The tests for all the containment levels are specified in terms of impact speed and angle as well as mass and dimensions of the colliding vehicle.

Acceptance Criteria

The principal acceptance criteria for these tests are as follows:

1. Behavior of the vehicle:
   - The vehicle shall not breach the barrier, and
   - The vehicle shall be redirected.
2. Behavior of the barrier:
   - No major part of the barrier shall fracture and become detached.
3. Severity index:
   - Both the acceleration severity index (ASI) and the theoretical head impact velocity (THIV) will be used before reaching any agreement on a single index.
4. Vehicle deformation:
   - The deformation of the vehicle interior shall be evaluated by completing the vehicle compartment deformation index (VCDI) form.

Generally, these criteria may not be evaluated on only one representative test. They may not be critical under the same impact conditions. In particular, a high containment level system that can meet the conditions of restraint for lorries might not meet the correct performance for the impact severity required for a light vehicle.

It has therefore been decided to carry out two impact tests for each specified performance class:

- One test for checking the maximum containment level, and
- An additional test on a small passenger car for checking the behavior of the vehicle and the impact severity for the safety of the occupants.

Drafted test methods are not yet ready. To determine them, attention was focused on the necessity of being coherent with the development of the types of vehicles of the future, without going too far from the previous conditions. A majority of existing barrier systems should easily find their place in the new scheme.

Conclusion

Work yet to be defined concerns all necessary prohibitions to achieve the harmonization. The European Construction Products Directive asks for labeling, so-called the "seal" or "mark," of all devices that are based on the conformity to harmonize European standards. What remains is to define all prohibitions of evaluation of conformity and an attestation procedure that will permit industries to put the seal on their products. The standards for the pedestrian barrier system will also be started.

European harmonization must obviously go further, particularly concerning performance standards for safety barriers, crash cushions, and pedestrian guardrails. Standardization in this field might be more difficult and require more time than expected. The current objective is to create a document and have it approved.

PERFORMANCE CLASSES AND IMPACT TEST CRITERIA FOR SAFETY BARRIERS AND CRASH CUSHIONS

Colin Wilson
United Kingdom Department of Transport

The first meeting of Working Group 1 took place in September 1990, when about 40 people from about 14 member countries met to produce harmonized standards for safety barriers and other systems. Representatives at the meeting included civil servants, scientists, manufacturers, and experts from research laboratories and universities. There were many problems: different languages, national standards, procedures, and regulations and perhaps a degree of national protectionism. It was soon discovered that there were different names for systems and components, and the first priority was to sort out the terminology to be used.

Safety Barriers

The following represent draft proposals. These proposals are nearing completion but are still subject to all necessary CEN voting procedures.

The idea of having performance classes for safety barriers is that a product will be able to be tested and assessed against a set of established performance criteria. Once these criteria have been complied with, a product can then be approved and registered against a particular performance class. It will be up to each member nation of the EEC and EFTA to decide what level of performance it requires on its roads. A product, therefore, does not have to comply with all the performance classes listed in the standard.

When Working Group 1 started, all participating nations entered their national performance standards on a large board. There was a great disparity of vehicle

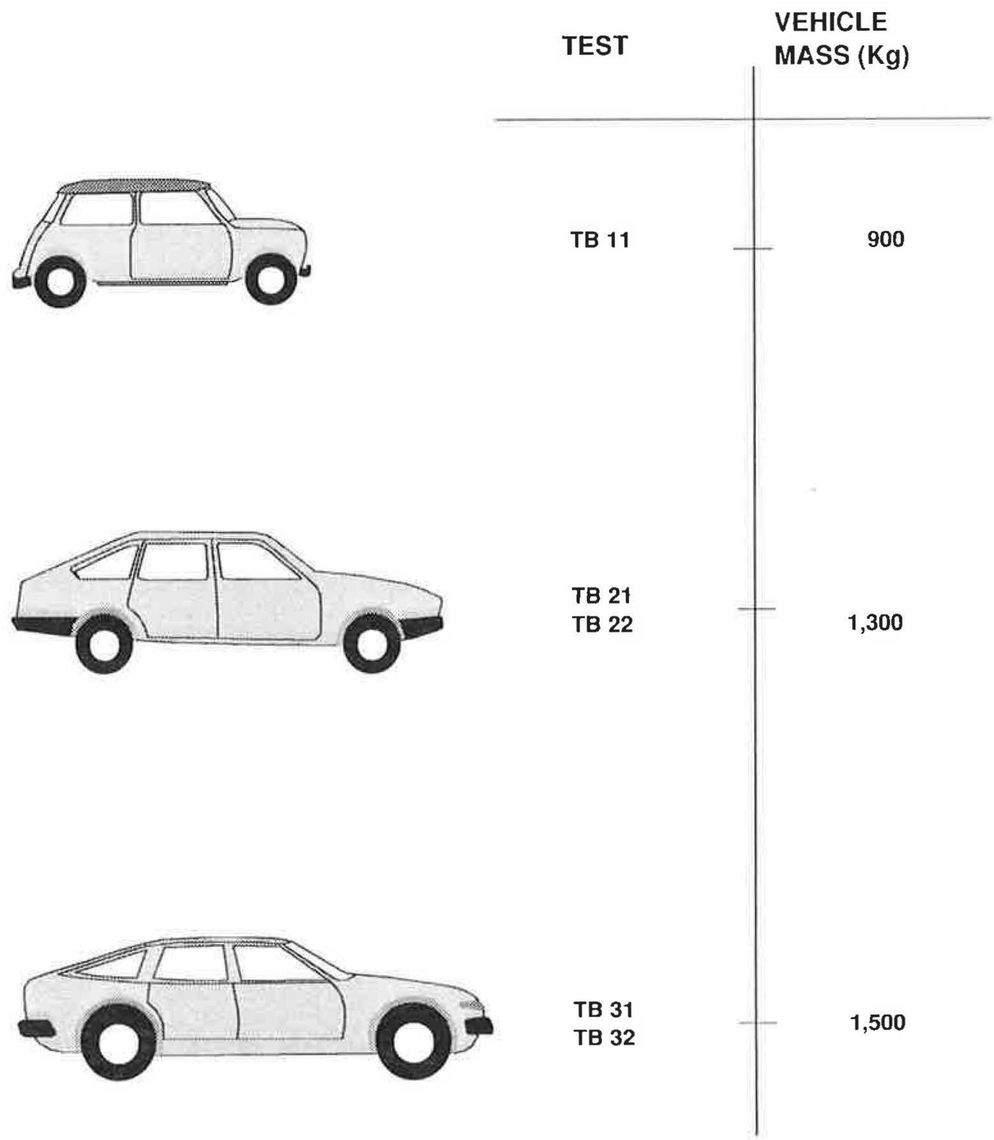


FIGURE 2 Three different weight categories of test cars.

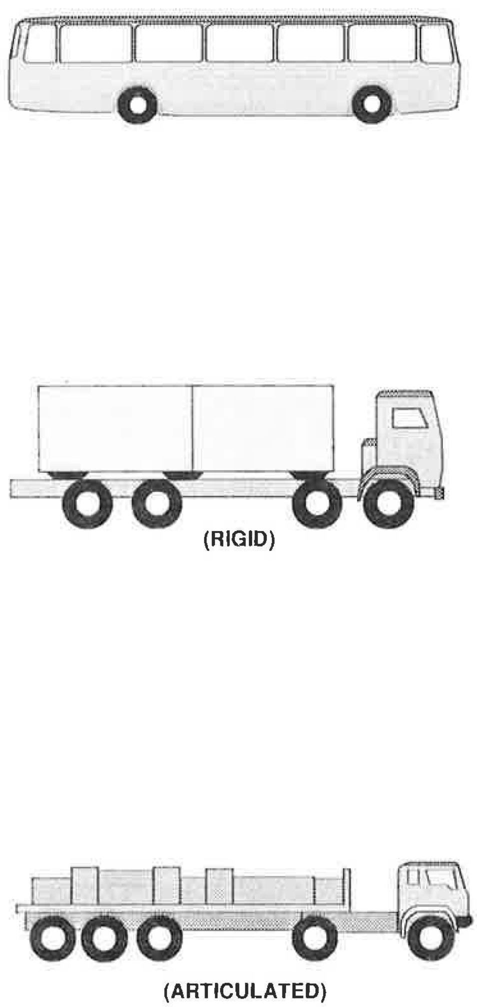
sizes, shapes, masses, and impact speeds, and a table of agreed-on vehicle types, masses, and impact speeds was drawn up. The standard test for the permanent vehicle restraint system will be the 1,500-kg car (see Figure 2).

When we started looking at what each nation used in heavy goods vehicle testing, a whole host of different vehicle masses, types, impact angles, and speeds was found. Barrier test (TB) 41 and TB 42 relate to a 10-tonne vehicle, and TB 61 relates to a 16-tonne vehicle. These different classes of vehicles are used in various countries. The 38-tonne articulated vehicle is used in France, the 30-tonne tanker is used in the United Kingdom, and the 13-tonne bus is used in Germany. In the United Kingdom the 16-tonne two-axle lorry also is used. It was necessary to rationalize the number of different heavy goods vehicles in the performance criteria list (see Figure 3).

Vehicle Impact Test Criteria for Cars

As indicated in Tables 1 and 2, the three basic elements are impact speed, impact angle, and total vehicle static mass. TB 11, TB 21, and TB 22 will basically be used for temporary restraint situations. TB 11 will cover both temporary and permanent vehicle restraint systems.

In vehicle impact testing for heavy goods vehicles and buses, one system will, if it is suitable for TB 71, probably be compliant with a TB 41 containment restraint system. There is a multitude of containment



TEST	VEHICLE MASS (Kg)
TB 51	13,000
TB 71	30,000
TB 81	38,000

FIGURE 3 Weight distinctions in three different heavy goods test vehicles.

levels from which to choose. Performance classes for safety barriers are determined by the following.

1. Containment Levels (see Table 3)

There are four categories, the first being for temporary safety barriers for use at road works, the second for normal containment, and the third and fourth being the higher and very high containment categories, which are used at hazardous locations. For the normal containment level, we use TB 32 (a 1.5-t car traveling at 110 km/h at 20 degrees) to check the structural stability of the restraint system. The small vehicle test, TB 11 (a 900-kg car impacting at 100 km/h at 20 degrees), will give an indication of the harshness and severity of the impact.

Clearly, when you get into the higher containment types of safety barriers, the need to carry out the smaller vehicle tests as well could be a major factor because one should never introduce a restraint system that not only will contain and redirect very heavy goods vehicles but also will create problems for smaller vehicles. In the United Kingdom, cars represent about 70 to 80 percent of all vehicles on the road.

TABLE 1 CAR IMPACT TEST CRITERIA

Test	Impact Speed (km/h)	Impact Angle (degrees)	Total Vehicle Static Mass (kg)
Cars			
TB 11	100	20	900
TB 21	80	8	1,300
TB 22	80	15	1,300
TB 31	80	20	1,500
TB 32	110	20	1,500

TABLE 2 HEAVY GOODS VEHICLES IMPACT TEST CRITERIA

Test	Impact Speed (km/h)	Impact Angle (degrees)	Total Vehicle Static Mass (kg)
Heavy Goods Vehicles			
TB 41	70	8	10,000
TB 42	70	15	10,000
TB 51	70	20	13,000
TB 61	80	20	16,000
TB 71	65	20	30,000
TB 81	65	20	38,000

2. Impact Severity Levels (see Table 4)

There are different procedures that are being adopted throughout the EEC. To some extent, what is happening in Europe is that some are using the acceleration severity index (ASI). In the United Kingdom the theoretical head impact velocity (THIV) and post head impact deceleration (PHID) is used. We therefore have impact severity level criteria but there is also an option: Where containment is going to be the prime requirement for the restraint system, say at a very hazardous location such as near fuel storage tanks, the main consideration is to stop the errant vehicle getting beyond the restraint system. In such cases, it may be that impact severity is not specified.

TABLE 3 CONTAINMENT LEVELS

	Containment levels	Acceptance test
Containment for temporary safety barriers only	T1 T2 T3	TB 21 TB 22 TB 41 + TB 21
Normal containment	N1 N2	TB 31 TB 32 + TB 11
Higher containment	H1 H2 H3	TB 42 + TB 11 TB 51 + TB 11 TB 61 + TB 11
Very high containment	H4a H4b	TB 71 + TB 11 TB 81 + TB 11

TABLE 4 IMPACT SEVERITY LEVELS

Impact Severity Index	Index Value		Index Value
A	ASI £ 1.0	PLUS	THIV £ 9
B	ASI £ 1.4		PHD £ 20g

3. Deformation of the Restraint Systems (see Tables 5 and 6)

The third performance criterion is the question of how much the restraint system deflects under impact, which has been defined as the dynamic deflection and working width (see Figures 4 and 5). There are many vehicle restraint systems, all operating differently. There is the weak post design that collapses to the ground, the design where the beam and post bend over, and the wire rope type of system. The draft CEN standard states that the working width is "the distance between the initial traffic face of the vehicle restraint system and the maximum dynamic lateral position of any part of the system under the impact."

This type of information is clearly needed for designers where there are obstructions and hazards that are going to be located behind the restraint system. One can imagine bridge piers, columns, signs, and all the

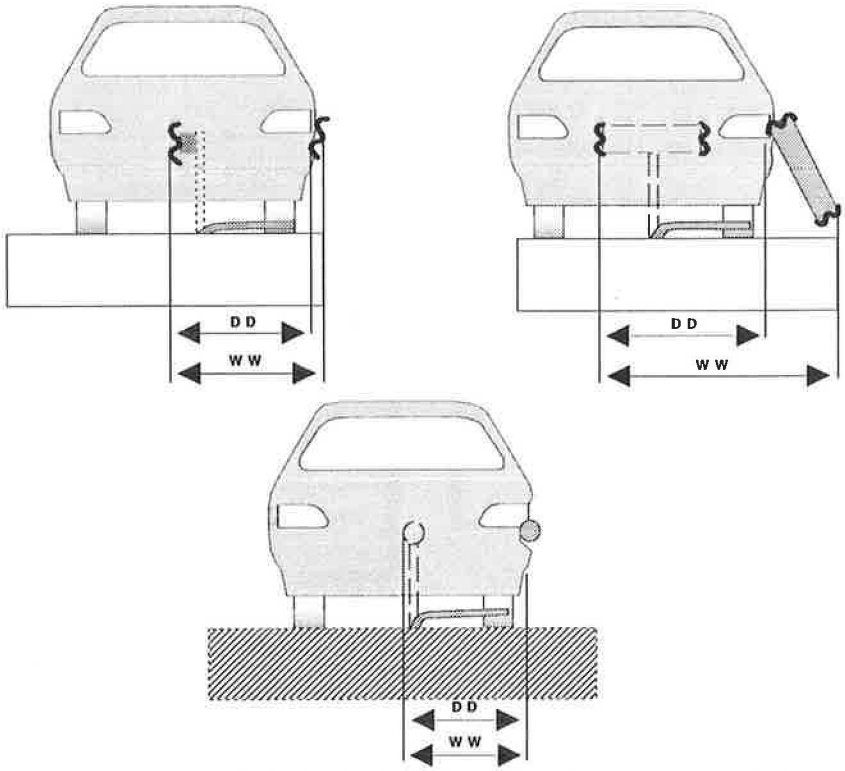


FIGURE 4 Dynamic deflection (D D) and working width (W W) for cars.

TABLE 5 DEFORMATION OF THE RESTRAINT SYSTEM FOR CARS

Containments levels CARS	PARAMETERS			
	Safety barrier and vehicle behavior	Impact severity level (ASI – THIV (PHD))	Vehicle deformation (VCDI)	Safety barrier deformation
T1	TB 21	TB 21	TB 21	TB 21
T2	TB 22	TB 22	TB 22	TB 22
T3	TB 41 + TB 21	TB 21	TB 21	TB 41
N1	TB 31	TB 31	TB 31	TB 31
N2	TB 32 + TB 11	TB 32 + TB 11	TB 32 + TB 11	TB 32

other road equipment and furniture that are within our highways.

The working width concept has also been extended into the higher containment criteria for heavy goods vehicles and buses, but most who have been involved in research of this type of device have found that there are a few other problems coming into the equation. Because of the higher center of gravities, it is likely that some

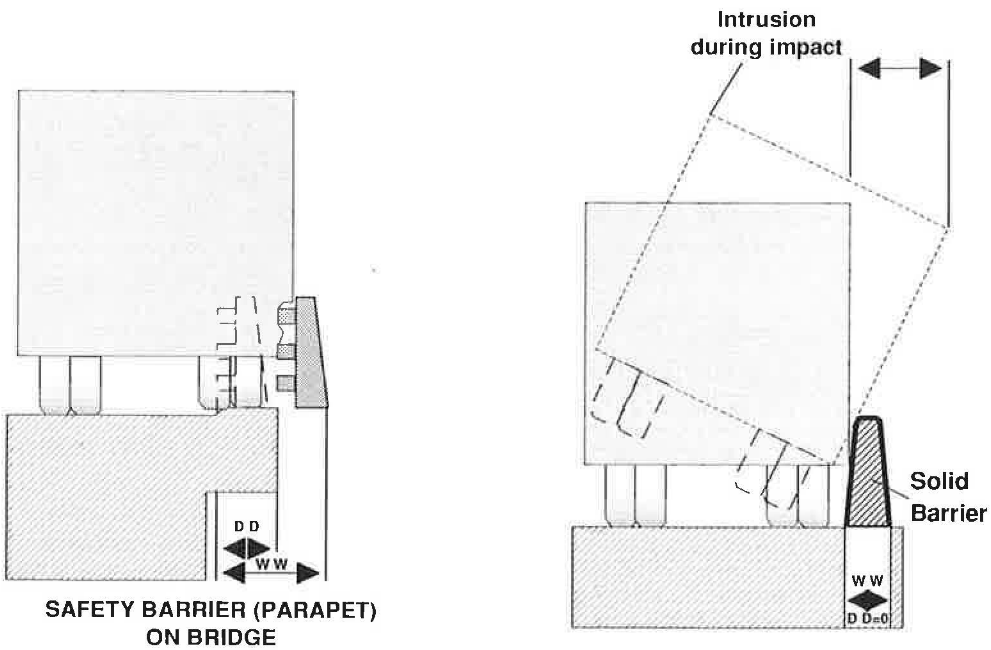


FIGURE 5 Dynamic deflection (D D) and working width (W W) for heavy goods vehicles.

TABLE 6 DEFORMATION OF THE RESTRAINT SYSTEM FOR HGVs and PSVs

Contain-ments levels HGV's and PSV's	PARAMETERS			
	Safety barrier and vehicle behavior	Impact severity level (ASI - THIV (PHD))	Vehicle deformation (VCDI)	Safety barrier deformation
H1	TB 42 + TB 11	TB 11	TB 11	TB 42
H2	TB 51 + TB 11	TB 11	TB 11	TB 51
H3	TB 61 + TB 11	TB 11	TB 11	TB 61
H4a	TB 71 + TB 11	TB 11	TB 11	TB 71
H4b	TB 81 + TB 11	TB 11	TB 11	TB 81

vehicle intrusion behind the barrier will result. The vehicle will be contained, but it may pitch and roll. This information may be very important for designers who are widening or refurbishing a road if there is a weakbridge column. For instance, can the amount of overhang observed in the impact test be allowed?

Another feature we observed in the United Kingdom when testing 30-tonne tankers on higher containment concrete safety barriers (1.2-m high) and parapets (1.5-m high) is that the rear of the vehicle can rise up to 1.25, 1.3, or even 1.4 m.

So while there may not only be a problem transversely, there could be one of available height at an overhead structure. What has been said in the draft standard is that while you cannot legislate for this in any performance standard, information on such intrusions should be recorded on the impact test report so that designers are aware of what potential systems can be used at different locations.

The classes of working width are to be split into different levels of deformation. At the lower levels of deformation, the classes will be in 0.2-m steps, but this increases up to 1.0 m where the deformation of the restraint system is very large.

The designer, when deciding which performance class of safety barrier to use, will be able to consider any approved systems that have the requisite containment level (i.e., vehicle mass and impact angle and speed), the impact severity level, and the appropriate working width.

There are various performance parameters for the different containment levels and the tests that will need to be undertaken for each parameter. The vehicle deformation parameter VCDI (vehicle compartment damage index) will be measured but will not be a mandatory performance criterion. This is, however, an indication of how much of the cockpit of the vehicle is damaged in the impact test.

Equivalent parameters and tests for the various containment levels for heavy goods vehicles and buses range from 10 tonnes (TB 42) to 38 tonnes (TB 81). While one can have very high containment safety barriers, the additional test with the 900-kg car (TB 11) will give values for the impact severity and vehicle deformation levels. However, there are many occasions in which the restraint of the errant heavy goods vehicle or bus is of paramount importance and the impact severity level will not be specified, although its test value will be recorded. Both ASI (acceleration severity index) and THIV/PHID will be recorded because both systems are currently used in the different member states. The proposal is that both measurements shall be established in impact test data for the next few years, and then the position will be reviewed to ascertain whether one or the other or neither of the indices will be adopted in the CEN standard.

Crash Cushions

Crash cushions have been part of road restraint system equipment used in several EEC countries but they have not been deployed to any great extent in the United Kingdom. They have, however, been extensively used in America for a long time, and U.S. knowledge and experience with them has helped Working Group 1 overcome some pitfalls in preparing the CEN draft standard. We have been looking very closely at what the United States has been doing in its update of NCHRP 230 (i.e., NCHRP 350).

Performance Classes for Crash Cushions

The current proposed criteria are generally similar to the NCHRP 350 matrix of test criteria, but we have tried to reduce the size of the matrix to that in NCHRP 350. As shown in Table 7, we have chosen three velocity classes: 50, 80, and 100/110 km/h.

Two different types of crash cushions, nonredirective and redirective, have been adopted. We have not included the gated and nongated definitions used in NCHRP 350 because discussions with Harry Taylor and Hayes Ross indicated that these two definitions are mainly associated with terminals and crash cushions. Working Group 1 intends to prepare a separate standard dealing with terminals.

To identify the type of tests that are required for the various parameters for crash cushions, we have devised a test notation that indicates the vehicle approach path, the test vehicle static mass, and the vehicle impact speed (see Figure 6).

Proposed Crash Cushion Impact Test Criteria

These include the "head-on center" impact, with both the 900-kg and 1500-kg vehicles with three different speeds. With the "head-on 1/4 vehicle offset" test, only the 900-kg vehicle will be tested but at the three specified impact speeds. The two side-impact tests will only involve the 1500-kg vehicle at 80 and 110 km/h impact speeds.

Proposed Performance Classes Test Matrix

Three velocities — 50 km/h, 80 km/h, and 100/110 km/h, were chosen. Certain tests will not be required where side impacts are not possible on the actual crash cushion (e.g., crash cushions installed in front of multiple toll booths). A matrix is shown in Table 8.

Impact Severity Levels for Crash Cushions

From the limited research and testing of crash cushions in the United Kingdom and the other EEC and EFTA

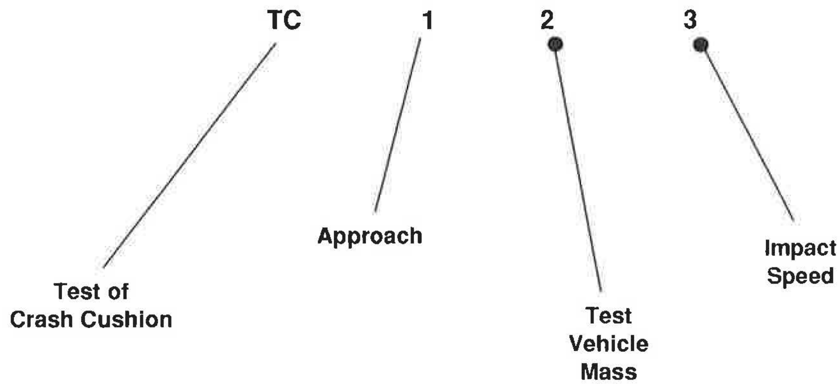


FIGURE 6 Test notation indicating vehicle approach path.

TABLE 7 CRASH CUSHIONS VEHICLE IMPACT TEST CRITERIA

TEST (*)	APPROACH	TEST VEHICLE STATIC MASS (kg)	VELOCITY (km.h)
TC1.1.1	Head-on, center	900	50
TC1.1.2			80
TC1.1.3			100
TC1.2.1	Head-on, center	1500	50
TC1.2.2			80
TC1.2.4			110
TC2.1.1	Head-on, 1/4 vehicle offset	900	50
TC2.1.2			80
TC2.1.3			100
TC3.1.2	Nose, at 15°	825	80
TC3.2.4		1500	110
TC4.2.2	Side impact at 20°	1500	80
TC4.2.4		1500	110
TC5.2.2	Side impact at 160°	1500	80
TC5.2.4		1500	110

countries, definitive impact severity levels must still be established. In the United Kingdom, THIV/PHID levels of below 12 m/s and 20 g, respectively, appear acceptable.

Conclusion

There are other acceptance criteria in the draft safety barrier and crash cushion standards. These include

TABLE 8 PROPOSED PERFORMANCE CLASSES

Performance Class		Acceptance Test (TC x.x.x.)
Velocity Class	Type	
A	NR	1.1.1, 1.2.1, 2.1.1
A	R	1.1.1, 1.2.1, 2.1.1
B	NR	1.1.2, 1.2.2, 2.1.2, 3.1.2, 4.2.2
B	R	1.1.2, 1.2.2, 2.1.2, 3.1.2, 4.2.2, 5.2.2
C	NR	1.1.3, 1.2.4, 2.1.3, 3.2.4, 4.2.4
C	R	1.1.3, 1.2.4, 2.1.3, 3.2.4, 4.2.4, 5.2.4*

redirection of the test vehicle and the requirement that no significant parts of the restraint system shall become detached and that there shall be no penetration of the test vehicle by the components of the restraint system. The test vehicle shall remain upright throughout the test, although a certain amount of rolling, pitching, and yawing will be acceptable. The test vehicle shall not underride or completely override the safety barrier or crash cushion. In addition, the ground anchorages and fixings of the restraint system shall be demonstrated to perform to the design specification. While most of these requirements have been agreed on for safety barriers, those for crash cushions are still being developed. Although work is far from complete, CEN Working Group 1 has made good progress with these matters.

TEST METHODS

Thomas Turbell
Swedish Road and Traffic Research Institute

As part of the CEN regulation, there are eight technical annexes that describe the test specifications a little further. This includes how-to methods of measuring the acceleration severity index (ASI), theoretical head impact velocity (THIV), post-impact head deceleration (PHD), and vehicle compartment deformation index (VCDI). They include how to compensate for instrumentation displaced from a vehicle's center of gravity and a test report from an International Standardization Organization (ISO) proposal that is very detailed. Also included is how to measure kinetic energy and average force, some measurement techniques for compensating for different locations of axle loads on the vehicles, and so on.

There are some problems with the test vehicles. Colin Wilson called his smallest one 900 kg, but this is including the 75-kg dummy, which is mandatory when testing with the small car. CEN allows for maximums for vehicle specifications, which will mean that different local cars will be used in Europe in these tests. They need not be the 1300-kg car or the 1500-kg car; they actually could be the same vehicle but with different amounts of ballast. We would like to tighten this up so that a fewer number of different cars in European testing are allowed.

There are some dimensions that should be measured inside the vehicle before performing the crash test. And then CEN looks at the relative change in these dimensions and sets an index for it. There are no requirements yet, but it should be recorded in all tests.

The impact velocity measurement is almost the same as the American model, the impact velocity of an unrestrained occupant located 0.6 m from the front and 0.3 m from the side of the passenger compartment. The main difference between the CEN and the American model is that CEN is a two-dimensional model (THIV) and the American model, occupant impact velocity (OIV), is two times one-dimensional so that one direction at a time is looked at. This is much easier to measure and calculate, and there is no need for a lot of instrumentation. But in principle they are the same.

The other index is the ASI. This is the resultant acceleration that is weighted in the different directions. For frontal impact and constant speed, with a 0.6 m flail space, ASI may be estimated at