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Railway applications - Crashworthiness requirements for railway vehicle bodies

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Bahnanwendungen - Anforderungen für die Kollisionssicherheit von Schienenfahrzeugkästen

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Foreword

This document (prEN 15227:2005) has been prepared by Technical Committee CEN/TC 256 “Railway Applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this document.

Introduction

The objective of the passive safety requirements described in this document is to reduce the consequences of collision accidents. The measures considered in this document provide the last means of protection when all possibilities of preventing an accident have failed. It provides a framework for determining the crash conditions that railway vehicle bodies should be designed to withstand based on the most common accidents and associated risks. It also defines suitable passive safety features to meet the requirements.

The requirements are compatible with those of EN 12663. The static compression load requirements on the vehicle ends, required by EN 12663, are intended to provide a basic structural integrity to the occupied areas in a collision-type accident. This document adds to the basic strength requirement by setting additional requirements for structural passive safety.

1 Scope

This European document applies to new designs of locomotives and passenger carrying rolling stock as defined in categories P-I to P-V of clause 3. The specified requirements relate to the conditions of use that prevail in these countries. The design of new vehicles for use in passenger trains is based on operations with compatible rolling stock that also meet this document. To satisfy this document it is not necessary to consider the consequences of operation with existing vehicle designs.

The requirements apply to the vehicle body, and to those mechanical elements directly associated with it that may be used to absorb energy in a collision, such as couplers, buffing systems, anti-climbers and obstacle deflectors, etc. They do not cover doors, windows, system components or interior features.

The requirements do not cover all possible accident scenarios but provide a level of crashworthiness that will provide an appropriate level of protection in most eventualities, when the active safety measures have been inadequate. The requirement is to provide a level of protection consistent with the probable collision risks and this is achieved by addressing the most common types of collision causing injuries and fatalities.

The applicable collision scenarios are given in clause 6 and Annex A gives guidance on suitable parameter values for use in these scenarios.

The document identifies common characteristics and methods of energy absorption that may be adopted to suit individual vehicle requirements so facilitating progress and design innovation. The document also specifies a suitable large obstacle model for representing collisions with a heavy road vehicle. Not all vehicles in a train have to incorporate energy absorption but passenger train configurations formed entirely of new vehicle designs shall, as a whole, comply with this document.

The document also specifies the requirements for demonstrating that the passive safety objectives have been achieved by comparison with existing proven designs, numerical simulation, component or full-scale tests, or a combination of all these methods.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12663, *Railway applications — Structural requirements of railway vehicle bodies*

EN 50126, *Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS)*

UIC 526-1, *Wagons – Buffers with a stroke of 105 mm*[1)]

UIC 571-2:2001, *Standard wagons - Ordinary bogie wagons - Characteristics*[2)]

1) in preparation

2) To be purchased from: Railway Technical Publications (ETF), 16 rue Jean Rey, F-75015 Paris

3 Definitions

For the purposes of this document, the terms and definitions given in EN 12663 and the following apply.

3.1
active safety
systems which reduce the probability of an accident occurring or the severity of the accident

3.2
broadly acceptable risk
level of risk that is regarded as not significant in the context in which it is experienced

3.3
cab car
a non-powered vehicle fitted with a driving cab and which is designed to operate in general traffic and not as part of a fixed configuration train unit

3.4
collapse zone
that part of the vehicle body (usually at the end) which is designed to collapse in a controlled manner if it experiences a load beyond the maximum normal service level

3.5
crushing
Excessive plastic deformation that significantly reduces the volume created by the structure

3.6
collision mass
the collision mass can be taken as the tare mass plus the mass of 50 % of seated passengers

NOTE Passenger and equipment mass can be represented as additional vehicle body mass.

3.7
full size test
a test on the structure of interest with the test specimen formed from all relevant full size components

3.8
limiting collision/case
(= design collision scenario)
the most severe collision/case for a given scenario it is appropriate to protect against and so is applicable for design purposes

3.9
locomotive
a vehicle the prime function of which is to provide motive power and which is designed to operate in general traffic and not as part of a fixed configuration train unit

3.10
operator
the organisation which has responsibility for defining the technical requirements for the railway vehicle in order that it will perform the intended operation and meet the acceptance criteria

3.11
passive safety
systems which reduce the consequences of an accident should it occur

3.12
plastic deformation
permanent deformation
Deformation associated with stresses above the material yield or proof stress and which is not recoverable when the load is removed

3.13
reference collision scenario
representative collision scenario on the basis of the collision accident analysis [ERRI B 205, RP 1]

3.14
regulations
requirements stipulated in legislation or in documents and other documents mandated by legislation

3.15
supplier
the organisation which has responsibility for designing the railway vehicle to satisfy the technical requirements of the operator

3.16
survival space
A volume of the vehicle body containing the occupants which has to be maintained during the limiting collision (e.g. the occupied areas; not including access only vestibules, gangways etc.)

3.17
train unit
the minimum operational configuration of a rake of vehicles covered by this document

4 Categories of railway vehicles

For the application of this document railway vehicles are classified into categories. These categories are related only to the structural requirements of the vehicles with respect to their crashworthiness. It is the responsibility of the operator to define which category is applicable to his operations. There will be differences between operators and this should not be considered as conflicting with this document.

Crashworthiness requirements apply to locomotives and vehicles carrying passengers, which range from main line operations to urban transit and tramway applications. These vehicles are divided into five performance categories as indicated in Table 1, with an indication of the type of vehicle generally associated with each:

Table 1 — Categories of railway vehicles

Category	Buffer load	Example
P-I	2 000 kN	coaches and locomotives
P-II	1 500 kN	fixed rake units
P-III	800 kN	underground and rapid transit vehicles
P-IV	400 kN	light duty metro and heavy duty tramway vehicles
P-V	200 kN	tramway vehicles

5 Passive safety requirements

This part of the document specifies the minimum functional requirements needed to protect the occupants of passenger rolling stock. It provides guidelines for defining the requirements if those in this document are not applicable, and indicates methods of achieving and validating the requirements.

As far as reasonably practical the following measures are to be employed to provide protection of occupants in the event of an accident:

1. Resisting overriding;

2. Absorbing collision energy;

3. Preserving survival space;

4. Limiting the deceleration rate;

5. Resisting intrusion into the survival space;

6. Minimizing the consequences of hitting a track obstruction.

Resistance to overriding is essential to ensure the loads arising, as a result of a collision, are transferred between vehicles into the mechanisms designed to accommodate them and absorb the collision energy by controlled deformation.

Collision energy absorbed in a controlled way is not available to cause other undesirable effects. It shall be absorbed in energy absorbing components and elements of the structure where it will present minimal risk to the passengers and crew.

Resistance against the crushing of the occupied areas of the vehicle structure, to provide a survival space, is an essential requirement to protect the passengers, the crew and the driver of the train.

The global deceleration of the vehicle should be limited to a level consistent with the strength of the equipment attachments. The deceleration level, in turn, determines the maximum acceptable resistance force to be developed in the structure during its collapse.

Intrusion of outside objects into the occupied spaces is an additional hazard that should be addressed by maintaining the integrity of the surrounding structure.

Obstacles that are generally below the vehicle floor height will pass beneath the main energy absorption mechanism. Such objects pose a risk of derailment. Fitting an obstacle deflector outboard of the leading bogie reduces this risk. The requirements for obstacle deflectors are presented in more detail in 7.6 and A.2.4.

NOTE As a by-product of providing occupant protection the level of damage to the vehicle body is likely to be reduced in less severe accidents (with lower repair costs). If the operator wishes to specify more restrictive damage limitations for any of the collision scenarios of clause 5 to reduce repair costs, this should be part of the contractual requirements and does not form part of the safety requirements of this document.

6 Collision scenarios

It is recognised that it is impractical to design the vehicle structure to protect the occupants in all possible accident situations or to consider all possible vehicle combinations. The requirement is to provide a level of protection consistent with the probable collision risks. The requirement may be expressed in terms of a limiting case for each of the reference collision scenarios listed below.

The accident scenarios described are not the only cases occurring on European networks, but they represent the most common collision situations and those that result in most of the casualties, see ERRI B205. The following reference collision scenarios shall, therefore, form the basis of the crashworthiness requirements of the vehicle body:

1. A front end impact between two identical train units;
2. A front end impact into a buffered rail vehicle;
3. Train unit front end impact with a heavy obstacle (e.g. lorry on road crossing);
4. Train unit (categories P-I…P-IV) impact into low obstacle (e.g. car on road crossing, animal, rubbish, etc.).

Scenario 1 was chosen since train-to-train collisions result in the highest number of serious injuries. The considered collision shall be between identical units.

Scenario 2 represents a collision with current classical buffered rolling stock when working in a mixed traffic environment (or with buffer-stops) where overriding is potentially more common.

Scenario 3 is a type of accident that is more difficult to prevent by active safety measures. The significance of this type of collision is dependent on the prevalence of level crossings, the operating speed and emergency braking rate of the train and the sighting distance.

Scenario 4 applies when a train unit collides with an obstacle having its centre of mass located below the level of the train unit headstock. There is an increased risk of derailment that can be reduced if an obstacle deflector is provided on the train unit.

The severity of the design limiting case for each scenario will depend on the train control and active safety systems and the features of the infrastructure as well as the masses and operational speeds of the rail vehicles themselves. A.1 provides more background on the choice of the collision scenarios and on the related crashworthiness requirements. A.2 of this document gives parameters for each scenario to be used for normal European operations. A.3 presents guidelines on how to determine the limiting cases for each design collision scenario where normal conditions do not apply.

The limiting collision scenarios for some operations may be contained in statutory regulations. In such cases these regulations shall be complied with and may be taken as the appropriate limiting case for the corresponding operating conditions. If there are no requirements specified in regulations and the normal European operating conditions assumed by this document do not apply, it shall be the responsibility of the operator to determine the applicable scenarios and the appropriate limiting design case for each.

The vehicles shall be designed to satisfy those design collision scenarios that correspond to the operational conditions they are expected to experience. If the operational conditions are such that a collision scenario cannot occur, or there is evidence that the probability of it occurring is so low as to be broadly acceptable, there is no need to consider the scenario in the vehicle design. Train control systems which segregate different types of traffic on the same system may satisfy this requirement. If vehicles cannot operate up to the collision speeds specified in this document (e.g. shunting locomotives) the scenarios shall be considered at the vehicle maximum operational speed.

If assessing a train unit with different vehicles at each end, only impacts between identical vehicles shall be considered under scenario 1.

If assessing a single locomotive or a cab car a reference train shall be used in each of the above scenarios. In the assessment the locomotive or cab car shall be considered as the leading vehicle only. The reference train used for validation shall be representative of (or encompass), in terms of crashworthiness parameters, all types of passenger vehicles it is to operate with and the reference train parameters used shall be clearly defined and recorded.

If assessing an individual coach for general use in the above type of train unit, its crashworthy performance shall be at least as good as that assumed for the reference train (or trains) used for the design of the locomotive(s) or cab car(s) with which it is intended to operate so that the train unit as a whole always satisfies the requirements of this document.

If a locomotive is to also operate with freight rolling stock it shall also be assessed with a simplified freight reference train consisting of a single freight wagon.

All vehicles, which conform in terms of their crashworthiness, at least equally to those adopted in the reference train, shall be accepted for use in the interoperable trains.

Annex D gives guidance on the choice of reference trains and the scope of approval that is possible without full re-assessment.

The collision mass, as defined in clause 2, shall be determined for each vehicle and applied in all assessments.

It is becoming more common for different categories of vehicles to share common track. Collision scenarios between these vehicles might need to be considered if the active safety measures do not reduce the probability of such collisions to a broadly acceptable level.

If the system has characteristics that result in significant collision risks (relative to the above) not already covered, they shall also be considered in the form of additional limiting collision scenarios.

No specific requirements are set to cover side impacts and ejection or intrusion through the side structure. Modern vehicles of monocoque construction have generally performed well, but the performance with respect to these attributes needs to be considered if new structural concepts are introduced.

This document does not require vehicles to be designed to withstand collisions with the infrastructure but meeting its requirements will provide an inherent level of protection in such incidents.

7 Structural behaviour

7.1 General principles

The objectives of this document shall be achieved by absorbing the energy appropriate to each relevant design collision scenario in a controlled manner. This shall be accomplished by following the principles outlined in clause 4 in such a way that structural collapse is confined to designated areas of the structure and the main passenger/crew space is preserved. These principles are described in more detail in the following clauses.

7.2 Overriding

Overriding constraint is necessary to limit the vertical displacements arising at vehicle interfaces and resist those vertical forces that are induced, so that the collision loads are directed to the energy absorbing structure. Vertical displacements and forces arise due to offsets between the interface contact/reaction points and the inertia forces associated with vehicle decelerations and accelerations.

Overriding constraint can be provided by:

a) a vertical contact face providing uniform resistance to deformation;

b) provision of anti-climb units (with associated coupler collapse/shear out);

c) bar coupler between vehicles with movement constraint;

d) any other system providing vertical movement constraint at an interface.

In case of option b) anti-climbers shall incorporate some form of interlocking feature, which ensures that the faces in contact cannot slide vertically over each other.

Anti-climbers usually incorporate some energy absorption. They should be located taking into account the space available, the coupler / drawing gear type and installation and the likelihood of collision with vehicles with different buffing and coupling configurations. For anti-climbers to work the coupler collapse stroke shall be sufficient for them to engage or the coupler attachment shall shear out from its mounting.

NOTE In cases involving side buffered vehicles the anti-climber head should positively engage with the buffer head where this is practical. If anti-climbers are located at side buffer positions it might be necessary to increase vehicle separation in order to permit normal operational movements.

Option c) takes advantage of a semi-permanent coupler bar as a means of providing vertical movement constraint. The bar and constraining structure shall have the strength to carry the associated loads.

The override constraint shall engage and operate with a vertical offset. The appropriate offset shall be determined from consideration of the operational conditions, taking into account the difference between low suspension setting with worn wheels and high suspension setting with new wheels plus the effects of any other conditions such as pitching due to braking. Under these conditions, the collision loads are to be directed into the intended energy absorbing structure.

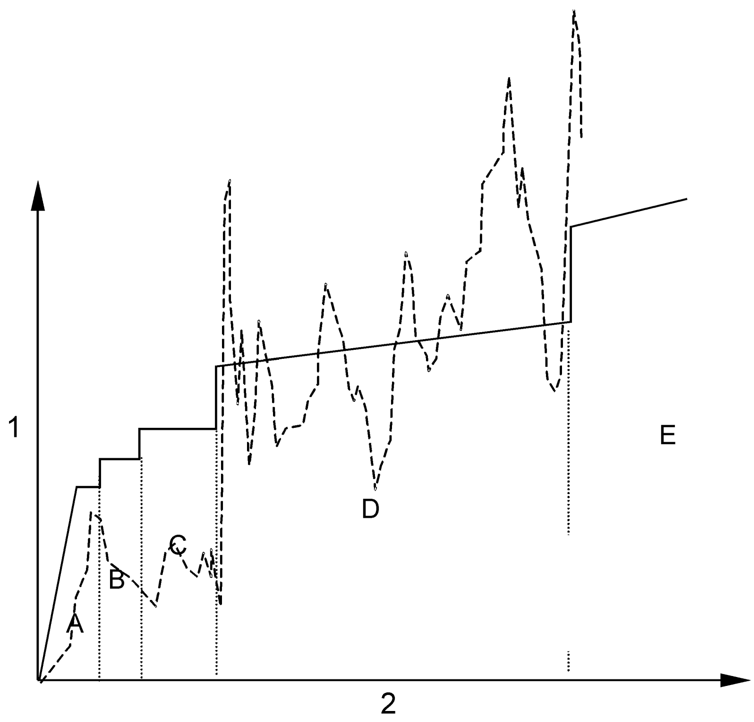
For all categories of vehicles the vertical shear force per vehicle end to be carried by the anti-climber mountings can be determined by simulation. If an accurate value is not available, the vertical ultimate design force should be taken as half the total tare weight of the heaviest vehicle at the interface, up to a maximum of 150 kN.

The acceptance criterion for the overriding limitation for scenario 1 is that the validation process (simulation) demonstrates that, with an initial vertical offset of 40 mm at the point of impact, contact of at least one wheelset of every bogie is maintained with the track throughout the collision simulation.

If the compression force at an interface is sufficiently low, overriding may not be induced and it may not be necessary to provide a resisting mechanism. Such a situation is most likely with separate light rail and city tram systems.

7.3 Controlled energy absorption

As a minimum there shall be sufficient energy absorption capacity to control the collision behaviour for each relevant collision scenario. At each vehicle interface energy shall be absorbed systematically. As energy is absorbed there shall ideally be a general increase in the resistance force with increasing displacement. Figure 1 shows the idealised fundamental behaviour.



Key

——	idealised behaviour
– – –	typical real behaviour
1	interface resisting force
2	displacement

Figure 1 — Progressive resistance (indicative only)

The energy absorbing elements involved in this process are:

A coupler - recoverable (normal buffing);

B coupler – sacrificial;

C anti-climber;

D structure collapse zone;

E passenger/crew survival cell.

Safety does not require all the elements to be present at an interface nor for the resisting force to increase continuously. In any practical structure there are likely to be significant perturbations in the collapse force but it should have the generally increasing trend as indicated in Figure 1.

The minimum requirements are that the normal buffing requirements are satisfied, there is a mechanism present to resist overriding and that the total level of energy absorption required at the interface is achieved.

It is desirable to minimise the variations on the average collapse force at each stage. Forces lasting less than 5 s^{-3} can usually be considered non-significant.

It is usually necessary to control the material properties to tighter limits than is normal in the material specifications (with more closely defined upper and lower bounds) in order to achieve consistent collapse behaviour.

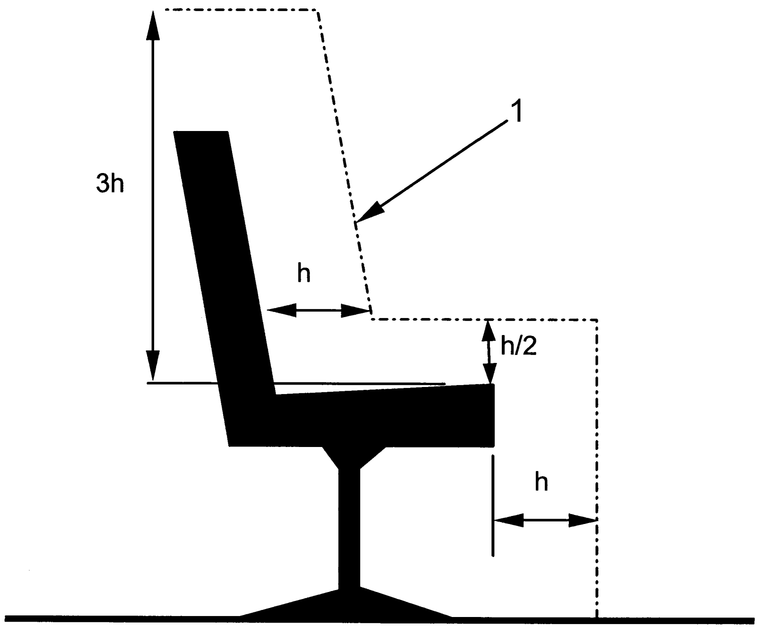
7.4 Survival space/egress

The provision of survival space for both passengers and crew shall conform to any applicable statutory or operating authority regulations.

The designated survival spaces shall keep their integrity during the full crushing of the collapse zones, even in the presence of significant peak-forces. (Integrity means the absence of gross plastic deformations and general buckling of the structure). Local plastic deformation and local buckling are acceptable if it is demonstrated that they are sufficiently limited, so as not to significantly reduce the passenger and driver survival spaces.

The deformation of the structure shall not obviously cause any vehicle equipment or parts (e.g. driver's desk, windscreens, etc.) to encroach into the designated survival spaces during the collision scenarios. The structure immediately ahead of the driver's survival space should, as far as practical, not fail in a manner that itself creates a hazard (e.g. exposed fracture surfaces and protrusions should be avoided).

At the driving position, there shall be a survival space for the driver maintaining a length and width of at least 0,75 m (or 80 % of the original cab length if this is less). This space shall maintain at least 80 % of the original height between the nominal floor and ceiling levels. If the survival space includes the driver's seat, a clearance shall be maintained ahead of the seat as shown in Figure 2 (with the seat in its median position).



Key
h = 300 mm
1 clearance profile

Figure 2 — Driver's seat clearance zone

If it is impractical to provide the survival space as described above and the operator agrees, it is acceptable for survival space to be provided in a compartment immediately adjacent to the driving position provided that there is immediate access to it.

The front windscreen shall be supported against the structure of the driver's cabin in a manner that will resist the windscreen as a whole moving backwards into the driver's survival space in all the reference scenarios. This requirement does not imply that the windscreen has to remain intact.

The structure forming the passenger survival spaces shall resist, without infringement, the maximum forces exerted upon it during the full collapse sequence of the energy absorbing elements. When subject to the defined scenarios, the loss of volume of passenger survival spaces shall be limited to not more than 1 % of the initial lengths of these areas over any 5 m length. Within a vehicle end vestibule, the reduction in vehicle length shall not be greater than 300 mm or 30 % of the original length, whichever is the smaller.

At least one escape route (via a designated egress door or escape window) shall be maintained for every survival space.

Specification of passenger and crew egress requirements is outside the scope of this Document but shall be taken into account when addressing its requirements. Where practical the driver shall be located inboard of the designated structural collapse zone. Alternative measures may be provided to give protection, such as a movable protective cell, and/or provision of a clear escape route. Where an escape route is defined, deformation of the structure under the defined scenario shall not prohibit its use.

7.5 Deceleration limit/collision pulse

The global rate of deceleration of a vehicle is determined by the magnitude of the net resisting force. The net resisting force is the difference between the forces acting on opposite ends of the vehicle at any instant of time. Force levels significantly higher than the average (as indicated in 7.3) are permissible provided they are not sustained.

The mean deceleration rate in the survival spaces should be limited as far as is practicable to 5 g, and shall not be more than 7,5 g. It will usually be necessary to accept higher levels of deceleration in the driving cab area close to the point of impact.

The method of determining the mean deceleration rate for each considered vehicle in the train set shall correspond to the time from when the net contact force on the vehicle exceeds zero to the time when it next falls again to zero.

The ultimate strength of the equipment attachments (as required by EN 12663) should be taken into consideration in determining the acceptable deceleration level.

7.6 Obstacle deflector

An obstacle deflector shall be fitted unless the main vehicle structure is sufficiently low (e.g. low floor LRVs and trams) to prevent objects that may cause derailment passing under the train. It should be placed as near to the front of the leading vehicle as practical to avoid forming a trap for objects under the vehicle. It needs to be of sufficient size to sweep such obstacles clear of the path of the bogie.

The obstacle deflector shall be a continuous structure designed so as not to deflect objects upwards or downwards and in plan view have a ‘V’ profile with an included angle of not more than 160°. It can be designed with a compatible geometry to function also as a snow plough. Under normal operating conditions, the lower edge of the obstacle deflector shall be as close to the track as the vehicle movements and gauge line will permit. The obstacle deflector shall remain clear of track and other local infrastructure features when deforming under impact.

The parameters of the mass to be cleared and the impact speed shall be appropriate to the application. The structural performance requirements for the obstacle deflector and its attachment to the vehicle structure are specified in A.2.4.

8 Validation of crashworthiness

8.1 Process

The passive safety objectives are given for complete train units. As it is impractical to evaluate complete train behaviour by testing, the achievement of the objectives shall be validated by dynamic simulations corresponding to the reference collisions scenarios. The use of numerical simulation alone is sufficient for accurate prediction of structural behaviour in areas were the deformation is limited. However, for areas with large deformations, a full-scale vehicle end structure test shall be carried out, in order to verify the corresponding numerical model. For a new design of structure at least one full scale vehicle end structure verification test shall be performed. The validation programme is therefore a combination of test and simulation (a combined method).

A plan or programme shall be produced to assure the conformity of the tests and the validation of the numerical simulations. This programme shall include technical reports covering each stage of that validation process from material properties through component tests to the final whole vehicle simulations.

The principles establishing that the crash performance of a structure is fully representative of production, are evaluated against the performance criteria by reviewing the definitive drawings, the requirements and technical reports covering the assessment.

It shall be permissible to use a reduced validation programme if:

- the passive safety is adapted from a proven design already validated by a rigorous methodology (the degree of validation shall depend on the closeness of the initial results to the specification).
- modifications have been made to a previously verified design and if:
  - the safety margin against the requirements is sufficient to accommodate any resulting inaccuracies;
  - any modifications do not significantly change the mechanisms providing the passive safety.

However, in this case, the crashworthiness performance should be validated to a level appropriate to the degree of change by:

- comparison with a similar solution (via engineering drawings or other technical data);
- a combination of computer simulations/calculations (e.g. FEA or multi-body modelling) and testing (quasi-static or dynamic).

The main steps for this combined method for a new design of structure are given below and more details of good test and simulation practice are given in Annex B.

8.2 Test of non-structural absorbing devices and collapse zones: Step 1

Appropriate testing on full-size test specimens shall be carried out in order to verify the performance of the crashworthy elements and give inputs to calibrate the models.

The test configuration shall be defined with respect to the following objectives:

- reflect as close as possible one of the scenarios;
- facilitate model calibration;
- utilise the maximum energy absorption capacity;
- demonstrate the relevant specific behaviour of the design concept.

It is permissible to verify the performance of inter-vehicle devices, energy absorption elements and anti-climbing devices or arrangements by appropriate individual full-size tests.

Data from quasi-static tests shall only be used to determine the behaviour of the energy absorbing mechanisms (honeycomb, composite elements, shear off devices, etc) where the result is not rate dependent, or where appropriate adjustment or validation can be made to ensure the correct dynamic characteristics.

8.3 Calibration of the numerical model of the structure: Step 2

After carrying out the full-size testing described in step 1, the manufacturer shall calibrate the numerical model using an iterative technique comparing the test results from step 1 with the numerical simulation in step 2.

The validation of the model uses two essential steps within the comparison between test and numerical simulation:

— global behaviour of the structure, areas where plastic deformations appear, and the sequence of the mechanisms of energy absorption;

— detailed analyses of all test results and more especially of the force levels and displacements of the important points of the structure.

8.4 Numerical simulation of the design collision scenarios: Step 3

A 3-D model of each different vehicle structure that will be subject to permanent deformation shall be created.

The models shall include the driver's cabin or vehicle end calibrated model from Step 2 and a compatible model of the rest of the vehicle to give complete 3-D representations of the whole vehicles. (Normally the first or the first two vehicles only need to be modelled to this level of detail. The remaining vehicles of the train can be represented by lumped mass/spring systems etc. representing their global behaviour.)

Simulations of all the relevant collision scenarios shall be carried out in order to have the vehicles approved against the requirements of this document.

Annex A
(normative)

Parameters of design collision scenarios for normal European operations

A.1 Introduction

To enable the crashworthiness requirements for a vehicle to be defined and assessed it is necessary to determine the design collision scenarios in terms of impact speed and the type and mass of potential obstacles.

For normal European operating conditions comparable with those of the collision accident analysis, see ERRI B 205, the parameters of the design collision scenarios and their related crashworthiness requirements listed in A.2 are applicable.

In special cases the design collision scenarios and their parameters for some operations may be contained in regulations. In such cases the regulations shall be complied with and may be taken as the appropriate limiting case.

Where there are no regulations specifying the limiting conditions and where the design collision scenario parameters in A.2 are not applicable, the operator is required to demonstrate that suitable and sufficient provision has been made to protect staff, customers and third parties from harm and appropriate techniques should be employed to assess:

— the probability of each collision scenario;

— the severity of each collision scenario and;

— the benefits achievable from each active and passive element of the proposed collision protection systems.

These assessments are to be used to determine the requirements for an overall protection scheme appropriate to the hazards and consequently the requirements for the limiting case collision scenarios, or reference accidents, to be used as the basis for the design and assessment of the crashworthiness of vehicle structures.

For normal European operating conditions the following paragraphs provide parameters for each of the collision scenarios, relevant application guidelines and related crashworthiness requirements. The parameters are presented for each of the vehicle categories specified in clause 4.

A.2 Parameters of the design collision scenarios and related crashworthiness requirements for normal European operations

A.2.1 Collision scenario 1 – Collision of two identical units - Design closing speeds

Passenger vehicles collision speed v_c [a]				
P-I	**P-II**	**P-III**	**P-IV**	**P-V**
Assumed mean braking deceleration 1,0 m/s^2 [b, c]				
36 kph	36 kph	36 kph [d]	36 kph [d]	15 kph

a Collision conditions: train units non-braked on straight track.

b Where the system's active safety measures are such that the collision risk is higher than the normal for European operations (e.g. as presented in ERRI B 205 Report), then a higher collision speed v_c shall be considered. The collision speed shall be based on local accident statistics (or those for similar operations) or on the results of other risk assessment measures.

c The collision speed may be reduced if the vehicles have a mean emergency braking rate $a_d > 1,0$ m/s^2. The reduced collision speed may be determined from the following formula: $v_{red} = v_c (1 – (11(a_d –1,0)/36)) \geq 25$ kph.

d The normal collision speed for vehicle categories P-III and P-IV may also be reduced to 25 kph if automatic train protection is present and if the network is isolated from other types of rolling stock and the service on all lines operates in one direction only.

A.2.2 Collision Scenario 2 – Collision with buffered rail vehicles / different train units – Design closing speeds

Passenger vehicles collision speed v_c [a, b, c, d]				
P-I	**P-II**	**P-III**	**P-IV**	**P-V**
36 kph [e]	36 kph [e]	36 kph [e]	36 kph [e] 10 kph [g]	10 kph [f]

a Collision conditions: train units/rail vehicles non-braked on straight track.

b Where the system's active safety measures are such that the collision risk is higher than the normal for European operations (e.g. as presented in ERRI B 205 Report, then a higher collision speed v_c shall be considered. The collision speed shall be based on local accident statistics (or those for similar operations) or on the results of other risk assessment measures.

c Assumed mean braking deceleration 1,0 m/s^2. The collision speed may be reduced if the vehicles in categories P-I, P-II, P-III and P-IV have a mean emergency braking rate ad > 1,0 m/s^2. The reduced collision speed may be determined from the following formula: $v_{red} = v_c\,(1 - (11(a_d - 1.0)/36)) \geq 25$ kph.

d The energy absorption behaviour of the buffers, see UIC 526-1, or automatic couplers of the other impacted vehicle shall be taken into account where appropriate.

e For category P-I and P-II vehicles the wagon to be considered shall be a wagon as specified in UIC 571-2, mass = 80T with category A buffers. For other categories of vehicle, where this scenario exists, the wagon shall represent the heaviest type of wagon used on the system if this has a lower mass.

f For normal European operation, a P-V unit working in a mixed traffic environment with a P-IV unit, shall be considered in collision with a rigid mass of 55T with a plane vertical face (this simplified obstacle representing the P-IV unit does not contribute to the energy absorption within this scenario).

g For normal European operation, a P-IV unit in a mixed traffic environment, shall be considered in collision with a regional train unit. This unit may be represented by the reference train in C.3.

A.2.3 Collision scenario 3 – Collision with heavy obstacle – Design closing speeds

Passenger vehicles collision speed v_c [a, c]				
P-I	**P-II**	**P-III**	**P-IV**	**P-V**
110 kph [b, d]	110 kph [b, d]	110 kph [b, d]	40 kph [d]	25 kph [e]

[a] Collision conditions: train unit non-braked on straight track.

[b] The collision speed for Categories P-I to P-III is based on an operational speed of 160 kph at level crossings. If the operational speed of the vehicles at the level crossings differs from 160 kph, the collision speed shall be adjusted according to the following formula: $v_c = v_{op} - 50$ kph, where v_{op} is the highest operational speed at the crossings. v_c should not be below 40 kph or the operational speed at the crossing, whichever is the lower.

[c] Assumed mean braking deceleration 1.0 m/s^2. The collision speed may be additionally reduced if the vehicles have an emergency braking rate a_d >= 1.0 m/s^2 according to the formula: $v_{red} = v_c (1 – (11(a_d –1,0)/36))$

[d] Heavy obstacle (e.g. lorry). For normal European operation represented by the deformable obstacle as defined in Annex C. The object shall be placed symmetrically perpendicular to the path of the train.

[e] Heavy obstacle for corner collision at crossroads (e.g. with light goods vehicle). For normal European operation this shall be represented by a rigid mass of 3T with a vertical surface covering the complete collision contact area of the tram. The collision face is to be at an angle of 45° to the tram longitudinal axis and centred on each of the front corners.

A.2.4 Collision Scenario 4 – Collision with small obstacle – obstacle deflector strength requirements

Passenger vehicles - Categories P-I to P-IV					
Operational speed [a]	≥ 160 kph	140 kph	120 kph	100 kph	≤ 80 kph
Static load at centre line [b, c]	300 kN	240 kN	180 kN	120 kN	60 kN
Energy absorption at centre line [d, e]	36 kJ	29 kJ	22 kJ	14 kJ	7 kJ
Static load at 750 mm lateral distance from C/L [b, c]	250 kN	200 kN	150 kN	100 kN	50 kN
Energy absorption at 750 mm lateral distance from C/L [d, e]	30 kJ	24 kJ	18 kJ	12 kJ	6 kJ

[a] For operational speeds different from the given values, the force and energy values may be interpolated.

[b] Each static load shall be applied independently in the vehicle longitudinal direction. The force has to be applied over an area of 0,5 m wide and up to 0,5 m high from the bottom edge of the obstacle deflector. (Note that the available height may be limited by cut-outs for the coupler or other equipment). The line of action of the force shall be horizontal and through the centre of each loaded area up to a maximum height of 500 mm above rail level.

[c] There shall be no significant permanent deformation of the obstacle deflector and its fixations to the car-body due to each static load.

[d] If the obstacle deflector is overloaded it shall deform plastically in such a way that it does not become detached or itself become a danger.

[e] Under plastic deformation an obstacle deflector required by this document shall absorb at least the energy values given in the above table.

A.3 Determining the design collision scenarios for collision risks which differ from the normal European operations

A.3.1 Collision scenarios

This clause gives guidance on how design collision scenarios may be established where the design collision scenario parameters in A.2 are not applicable and in the absence of other regulations.

Clause 5 of this document requires the reference collision scenarios to be considered.

To determine the limiting case for each scenario (design collision scenario) it is necessary to analyse the risks based on the characteristics of the train unit and the characteristics of the collision obstacle, at the point of impact, and the probability of a collision occurring, in the context of the particular railway system.

The probability of a particular collision scenario occurring will be derived from consideration of the type of railway, its operating characteristics and the contribution of active collision protection systems.

The characteristics of each scenario will be defined by the following parameters:

— train unit configuration;

— masses of the train unit;

- mechanical characteristics of the vehicles making up the train unit, including stiffness, coupling system, energy absorption capabilities…;
- speed at impact;
- characteristics of a collision obstacle.

A.3.2 Risk analysis

Analysis of the risks arising from each of the potential collision scenarios shall be undertaken in accordance with the requirements of any applicable regulations.

The risk assessment shall consider the collision risks presented by the complete railway system within which the railway vehicle to be designed is intended for operation, including the contribution of control and signalling systems (active safety).

The principal requirement for the risk analysis is to ensure that the risks arising from collisions involving new train unit types are fully understood and that the risks are no higher than with existing train units. All reasonable actions should be taken to minimise the risks from collisions.

In the absence of regulations the train operator shall be responsible for ensuring appropriate risk analysis is conducted to define the collision scenarios, and provide input regarding the characteristics of the railway and obstacles.

The train operator may discharge their responsibility by engaging the train supplier or an alternative specialist organisation to undertake the analysis.

The train supplier shall provide input to the risk analysis regarding the characteristics of the new train units.

It is recommended that both “causitive” and “consequential” risk analyses are used, based on the methods as defined in EN 50126 and taking into account a statistical analysis of relevant collision history data (i.e. ERRI - B205 study of train collisions in Europe - clause 7).

Available analysis techniques include:

- Hazard and Operability (HAZOP) studies;
- Failure Modes and Effects Analysis (FMEA);
- Fault Tree Analysis (FTA).

Where existing analyses are available for similar vehicles operating in a similar context, it is sufficient to review the applicability of the previous analyses.

A.3.3 Factors to be considered in the risk assessment

Factors which may affect the impact speed of the train unit include:

- the maximum operational speed of the train unit;
- the type of operation and the distance from a compulsory stopping point;
- the safety signalling system, including the provision and characteristics of active safety systems.

A rapid transit train unit operating a service with short inter-station distances may never achieve its ultimate speed potential. However, an inter-city train may reasonably be expected to achieve its full potential operating speed between stations.

Where Automatic Train Protection (ATP) systems are in use, approach to another train unit, or other obstacle, may be strictly controlled and speed limited to a very low level. Speed restrictions following failure of the control system should also be considered.

Other factors to be considered are:

- sections of railway where bi-directional running occurs;
- characteristics of the operational control systems;
- signal and hazard sighting distances;
- maximum emergency braking rates.

Factors which may affect the types of collision obstacle to be considered include:

- Is it a “closed” railway - such as a rapid transit system, with only one train type?
- Is it an “open” railway with mixed traffic?
- Are there any level crossings? - If not there is no need to consider the road crossing collision scenarios.
- Is the railway a tramway with street operation?
- Is the railway protected from trespassers?
- Is there fencing? Is it secure? Will it keep out large animals?
- Is there a relevant history of people placing obstacles on the line (either by accident or maliciously)? What type and size of obstacle?
- Is there a relevant history of obstacles on the track resulting from natural features in the vicinity of the railway?

A.3.4 Collisions following derailment

Collisions following derailment are relatively uncommon events and it is not possible to predict accurately the behaviour of a derailed train or establish associated limiting case collision scenarios. The protection provided under the requirements of this document will mitigate the effects of such incidents, but further consideration of the effects is outside the scope of this document.

A.3.5 Bibliography of relevant accident information

The following are documents containing relevant collision history data and were available at the date of publication of this document:

- Heavy Rail:

References see clause 2 or bibliography: ERRI B 205, SAFETRAIN and HMRI annual report 2000,.

- LRV:

References see bibliography: SAFETRAM and following

These examples may be used as a basis for definition of the limiting case collision scenarios for new train units, but the risk analysis has to ensure the scenarios and consequential risks are appropriate to the actual operating conditions and characteristics of the new train units.

Annex B
(normative)

Requirements of a validation programme

B.1 Test specifications

For the combined validation method, the first objective is to verify the vehicle numerical models to be used. The extent of the test vehicle structure shall include at least the structure of the driver's cabin or other vehicle end structure that is designed to absorb energy in a controlled manner, complete with the energy absorption devices and elements representative of any equipment having a significant effect on the crash performance.

Calibration tests on components, with associated simulations, are recommended in advance of the full-size interface test in order to give confidence in the performance of the cab or vehicle end assembly prior to the full-size test.

For the individual testing of the energy absorption elements (couplers, anti-climbers and complete cab or vehicle end structural collapse zones) the effective speed and mass are to be chosen so that the energy absorbed by these elements is equivalent to that absorbed by them during the design collision scenario. The most important factor is to verify the full energy absorption characteristic associated with each element.

Material certification and/or testing should be carried out to verify the properties of materials defined within the simulation. These may need to be specified / controlled more precisely than the values required by the normal material specifications.

Elements such as the obstacle deflector and the coupler can be subject to separate performance tests as it is important to ensure control of the calibration test for the numerical model, which is then used for the simulations of the reference accidents.

For a full interface dynamic test, the speed of impact, the type of obstacle, as well as it's mass is to be chosen so that all stages of the energy absorption mechanisms are activated. If the energy absorption mechanisms have already been fully validated individually, this test need not reproduce the designed energy potential of the interface, but the total energy absorbed shall be equivalent to at least 50 % of the full requirement. The most important criterion is to verify the modelling correctly reproduces the behaviour of all the mechanisms.

The tests shall be performed on a full size structure or sub-assembly that is created in a representative manner to that of the production vehicle structural elements being verified.

The crashworthiness test specifications shall require the results of the tests to be fully documented, and shall contain as a minimum:

- records of the test configuration, general views and detailed drawings using, where necessary, high-speed cinematography and video with speeds equivalent to at least 500 images per second, allowing comparison of the kinematics of the test with the corresponding simulation;
- the measurement of forces, record of the deformations, collision speed, decelerations for performance comparisons (energies, deformations etc) of the various energy absorption devices during this test and during the component tests;
- the dimensional measurements before and after tests in the areas defined and agreed prior to the test.

The test speed of impact should be at least half the speed corresponding to the like-to-like vehicle impact (scenario 1). The manufacturer shall justify the test configuration.

Minimizing the risk of measurement problems during the test is important. Such essential parameters as the speed, forces, and the displacements shall be measured and confirmed by at least two independent measurement systems. It is also recommended that some other essential recordings are duplicated (e.g. impact time, accelerations, speeds, etc.).

Criteria for acceptance are:

— key verification criteria for a collision test are to be measured with the appropriate accuracy as speed of impact ± 0,5 km/h and mass of the vehicles ± 5 %;

— all the recordings necessary for the calibration of the numerical model shall be achieved;

— the uncertainties on the achieved measurements during the tests and those on the parameters of the numerical model shall be quantified and presented in the report.

B.2 Numerical simulations specifications

For new vehicle and train concepts it may be convenient to perform a simplified motion analysis of the global crash behaviour of the whole train unit in order to determine deformations, velocities, accelerations, forces and absorbed energies for the full duration of the collision. The simulation should represent all significant structural elements and components. These comprise those that affect how the structure carries load, deforms under load and determines the occupant's survival space.

The pre-test numerical simulations may be used to determine the level of the absorbed energy, the mean force level and any crushing or deformation of the structures, which would be observed during the test.

The numerical simulations are to be carried out utilising software designed to model high-speed crash dynamics. The principle of successive verifications of the numerical models corresponding to the rolling stock sub-assembly test calibrations shall be adopted. This method ensures the best representative modelling for the vehicle structural extremities. Care has to be taken when meshing the model and with the implementation of the different characteristics of the finite elements.

To construct the mesh the following should be used:

— differing physical and mechanical characteristics;

— management of assemblies;

— possible contacts.

The size of the mesh and choice of elements should be adapted to the anticipated distortion of the structure etc, and this needs to be justified and described in the simulation calculation report resulting from the modelling. A high quality of meshing is essential for a good definition of the simulated physical phenomena.

The accuracy of the crash calculations and the predictions of the numeric simulations depend, among other things, on the validity of the material laws and how they are adapted to the physical model, as well as of the geometric parameters of the elements. Material properties used in the calculations should be based on experimental data (tensile test results for example), and the experimental curves for the material characteristics shall be presented in the report (with the influence of the dynamic effects).

The kinematics of the modelled vehicle shall be correctly achieved and a checklist can be used to verify the quality of the numerical simulation. In particular, the model of a whole vehicle should include the bogies and representation of all heavy equipment that can affect the dynamic behaviour.

The calibration of the numerical simulations from the tests results is dependant on the total kinetic energy, the level of energy dissipated by the model, the maximum level of force and the displacements (with respect of the locations of the accelerometers, the load cells and the strain gauges). Furthermore, the correlation of the numerical simulations against the tests has to be verified with respect to the sequence of events occurring during the impact (scenarios include several phases of energy absorption). The deformations determined in the analysis need to correspond to those observed during tests.

The criteria of acceptance are:

— the level of energy dissipated by the model shall be within 10 % of that measured in a test;

— the global displacement (stroke) of the model shall be within 10 % of that measured in a test;

— the simulation shall produce a global force curve, (with peaks and troughs and levels etc) which corresponds to that measured in a test. the presence of high frequency transients lasting less than 5 ms may be ignored in making this comparison.

Any uncertainties in the measurements made during testing and also in the numerical modelling shall be quantified and presented in the report. Any gaps observed in the parameters of the calibration defined previously shall be quantified, justified and presented in the report (and also the differences between initial simulations and the tests results). The conformity of the test with respect to the initial simulation results mainly from the quality of the numerical model and the precision of the kinematics. In the ideal case, only the mass and the speed can be adjusted in the initial simulation in order to calibrate the test.

The simulation of the reference scenarios has to be achieved with a numerical model that faithfully replicates the geometry of the structures, in order to achieve the validation of the overall requirements described in the technical document.

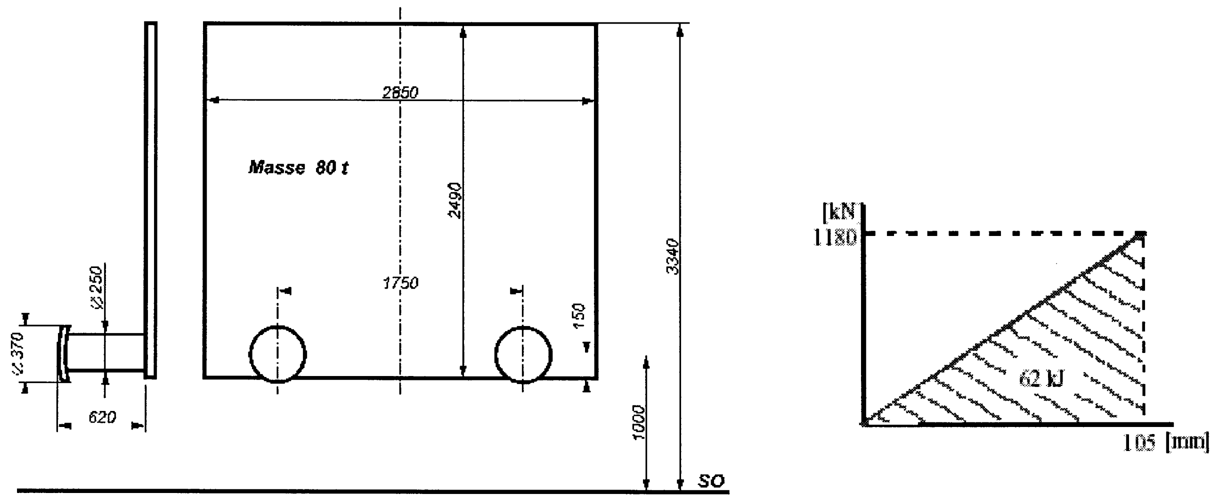
The calculation report will contain a description of the scenarios and both the obstacle and the rolling stock modelling. The imposed criteria of validation and the results of this simulation will be presented in the form of measurable objectives, as well as the behaviour of the rolling stock according to the specifications in the requirements document.

Annex C
(normative)

Reference obstacle definitions

C.1 80 tons wagon

For the collisions between a train-set and a buffered wagon of 80 tons, the wagon shall correspond to a unified freight wagon with bogies of type 1, as defined in UIC 571-2. It shall be equipped with side buffers of category A with a stroke of 105 mm, specified in UIC 526-1. The definition of the obstacle interface shall correspond to Figure C.1.



NOTE Characteristic of 2 buffers

Figure C.1 — Buffered wagon interface

C.2 Large deformable obstacle

For the collisions between a train and a large heavy obstacle at a level crossing, the equivalent deformable obstacle shall take the form of a complete numerical model represented in the specific crash simulation software.

The obstacle to be used is defined in terms of the following characteristics and is illustrated in Figure C.2.

Required large obstacle characteristics:

a) geometry, as indicated in Figure C.2;

b) mass = 15 000 kg;

c) centre of gravity at 1 750 mm above rail level;

d) uniform density of upper, Part A (to comply with c);

e) uniform density of lower, Part B (to comply with c);

f) homogeneous stiffness;

g) continuous axial uniformity;

h) zero surface friction.

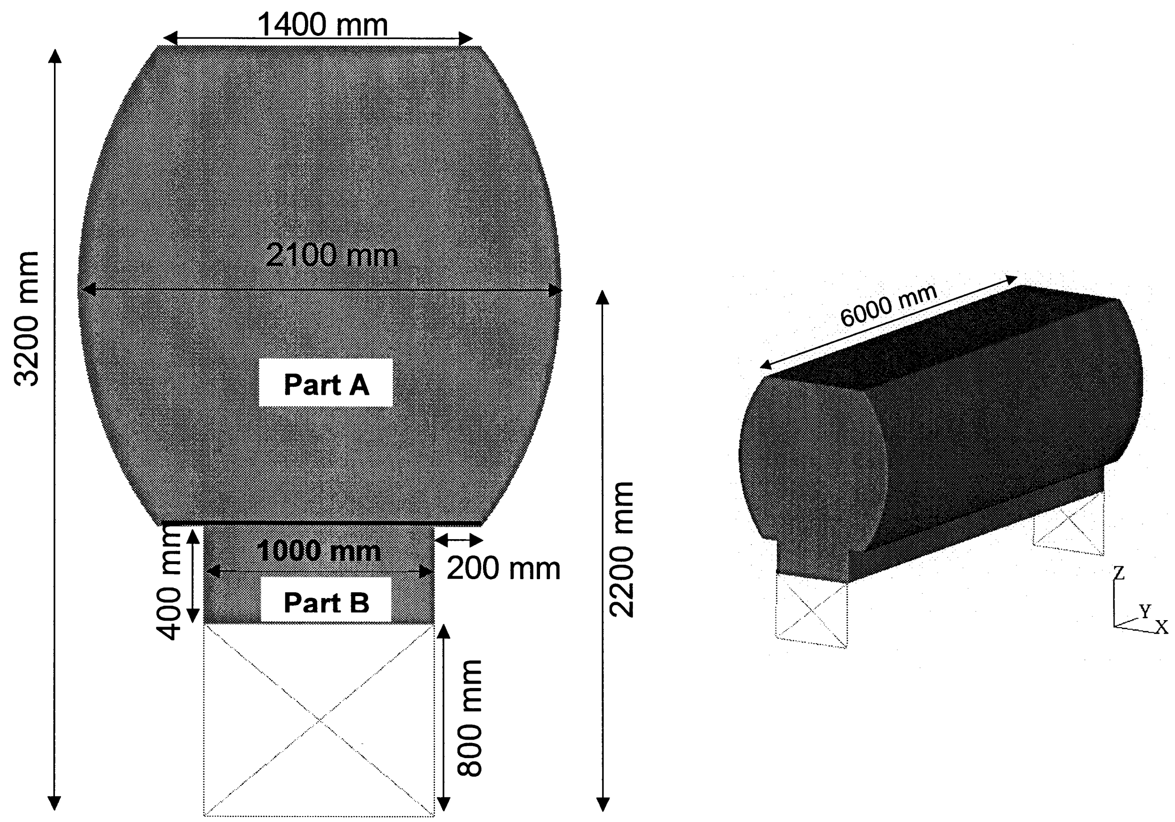


Figure C.2 — Large object geometry

The stiffness of this obstacle shall conform to the characteristics of the force - displacement curve given in Figure C.3 when impacted at its centre by the solid sphere defined below:

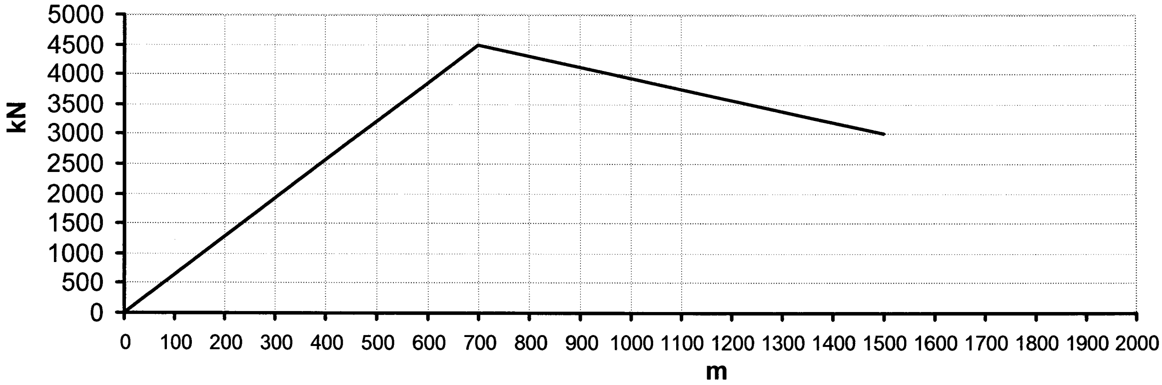
a) impactor shape, solid sphere of 3 m diameter;

b) impactor mass – 50 000 kg;

c) impact speed – 30 m/s;

d) impactor to have only longitudinal motion;

e) minimum longitudinal force – displacement characteristic to be as Figure C.3.



Key

Vertical axis: Force in kN

Horizontal axis Displacement in m

Figure C.3 — Object stiffness

C.3 P-IV Reference obstacle

The reference train to be used as the collision object in footnote g of A.2.2, for P-IV type vehicles operating in a mixed traffic environment, is defined as follows. For such operation, a collision shall be considered with either:

— a P-II type train unit of at least 125 tonnes that fully satisfies the requirements of this document;

or

— a suburban train unit typical of those in service over the common lines, as agreed with the operator, that fully satisfies the requirements of this document.

Annex D
(normative)

Reference train definitions

D.1 Reference train for locomotive and cab car design

A reference train shall be used for the design of locomotives and cab cars that do not form part of a fixed rake of vehicles. The reference train has to be representative, in terms of crashworthiness, of all types of vehicles that it is intended to use in the trains headed by the locomotive or cab car. Where different types of vehicle will be used, the reference train crashworthiness parameters shall be determined by the limiting envelope of the crashworthiness parameters of the relevant vehicles.

It follows that the operator has to define the parameters of the reference train based on the intended vehicle use.

The reference train can be defined by adopting the following principles:

- use a minimum of four vehicles;
- use the collision mass of the heaviest vehicle it is intended to operate with;
- use the minimum energy absorption to be provided in the intermediate vehicles;
- incorporate the maximum collapse force designed for the energy absorbing structure.

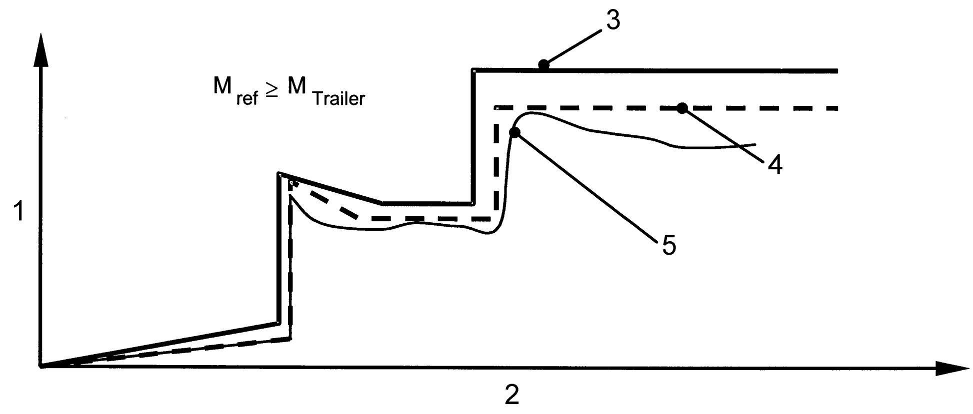
If there is a significant difference in the combinations of energy absorption and vehicle mass it may be advantageous to consider more than one reference train.

For scenarios 1 and 2 it is desirable that the interface ahead of each vehicle can absorb the energy of that vehicle. For category P-I to P-IV vehicles this requires energy absorption per vehicle interface of approximately 15 kJ/tonne. The energy absorption characteristics of the reference train vehicle ends shall be expressed in the form of a force – displacement graph as indicated in Figure D.1. Transient peaks should be included.

Leading vehicles shall be accepted to run without further assessment with coaches that have the following characteristics with respect to the vehicles in the reference train:

- the mass shall be equal or less;
- the peak force shall be equal or less;
- the mean force shall be equal or less.

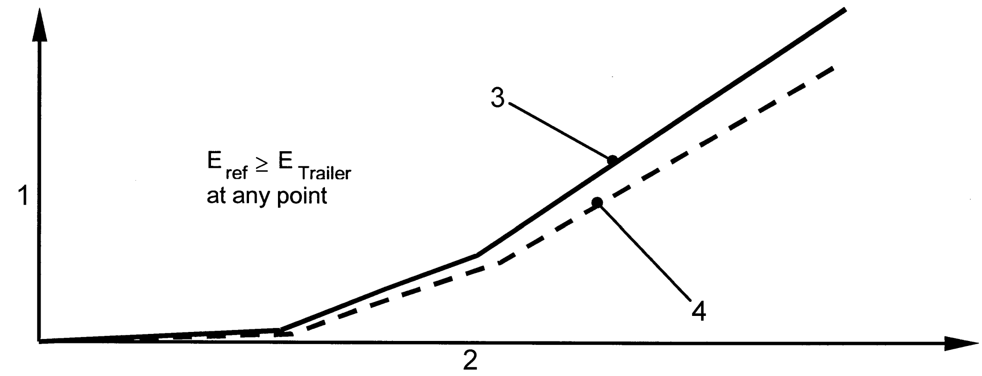
To compare the mean levels depending on the deformation displacement, the energy-displacement characteristics shall be used, Figure D.2. The energy-displacement curve shall be equal or lower than the one of the reference vehicle. If only coaches designed to absorb their own collision energy in scenario 1 (see below) are used, it is sufficient to consider the characteristic of the first trailer.



Key

1 Force
2 Displacement
3 Assumed reference
4 Trailer approximation
5 Trailer Characteristic

Figure D.1 — Force-displacement characteristic



Key

1 Energy
2 Displacement
3 Assumed reference
4 Trailer characteristic

Figure D.2 — Energy-displacement characteristic

D.2 Individual coach design

The reference train used for the design of locomotives and cab cars determines the crashworthiness characteristics required for coaches to be used in trains headed by these vehicles.

For an individual coach design to be acceptable in a train formation, the parameters that relate to crashworthiness shall be at least as good as those assumed in the reference train vehicles forming the basis of the locomotive or cab car design. This may be demonstrated by comparing the new coach design with the parameters of the existing reference train or by re-assessing the whole train formation using a reference train encompassing the parameters of the new type of coach.

To be compatible with general use, P-I to P-IV vehicles should have an energy absorption capacity per vehicle interface of approximately 15 kJ/t, as indicated above.

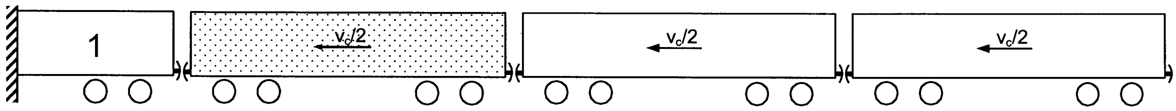
If an individual coach design is intended to run in any position in a train formation, the position behind the leading vehicle (locomotive or cab car) can be assumed the worst case.

If the coach is designed to absorb its own collision energy, its characteristic can be used for a reference train in a scenario 1 simplified as indicated in Figure D.3, with:

— stationary half vehicle against solid wall;

— impacting coaches starting at half the speed of scenario 1;

— coach to be used in the assessment as the leading moving vehicle.



Key

1 stationary half vehicle

Figure D.3 — Simplified assessment

Any coaches at least complying with this scenario can be freely operated together with each other and any compatible leading vehicle.

If the energy capacity of a coach is insufficient for this condition, it has to be compensated for by increased energy absorption of other vehicles in the train formation (mainly the leading vehicle). This particular requirement can be considered by a reference train with enhanced energy absorption capacity. Coaches shall be accepted without further assessment in any train formation of leading and trailing vehicles, which conform to the following characteristics of the reference train:

— mass of trailing vehicles shall be equal or less;

— mass of leading vehicles shall be equal or more;

— the peak force shall be equal or less;

— the mean force shall be equal or less.

To compare the mean force levels the energy-displacement characteristics shall be used. To be acceptable, the energy-displacement curve (see Figure D.2) shall be equal to or lower than the one of the reference train vehicle.

All vehicles which at least conform to the crashworthiness performance envelope of the relevant reference train shall be considered as conforming to this document when operated with corresponding end vehicles. Figure D.1 illustrates an acceptable force characteristic for a new trailer vehicle relative to that assumed in the design of the locomotive or cab car.

D.3 Freight locomotive reference train

It is not possible to have a fully representative reference train for freight operations. Therefore, a simple reference train shall be used for the design of locomotives for freight applications that consists of a single wagon, to the same specification as that impacted in scenario 2, coupled behind the locomotive.

Freight multiple units (i.e. fixed train units) shall be treated in a similar manner to passenger multiple units.

ANNEX ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive ....[3]

This European Standard has been prepared under a mandate given to CEN[4] by the European Commission and the European Free Trade Association to provide one means of conforming to Essential Requirements of the European Directive

Council Directive 96/48/EC of 23 July 1996 on the Interoperability of the trans-European high-speed rail system[5].

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard *((except clause(s) ....[6]))* confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements *((except Essential Requirement(s).............[7]))* of that Directive and associated EFTA regulations.

WARNING: Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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[3] Add the reference of the Directive(s), e.g. 96/48/EC (later (as in preparation) also 2001/16/EC).

[4] Add CENELEC and/or ETSI, as appropriate (for the mandates M/275, CENELEC and ETSI are always used. Please note, that also in the standard paragraph of the Foreword CENELEC and ETSI are used; mandate M/334 is in preparation, ask Thierry, if necessary information will be needed).

[5] **Official Journal of the European Community No L 235/6 of 17.09.96.** (NOTE This footnote is integral and appears always if this text for this Council Directive has been used.)

[6] Add the number of the clause(s).

[7] Add the number of the Essential Requirement(s).

Bibliography

[1] ERRI B205 Report: *Statistical Analysis of Collision Accidents Database. Sponsoring body: UIC Passenger Commission*

[2] SAFETRAIN – *Train Crashworthiness for Europe, Sub-task 1.1 Collision Risk Analysis, Final report.*

[3] HMRI annual report 2000

[4] SAFETRAM – *Passive Safety of Tramways for Europe, Technical Reports WP 1*

[5] *Identification of Reference Accident Scenarios for City and Periurban Trams*

[6] *Statistical and Risk Analysis of Accidents for Periurban Trams (DB and SNCF)*

[7] *Theoretical Observations of Collisions on Level Crossings*, Sven Füser, 2001