. In 4 tests according to the EEVC-procedure dummy responses completely fulfilled the performance criteria. Also in 4 EEVC tests more than 5 (out of 9) criteria were not met. In the remaining 14 EEVC tests, 1 to 5 dummy responses failed the requirements. This indicates that for a substantial part of the car types included in the database, modifications to current car design are likely to result in side impact approval for these vehicles. Examples of the benifical effect of vehicle modifications on the basis of EUROSID-1 responses are in progress and some of them are already presented [11].

Up to now, the database presented in this paper contains 31 MDB-type side impact tests with EUROSID-1. The intention is to extend this database in the future. Car-to-car impacts, tests with other side impact dummies, more vehicle types and possibly cadaver tests will be included in the database. Furthermore additional database parameters concerning car design and barrier specifications will be included. This paper has shown some features of such a database to help improving vehicle side impact crashworthiness.

Acknowledgement

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ANNEX 1: EUROSID-1 responses in tests according to the EEVC-procedure with European passenger cars;

Driver position, 22 tests

HEAD	parameter	Min	Max	Average	No.T	No. F
	HPC	202	664	398	22	0
	peak head res acc.	38	154	76	22	
	peak head res acc 3ms	37	102	62	18	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak lateral T1 acc.	54	157	89	22	
	TTI upper rib	70	185	123	22	
	TTI middle rib	73	188	129	22	
	TTI lower rib	82	166	119	21	
	V*C upper rib	0 28	1.99	0.93	22	10
	V*C middle rib	0.35	2.02	1.05	22	13
	V*C lower rib	0.29	1 92	1.05	22	11
	peak upper rib displ.	24	55	38	22	8
	peak middle rib displ	25	52	41	22	9
	peak lower rib displ.	21	57	41	22	10
	peak upper rib acc	77	383	189	22	
	peak middle rib acc	72	343	214	22	
	peak lower rib acc	92	307	186	21	
	peak lateral T12 acc	70	157	97	22	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak front force	0 2	1.3	0.4	22	
	peak middle force	0.2	2.1	0.8	22	
	peak rear force	0.5	2.0	1 0	22	
	peak total force	0 7	4.2	2.0	22	5
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc	53	112	81	22	
	peak res. pelvis acc.	55	119	86	22	
	peak pubic symph force	0 9	5 3	3.3	22	0

Passenger position, 12 tests.

HEAD	parameter	Min	Max	Average	No T	No F
	HPC	48.13	311 48	170 22	12	0
	peak head res acc	24 76	105.71	66.17	12	
	peak head res acc 3ms	21 44	78.33	53 51	12	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak lateral T1 acc	16.65	31 68	24.88	12	
	TTI upper rib	23 11	53.00	30 31	12	
	TTI middle rib	23.30	43 30	30 25	12	
	TTI lower rib	23 70	44 00	31 56	12	
	V*C upper rib	0.00	0 17	0.04	12	0
	V*C middle rib	0 00	0.20	0.05	12	0
	V*C lower rib	0 01	0.17	0.05	12	0
	peak upper rib displ	1 00	23 00	10 25	12	0
	peak middle rib displ	4 00	22 00	10 75	12	0
	peak lower rib displ	5 00	21 00	11.83	12	0
	peak upper rib acc	21.92	69.91	30.87	12	
	peak middle rib acc	23.15	43.12	31.00	12	
	peak lower rib acc	22 91	56.07	33 92	12	
	peak lateral T12 acc	16 87	48 84	30 26	12	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak front force	0.16	1.09	0 51	12	
	peak middle force	0 20	1 48	0.52	12	
	peak rear force	0.16	0.66	0.33	12	
	peak total force	0 49	3 14	1 33	12	1
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc	32.00	66.83	44 94	12	
	peak res. pelvis acc	35.97	70 62	50 95	12	
	peak pubic symph force	2.06	5 55	3 55	12	0

ANNEX 2: EUROSID-1 responses in tests according to FMVSS 214 with American passenger cars;

Driver position, 3 tests

HEAD	parameter	Min	Max	Average	No T	No F
	HPC	132 80	184 50	158 33	3	
	peak head res acc	-	-	-	-	
	peak head res acc 3ms	-	-	-	-	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral T1 acc	-	-	-	-	
	TTI upper rib	95 20	108 80	101.53	3	3
	TTI middle rib	86 20	118 80	100 67	3	2
	TTI lower rib	70 50	110 10	87 80	3	1
	V*C upper rib	-	-	-	-	
	V*C middle rib	-	-	-	-	
	V*C lower rib	-	-	-	-	
	peak upper rib displ	33 20	46 50	38 40	3	
	peak middle rib displ	25 90	41 30	33 77	3	
	peak lower rib displ	15.20	34 90	26 57	3	
	peak upper rib acc	-	-	-	-	
	peak middle rib acc	-	-	-	-	
	peak lower rib acc	-	-	-	-	
	peak lateral T12 acc	-	-	-	-	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak front force	0.30	1.10	0 60	3	
	peak middle force	1.20	1 80	1 53	3	
	peak rear force	0 90	2 20	1 40	3	
	peak total force	2.37	3 77	3 17	3	
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc.	75 30	118 10	94.27	3	0
	peak res pelvis acc	-	-	-	-	
	peak pubic symph force	3 50	5 20	4 30	3	

Passenger position, 3 tests.

HEAD	parameter	Min	Max	Average	No T	No F
	HPC	142 70	305.90	225.20	3	
	peak head res acc.	-	-	-	-	
	peak head res acc 3ms	-	-	-	-	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral T1 acc.	-	-	-	-	
	TTI upper rib	30 40	72.50	49 77	3	0
	TTI middle rib	46 40	80 10	67 20	3	0
	TTI lower rib	89 60	183 70	129 00	3	2
	V*C upper rib	-	-	-	-	
	V*C middle rib	-	-	-	-	
	V*C lower rib	-	-	-	-	
	peak upper rib displ	9.00	30 70	17 73	3	
	peak middle rib displ	15 60	56 20	35 63	3	
	peak lower rib displ.	16 30	41 30	28 80	2	
	peak upper rib acc	-	-	-	-	
	peak middle rib acc.	-	-	-	-	
	peak lower rib acc	-	-	-	-	
	peak lateral T12 acc	-	-	-	-	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak front force	1 20	2.10	1.63	3	
	peak middle force	0.60	2.20	1 33	3	
	peak rear force	0.30	0 90	0 67	3	
	peak total force	2 20	5 13	3 51	3	
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak lateral pelis acc	117.10	183 70	141 37	3	1
	peak res. pelvis acc	-	-	-	-	
	peak pubic symph force	4 20	5 00	4 60	2	

ANNEX 3: EUROSID-1 responses in tests according to the EEVC-procedure with European passenger cars;

M ≤ 1200 kg, driver (7 tests)

HEAD	parameter	Min	Max	Average	No.T	No. F
	HPC	243	496	348	7	0
	peak head res acc.	53	96	70	7	
	peak head res acc 3ms	48	78	68	3	
THORAX	parameter	Min	Max	Average	No T	No F
	peak lateral T1 acc.	57	129	78	7	
	TTI upper rib	100	150	121	7	
	TTI middle rib	114	169	136	7	
	TTI lower rib	103	145	121	6	
	V*C upper rib	0.28	1.62	0 89	7	3
	V*C middle rib	0 62	1 60	1 03	7	5
	V*C lower rib	0.29	1.67	0 99	7	4
	peak upper rib displ	33	44	39	7	2
	peak middle rib displ.	36	45	41	7	2
	peak lower rib displ	21	52	38	7	3
	peak upper rib acc	162	265	196	7	
	peak middle rib acc	161	330	247	7	
	peak lower rib acc.	122	244	191	6	
	peak lateral T12 acc	75	108	91	7	
ABDOMEN	parameter	Min	Max	Average	No T	No F
	peak front force	0.3	1 3	0.6	7	
	peak middle force	0 6	2 1	1 1	7	
	peak rear force	0.7	2 0	1.1	7	
	peak total force	1 7	4 2	2.6	7	3
PELVIS	parameter	Min	Max	Average	No T	No.F
	peak lateral pelis acc.	77	112	98	7	
	peak res. pelvis acc	81	119	104	7	
	peak pubic symph. force	3 2	5.3	4 4	7	0

1200 < M ≤ 1450 kg, driver (7 tests)

HEAD	parameter	Min	Max	Average	No.T	No F
	HPC	202	664	418	7	0
	peak head res acc	38	154	100	7	
	peak head res acc 3ms	37	102	68	7	
THORAX	parameter	Min	Max	Average	No T	No F
	peak lateral T1 acc	54	157	103	7	
	TTI upper rib	70	185	139	7	
	TTI middle rib	73	188	136	7	
	TTI lower rib	82	166	133	7	
	V*C upper rib	0.30	1 99	1 29	7	6
	V*C middle rib	0 35	2.02	1.25	7	5
	V*C lower rib	0 39	1.92	1 25	7	4
	peak upper rib displ.	24	55	44	7	6
	peak middle rib displ.	25	52	43	7	5
	peak lower rib displ	32	57	43	7	3
	peak upper rib acc.	88	383	237	7	
	peak middle rib acc.	72	343	220	7	
	peak lower rib acc	98	307	220	7	
	peak lateral T12 acc	73	157	107	7	
ABDOMEN	parameter	Min	Max	Average	No T	No F
	peak front force	0 3	0 6	0 4	7	
	peak middle force	0 4	1.1	0 7	7	
	peak rear force	0.5	1 6	0.8	7	
	peak total force	1 2	2.6	1.7	7	1
PELVIS	parameter	Min	Max	Average	No T	No.F
	peak lateral pelis acc.	53	89	73	7	
	peak res pelvis acc.	55	103	79	7	
	peak pubic symph force	0 9	4 4	2.8	7	0

ANNEX 3 (continued)

M > 1450 kg, driver (8 tests)

HEAD	parameter	Min	Max	Average	No T	No F
	HPC	278	648	422	8	0
	peak head res acc	45	93	59	8	
	peak head res acc 3ms	43	73	54	8	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No.T**	**No F**
	peak lateral T1 acc.	69	132	85	8	
	TTI upper rib	76	155	111	8	
	TTI middle rib	84	155	117	8	
	TTI lower rib	83	149	106	8	
	V*C upper rib	0 28	1 22	0 64	8	1
	V*C middle rib	0 43	1 36	0.88	8	3
	V*C lower rib	0.41	1.66	0.94	8	3
	peak upper rib displ	24	39	33	8	0
	peak middle rib displ	30	46	38	8	2
	peak lower rib displ	31	49	40	8	4
	peak upper rib acc	77	260	139	8	
	peak middle rib acc	94	266	180	8	
	peak lower rib acc	92	240	151	8	
	peak lateral T12 acc.	70	150	94	8	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No T**	**No.F**
	peak front force	0.2	0.4	0 3	8	
	peak middle force	0.2	1.2	0.7	8	
	peak rear force	0.5	1.4	0 9	8	
	peak total force	0.7	3.0	1.8	8	1
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc.	61	86	73	8	
	peak res pelvis acc	70	90	77	8	
	peak pubic symph force	1.6	3.4	2 7	8	0

ANNEX 4: EUROSID-1 responses in tests according to the EEVC-procedure with European passenger cars;

2/3-door vehicles, driver (5 tests)

HEAD	parameter	Min	Max	Average	No T	No F
	HPC	202.45	495.70	341 82	5	0
	peak head res acc.	48.48	86 34	61.09	5	
	peak head res acc 3ms	40 00	48.46	45 00	3	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No T**	**No.F**
	peak lateral T1 acc	54 24	72.45	63.15	5	
	TTI upper rib	69.88	108.60	88 69	5	
	TTI middle rib	72 95	128.03	98.92	5	
	TTI lower rib	81.77	106.10	93.18	5	
	V*C upper rib	0.28	0 59	0 44	5	0
	V*C middle rib	0.35	0.80	0.58	5	0
	V*C lower rib	0.29	0.79	0.46	5	0
	peak upper rib displ	24 00	39.00	33.20	5	0
	peak middle rib displ	25.00	42.00	34 60	5	0
	peak lower rib displ	21.00	47 00	31 20	5	1
	peak upper rib acc.	76.80	189.70	127 79	5	
	peak middle rib acc.	71.96	221 60	141 13	5	
	peak lower rib acc	92.27	139.90	111 26	5	
	peak lateral T12 acc.	72.72	82.66	77 81	5	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak front force	0.27	1.31	0.63	5	
	peak middle force	1.09	2.05	1.41	5	
	peak rear force	0.65	2.00	1.21	5	
	peak total force	2.31	4 16	3.10	5	3
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc.	72 36	111 90	91 43	5	
	peak res. pelvis acc.	73 72	119 00	97 78	5	
	peak pubic symph force	2.81	5.25	3.97	5	0

4/5-door vehicles, driver (17 tests)

HEAD	parameter	Min	Max	Average	No.T	No F
	HPC	243	664	414	17	0
	peak head res acc.	38	154	80	17	
	peak head res acc 3ms	37	102	65	15	
THORAX	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral T1 acc.	57	157	96	17	
	TTI upper rib	91	185	133	17	
	TTI middle rib	98	188	138	17	
	TTI lower rib	87	166	127	16	
	V*C upper rib	0.28	1.99	1 07	17	10
	V*C middle rib	0 64	2.02	1.18	17	13
	V*C lower rib	0 60	1.92	1 23	17	11
	peak upper rib displ	24	55	40	17	8
	peak middle rib displ.	32	52	42	17	9
	peak lower rib displ	31	57	43	17	9
	peak upper rib acc	102	383	206	17	
	peak middle rib acc.	131	343	235	17	
	peak lower rib acc.	129	307	209	16	
	peak lateral T12 acc.	70	157	103	17	
ABDOMEN	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak front force	0 2	0 6	0 4	17	
	peak middle force	0.2	1.5	0 6	17	
	peak rear force	0 5	1.6	0.9	17	
	peak total force	0.7	2.9	1 7	17	2
PELVIS	**parameter**	**Min**	**Max**	**Average**	**No T**	**No F**
	peak lateral pelis acc	53	105	78	17	
	peak res. pelvis acc.	55	107	83	17	
	peak pubic symph force	0 9	4 6	3.1	17	0