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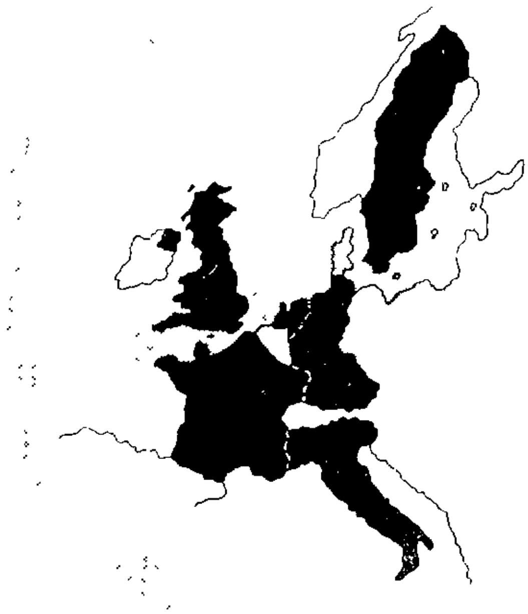

European Experimental Vehicles Committee

Structures

Improved side impact protection in Europe

Presented to the Ninth ESV Conference Kyoto Nov 1982

EUROPEAN EXPERIMENTAL VEHICLES COMMITTEE

WORKING GROUP N° 6 - STRUCTURES IMPROVED SIDE IMPACT PROTECTION IN EUROPE

PRESENTED TO THE NINTH ESV CONFERENCE KYOTO NOV. 1982

Terms of Reference

Review the available accident date in Europe concerning side impact collisions involving passenger cars and make recommendations for a suitable test procedure and standards for reducing injuries to vehicle occupants in such accidents. It will consider the validity of the USA proposals for side impact collision tests as a mean of reducing injuries involving European cars.

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CHAPTER 1 : INTRODUCTION : THE NEED FOR A STANDARD SIDE IMPACT TEST

The work of the WG 6 "Structures" can be looked at as continuation of the WG 5 "Impact Test Procedures" which dealt with frontal, side and rear collision and rollover.

The main points of WG 5 were :

- The Group proposes a test with a stationary case car struck by movable barrier under an angle of 90°.
- The barrier should be deformable for the long term solution but no further details could be given at that time because of missing research results.
- For the short term solution no concrete test procedures (i.e. with the same type of car) could be adopted either because of some basic disadvantages of each of those proposals.

Concerning side collision a lot of questions remained open.

The frequency of side impact accidents comes second to the frequency of frontal impact accidents, and according to our present knowledge of accident statistics, it is the vehicle-to-vehicle collision which has the greatest statistical significance of all accidents involving side impact (1,2).

According to various studies, side impacts involving a collision with a private car represent 15 to 20 % of private car accidents (2, 3, 4). This percentage varies according to the country, but also according to the definition of side impacts, one is given for instance in (5).

Side impact accidents are more serious than accidents which occur according to the other configurations : in 4 European countries (West Germany, France, Italy and the United Kingdom), 21,6 % to 31,2 % of serious or fatal car accidents are side impact accidents (6) and the occupants most seriously injured are those seated at the side on which the impact occurs (5). Lastly, during recent years, protection improvement has concerned essentially frontal impact which suggests a deeper study of the side impact, as the means of protection (ie seat belts) proposed for frontal impact have little effect in side impact ; their principal contribution in this type of impact is to prevent ejection and a restraint to some extent to the offside occupant (2). These particulars are sufficient to justify the principle of systematic studies of side impacts and protection from injury.

CHAPTER 2 : CRASH CONFIGURATIONS AND CONSEQUENCES OF SIDE IMPACT ACCIDENTS

Different studies have been made from analysis of real accidents, describing the conditions of impact and the typology of injuries from side impact accidents.

In (7) is given an overlook over the situation of all collision types devided in 12 main groups. If they are jugded by criteria from several authors (8, 9) the rectangular side collision ranks third behind two frontal collision types.

On the basis of an accident survey conducted in France (10), it appears that the most frequent and the most serious side impact accidents correspond to a point of maximum intrusion close to the projection of the H point of the vehicle collided with, as indicated in figure 1. The same document indicated that over half of serious or fatal accidents occur according to an angle of between 55° and 85° of the colliding car in relation to the collided car.

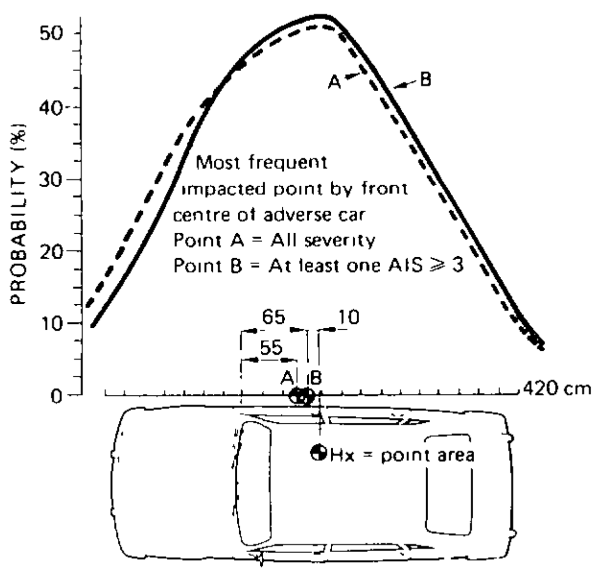

Fig. 1 · Location of impacted area in side impact (10)

Many details of the types of damage to car sides and of how occupants are injured are given in a United Kingdom study (11) and a more detailed analysis of these accidents is now being carried out. For example it shows that in 62 % of all side impact accidents and in all fatal cases, the front door of the car run into is directly implicated by the impact.

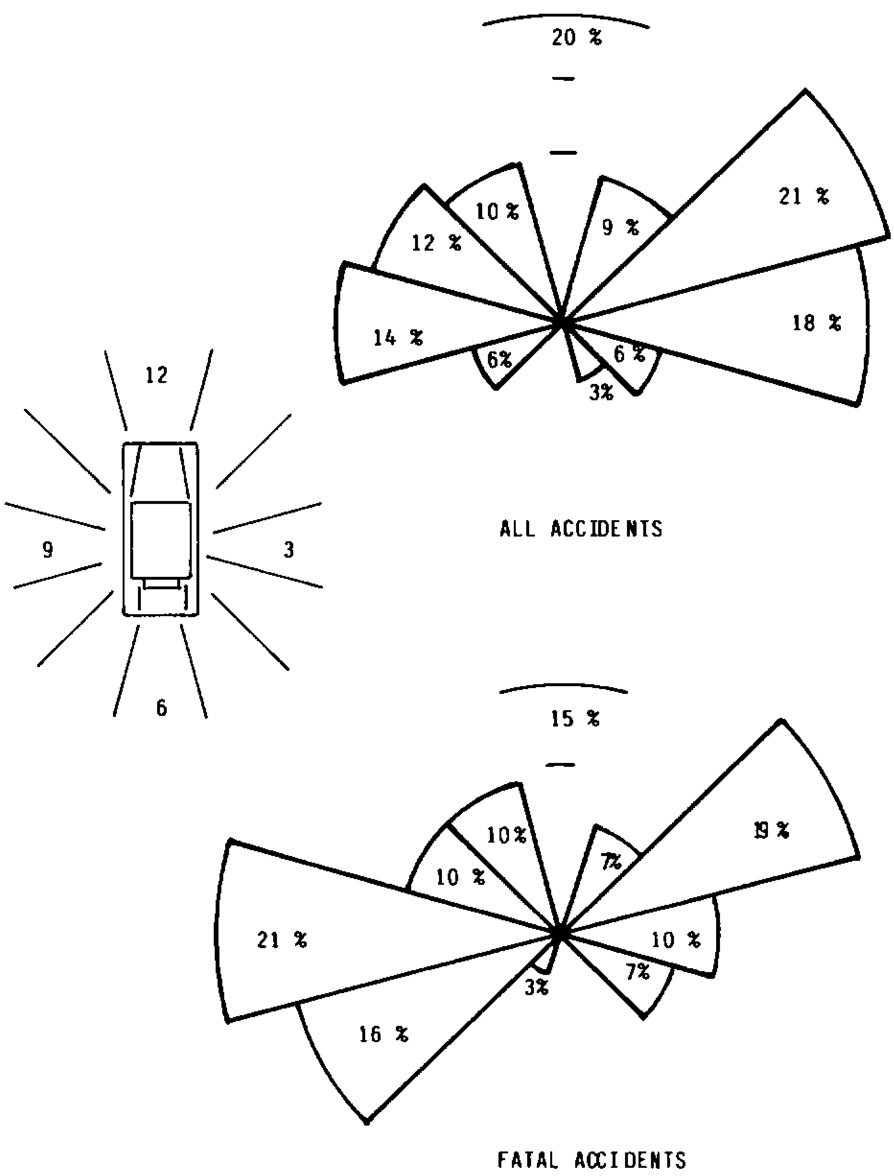

Fig. 2 : Frequency of impact direction in side impact accidents (11)

This study of right hand drive cars also shows that the most frequent clock direction is 2 o'clock for overall side impacts and 9 o'clock for fatal accidents. This study also shows that more than three-quarters of fatal accidents occur according to hour directions between 2 o'clock and 4 o'clock and between 8 o'clock and 10 o'clock, as indicated in figure 2. It should be noted that the example of this study has been rectified to be statistically representative of the English situation. A study carried out in the Netherlands on more than 8 000 accidents (12) confirms the preceding results, in particular in respect of the damaged side zones of the vehicle in question.

In (1) it is said, that a side impact in the passenger cell area involves a far greater injury risk than in other configurations and that a greater safety benefit can be expected from a test requirement which is intended to optimise the deformation behaviour of the side structure in the area of the passenger cell.

Figure 3 shows a statistically representative collision configuration including vehicle speeds and masses (2, 10, 13, 14). The angle of approach is 90 degrees and the longitudinal centre plane of the colliding vehicle contacts the other vehicle at the latter's R-point projected into the outer body surface. The speed of the colliding vehicle is 50 km/h, and that of the other vehicle 40 km/h. This gives a relative collision speed of 65 km/h, corresponding to the 90th percentile point of the distribution function (15). The colliding vehicle has a mass of 1100 kg corresponding to the maximum of the distribution density.

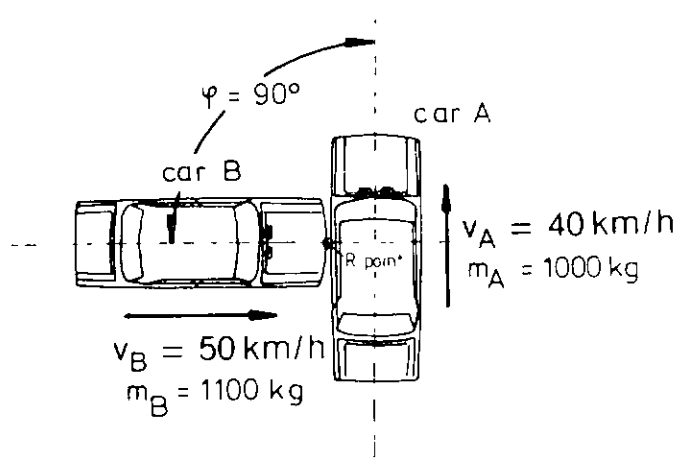

Fig. 3 Cumulative percent for curb weight (1)

According to our present knowledge (1, 16, 17) the influence of the speed of the moving test object on the forces on the occupants is only minor, so that it may be disregarded in a test specification.

Side impact accidents can have different colliding objects. In West Germany more than 70 % are car to car collisions, about 20 % are car to obstacle collisions and in about 10 % the cars are struck by trucks (2, 5, 13). Table 1 sums up the relative implications of the various objects in the United Kingdom and the Netherlands.

	NL (serious)	U.K. (serious)	U.K. (fatal)
private cars	65,6	71	53
commercial vehicles	12	9	16
pole/tree	15,5	13	23
motorbikes	2,1	5	0
other	4,8	2	7

Table 1 : Percentage of implications of various obstacles in side impact.

This table shows that there is an over-representation of commercial vehicles and poles in fatal accidents in comparison with serious lateral accidents : however the car/car impact remains by far the most important as it concerns more than half of fatal side impact accidents and approximately two-thirds of side impact accidents of different severity, whilst fixed obstacles are implicated in less than a quarter of fatal accidents and one-sixth of side impact accidents resulting in bodily injury.

The collision frequency and the mass ratio in car/car and car/truck side collisions in Germany in shown in Fig. 4 (5).

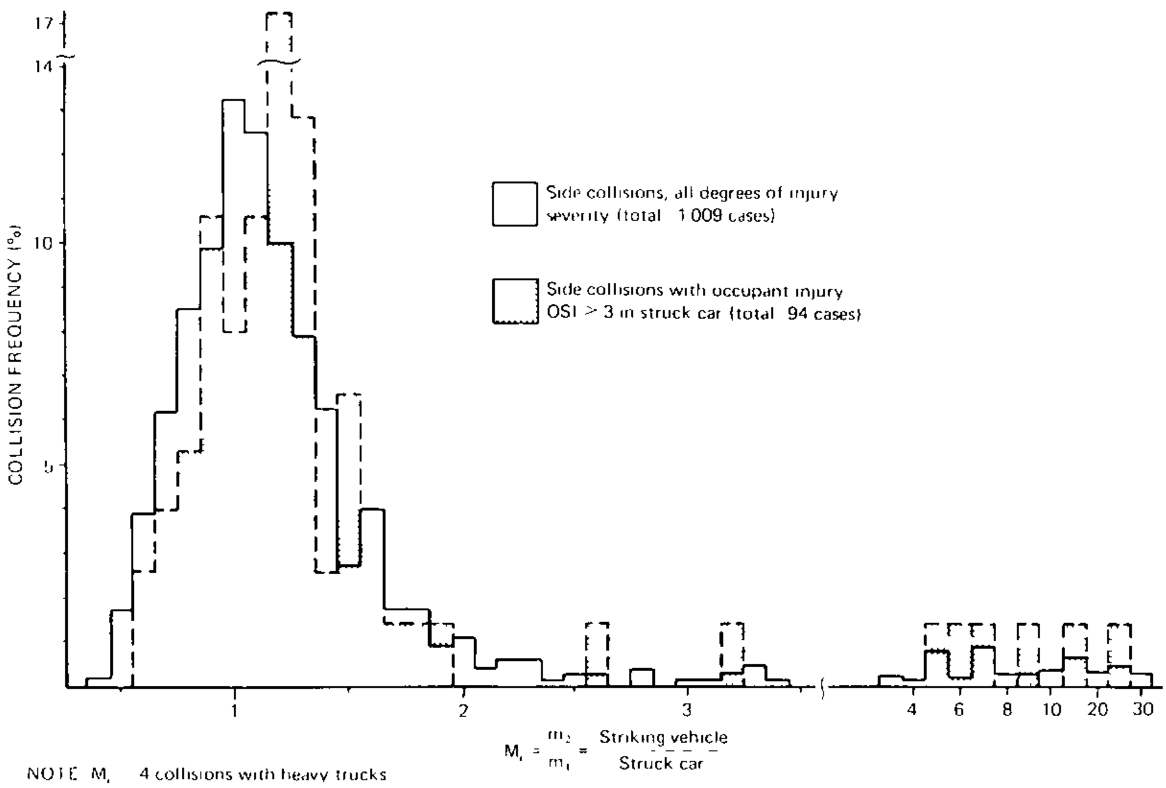

Fig. 4 · Collision frequency and mass ratio in car/car and car/truck side collisions.

In this percent frequency distribution the shifting of emphasis of the maximum collision frequency and, in particular, the far higher percentage of lorries involved in collisions with injuries such as severity AIS 3 become evident.

Some 75 percent of all vehicles involved in side collisions were impacted at a speed of less than 45 km/h, and 95 percent of all collision speeds lie within the range up to 60 km/h ; the maximum relative speeds in unfavourable circumstances can be deduced from this.

Here, one must, however, take into account the fact that real-life speed variations are far less and that in collisions at intersections (18) only 40 to 45 percent of the kinetic initial energy is transformed into deformation energy, the remainder being consumed in post-crash mouvement. On the basis of these data, it can be assumed that a test speed of 50 to 60 km/h in lateral collisions will embrace at least 90 percent of all real-life collisions (5).

In this sample of Cesari (13) the average overall severity index is 2,9 for the side impact and only 2,3 for the frontal impact.

As a consequence of the high degree of injuries, however, 28 % of all fatally injured, 20 % of all seriously injured (as from AIS 3), and 27 % of all injured (as from AIS 1) occupants in car/vehicle accidents are to be found in cars with a side impact (14, 5).

The occupants the most seriously and most frequently injured in side impact accidents are those seated at the side where the impact occurs and severe injuries to impact-side occupants (severity degree AIS 3) are recorded in cases of head injuries (1,5 times), chest injuries (3,5 times) abdominal injuries (5 times) as often as to opposite-side occupants (5).

The study carried out in the United Kingdom (4) shows that in the case of the injured among whom at least one injury has an "AIS" 3, the head, the thorax, the abdomen, and the pelvis, are the parts of the body most frequently injured, and in the case of the most seriously injured (AIS 4, 5, 6), abdominal and thoracic injuries are more frequent than cephalic injuries.

Certain injuries are more frequent in side impact accidents in comparison with the other accident configurations and this is particularly true for pelvic and thoracic injuries (2, 10, 15).

CHAPTER 3 : INJURY MECHANISMS IN SIDE IMPACT

Contrary to frontal impact where it has been established that the velocity change of the involved car is the main parameters which fix the force of the impact, this parameter has only a very secondary effect in side impaet accidents.

The parameter which is most directly linked to the severity of side impact accidents is the speed of the vertical surface of the vehicle which is run into, at the moment of contact with its occupant (19, 20).

The front structure of the modern passenger car is capable of absorbing about 2 ou 5 times as much energy as the side structure (1). In a side collision with contact in the area of the passenger cell the occupant sitting on the side of impact will be struck by the side structure intruding into the passengers compartment while still in his original seating position, and will be accelerated toward the opposite side of the vehicle before the speed of the vehicle itself begins to change to any appreciable extent. In terms of the loadings imposed upon the occupants, therefore, the motion of the vehicle itself is of merely secondary importance. The decisive factor is actually the large relative motion between the side structure and the vehicle, in other words the rate of intrusion.

It should be noted that in this situation, due to intrusion, this vertical surface speed is much greater than the speed variation of non-deformed structures on the vehicle collided with, as may be seen in figure 5.

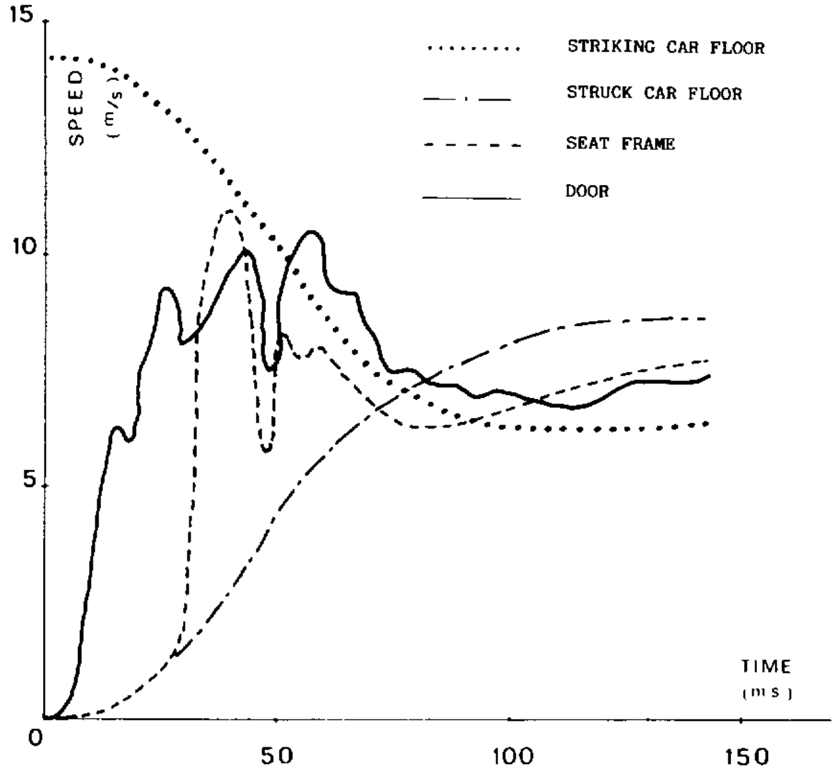

Fig. 5 : Velocity change in side impact in a 50 km/h test (20)

From this fact, in order to improve safety in side impact, on the one hand, the speed of contact of the occupant/surface should be decreased, either by increasing the resistance of the side body of vehicle, or if necessary, by reducing the rigidity of the front of vehicles in frontal impact. These modifications should be completed by installing padding on the inside of the side panel so as to improve the distribution of the impact on the human body and to reduce the pressure.

CHAPTER 4 : THE PROBLEM OF COMPATIBILITY IN SIDE IMPACT

The principal mechanism at the origin of injuries in side impact accidents being the speed of the surface, and this being a function of the relative rigidity of the front of the striking car and the side of the struck car, protection in side impact is subject to compatibility between the lateral and frontal structures of vehicles on the roads.

The interaction between the striking car and the struck car occurs essentially, on the one hand between the front bumper and the side sills on the lower part of the body, and on the other hand, between the front wings and the A and B pillars and the doors. In order that the compatibility be assured, the sills should be more rigid than the bumper, and the pillars be more rigid than the wings.

To take into account the fact that the trajectory of the striking car is rarely orthogonal to the struck car, the doors also should be sufficiently resistant to be compatible with the force created by the wings of the colliding car (21).

Concerning the reached status of compatibility there can be refered to a project financed by the German Ministry of Research and Technology. In (7) there are reports on the results of collision tests with a modified Audi 100 into a modified VW Golf (collision angle 90°, collision speed 50 km/h, mass ratio 1,42 for the modified status). It is shown that the loadings of dummies (resultant acceleration, HIC, SI, etc...) can be kept very far below the critical values. The main modifications were · reinforcement of compartments (door guard beam at bumper height, modification of B pillar, door padding inside with foam and steel) and it was reached compatibility of deformation forces of front and side structures was achieved. Furthermore the frontal safety of the modified cars was increased also and the modifications, which did not increase the cars'weight, has a calculated cost/benefit ratio of about 1.

In addition to the design compatibility, the question of the influence of the relation between the masses of the two vehicles in the collision should be posed.

A study has shown that the increasing of striking car weight has a few influence on dummy loadings (22), whereas a study in progress in Germany (23) shows that when VW Golf is struck by a 123 Mercedes, the intrusion is clearly higher than when it is hit by another VW Golf. The maximal intrusion is increased of about 50 %, but in this case there is at the same time modifications of the striking car weight and the striking car architecture.

An american study (24) also showed that the weight of the colliding car influenced the seriousness of the injuries.

FIAT Company has started 10 years ago studies in the field of compatibility inside impact. These studies have resulted in the elaboration of a testing method, and in design of a barrier in the aim of making and quantified evaluation of the compatibility. This barrier is described in paragraph 6.1 of this report.

CHAPTER 5 : TEST METHODS FOR SIDE IMPACT SAFETY ASSESSMENT

Different test methods have been proposed to evaluate the protection of the occupants in side impact, and these may be classified in two categories · full-scale tests and tests of components.

The combined efficacy of padding and structure re-inforcement can be established from fulls-scale tests on cars. A complete vehicle containing dummies is used, this vehicle being generally run into by a mobile barrier representing the colliding car. The dummies should be built so that the criteria of specific injuries can be recorded. Work on the design of dummies which is being sponsored by the EEC, and which is on the point of being completed, provides for the possibility of using more lifelike dummies for full-scale tests, than are currently available. Proposal have been made several times to use sub-system as an alternative to whole-vehicle tests. These tests should contain on the one hand, an exterior loading (either static or dynamic) of the structure, on the other hand, loading on the padding with shapes representing the different parts of the body liable to be in contact with these paddings. This method is certainly simpler than whole-vehicle tests, but has the inconvenience of evaluating separately the two types of features likely to influence the protection in side impact, without discovering their cumulative effect and thus the total protection offered.

The members of the EEVC working group 6 considered that full scale tests were preferable to component tests in order to be the basis of future regulations concerning protection in side impact. However, component tests will probably be necessary in order to complete the verification in zones where the dummy had no contact during the test, but where contact could occur during other types of real accidents.

The whole vehicle impact test could be a car/car impact , however this solution has the inconvenience of only allowing the safety offered to be verified when the vehicle in question is run into by the one chosen car model, usually an identical one, which is not a frequent occurence.

Moreover, this solution should be to the advantage of some cars and penalize some others. On account of this, the group abandoned this solution.

The other possibility for whole-vehicle tests is to use a mobile barrier. This barrier could either be completely rigid, or have a deformable front surface. The advantages of rigid barrier are particularly the low cost of the tests and their repeatability. However, being totally undeformable, they do not absorb energy during impact, and thus do not permit the mechanism of deformation of the struck car to be reproduced accurately.

Especially it is the door velocity change which is the main factor linked to the severity of injuries sustained by nearside car occupants.

Mobile deformable barrier should have more realistic behaviour than rigid ones for representing the car/car impact. There are two sorts of mobile deformable barrier :

A - a barrier which simulates the average characteristics of a vehicle population. Its front surface is constituted of deformable elements of different rigidity representing the stiffness of the principal frontal elements of a vehicle. The barrier serves to reproduce a typical impact and the results are noted either on the dummies which occupy the struck car and these are compared with the protection criteria or on the struck car structures in terms of panel velocity change and of intrusion.

B - a more complex barrier which does not simulate a car front, but constitutes an appliance for noting local rigidities (force and deformation) at every moment on every zone of the collided car (the front face contains a large number of identical elements). In agreement tests, the results are recorded either on the barrier or on the struck car ; in compatibility tests the results should be judged in comparison with those of other vehicles, with the help of a mathematical model.

The favorable and unfavorable features in the two solutions are :

Solution A : is simpler and less expensive in terms of both development and use.

The more the characteristics of the tested car depart from those simulated by the barrier, the less reliable the compliance judgement is.

Following the evaluation of the vehicles on the road, this barrier needs to be modified.

It allows compatibility to be only indirectly evaluated, not quantitatively.

Solution B : is more complex and expensive to develop and use.

It is independent of the characteristics of the car against which it is used and is always stable, not being affected by the evolution of the vehicles on the road.

It allows compliance tests, research tests, as well as quantitative evaluation of compatibility on a car with respect to each tested model.

The members of the group thought that the second solution should be very interesting in the study field, but that the first solution was more appropriate for regulatory tests.

CHAPTER 6 : DESCRIPTION OF EXISTING DEFORMABLE BARRIERS

Various studies on the development of deformable mobile barriers have been carried out recently. These are principally the FIAT, NHTSA, CCMC, TRRL and UTAC barriers.

1) The FIAT barrier (25)

This barrier has a flat front surface incorporating 36 honeycombed parallelepipeds, each fixed to a load cell. Figure 6 shows this barrier and it can be noted that its dimensions are inspired from the flat USA type barrier. This barrier is destined to be used in frontal impacts as well as in side impacts. A complex mathematical program is necessary to evaluate the compatibility with other vehicles that the results allow the data relative to the force and crush caused by the impact to be analysed. It is possible to reduce the front width from 1830 to 1600 mm by removing a module column, and to modify the ground clearance from 170 to 200 mm.

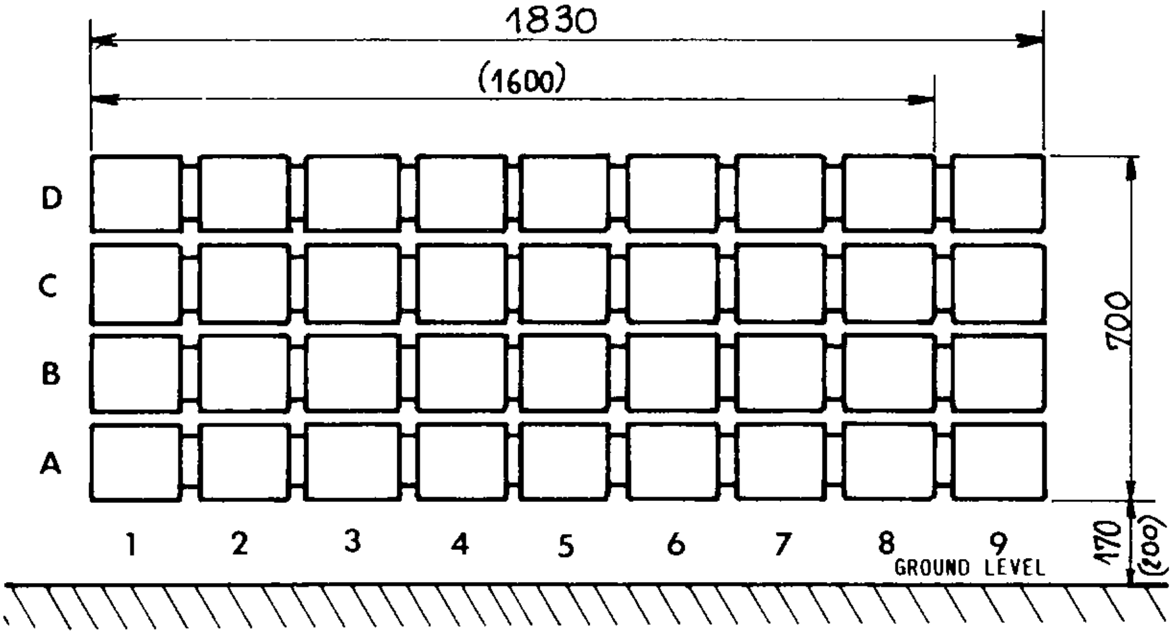

Fig. 6 : FIAT barrier front face (25)

2) The NHTSA barrier (26)

In 1977, NHTSA completed a research programme concerning the protection of automobile occupants. This programme resulted in the construction and the validation of a deformable mobile barrier shown in figure. 7. The characteristics of this barrier are derived from the masses and the dimensions of vehicles registered in 1978 in the USA, which explains the values greater than those existing in Europe.

During the study, the construction of the barrier evolved from a complex solution in the shape and number of elements, to arrive at a much more simple construction with simulation of a front bumper. The test procedure proposed by NHTSA has a crab-like displacement.

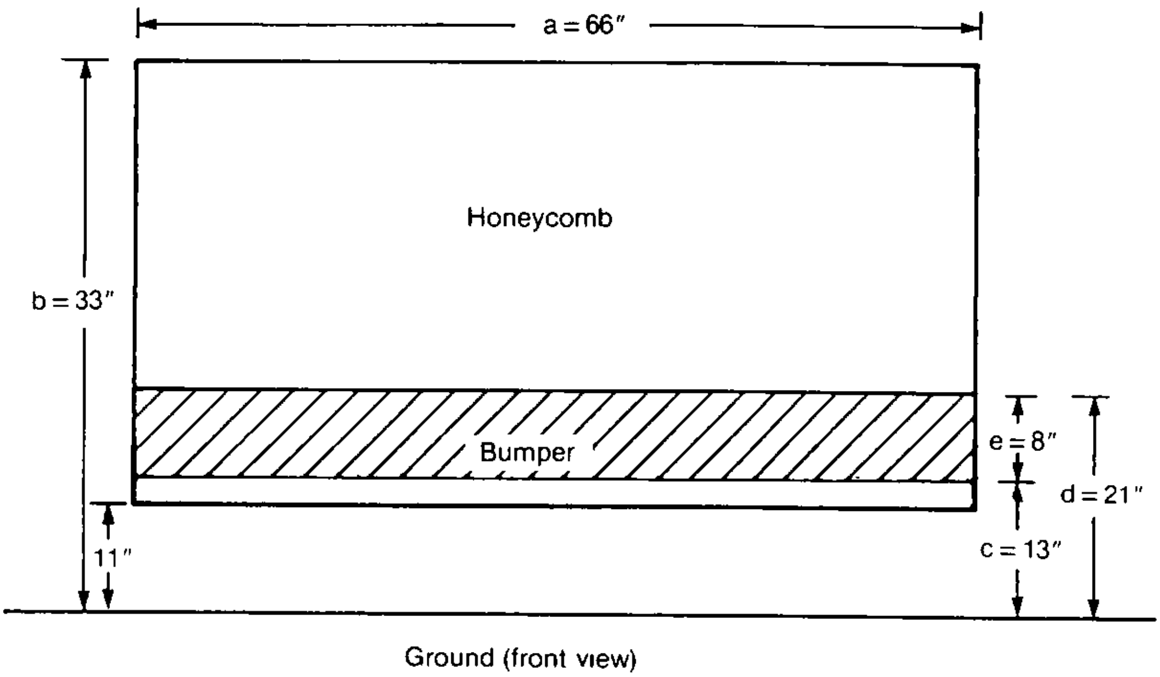

Fig. 7 : NHTSA barrier front face (26)

3) The CCMC barrier (27)

CCMC determined the characteristics of a mobile deformable barrier from the characteristics of vehicles sold in 1976, in 12 European countries. This resulted in a barrier of 950 kg whose dimensions and frontal characteristics are shown in figure 8. It should be noted that this barrier has a flat front surface and its deformable part is made of polyurethane foam. The force/deformation laws adopted for this barrier are deduced from tests of frontal impact against a dynamometric wall at 50 km/h.

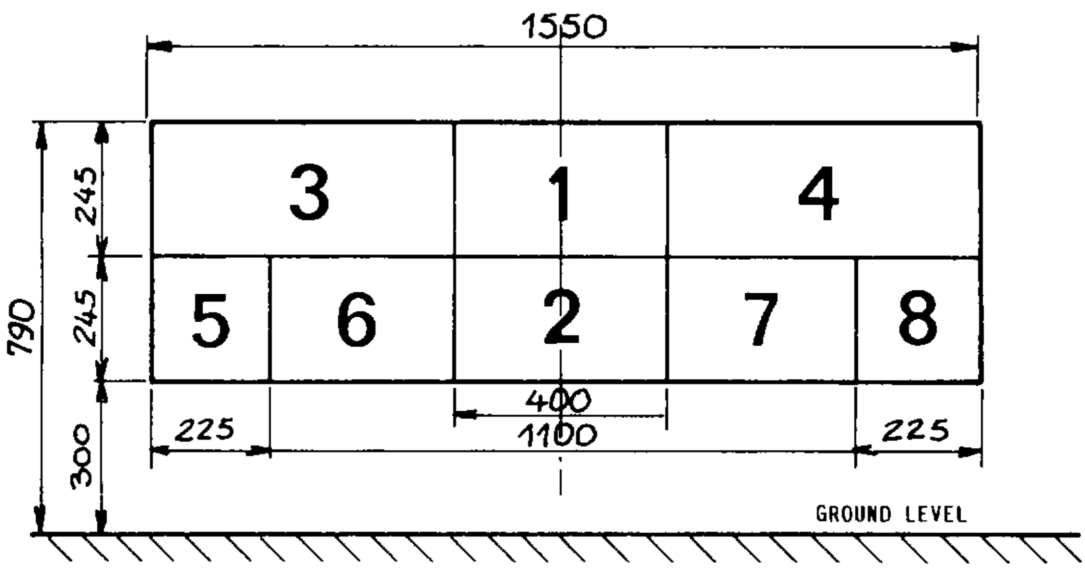

Fig. 8 : CCMC barrier front face (27)

4) The TRRL barrier (28)

TRRL have recently developed a mobile deformable barrier whose front zone is made up of 40 deformable blocks. Each block is made by stacking up rectangular and cylindrical steel cans which are partially filled with foam in order to make them more rigid. This construction allows the rigidity of various blocks to be varied. The front surface of this barrier is 1500 mm wide and 600 mm high, but, within limits any size and pattern of frontal stiffness can be represented.

5) The UTAC barrier (29)

A collaboration between French automobile constructors and UTAC, at the initiative of the public authorities, has resulted in a definition of the specifications of a mobile deformable barrier representing the average car most often used in France.

For this, ten car models were chosen, and analysis of their dimensions and of their force/deformation laws noted in the course of frontal impact tests at 35 km/h against a dynamometric wall, permitted the characteristics of this barrier to be determined. As indicated in figure 9, the front face of this barrier is 1400 mm wide, 500 mm high and has a ground clearance of 350 mm. The profile of the front face is constructed in such a way as to simulate the average profile of the cars in question.

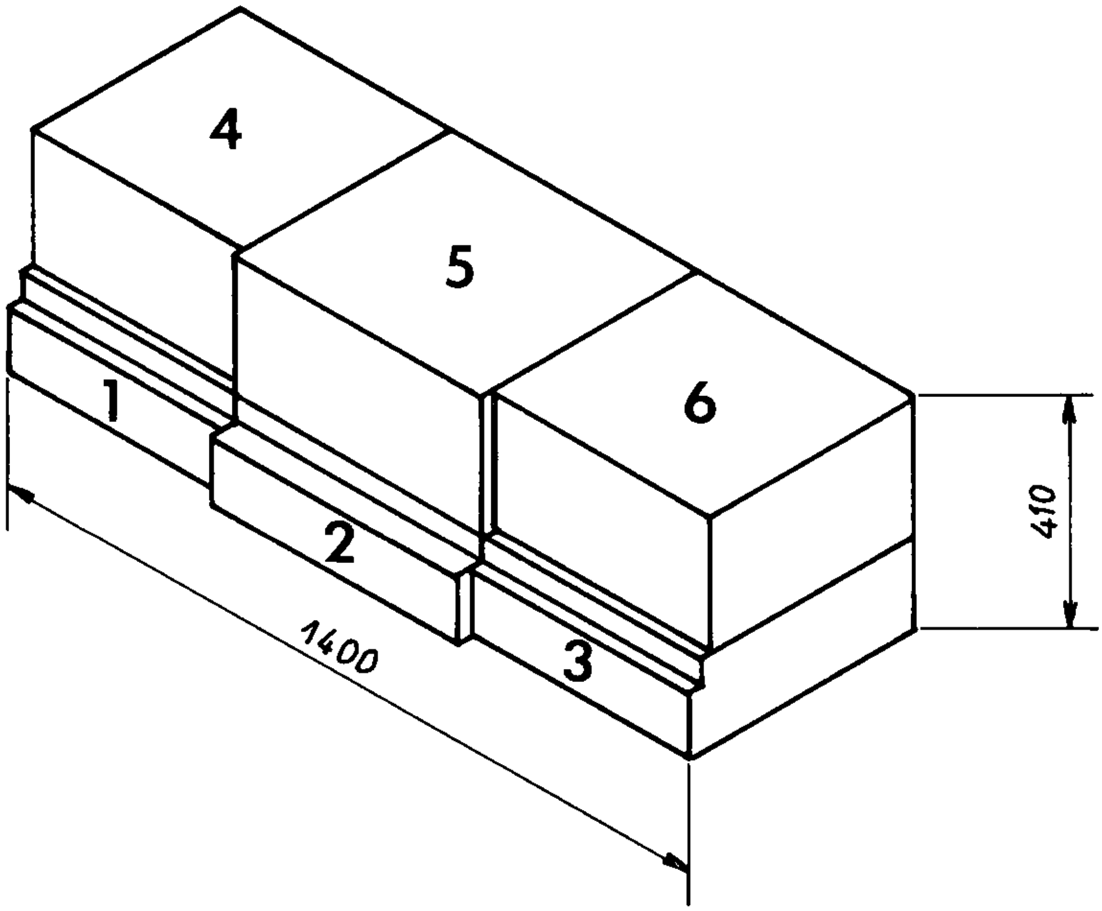

Fig. 9 : UTAC barrier front face (29)

6) Comparison of the characteristics of the mobile deformable barriers

The principal characteristics of the 5 mobile deformable barriers described in this chapter can be compared in table 2. It can be seen that the CCMC, TRRL and UTAC barriers have rather similar features.

	NHTSA	CCMC	UTAC	TRRL	FIAT
WEIGHT (kg)	1566	950	915	1190	900/2300
WIDTH (mm)	1676	1550	1400	1500	1830 (1600)*
WEIGHT (mm)	559	490	410	600	700
GROUND CLEARANCE (mm)	330	300	380	200	170 (200)
SHAPE OF FRONT FACE	flat+bumper	flat	flat+bumper	flat	flat
THICKNESS OF DEFORMABLE ELEMENT (mm)	483	400	500	560	300 (500)
MAXIMAL CRUSH (mm)	350	300	360	420	200 (360)
TOTAL FORCE (KN) For 200 mm crush	150	220	175	90/320	450 (400)
for 300 mm crush	490	350	205	320	N.A. (400)

* Values in bracket correspond to possible modifications of FIAT barrier

Table 2 : Comparison of main characteristics of mobile deformable barriers

The most notable difference concern the ground clearance and the force/total deflexion law.

With regard to the ground clearance, it is certain that it has a great influence on the results of the test and on the solutions to be taken into account to improve protection in side impact accidents. Large ground clearance seems to correspond better to the geometry of present day vehicles, but smaller ground clearance seems to be likely in a desirable evolution of future vehicles and these allow use to be made of interesting protection solutions which, moreover, improves the compatibility.

With regard to the law of force/deformation, the UTAC and CCMC studies arrive at similar laws for a crush up to 250 mm ; for higher values, CCMC's proposal is situated above that of UTAC, but this seems to be due to test conditions on a dynamometric wall which served to determine this law ; UTAC used test results at 35 km/h, which seems more realistic than tests at 50 km/h which CCMC took into account ; moreover the CCMC tests were made with dynamometric barriers which are different in the geometry and the number of force measuring blocks.

As the UTAC studies were made with non braking cars, and taking account the behind remark, the group members agreed on the complete definition of a deformable barrier which is the synthesis of all the elements defined by the CCMC, TRRL and UTAC barriers.

This result has to be pointed out, because the works of governmental authorities which have as objectives the definition of international standards would take into account the results of EEVC WG 6 works to improve in an acceptable delay the definition of a side impact full scale standard test.

However the group thinks that the stiffness of the barrier deformable face would be modified if in the future the stiffness of car front end decreased.

CHAPTER 7 : PROBLEMS RELATED TO THE CHOICE OF A SIDE IMPACT TESTING METHOD

This chapter summarizes the discussions of the Working Group and comments upon the alternative possibilities for the main features of a car side impact test. Chapter 8 gives the test procedure preferred by the Working Group as a result of their discussions.

1. A full-scale side impact test or systems testing

When a car is struck in the side, occupants are injured almost instantaneously if they are adjacent to the point of impact : there may only be a light sheet steel door between them and the striking vehicle. Injuries may be by direct blows to the head or by being struck by the intruding side structure being forced inwards. A few injuries occur a brief instant later if the occupant becomes crushed between the intrusion and something inside. Other occupants further from the point of impact have a lower risk of injury but head injuries are common when they are thrown across the car.

For those close to the intruding side, their initial distance from the side is critical because the speed of intrusion declines rapidly as the intrusion proceeds. There are two means of protection. Firstly it is appropriate to pad all components likely to strike the human body in accidents. The stiffness of the padding should match the human tolerance level of the part of the body likely to hit it. The depth of padding should be large enough to prevent it bottoming out in the agreed test conditions. This depth depends on the attenuation of the initial velocity of intrusion (ie the relative velocity of the striking vehicle). The second means of protection is to strengthen the side structure so that it is pushed inwards more slowly and not so far. This reduces the depth of padding needed and so there is some scope for variation in design between having a large depth of padding and a mixture of side strengthening and padding.

The full-scale test records the combined effectiveness of the padding and the side strengthening. It uses a complete car with dummies inside, which is struck by a mobile barrier with its face representing striking cars. The dummy must be especially designed to record side impact loadings to the head, shoulders, thorax, abdomen, pelvis and femur, in so far as this is possible. Much work has been carried out to develop such dummies in both USA and Europe, the latter mostly under EEC sponsorship. It seems likely that all these loadings, a part from those on femurs, can be recorded if required. This being so there is much to be gained from having a full-scale dynamic test using these dummies. However only one accident situation can be simulated and side impact accidents are very variable in their details. It has been noted that head impacts occur against almost every thing along the upper parts of the sides at one time or another. Impacts to the thorax occur both adjacent to the seated position and forwards of this and similarly so for the pelvis. It is considered that the best way of cheeking for the head impacts in accidents is to use a head form projected into various points along the cant rails, A and B posts, and possibly against the door.

It has been proposed by various organisations that an alternative to a full-scale impact test would be a set of sub-systems tests. These would include an external loading of the side structure of the car, either dynamic or possibly static. The internal design of the padding would be checked by separate head, chest and pelvic forms impacted into the parts of the side that these parts of the human body might possibly strike. There is no doubt that this system procedure would be cheap and convenient for vehicle manufacturers. One objection is that it pre-supposes a particular combination of side strengthening and depth of padding, whereas the full impact test leaves that choice to the vehicle designer. There is no doubt that the full test is needed for much of the preliminary study of side impact and for the development of a complete understanding of how much side impact protection can reasonably be provided. A series of sub-systems tests is a good means of checking the whole of the side but he full-scale test is better at checking the interaction of the head, body and lower limb impacts with each other and for checking for unexpected effects from vehicle components. Some compromise between the two procedures may be the best answer.

2. The barrier face - rigid or deformable

In the past car front to car side impacts have been represented by mobile barriers running into the sides of cars being tested and some barriers have had rigid faces and other deformable faces. A deformable front face can be designed to accurately represent the front of a car as it crushes but because the designs of car fronts vary a great deal, it is necessary to choose a particular design to represent the whole range of car fronts. This is discussed elsewhere and it is pointed out that most side impacts are not truly perpendicular and so it is the front corners of cars which are primarily involved.

One advantage of a rigid barrier face is that the most violent impacts into the sides of cars are by Heavy Commercial Vehicles and when cars slide sideways into fixed objects such as trees. The most important difference is that a rigid barrier absorbs no energy in an impact whereas a deformable barrier can absorb its share of the energy to be dissipated. When a rigid barrier is used, the velocity of impact is reduced to compensate for this, possibly by reducing it by a factor of (1/2) when the impact being simulated is between cars of equal mass. Although this means that the correct degree of damage is caused in the car under test, it gives a low speed of initial penetration of the car door which may reduce the impact into occupants in some circumstances. It seems that a rigid barrier face cannot accurately represent a car to car impact but the approximation to it may be close.

The details of shape and design for a deformable face are discussed in Section 3.

Consideration of the design for a rigid face has led to using a narrow width of about 1 metre to avoid the impact being largely absorbed by A posts and wheel arches. Arguments can be made for either impacting the sills or having a face set up just to pass over them. In any case it is important that rigid barrier faces are rounded at their edges to avoid the edges cutting into the skin of the car and its doors.

One advantage of a rigid face is that it is cheap to use because it can be used many times. A deformable face can be used only once and its structure must be accurately reproducible.

With a rigid barrier it is possible to cover the face with load cells to measure the total load on each area during the impact and there might be say four cells in both upper and lower rows of a small face and double that number for a large face. With a deformable face there is less need for load cells because the exact imprint of the impact can be seen if the face material does not recover. The yield stiffness of the material is known and so unlike load cells, no measurement of car side stiffness can be recorded, but when the car local stiffness exceeds that of the face, it is the face that deforms and the resulting imprint can be measured. It is of course quite possible to mount sections of the deformable face on to load cells and so to record both loading and depths of crush. It is important to note that load cells and the overall deceleration of the barrier record the stiffness of the side as it collapses during the impact. With the deformable face the deceleration during the side impact may be lower because the barrier rather than the car may be deforming.

3. Barrier design

The design of a mobile barrier for side impact testing with all the different possibilities in the selection of a deformable face, is discussed in the following five sub-sections.

3.1 Barrier design - effect of barrier mass

There are two obvious alternatives ; either the barrier mass should be constant for all tests or it should be ballasted to equal the mass of the car being tested. The latter ensures that the cars under test are all subjected to a change of velocity of a half of the impact speed of the mobile barrier. The former gives greater changes in velocity to cars of lower mass. Although this former possibility may appear not to be fair to small cars, it is preferred because in real accidents each car model is exposed to the same mix of car models and on average smaller cars must suffer the more severe impacts.

Although previous test procedures have mostly used a barrier mass of 1100 kg, it is generally considered that for the future a mass of from about 900 to 950 kg will be appropriate.

3.2 Barrier design - height of barrier and position above ground

Because mobile barriers represent car fronts, their top forces are usually about 800 mm above ground which is about the height of the lower edges of the glass windows in doors. Only a few cars are struck in the side by heavy goods vehicles or slide sideways into fixed objects but these lead to about a third of the fatal side impacts. In these cases there is usually intrusion at up to the roof level and it is often the occupant head impacts which result from this that can be fatal. However this is not discussed for the moment.

With regard to the lower edge of the barrier face the question is whether this should interact with car sills by putting the lower edge at say 200 mm above ground, or be positioned just above them at 350 mm. At present many models of car have little front structure below their front bumpers and these cans easily override the side sills of other cars. This potentially dangerous situation must be prevented by encouraging car designers to build air dam structures lower down and of adequate strength for side impacts. With a rigid faced barrier it was found that a rounded lower edge just above the sills interacted with the B posts of cars so much that the sills were greatly distorted and absorbed almost as much energy as if struck. This would encourage strong sills and attachments to B posts. With a deformable face this loading of the sills would be less severe and the alternatives are either a face missing the sills which would be adequate for lesser impacts or one striking the sills for higher impact levels. The latter would be better for encouraging strong side sills for cars. A corresponding impact test into the fronts of cars is needed to ensure that in future car fronts are designed to be strong low down.

3.3 Barrier design - width of barrier

Although it would appear logical to have a barrier of full car width (1600 mm), accident investigations show that almost all side impacts are not exactly perpendicular and a front corner of the striking car usually intrudes into the struck car and then slides round leaving a deep imprint of less than 750 mm width. This is injurious when the intrusion is into the passenger space. There are two ways in which this can be simulated in a perpendicular impact. Either the mobile barrier face can be deformable with its centre more rigid than its outer wings or the barrier face can be a metre or less in width and aimed to miss both the strong points of the body side at the A post and the rear wheel arch. The choice lies between these two extremes, that is between a rigid or deformable face of say 1 metre wide and a full width of 1600 mm wide with a suitable design of deformable face.

3.4 Barrier design - lateral shape of face and stiffness distribution

As discussed there are two basic assumptions for the design of a barrier face. It can either be representative of the fronts of cars, possibly averaged over a number of models in proportion to their popularity, or it can be modified from this to meet particular objectives. If it is desired to represent actual car fronts it should be flat or almost flat across its width with a stiffness which is greatest at the centre and somewhat less towards the sides. However some car models do not follow this pattern and the front ends of their wings may be relatively stiff. An averaged design might have the outher sections about two-thirds the stiffness of the centre. A modified design of barrier face to emphasise the most common impact whereby a corner of a front penetrates the side of a car might have a stiffness representative of a wing or front corner at its centre and still lower stiffness at its outer sections of perhaps a half of the center stiffness. This reduction at the outer sections would ensure that sufficient intrusion could occur at the doors however stiff the A posts and rear wheel arches might be. There are arguments for the centre section to be from 400 mm to 1000 mm wide.

This discussion implies that a deformable barrier should have three sections laterally, namely a centre section and two similar outer sections. It would be possible to have five sections rather thant three, but this would seem to be an unnecessary complication. On the other hand to have a uniform lateral distribution of stiffness would seem to be unsatisfactory for the reasons discussed.

3.5 Barrier design - vertical shape of face and stiffness distribution

Currently there are several different front profiles for cars. Many are vertical or almost so, with just the bumper protruding forwards. Most have small bumpers but a few in the middle 1970s had large bumpers in both depth and forwards protrusion. Other cars have little structure above or below their bumpers. Recent cars often have a low top edge but a large air dam below for reasons of low aerodynamic drag. Looking to the future, low aerodynamic drag and the needs for pedestrian protection will have greater prominence. A good shape for the latter is a fairly flat vertical face or one that slopes back slightly from vertical. It would have no hard protrusions and would have an air dam low down.

With these considerations and those of section 3.2 in mind, it may be sufficient to have a vertical barrier face. Although a bumper protrusion could be added, it may be left out if future cars are being represented. In any case most bumpers are fairly soft and are partially crashed before a side impact is completed. (The exceptions are the large bumpers of the "safety" cars of the 1970s).

The stiffness distributions of fronts of cars are variable with from one-third to two-thirds of the strength being in the upper half (500 to 800 mm above ground) rather than in the lower half (200 to 500 mm above ground). However it is almost certain that if future cars are to have a good side impact performance in car to car impacts, then the upper halves of the fronts must be relatively soft. In other words good side impact protection cannot be provided by simple modifications to the sides of present day car designs unless the upper halves of the fronts of cars which will strike them are of similar low stiffness. In fact it is clearly desirable that the upper car fronts should be somewhat less stiff that the effective stiffness of doors and B posts.

There seems to be a strong argument for having only two levels to stiffness in the vertical pattern on upper and a lower, because it is desirable that the lower part of a car front is much stiffer thant the upper. Bumper heights have caried through the years but their upper edges are usually not more than 450 mm to 500 mm above ground. So it is convenient to divide the height into regions of from 200 to 500 mm and from 500 to 800 mm.

CHAPTER 8 : DESCRIPTION OF THE PROPOSED SIDE IMPACT STANDARD TEST

This chapter contains a detailed description of the side impact test which the group adopted.

The information contained in this chapter corresponds to what the members of the group think, either after the work carried out on the mobile barriers, in particular by UTAC in France and by CCMC, or deduced from the contents of the regulations of integrated tests in frontal impact.

The information corresponds to the present stage of knowledge, and in any case, the test procedure must be supplemented by definition of the characteristics of the dummy to be used and by the protection criteria to be measured, and the values which must not be exceeded. These two fields are not the domain of the group, and moreover, the end of phase IV of the EEC's biomechanical programme (30) must be awaited in order to be able to clarify these two points.

1. Field of use

This test concerns private cars with a maximum seating capacity of 6 including the driver.

2. Test conditions

2.1. The vehicle to be tested will be stationary

The impactor will be mobile.

2.2. The trajectory of the impactor will be perpendicular to the collided car

The median plane of the impactor will pass through point R (or its projection on the exterior face of the vehicle) from the driver's seat of the collided car.

2.3. The test will normally be carried out on the driver's side of the vehicule when this has a symmetrical structure.

However, when an asymmetrical structure is used which is likely to affect the performance of the structures of the opposite sides, one of the following solutions will be used :

a) upon the constructor's request, an additional test on the side opposite to the driver will be carried out.

b) the constructor will furnish the authority carrying out the ratification with information regarding the compatibility of performances in comparison to the initial test.

c) the ratifying authority, having assured itself of the merits of the vehicle's construction, decides to have a test effected on the side opposite the driver, this position being considering as the worst.

2.4. The impactor will weigh 950 kg.*

2.5. The impact speed will be 50 km/h (+0, -2). This speed will be stabilized at least 0,5 m before the impact.

3. Characteristics of the impactor

3.1. The impactor will be a mobile barrier with a deformable front face.

3.2. The deformable impact zone should be 1500 mm wide and 500 mm high.

3.3. The ground clearance of the collision zone is 250 mm.

3.4. There are 6 deformable elements, divided into two rows of three elements.
All the elements have the same width (500 mm) and the same height (250 mm) ; the elements of the upper row are 440 mm in depth and those of the lower row 500 mm in depth.

3.5. The details of the barrier construction are indicated in the appendix.

4. Preparation of the vehicle

4.1. The vehicle to tested should possess all the equipment likely to have an influence on the results of the tests.

4.2. The weight of the vehicle at the time of the test will be the weight when empty and in working order.

4.3. The petrol tank will be filled with an uninflammable liquid of a density between 0,7 and 1 whose weight corresponds to 90 % of the weight of a full tank of petrol.

4.4. The other fuel circuits can be empty, but the weight of the liquid must be compensated.

4.5. The weight of the measuring instruments must be compensated by lightening some parts which do not have a great influence on the results of the test.

4.6. The windows should be closed. The back window may possibly be open.

4.7. The doors will be closed, but not locked.

4.8. Controls will be in a neutral position.

4.9. The other accessories will be in the most frequently used positions.

4.10 The arm-rests, if they exist, will be lowered.

* The German delegate would have prefered that the barrier weight should be 1100 kg in order to take into account a mass ratio of 1.3

4.11 The front seats will be positioned 50 mm in front of the point R, or in the closest notch to this position.

5. Dummies

5.1. Two dummies will be installed, one in the front seat, and one rear seat on the impact side. If it is not possible to put a dummy in the back seat, the test will be made with one dummy in the front *, but the constructor must prove that the protection offered in the back is at least equivalent to that of the front seats.

5.2. The dummies will comply with the specifications retained.

5.3. The dummies will be installed according to the procedure described in the ECE/ONU proposed standard for frontal impact.

5.4. The point R will be determined according to the procedure described in the ECE/ONU proposed standard for frontal impact.

5.5. The standard restraint system shall be put in use. If this apparatus includes belts, these should be of the approved type.

6. Evaluating the results of the tests

The completed test, carried out according to the above method, will be considered satisfactory if the following conditions are fulfilled.

6.1. No door should open during the test.

6.2. The performances noted from the dummies should comply with the criteria adopted.

* The German car manufacturers propose that the mass of the car should be increased with 75 kg (equal to the dummy's mass) in that case.

6.3. Only slight fuel leaks are permitted during the collision. In the even of continuous loss of liquid after the collision, this should not be higher than 30 gr/minute.

6.4. It should be possible, after the collision, without having to resort to tools

- to open a sufficient number of doors to allow evacuation of all the occupants of the vehicule,

- to free the dummies from the restraint system without exceeding a force of 5 daN on the control,

- to take out the entire dummies

6.5. After the test, no interior device, nor any component must have broken loose in such a way that projections or sharp bends in the metal could significantly increase the risk of injury.

Note

A generalization of the above remarks incorporating additional component tests, should be made before applying the rule.

CHAPTER 9 : RECOMMENDATIONS FOR THE FUTURE

The standard test procedure described in chapter 8 was not validated as, in particular, the barrier described in that chapter is not yet built. Therefore, the first point to be examined is the validation of the barrier. This should be made in respect of the reproducibility by at least six tests.

Its deformations should be compared to those of real vehicles in car/car collisions under the same conditions. Finally, its reactions should be tested in tests against different vehicles.

The chosen value of the ground clearance is a compromise between what is presently realistic and what is desirable to improve the safety in side impact. This value could decreased if it is possible in the same time to lower sufficiently the level of front end rigid parts.

The problem of compatibility is not resolved by this test and a test extended to the front of the car in a frontal impact against a mobile barrier should be envisaged in order to verify that the front of the car is compatible with the characteristics of the chosen barrier. This could be done by impacting the barrier described into the front of the stationary car at 50 km/h. Measurements would be made either of the barrier's peak deceleration (and hence the force it had experienced) or of its deformation (and hence the energy it had absorbed). In either case the measured values would be required to be below an agreed allowable figure. It is essential that a notion of omnidirectional compatibility in the conception of vehicles be recognized as a major objective to increase road safety, and protection in side impact is only a part of this general need. The test described above should be justified by a cost effective study.

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APPENDIX

1 - CHARACTERISTICS OF THE DEFORMABLE MOVING BARRIER PROPOSED BY E.E.V.C.

2 - CHECKING TEST OF CHARACTERISTICS OF THE MOVING DEFORMABLE BARRIER

APPENDIX 1

CHARACTERISTICS OF THE DEFORMABLE MOVING BARRIER PROPOSED BY E.E.V.C.

1. GENERALITIES

The barrier consists of a rigid undeformable trolley, able to move freely at the moment of impact. Its front part supports a front impactor made of a material which can be deformed when impacted. This impactor is positioned symmetrically about the longitudinal midsaggital plane of the trolley.

2. CHARACTERISTICS OF THE BARRIER

The total mass must be equal to 950 ± 20 kg.

Front and rear wheel gauges must be equal to 1500 ± 70 mm.

The wheel base must be equal to 3000 ± 10 mm.

The centre of gravity must be situated in the longitudinal median plane, 1000 ± 10 mm behind the front axle and 500 ± 10 mm above the ground.

The distance between the front face of the front impactor and the centre of gravity of the barrier must be equal to 1800 ± 20 mm.

3. CHARACTERISTICS OF THE FRONT IMPACTOR

3.1. Geometrical characteristics

The front impactor consists of six independent joined parts. Forms and sizes and position of these parts are indicated in figure 1.

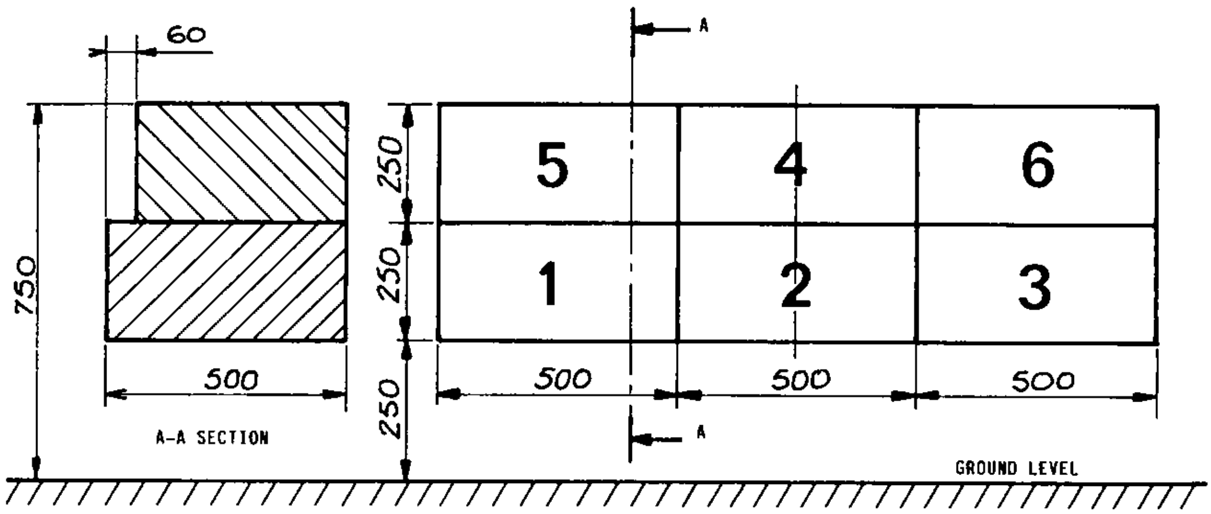


Fig. 1 : Proposed design of the front end (deformable part) of the EEVC barrier.

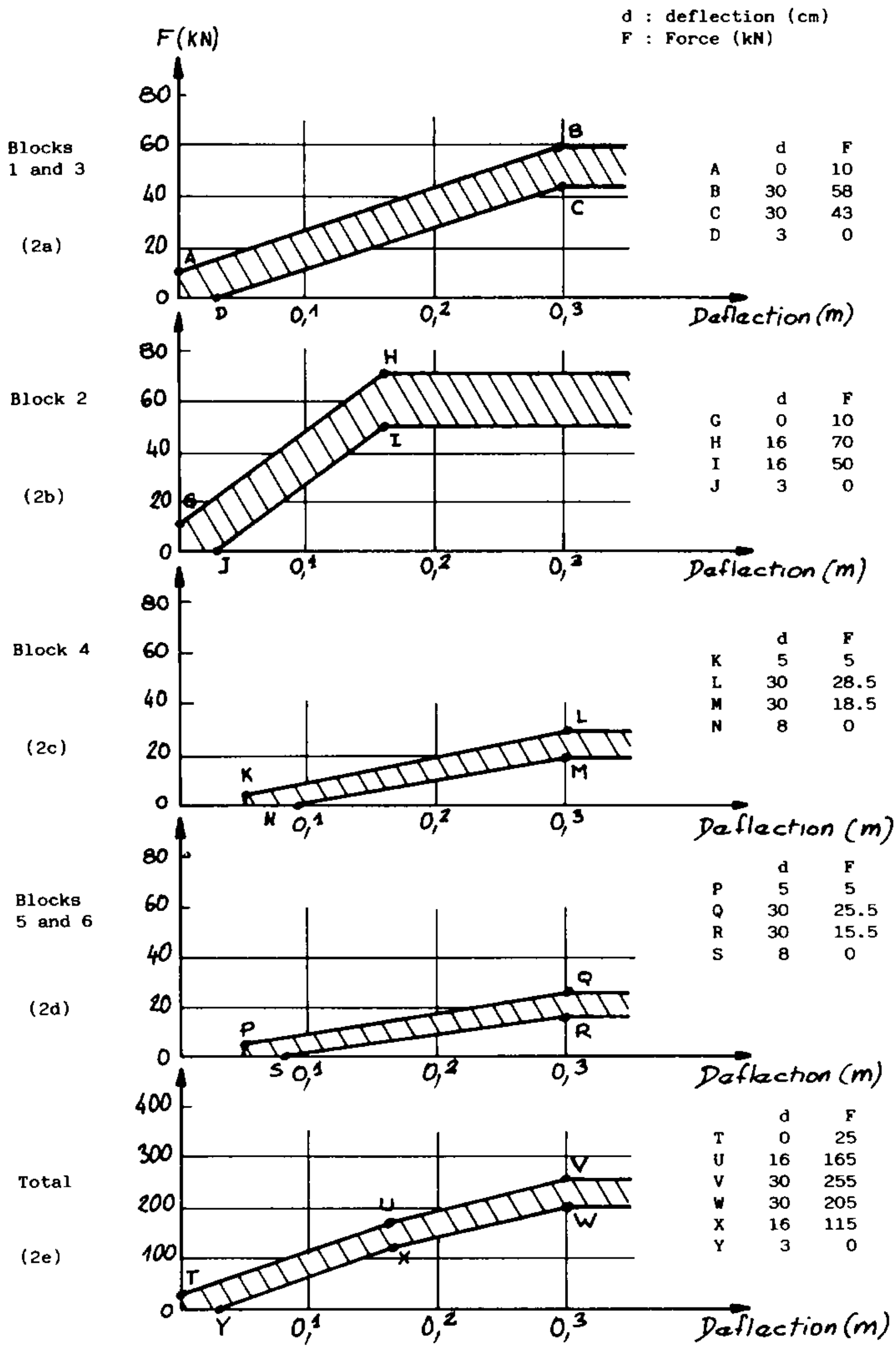
3.2. Front impactor stiffness

Parts 1 and 3 are identical parts. Figure 2 shows their stiffness. Their force-deflection curves must be drawn in the hatched region of graph 2a.

Parts 5 and 6 are identical parts. Graph 2 d shows their stiffness, their force-deflection curves must be drawn in the hatched region of this graph.

Graph 2b shows the stiffness of part 2, its force-deflection curve must be drawn in the hatched region on this graph.

Graph 2c shows the stiffness of part 4, its force-deflection curve must be drawn in the hatched region of this graph.



Blocks 1 and 3 (2a)

	d	F
A	0	10
B	30	58
C	30	43
D	3	0

Block 2 (2b)

	d	F
G	0	10
H	16	70
I	16	50
J	3	0

Block 4 (2c)

	d	F
K	5	5
L	30	28.5
M	30	18.5
N	8	0

Blocks 5 and 6 (2d)

	d	F
P	5	5
Q	30	25.5
R	30	15.5
S	8	0

Total (2e)

	d	F
T	0	25
U	16	165
V	30	255
W	30	205
X	16	115
Y	3	0

During the checked test, for a definite deflection measured loads with parts 1 and 3 on the one hand and with parts 5 and 6 on the other hand, have not to differ from more than (10 %).

Fig. 2 : Force-deflection characteristics of the EEVC barrier

The front impactor force-deflection must be drawn in the hatched region of graph 2e (figure 2).

Verification of front impactor stiffness will be determined from moving deformable barrier to load cell fixed barrier tests. These tests will be conducted at 35 ± 2 km/h.

The dissipated energy (1) against parts 1 and 3 during the test will be equal to 10 (± 2) kJ for each of these parts.

The dissipated energy against parts 5 and 6 will be equal to 3,5 (± 1) kJ for each of these parts.

The dissipated energy against part 4 will be equal to 4 (± 1) kJ.

The dissipated energy against part 2 will be equal to 14 (± 2) kJ.

The total dissipated energy during the crash will be equal to 45 (± 5) kJ.

The front impactor deformation measured after the test on the level of points B (figure 1) must be equal to 350 (± 20) mm.

(1) Indicated energies are energies which are absorbed by the system when the front impactor deflection reaches the greatest value.

N.B. Curves and tolerances given are objects to be reached and could be changed as a function of materials used to build the front impactor and of first results of tests made with a prototype.

APPENDIX 2

CHECKING TEST OF CHARACTERISTICS OF THE MOVING DEFORMABLE BARRIER

1. INSTALLATION

1.1. Testing ground

The test area shall be large enough to accomodate the run up track of the moving deformable barrier, rigid barrier and technical installation necessary for the test. The last part of the track, for at least 5 m before the rigid barrier, shall be horizontal, flat and smooth.

1.2. Rigid barrier

The rigid barrier shall consist of a block of reinforced concrete not less than 3 m wide in front and not less than 1,5 m high. The rigid barrier shall be of such thickness that it weighs at least 70 metric tons. The front face shall be vertical, perpendicular to the axis of the run up track and covered with load cells being able to measure at the moment of impact the total load of each part of the moving deformable barrier front impactor.

The rigid barrier shall be either anchored in the ground or placed on the ground with, if necessary, additional aresting devices to limit its displacement. A rigid barrier with load cells with different characteristics, but giving results at least equally conclusive may likewise be used.

2. PROPULSION OF MOVING DEFORMABLE BARRIER

At the moment of impact the moving deformable barrier shall no longer be subject to the action of any additional steering or propeling device. It shall reach the obstacle on a course perpendicular to the collision wall.

3. MEASURING INSTRUMENTS

3.1. Speed

The instrument used to record the speed on impact shall be accurate to within 1 per cent.

3.2. Loads

Measuring instruments shall meet the prescriptions set forth in the Norm ISO N° 6487. Channel class of load measuring chain must be class 60.

Mechanical resonances associated with transducer mounting should not distort readout data.