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Proposals for amendments to annexes A and B of ADR: construction and approval of vehicles

Section 9.7.6 – Rear protection of vehicles

Addendum to ECE/TRANS/WP.15/2010/6

Transmitted by the Government of Germany

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"Rear protection"

of tank-vehicles for the transport of dangerous good

Feasibility study

Berlin, 19 March 2009

Contents

1. Presentation of the problem

The European Agreement concerning the international carriage of dangerous goods by road - the ADR - contains, inter alia, also the requirements for the rear protection of dangerous goods vehicles, the “Rear Protection of Vehicles” (see ADR 2007, Section 9.7.6). These requirements apply, by definition, only to tank-vehicles, battery-vehicles and vehicles with demountable tanks and a capacity of more than 1 m³, and are in the future also to be used for MEMU (see ADR 2009, Section 9.8.5).
The relevant requirements have been contained in the ADR since the 1980s already. Owing to the “THESEUS” research project (tank vehicles with maximum attainable safety through experimental accident simulation), implemented in Germany at the beginning of the 1990s, which dealt with the safety of tank vehicles, it was also possible to gain new findings as to the necessity (on the basis of accident statistics) as well as the suitability (on the basis of research results) of certain design solutions with regard to rear protection. (cf. THESEUS 1995, p. 163)

Taking the results of this project as a basis, Germany, in the second half of the 1990s, submitted a proposal to the WP.15 (ECE Working Party on the Transport of Dangerous Goods)- which was specified in a second draft - to efficiently improve the safety-relevant features of rear protection and to enshrine them in the ADR (see 3.3: WP.15 – proposals for amendment).

The majority of the ADR Member States, was, however, not willing to adopt the German proposal and later attempts to raise this subject again in WP.15 failed.
The main argument put forward by those states rejecting this proposal was the rear-end collision accident statistics which were not comprehensible in their states since “… without a speed limit, vehicles run too fast on the German motorways”. This does not apply to HGV in Germany since the admissible speed is not higher than in other states. According to the data available, relevant rear-end damage was only detected as a cause of accidents involving solely HGV-HGV accidents. Moreover, the proof to be provided in connection with the energy absorption of the rear protection could not be furnished by simple means. There was no test procedure for the rear protection.
Since then, about ten years have passed. In Germany, in some cases serious rear-end collisions occurred with considerable injury to persons and material damage

which were notified within the framework of the notification of occurrences in accordance with Section 1.8.5 of ADR.

The continuous occurrence of rear-end collisions with tank vehicles carrying dangerous goods is the reason for Germany to still consider it necessary to protect this vehicle category at its rear end more effectively than has up to now been demanded.

A further problem to be mentioned here is the inconsistent application/implementation of the current ADR requirements with regard to rear protection at European level. Many Member States interpret the EU underrun protection as complying with the requirement of the ADR rear protection and, therefore, do not provide for this type of protection as a separate measure. In Germany, too, the EU underrun protection is in many cases designed in such a way that it complies with the ADR requirements as to rear protection as well as with the requirements as to underrun protection.

2. Objective

Owing to the above-mentioned problems, it is endeavoured with this report, which includes an inventory of the action taken up to now, to resume the procedure to amend the ADR by a requirement for rear protection, while taking more recent findings into account.
The aim of this protection measure is to avoid accidents involving tank vehicles carrying dangerous goods and/or the ensuing release of hazardous materials in order to reduce the accident consequences.
A proposal is to be submitted to WP.15 which is to be supported by simple theoretical considerations. These considerations should be verified by practical tests in order to document the higher effectiveness of rear protection. Calculations on the basis of the dynamic finite-element method are currently not taken into consideration.

3. History

Within the framework of the work undertaken in the field of rear protection up to now, the following studies have to be mentioned as outstanding:

3.1 TOPAS (1986)

(“Tank vehicle with optimized passive and active safety devices“).
A tank vehicle equipped with numerous safety devices which were destined to reduce the serious accidents with tank vehicle combinations which had occurred in the past. The TOPAS tank vehicle combinations - a joint development by Daimler Benz AG, the tank manufacturer Haller and the road haulier Raab Karcher - were among other things equipped with an electronic tyre-pressure monitoring, an automatic fire extinguishing system, a non-wearing additional brake, antilock system and antislip control. In order to improve vision, mirror systems and a rear camera were installed. In total, three vehicles were tested. (see Winkler, M., 2005, p. 21f.)
The safety features, however, led to a significant rise in costs. Thus, the TOPAS tank vehicle combination cost in the year of its introduction (1987) approximately 520,000 Deutschmarks - about 150,000 Deutschmarks more than conventional tank vehicles.

3.2 THESEUS (1990-1995)

(“Tank vehicles with maximum attainable safety through experimental accident simulation").
Within the framework of the THESEUS project, a safety-related evaluation of the overall system consisting of the vehicle, the tank and safety devices was made in order to make the safety level of the individual components assessable by means of an analysis. The survey period comprised the years 1989-1993.

A distinction was made between three types of accidents with regard to their probability of occurrence, determined on the basis of literature research and surveys among companies.

- Single-vehicle accident:
  The type of accident with the highest risk was the single-vehicle accident. In two thirds of these accidents, hazardous materials were released because the vehicle overturned. The ratio of overturning when cornering and running-off of the roadway on a straight section was 50:50. (cf. THESEUS, 1995, p. 16) (remedial action may be taken for example by the lane assistant)
- Rear-end collision:
  The second most frequent type of accident was a vehicle impacting a tank vehicle. Approximately 10% of the quantity of hazardous substances released was attributable to this type of accident. The average collision speed for this type of accident was according to THESEUS 20 km/h (cf. THESEUS, 1995, p. 16 and 21) (remedial action may be taken for example by collision protection).
- Lateral collision:
  The third most frequent type of accident was the lateral collision between a commercial vehicle and a tank vehicle with a release of 4% of hazardous substances. (cf. THESEUS 1995, p. 21)

3.3 WP.15 Proposals for amendment

Within the framework of the THESEUS project, new findings were gained on the rear protection of tank-vehicles which were taken up in some proposals submitted to the WP.15 of the UNECE by the Federal Republic of Germany. These proposals were mainly elaborated by the Working Group on Vehicle Engineering of the Committee on Tanks and Technology (ATT).

Rear protection of tank-vehicles for the transport of dangerous goods

With the proposals submitted to WP.15 concerning the rear protection, Germany attempted to diminish the indefiniteness of the relevant ADR requirements which had been criticized, in such a way that a technical standard value – impact-energy absorption, the energy absorbing capacity of the rear protection – was to be newly included in the ADR requirements.
For this purpose, 150 kNm of energy-absorbing capability was defined as the value to be at least reached by the rear protection. The source for this value were diverse rear-impact tests within the framework of THESEUS. On the basis of the kinetic energy of vehicles in motion hitting the rear end of a stationary tank vehicle, the energy percentages were determined which in the case of a collision are brought into the tank. From these values, the parameter of 150 kNm was derived.
In the light of the risk-oriented analyses which have been developed in the meantime, a review of this limit value is also considered to be useful (see 9.: Minimum energy-absorbing capability).

In the following, the history of the proposals submitted to WP.15 concerning the rear protection is briefly described for the period from 1997 to 2007. The complete proposals (1997, 1999, 2002 and 2007) as well as the pertinent wording of the provisions (Chapter 9.7.6 ADR 2009 and marginal 10220 of Annex B to the Carriage of Dangerous Goods by Road Regulations to ADR 1993) are enclosed. These proposals did not meet with the consent of the majority of the ADR Member States and were, thus, rejected. Since then the subject has been dropped.

The following proposals had been submitted:

1997:

TRANS/WP.15/R.430 of 6 March 1997

Amendment of marginal 10 220 (request for an adequately rigid bumper extending over the entire width of the tank with a distance of 100 mm to the tank) by the following elements:

- Alternatively, tank protection may consist of a reinforced tank end
- Double wall is possible
- The energy-absorbing capability must at least correspond to that of a double tank wall with a thickness in accordance with marginal 211 127(4).

- Verifiability by determining the specific energy-absorbing capability.
- A combination of a reinforced tank end and a bumper is possible following approval by the relevant authority.

Justification of the WP.15 proposal

a) The THESEUS research project shows the rear tank end as the main impact point in the case of accidents.
b) The bumper does not cover the whole area of the tank end.
c) The THESEUS research project shows that a rear protection does not always prevent damage to the tank, for example the shaft of the windscreen wiper of the impacting vehicle may penetrate the rear tank end.
d) The protection of the complete area of the tank end can, for safety reasons, best be achieved by a double end wall.
e) Example: Accident involving a bus where the middle deck penetrated the tank end and the kerosin leaking into the bus ignited; bumper does not provide protection in such cases, a double tank end wall would have been a better solution.
f) In Germany, the effectiveness of double tank end walls was proven by tests.
g) The requirements are interpreted differently within Europe, e.g. design of the rear underrun protection as rear impact protection.

1999: Changes compared with the proposal of 1997
TRANS/WP.15/1999/15/REV.1

Suggestion: Delete Chapter 9.7.6
Add a new Chapter 6.8.2.1.29

Introduction of a minimum collision absorbing energy of 150 kNm up to which the tank must show no leakage.
Examples of a suitable protection by the design of the tank:

- Shell with a minimum thickness according to Chapter 6.8.2.1.17 and/or 6.8.2.1.18 (non reduced thickness) multiplied by the factor 1.2.
- A double rear end wall consisting of an inner shell of at least the reduced thickness according to the table in 6.8.2.1.19 and an outer shell with a thickness of at least 2 mm steel, respectively 3 mm aluminium alloy. The distance between the

two shells of the double wall should at least be 50 mm. If in the final edition of EN 13094 a distance between the two shells is required, reference should be made to this standard. (Note: DIN EN 13094-2008-10 is available; the minimum distance is defined in 6.9.2.2.b).

Justification of the WP.15 proposal

Items a, b, c, e, g as above and furthermore:

- The aim of the rear tank protection is to protect the <u>tank</u> against a rear impact, therefore the relevant chapter for this requirement is not 9.7 but 6.8.
- On the basis of eight real vehicle/vehicle collisions, an average energy- absorbing capability of 150 kNm was determined, a value which should be reached by the protection system.
- Factor of 1.2 for individual and non-reduced tank walls because of the comparability with double walls since the space between the double tank walls is also able to absorb energy.
- It cannot be guaranteed that 150 kNm of energy-absorbing capability are always sufficient but many rear-end collisions would thus be covered.
- Recommendation: Provide for alternative means of impact protection; design types other than those in examples 1 and 2 (Note: Examples only in original form, see Encl. 5) to be verified by means of calculation or by tests.
- Forces resulting from an impact onto the rear wall will be led into the cylindrical part of the tank wall.
- The proposal cannot be justified by a scientific cost-benefit analysis.

2002: Changes compared with the proposal of 1999
TRANS/WP.15/2002/11

Proposals for the amendment of Annexes A and B of ADR
Amendment of Chapter 9.7.6 as follows:

Wording identical to the proposal of 1999, apart from the deletion of the sentence: “The purpose of the rear protection is to protect the tank from rear impact, so the right place for this requirement is not chapter 9.7 but 6.8”.

2007: Changes compared with the proposal of 2002
(Proposal was NOT submitted to UNECE)
TRANS/WP.15/2007/XXX

- To ensure a sufficient protection of the tank, the rear end of the tank must not be designed in reduced wall thickness.
- Action to be taken:
- Amend 6.8.2.1.19:
- The rear end-wall shall have a minimum thickness according to 6.8.2.1.17 respectively 6.8.2.1.18 in any case.
- Alternatively: The rear end of a shell shall be designed as a double rear end-wall consisting of an inner shell of at least the reduced thickness according to the table in 6.8.2.1.19 and an outer shell with a thickness of at least 2 mm steel respectively 3 mm aluminium alloy.
- Minimum distance between the two shells of the double wall: 50 mm
- Delete 9.7.6:
  “Rear protection of vehicles”: Bumper with a distance of at least 100 mm, unless the rear equipment of the tank has a protective device with a protective effect such as the bumper.
  - This provision (concerning rear end-walls) does not apply to vehicles used for the carriage of dangerous goods in tank-containers or MEGCs,
  - For the protection of tanks against damage by lateral impact or overturning, see 6.8.2.1.20 and 6.8.2.1.21.
  - Add a new transitional measure 1.6.3.22

Justification of the WP.15 proposal

Items a, b, c (without example) g as above and furthermore:

- Safety will increase when the rear end-wall is built in non-reduced thickness because the end of the tank is reinforced over its whole surface and not only in the region where the bumper is placed.
- Feasibility: no problem.
- Enforceability: Tanks and vehicles designed in conformity with the existing provision of 9.7.6 may be used further. However, where an old tank with reduced thickness of the rear end-wall is coupled to a new vehicle, it has to be verified that the new vehicle is also in conformity with the requirements in 9.7.6; applicable until 31 December 2008.

4. Arguments for the recast of a WP.15 proposal

The „THESEUS“ research project analyzed, among other things, the situation of road accidents involving dangerous goods vehicles in the first half of the 1990s. It can be stated without a doubt that the traffic situation has since then noticeably changed which is for example attributable to the following reasons:

- Free transit traffic in Germany in the east-west direction
- Relative and absolute increase of the share of dangerous goods transport
- Modified and enlarged road network
- New traffic guidance systems
- Introduction of the tolling system
- Higher power output of commercial vehicles
- Introduction to the market of driver assistance systems

In this respect, a changed traffic situation has also to be assumed for dangerous goods vehicles. The correlation with rear-end collisions must be the subject of a separate investigation. We, therefore, recommend the critical assumption/application of the relevant THESEUS results (keyword: frequency of the accidents included therein, dating from the years 1987-1993). The pertinent regulations for the transport of dangerous goods with regard to the rear protection of tank vehicles seem to be virtually unchanged since this time.

Today, it is still required in 9.7.6. of ADR that “a bumper sufficiently resistant to rear impact shall be fitted over the full width of the tank at the rear of the vehicle. There shall be a clearance of at least 100 mm between the rear wall of the tank and the rear of the bumper (this clearance being measured from the rearmost point of the tank wall or from projecting fittings or accessories in contact with the substance being carried)”. (ADR 2009, Section 9.7.6)
This provision still does not lay down any performance parameters, no definition as to the height and no performance level for the requirement of “sufficiently resistant”. Contrary to the rear protection, there are clearly defined test methods and forces for the underrun protection (Directive 2006/20/EC). These procedures and forces are described in more detail in Chapter 10 "The EU underrun protection”. The insufficiently exact description of the rear protection in the ADR, giving room to broad interpretation, makes it possible for the manufacturers to design the underrun protection in such a way that it can also be considered as a rear protection (for example no provision is made for a minimum height for the fitting of the rear protection). It remains, however, to be tested whether this type of rear protection complies with its actual objective – the protection of the tank – or whether this design is a compromise between two contrasting protection objectives – the protection of the tank and the protection of persons.
For the rear protection of tanks, special test criteria seem to be indispensable in order to guarantee the adequate protection of the tank.

5. State-of-the-art of the requirements

The provisions of ADR are subject to regular amendments every two years (biennium) in order to take account of the newest technological and/or formal developments which have occurred in the meantime. When amending a requirement, it must also be considered whether the original reason for adopting the provision is still sufficiently covered and whether the assignment is clear.
With this in mind, in the following the question is discussed as to whether the current section "Rear protection of vehicles” is to remain in Part 9 “Requirements concerning the construction and approval of vehicles” of ADR or is to be included in Chapter 6.8 “Requirements for the construction of fixed tanks/tank-containers” or somewhere else.

Rear protection of tank-vehicles for the transport of dangerous goods

Up to now, the rear protection of vehicles has been dealt with in Part 9 “Requirements concerning the construction and approval of vehicles” of the ADR 2009 (Section 9.7.6, see Appendix 2).

In the present latest draft WP.15/2007/xxx (see Enclosure 7) of August 2007 it is proposed to place the section which refers to the rear protection in Part 6. Part 6 refers, among other things, to the “Requirements for the construction and testing of tanks”. Here, it would be possible to include the provisions concerning rear protection in Subsection 6.8.2.1: “Construction“, i. e. the construction of tanks (6.8.2.1.19, see Appendix 1).

By specifying a definite design for rear protection, it would be possible to directly assign this subject to one of the two Chapters of ADR mentioned above:

If the rear protection was for example designed in the form of a double end-wall for tanks, Chapter 6.8 would be the right one and in the case of a bumper this would be considered as being combined with the vehicle and would, thus, have to be included in Part 9.

However, if no standards are defined for the design but only a minimum resistance is given as a criterion for rear protection, for example to verified by a test, it seems necessary to test the vehicle-tank unit. This is due to the fact that in the case of a vehicle-tank combination, there will be a load change as compared with the otherwise individually tested components which also results in a changed mass inertia of the system. In this case, it seems appropriate to assign this subject to Part 9 since the relevant tests with the complete vehicle are more useful.

Moreover, in order not to limit the various design solutions right from the onset, the ADR should not lay down the type of design. This would disregard innovations and future market and material developments which might possibly offer a better protection than the current systems. For this reason, too, a test involving the complete vehicle would be useful. Furthermore, it might be conceivable that a solution is found which combines several components which concern the tank as well as the vehicle. If the solution was to apply either to the tank or to the vehicle, this possibility would not be taken into consideration.

With the variant of a load test it would, in addition, be possible to achieve a higher acceptance among the manufacturers and forwarders since it would be up to them to choose the most cost-effective solution.

Owing to the advantages mentioned above, it is recommended to leave the rear protection provision in section 9.7.6.

6. Accidents

In order to obtain an overview of the situation of rear-end collisions in the ADR Member States, it is on the one hand necessary to consider the accident figures of the ADR States compared with the figures in Germany and on the other the occurrences in Germany to be notified in accordance with ADR 1.8.5.

6.1 Rear-end collisions in the ADR Member States

One of the main arguments of the ADR Member States for rejecting the German proposal to WP.15, namely to effectively enhance the safety-relevant parameters of rear protection and to lay them down in the ADR was that "… without a speed limit in Germany vehicles run too fast on the motorways". In order to invalidate this argument, a comparison was made between the overall accident figures and the figures of rear-end collisions in Germany with those of the other ADR Member States. The data underlying this comparison were taken from the *UNECE Transport Division Database* and are not differentiated according to vehicle categories (see UNECE Transport Division Database: Road Traffic Accidents, 2008). To make it possible to compare the overall accident and the rear-end collision figures of the ADR Member States with those of Germany, all these states, with the exception of Germany, were combined and a fictitious "average ADR state" was formed. The reference period for this comparison covers the years 1994 to 2003. For each year under review, only those ADR Member States were considered which provided the overall accident figures, including the rear-end collision figure, as well as the figures for road deaths and injured persons. Table 1 shows those ADR Member States which formed the fictitious "average ADR state" in the year under review.

Table 1: Overview of the ADR Member States: the checkmarks mark those states which formed the fictitious "average ADR state" for the year under review.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Azerbaijan		✓	✓	✓	✓	✓	✓	✓	✓	✓
Belgium	✓	✓	✓	✓	✓	✓	✓	✓		
Bulgaria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Estonia		✓	□	□	□	□	□	□	□	□
Finland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	□	□	□	□	□	□	□	□	□
Greece	✓	✓				✓	✓		✓	✓
Ireland	✓	□				✓	✓		✓	□
Italy	✓	□	□	✓	□	□	✓	□	✓	
Kazakhstan		✓	✓		✓	□	✓	□	✓	□
Croatia	✓	✓	✓	✓	□	□	□	□	□	□
Latvia		✓	✓	✓	□	□	✓			
Lithuania					✓	□	✓	□	✓	□
Macedonia						✓	□	□	□	□
Moldavia	✓	□								
Netherlands	✓	□	□	✓			✓	□	✓	□
Norway	✓	□	□	✓	□	□	□	□	□	□
Austria										✓
Poland				✓	□	□	✓	□	✓	□
Portugal	✓	□	□	✓	□	□	✓	□	✓	
Romania					✓	✓	✓	□	✓	□
Russia				✓	□	□	✓	□	✓	□
Sweden	✓	□	□	✓	□	□	□	□	□	□
Switzerland	✓	□	□	✓	□	□	□	□	□	□
Slovakia			✓		✓	□	✓	□	✓	□
Slovenia			✓	✓	□	□	✓	□		✓
Spain	✓	□	□	✓	□	□	✓	□	✓	□
Czech Republic	✓	□	□	□	□	□	□	□	□	□
Hungary	✓	□	□	□	□	□	□	□	□	□
Belarus			✓	✓	✓	✓	✓	✓	✓	✓

6.1.1 Evaluation

The figures for Germany show that the ratio between the accident figures and the rear-end collision figures included therein is nearly steady during the period from 1994 to 2003 (see Fig. 1 and Table 2). The percentage of rear-end collisions in the overall accident situation varies between a minimum of 15.8% (1994 and 2003) and a maximum of 17% (1997 and 2001). Accordingly, in 1994 and 2003, every 6.3rd accident was a rear-end collision whereas this figure was only 5.9 in the years 1997 and 2001.

During the whole period from 1994 to 2003, every 6th accident on the average was a rear-end collision and the average share of rear-end collisions in the whole accident figures amounts to 16.5%.

In contrast, compared with Germany the figures of the average ADR state vary considerably during the period under review. Thus, the percentage of rear-end collisions reached with 12.6% its highest value in 2001, which means that on the average every 7.9th accident was a rear-end collision. In 1997, only every 10.2th accident (9.8%) was a rear-end collision.

During the whole period under review, every 9th accident on the average was a rear-end collision, which corresponds to a percentage of 11.3%.

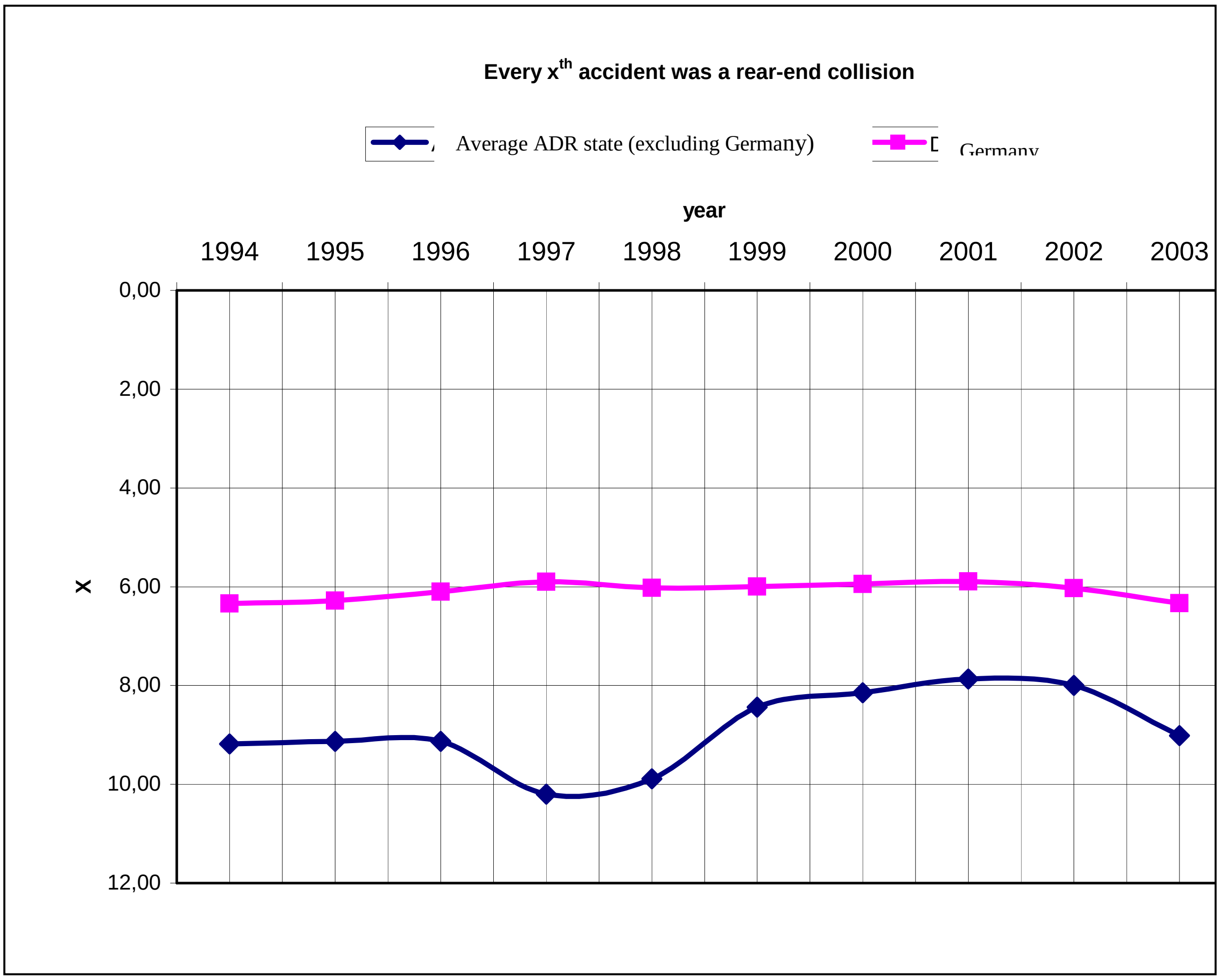

Fig. 1: Share of rear-end collisions in the overall accident figures in Germany and the other ADR states (average ADR state excluding Germany)

Table 2: Overview of the accident data in Germany and the average ADR state (excluding Germany) from 1994 to 2003

	Germany	Average ADR state (excluding Germany)
Overall number of accidents (from 1994 to 2003)	3,782,502	353,817
Overall number of rear-end collisions (from 1994 to 2003)	622,318	39,844
Average number of accidents per year	378,250	35,382
Average number of rear-end collisions per year	62,232	3,984
Share of rear-end collisions in the overall number of accidents per year		
Maximum	17.0%	12.6%
Minimum	15.8%	9.8%
Average share of rear-end collisions in the total number of accidents	16.5%	11.3%
On the average, every x^{th} accident per year was a rear-end collision		
X	6	9

Table 2 shows that the number of accidents in Germany is approximately tenfold higher than that of the average ADR state. This difference can mainly be attributed to Germany's high population and the related higher number of vehicle registrations as compared with other ADR states (cf. in this connection also: UNECE Transport Division Database: Road Vehicle Fleet, 2008).

In the following, data concerning the number of road deaths and injured persons are taken as a basis for this comparison. In this case, too, only those states were taken into consideration for the "average ADR state" which provided accident figures, rear-end collision figures as well as figures concerning road deaths and injured persons for the year under review (see table 2).

The comparison between Germany and the average ADR state shows that the ratio of the number of injured persons to the number of rear-end collisions is nearly equal (see Fig. 2). Thus, in the period from 1994 to 2003, there were 1.45 injured persons on average per rear-end collision in Germany. During the same period, there were 1.47 injured persons per rear-end collision in the average ADR state.

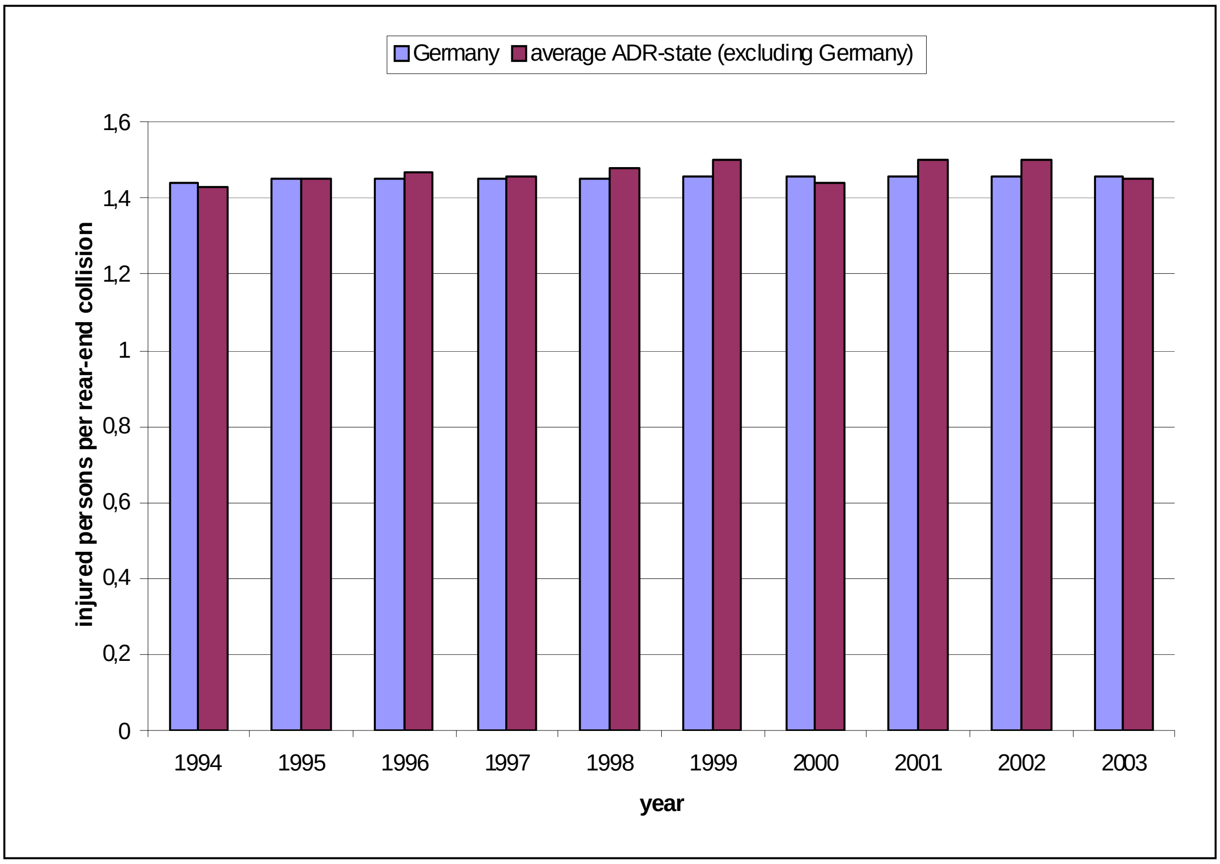

Fig. 2: Injured persons per rear-end collision in Germany and in the average ADR state (excluding Germany)

When considering the number of deaths per 1000 rear-end collisions, however, a greater difference becomes evident (see Fig. 3). Thus, the number of persons killed as a consequence of a rear-end collision is about four times lower per crash in Germany than in the average ADR state.

In Germany, the highest number of 8 deaths per 1000 rear-end collisions was reached in 1994 and 1996 and the lowest number of 5 deaths in 2001.

For the whole period under review, the average number of deaths is 7 per 1000 rear-end collisions. Thus, one person is killed in about every 155th rear-end crash. In the average ADR state, by comparison, the highest number of deaths per 1000 rear-end collisions is 35 (2003) and the lowest number 25 (1996).

During the whole reference period from 1994 to 2003, there were 30 deaths per 1000 rear-end accidents per year on the roads of the average ADR state. Accordingly, about every 35th rear-end collision led to one road death.

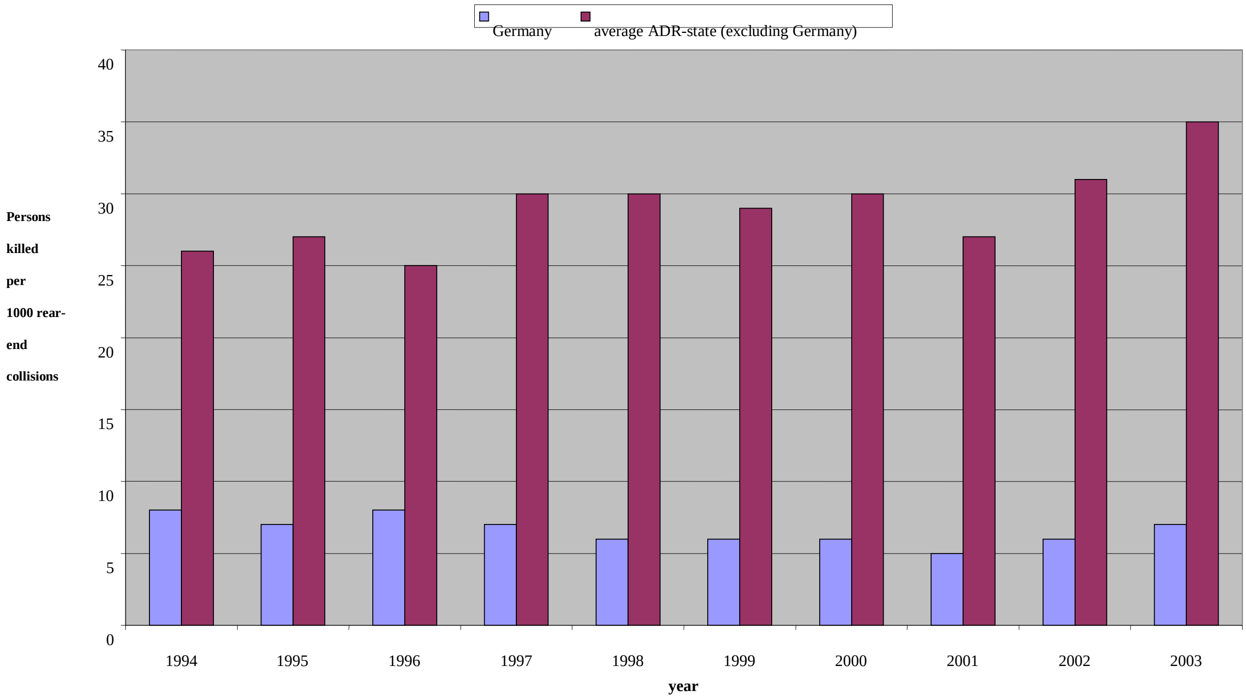

Fig. 3: Persons killed per rear-end collision in Germany and in the average ADR state (excluding Germany)

As already mentioned in the introduction, the “average ADR state” which was formed for this comparison, does not include all ADR Member States. This is mainly attributable to the fact that some ADR Member States only provided incomplete data or no data at all for the relevant reference period (1994-2003).

The average number of states taken into consideration is about 24 out of a total of more than 40 Member States, meaning that the figures for the average ADR state per year were only calculated from about half the ADR Member States (see table 1). Furthermore, in several of the ADR Member States there is no uniform regulation and/or specification for the classification of accident victims into the accident statistics. A further problem of the data basis is that no distinction is made between vehicle categories which makes it impossible to specify the data for the individual vehicle types.

The informative value of the average values determined for the average ADR state is, therefore, to be considered and evaluated in a somewhat restricted manner. In order to make such comparisons more meaningful, it would be necessary to improve the data density or to make all data publicly accessible.

6.1.2 Conclusion

The comparison made between Germany and the fictitious “average ADR state” shows that the problem of rear-end collisions is not exclusively restricted to Germany. The data set forth above illustrate that there is also an essential percentage of rear-end collisions in the “average ADR state".

The fact that the problem of rear-end crashes is not solely a German one becomes particularly apparent if one compares the accident consequences which prove that the fatalities in rear-end collisions on the roads of the "average ADR state" are four times higher than in Germany.

6.2 Notification of occurrences in accordance with 1.8.5 of ADR

Since 2003, all ADR Member States have been obliged to notify certain incidents involving dangerous goods in the form which is currently applicable. The 2001 edition of ADR already contained the requirement in 1.8.5. “Notification of occurrences involving dangerous goods". In this edition, no definite criteria were laid down supporting the obligation to notify an incident and no model for report on occurrences was shown, either. Remedial action was taken and now the incidents notified are collected by the competent authorities (in Germany the Federal Railway Office (EBA) and the Federal Office for Goods Transport (BAG)) and are passed on to the Federal Ministry of Transport, Building and Urban Development (BMVBS) for evaluation. A group of experts discusses in advance the data with regard to irregularities and further action. Subsequently, working groups of the Committee on the Transport of Dangerous Goods are entrusted with the task of investigating these incidents more thoroughly. A point of criticism to be noted as regards the use of all these data of occurrences of the ADR Member States is that currently no central data collection and evaluation of the reports on occurrences is performed in the ADR states.

When reviewing the (German) data, inconsistencies became apparent which occurred despite the standard report form (a model of the report form is shown in Subsection 1.8.5.4. of ADR and is annexed to this report as Enclosure 8). The reasons for this are probably on the one hand that the persons (up to now mainly rescue services) only fill in this report once. On the other hand, the interpretation of some elements is up to the user. In order to evaluate these data for the purpose of vehicle engineering, it would also be desirable to include the impact speed ("delta ν”) in the report on occurrences, retrieved for example from the tachographs or possibly available accident recorders.

In principle, however, the reports on occurrences are in any case a welcome data source for investigations in connection with rear protection devices.

6.2.1 Descriptive review of the reports on occurrences for the road sector in 2007

In 2007, 84 incidents were reported in Germany which occurred on the roads and complied with the criteria for reportable accidents in accordance with 1.8.5 of ADR. The accidents reported include, apart from the accidents on public roads, also accidents in machinery and equipment yards. Therefore, the reports on occurrences available were each classified in one of two groups: Occurrences with „traffic-related causes“ and occurrences with “operational causes”. Occurrences with traffic-related causes are accidents happening as a consequence of the traffic situation.

Occurrences with operational causes are accidents or incidents which must be reported due to operational errors which are frequently, however, only detected during roadside checks. An example in this connection is damage at drums for hazardous substances caused by a forklift truck during loading.

54 out of all occurrences reported can be attributed to traffic-related causes. Since only traffic-related occurrences are of importance to the rear protection of vehicles, attention will solely be attached to such incidents in the following.

First of all, the data collected were systematically evaluated according to types of accident. In this connection, it was found that the major share of the accidents occurred due to running-off the roadway.

The second most frequent type of accidents are rear-end collisions with a share of 24%. All other accident types are combined under the heading "other accidents" and account for 15% of the traffic-related accidents (see Fig. 4).

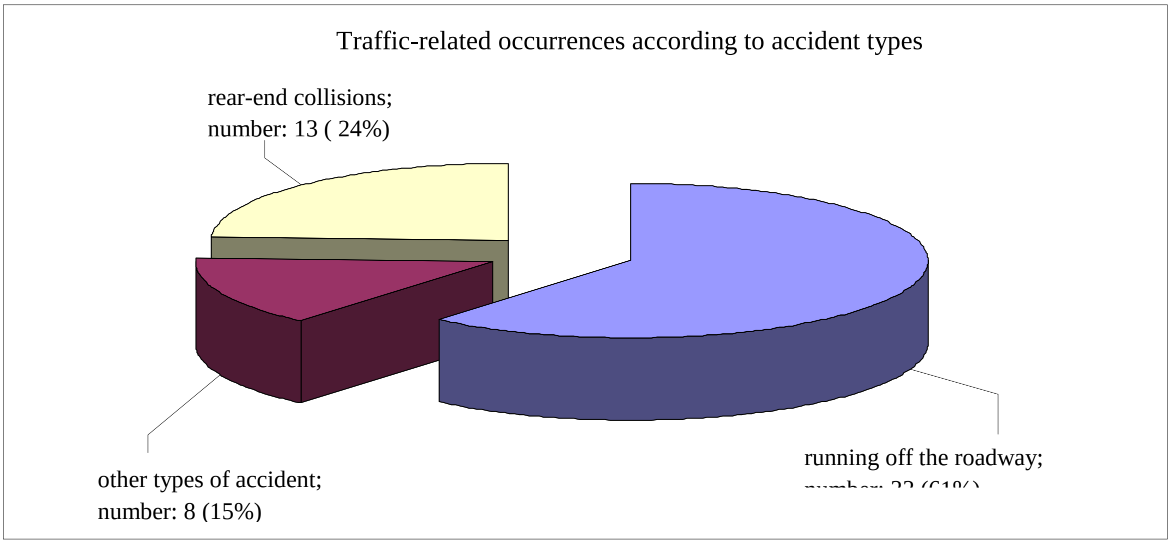

Fig. 4: Traffic-related occurrences according to accident types

As regards the rear-end collisions, it has to be kept in mind that they are basically without exception HGV-HGV accidents. Only in one case a caravan was involved which was hit by an articulated lorry carrying dangerous goods. In a further case an accident involved two light vans. Reportable occurrences with passenger cars were not recorded. A possible reason for this might be that in the case of car-HGV rear-end crashes the accident would not be considered as a reportable occurrence according to the criteria given, due to the minor damage done to the HGV.

In 62% of the rear-end collisions, hazardous materials were released. Accordingly, there was no release of hazardous materials in 38% of the cases reported. The analysis focused jointly on tank vehicles and general cargo vehicles (see Fig. 5).

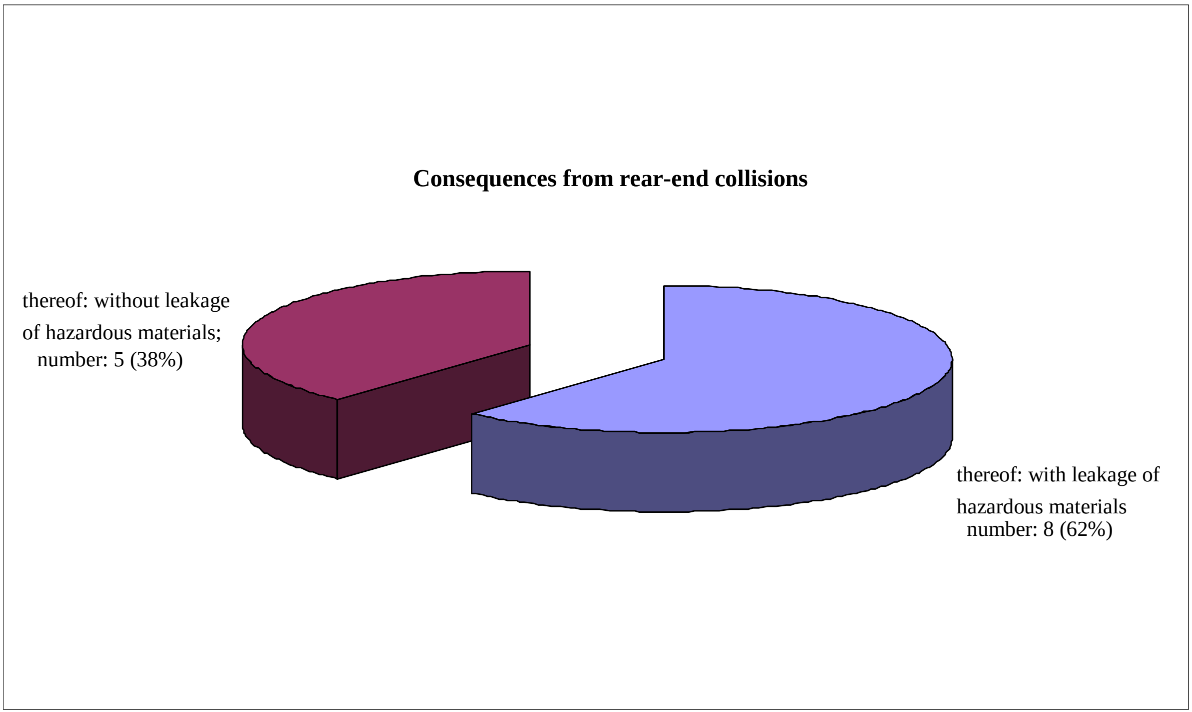

Fig.5: Consequence from rear-end collisions

The subdivision of the rear-end collisions according to the involvement of general cargo and tank vehicles, while neglecting a classification according to the release of hazardous materials, leads to the clear distribution shown in Fig. 6.
The major share, i.e. 38%, is attributable to rear-end collisions with general cargo vehicles, closely followed by rear-end crashes with tank vehicles accounting for a share of 31%. Accidents where general cargo and tank vehicles hit a vehicle running ahead, resulting in damage to their own front end, occurred less frequently (8% in the case of tank vehicles and 23% in the case of general cargo vehicles).
As can be seen from Fig. 6, the most frequent occurrence was rear-end damage to general cargo vehicles which led in 80% of the cases to the release of hazardous materials.
Only in one of these cases no hazardous materials were released.

The red section shows the number of rear-end collisions with tank vehicles. There were four reportable occurrences with rear-end damage to a tank vehicle. In all these cases it were HGV impacting tank vehicles. Only one accident led to the release of hazardous materials.

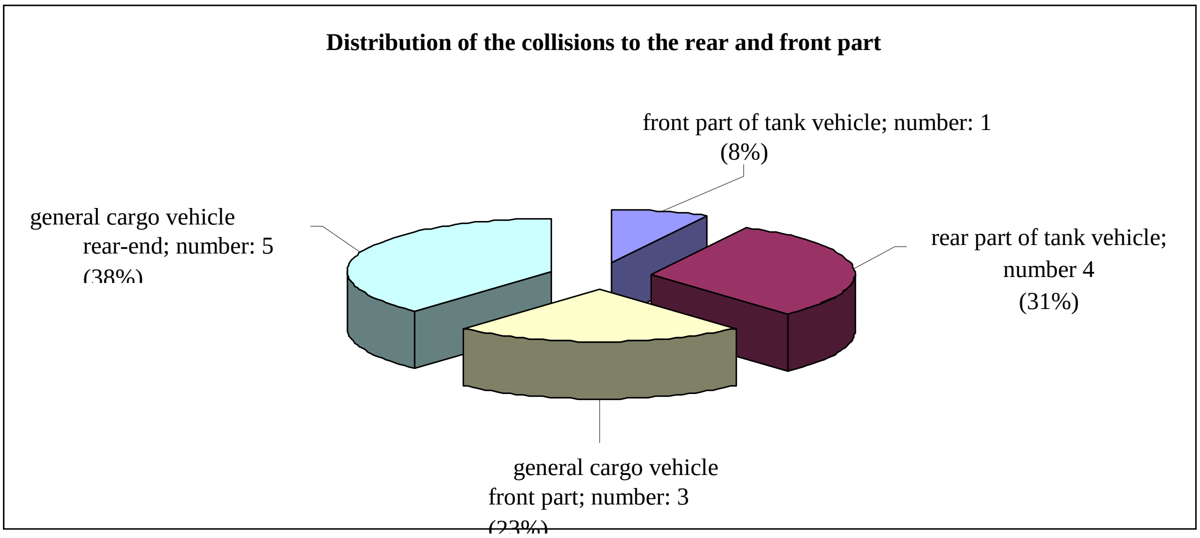

Fig.6: Distribution of the rear-end collisions to the rear and front part

Since 13 out of 54 reportable traffic-related occurrences (see Fig. 4) are rear-end collisions, we see a requirement for action with regard to the rear protection of vehicles.

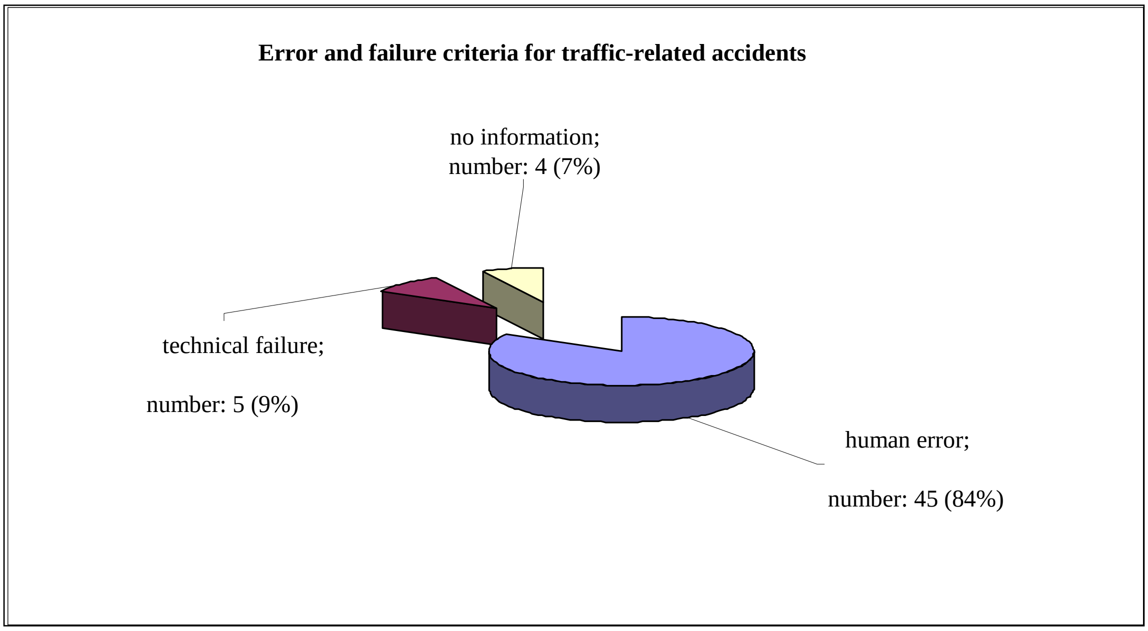

Fig.7: Error and failure criteria for traffic-related accidents

When considering the causes of errors and failures for all traffic-related accidents (irrespective of a release of hazardous materials), it becomes apparent that 84% of the accidents are due to human error and 9% to technical failure (see Fig. 7). Thus, in both cases (accidents with and without the release of hazardous materials), the major part of the reportable occurrences is to be attributable to human error.

6.2.2 Accident data

The above observations are based on the reports on occurrences (data) provided by the Federal Ministry of Transport, Building and Urban Development (BMVBS). In order to make the data basis more robust, the following procedure was chosen: Internal data from an accident data base of the Federal Institute for Materials Research and Testing (BAM) were analyzed the basis of which includes current incidents from the daily press, breaking news, internet, the Central Reporting and Evaluation Office for Hazardous Incidents in Process Engineering Facilities, etc.. Further data sources were the Internet Database for Accidents involving Dangerous Goods Vehicles (GUNDI) established by the Storck Publishing House (http://www.gefahrgut.de/gundi). For the evaluation of the occurrences, redundancies were avoided. According to a report issued by the publishing house, the GUNDI data base was discontinued in mid-2007 until further notice. Consequently, the data evaluated from the reports on occurrences in accordance with 1.8.5. from the year 2007 cannot correlate with those of the Storck Publishing House.

The intention was, on the basis of an assessment of this information, to place the essence of the reports on occurences made available by the BMVBS on a broader data basis and, thus, to verify or falsify the findings derived therefrom. As an interim conclusion of this additional data evaluation, the following can be stated:

During the last ten years, the total number of road accidents with a release of dangerous materials is, according to the GUNDI data base, five accidents per year on the average, using the key words "tank vehicle" (as an accident object involved) and "hazardous materials" (for the search in all fields) for research purposes. Without completely subsuming the exact figures from GUNDI and the internal data base, the data situation is confirmed, taking the detailed data from the reports on occurrences pursuant to 1.8.5 as a basis.

In the research report 659 „Risk assessment for hazardous materials carried by tank vehicles with higher payloads with regard to the provision of filling stations (44 t report)" prepared by the German Scientific Society for Petroleum, Natural Gas and Coal, the GUNDI database was already evaluated with the result that the absolute number of accidents involving tank vehicles was verifiably reduced from 1996-2006. The downward tendency of the accident figures until the year 2006 was, however, interrupted in 2007. Here, a slight increase has to be noted which can also be

detected from the reports on occurrences for 2007 which was made available by the BMVBS.
For the years to come, no forecast can be made as to the development of the accident figures, since many minor changes of the outline conditions in daily road traffic may lead to major consequences such as the tightening parking space situation for HGV along the federal motorways which may enhance the probability of rear-end collisions in the future by forcing the drivers to drive on while exhausted or to park their vehicle inappropriately. For this scenario, too, the rear protection as requested may be an instrument for the protection of the tank vehicle.

7. Rear protection

Owing to the application of the requirement for rear protection in the ADR to certain vehicles only, the aim is to cover the vulnerable points at the rear end of the vehicle which are frequently damaged in the course of accidents by additional measures.
In the following, various approaches for rear protection are presented and compared with each other.

First of all, all proposals are serving the purpose of enhancing the safety of the tank or of the tube (battery-vehicle) in order to prevent the release of hazardous materials in the course of an accident. Since these measures are intended to mitigate the accident consequences they are considered as passive safety measures. As the variant which will finally be favoured will in any case be an additional device to the existing tank vehicle system, a reduction of the payload has to be assumed while the maximum authorized mass remains the same and the vehicle-trailer system is unchanged. This circumstance must also be taken into account in the evaluation of the individual measures in order to achieve a well-balanced relationship between the gain in safety and the reduction of the payload. Furthermore, the permissible overall vehicle length may also be a limiting criterion.
In the case of active safety measures, i.e. measures intended to prevent the accident, the above-mentioned disadvantages might be less distinctive. In general, these systems are relatively small and therefore light. Some parts or system parts necessary for this purpose are in many cases contained in modern vehicles. A problem in connection with the introduction of active safety measures is that these measures would often have to be installed and thus also required in the vehicle of the

other party involved in the accident in order to protect the vehicle carrying dangerous goods. The automatic distance control or the brake assistant are for example only effective for the potentially impacting vehicle. This can be a HGV without dangerous cargo in which the active safety system would have to be installed to prevent the accident. Since the ADR can only impose safety measures for HGV carrying dangerous goods, the approach already mentioned here, i.e. to prescribe useful active safety measures for all HGV by the German Road Traffic Registration Regulations, new designation: Regulations for the Licensing of Road Vehicles, is to be favoured. Thus, the active safety measures would have their best effect and many accidents with serious consequences might be avoided. The dangerous goods legislation can only support the request for such action (exerting influence on WP.29).

A possible approach for new requirements as to rear protection might either be an individual measure or a combination of different complementary technological measures.

The evaluation of individual measures by means of suitable test methods as is done in the case of underrun protection is easier than the testing of several combined measures.

All systems of passive safety must provide for the possibility of energy absorption by the protective structure - in general the vehicle frame.

Apart from this, most passive safety measures are restricted to the rear end of the tank vehicle. An exception in this context is the levelling of the bumper heights which also affects the front parts. Moreover, the reduction of parts which are aggressive to the shape on the front part of commercial vehicles contributes to the gain in safety. In this respect, the same is true as for all active safety measures, namely that the introduction of this measure is the more effective the more vehicles are equipped with these devices (see above).

In many cases, the underrun protection required in the EC Directive 70/221/EEC is considered to be suitable to comply with the ADR requirement as to the rear protection. This means virtually a reinforced bumper at the rear end of the HGV. This bumper is to prevent an impacting vehicle to penetrate to the rear bottom of the tank

at all. The accident energy is to be absorbed by the vehicle frame, thus protecting the tank body.
In the case of self-supporting semi-trailers, the accident energy is mainly absorbed by the rear tank wall. The bending of this wall cannot be excluded particularly since the tank itself is not designed to be accident-proof.
A further possibility, rather to be found for battery-vehicles, is to install a crash bar at the rear end of the vehicle above the frame edge, extending over the whole area of the tank and/or individual tubes. The protective grilles which are today installed at the rear end are, together with the newly introduced valve protection caps, to ensure an optimum protection of the rear end of battery-vehicles.
Other systems beyond the ones described for the improvement of passive safety are not used in practice. Systems destined to actively prevent rear-end collisions are currently not prescribed.

The aim is to avoid the release of hazardous materials in order to reduce the consequences of an accident. This can be achieved by means of a „two-step model“: It should primarily be attempted to prevent accidents by means of active safety measures. If this cannot be achieved, passive safety measures are to mitigate the accident consequences and to prevent the release of hazardous materials from the tank.

8. Technical solutions for rear protection

Various measure are realizable which will in the future enhance the safety of tank vehicles/battery-vehicles in rear-end collisions. In order to demonstrate the variety of possible solutions some are described in the following. For the sake of completeness, those systems are also mentioned which, if they are installed at all, are currently in use to guarantee the protection required in accordance with section 9.7.6 of the ADR.
In the following, the systems are subdivided into systems for improving passive safety (mitigation of accident consequences) and active safety (prevention of accidents).

Rear protection of tank-vehicles for the transport of dangerous goods

Systems for improving passive safety (mitigation of accident consequences):

1. Bottoms with increased wall thicknesses e.g. $e_{bottom} = e_{min} \cdot 1.2$

   Advantage: - higher penetration energy is required

   Disadvantage: - reduction of the payload
   - higher welding stresses

2. Bottom in the danger zone should be structurally reinforced e.g. welding of sheet-metal sections (as a kind of fibre belt) or tubes (as crash bar) directly to the tank body/bottom.

   Advantage: - higher penetration energy and penetration distance necessary

   Disadvantage: - reduction of the payload
   - force transmission into the tank body

3. Additional protection of the tank at the rear end crash bar mounted to the chassis, detached from the tank body

   Advantage: - force transmission into the chassis, not into the tank body

   Disadvantage: - reduction of the payload

4. Double rear bottom (clearance at least 100 mm, foam-filled)

   Advantage: - higher penetration energy and penetration distance necessary

   Disadvantage: - reduction of the payload
   - problems with corrosion
   - maintenance problems

5. Exploit the potential inherent in modern energy-absorbing elements to reduce deformation in the “assembly”.

   Advantage: - reduction of major accident energies is possible
   - exchange of a whole assembly is possible

   Disadvantage: - additional space required

6. Design of the tank body itself as an energy-absorbing element: defined compression at the homogeneous parts of the tank body

   Advantage: - higher energy absorption is possible

Disadvantage: - defined tank elements are necessary
- compliance with a tolerable limit value is difficult
- time-consuming and high cost of development
- proportionality is questionable

7. Levelling the height of rear and front bumpers for all commercial vehicles and ensuring the relevant design

Advantage: - compatible conditions for the parties involved in the accident
- no additional weight and space required

Disadvantage: - competence for this measure is not with the WP.15

8. Increase the distance between the tank body and the rear protection

Advantage: - higher deformation distance

Disadvantage: - reduction of the useful length

9. Reduction of form aggressive parts in the front area of commercial vehicles

Advantage: - reduction of the risk of penetration

Disadvantage: - competence for this measure is not with the WP.15

The above-mentioned modifications may be performed during the manufacturing of the vehicle or tank or retrofitted afterwards, requiring some additional constructional work.

An interesting possibility of improving the safety reserves of tank vehicles, also of those vehicles which are already in service, might be the installation of an airbag at the rear end. The functioning of this device is well-known from other fields of use but it would have to undergo a comprehensive further development and testing for this purpose (material, drive unit, valve openings etc.).

The following considerations were made in this connection:

10. Rear air bag(s)

Advantage: - this technology has already been an integrated element in car manufacturing and has been tested frequently.
- technology can be used in addition to existing systems as a complementary element
- can be retrofitted (in old vehicles)
- easy to produce and/or easily accessible on the market

- cost-effective
- the form can be individually adapted and/or manufactured
- implementation into sets of regulations on the precedent of existing regulations possible without great effort
- light, minor restriction with regard to the payload
- familiar technology and, thus, easy to implement (well-known solutions are preferred over new ones)
- even motorcyclists will profit from this technology (no edges)

Disadvantage:

- additional risks due to pyrotechnics
- not theft-proof (black market)
- when setting off it might shock other persons (noise), risk of accident or distraction
- limited energy absorbing capacity
- mass to be absorbed, exploding of the airbag if no openings of the ventilation system are available. With openings of the ventilation system the airbag would, if used, have no effect due to the mass acting on it (the time until the impact is longer than for passenger airbags, thus the pressure would already have automatically escaped)
- selective inflow of the gas can also lead to the explosion of the airbag if it has already been exposed to strains or if the airbag gets entangled
- the folding of a big airbag requires a high development effort
- a gas generator ignited by an explosion is necessary since the pressurized-gas accumulator is not suitable (too slow)
- risk of explosion of the hazardous materials carried if the airbag is ignited (→explosion-proof design, sensor

system to determine the prevailing atmosphere before igniting the airbag)

- risk of crushing and thus explosion of the ignition modules in the case of an accident →installation in less endangered vehicle areas

Other measures with pyrotechnical support also seem to be suitable:

- "lid lifting devices" such as installed at the front lid of passenger cars for pedestrian protection
- quick release elements e.g. blinds or teflon curtain (guided in a frame)
- backward deployment of a bumper element and opening up of an impact element

Systems to improve the active safety (prevention of accidents):

11. Keep distance to spontaneously impacting vehicle ("emergency-braking assistant")

    Advantage: - no collision possible

    Disadvantage: - influencing other road users

12. For vehicle category N3 (more than 12 t of permissible mass) permanent distance control should be obligatory (radar) ("run-up speed control")

    Advantage: - no collision possible

    Disadvantage: - WP.15 cannot exert influence

    - possible activation by swinging-in passenger cars

13. Provide for optical and accoustic signals to warn the vehicle running up if the distance is too short (at the tank vehicle as well as at the vehicle running up)

    Advantage: - reduce the response time of the driver

    Disadvantage: - none

14. Uncontrollable signal e.g. exterior lamp at the commercial vehicle: driving time exceeded

    Advantage: - reduce response time, make response possible

    Disadvantage: - low acceptance

Currently, the driver assistance system „emergency- braking assistant" mentioned in No. 11 and also related systems are the subject of lively discussions in the media. These are meant to be "intelligent" and "anticipatory" braking systems. These systems are controlled by microcomputers issuing quick braking commands in order to optimize the deceleration and the driving stability according to the prevailing situation. By measuring the time required for changing from the accelerator pedal to the brake pedal, the system is to detect a situation for emergency braking. Immediately, pressure is build up in the brake lines to improve the deceleration of the vehicle while the braking pressure can be determined, as required, via wheel modulators for each wheel. A brake light combined with this system indicates, by blinking and the subsequent activation of warning lights, to the traffic approaching from behind that an emergency braking manoeuvre is being performed.

In the case of a wet carriageway, modern braking systems, by temporarily attaching the brake lining to the brake discs, make it possible to wipe off the water film from the brake discs. This enables the brake to function more quickly and with full effect. If the systems detect a condition which is critical with regard to the dynamics of vehicle movements, action may be taken together with the electronic stability programme (ESP) and one or more wheels be decelerated. These brake systems also support, as a rule, other functions such as the anti-lock system and the brake assistant system.

An additional improvement of existing systems might be the request for an EBS, an electronic brake system. EBS is to integrate the basic functions, i.e.

brake control, antilock-system and traction-slip control, into one system. Compared with the conventional pneumatic control, this electronic control offers some advantages such as shorter response times of the system and, thus, also shorter braking distances since the control is effected with almost light velocity and not sound velocity as is the case with pneumatic control (see VDA – German Association of Automotive Industry -, 2003 as well as Pehle, 2004). In addition, the electronic brake system offers an integrated coupling-force control (CFC) which, for the decelaration of a vehicle combination, better coordinates the brake power of the trailer with that of the tractor.

A useful supplement of these solutions is again the extension of the system by an electronic stability programme. This system is to bring about a considerable reduction of the rollover tendency or risk by stabilizing the vehicle in critical driving situations.

The approaches described here are to be subject to a more thorough safety-related evaluation as to their formal suitability with regard to the ADR as well as their enforceability, in consideration of other parameters in excess of those mentioned. In this regard, a well-targeted and continuous discussion of the subject of rear protection is considered to be useful.

9. Minimum energy-absorbing capability

Rear protection is to be enhanced for the reasons already mentioned above.
In order to ensure the comparability of various design variants, the relevant energy-absorbing capability level is to be laid down up to which a tank vehicle has to resist without leakage. The definition of such a limit value makes it necessary to know the masses of the vehicles involved and the impact velocity/relative velocity at which or below which the major share of the accidents happens.
According to the THESEUS Summary Report, this speed is 20 km/h for rear-end collisions as was found out when assessing the accident data from 360 accidents recorded (see THESEUS, 1995, p. 16). The aim of the rear protection as stipulated by THESEUS is the improvement of the protection against impacting commercial vehicles but the collision speeds mentioned there are significantly higher than 30 km/h (see THESEUS, 1995, p. 163). There are no current data available concerning the impact velocities for rear-end collisions involving HGV so that an average impact velocity of 25 km/h is assumed in the following. This value is also taken as a basis for the rear-end collision tests described below.

9.1 Data basis

To determine the deformation work of the tank vehicle, calculations were made for eight rear-end collision tests which were also carried out within the framework of the THESEUS study. The test specification comprised the exact vehicle masses and speeds. The mass of the impacting vehicle varied between 15,900 kg (tests SH 92.13 and SH 93.02) and 22,075 kg (test SH 94.08). The mass of the vehicle hit amounted to 37,600 kg. The impact velocity ranged between 25 km/h and 27 km/h (see THESEUS, 1995, table 4.2, p. 110 and table 4.8, p. 124). The deformation work absorbed by the rear end of the tank vehicle reached approximate values between 125 kJ and 185 kJ (see table 3). The average value calculated on the basis of the eight tests was 165 kJ.

1. Approximate values of the deformation work absorbed by the rear end of the tank vehicle in the course of the test to analyze the stress on the tank bottom, modified according to: THESEUS, 1995: Table 4.9, p. 126

Test No.	SH 92.10	SH 92.11	SH 92.12	SH 92.13	SH 93.02	SH 93.03	SH 93.13	SH 94.08	$\bar{x}$
Tank deformation work [kJ]	175	155	185	180	125	150	165	185	165

If the limit value was, as intended, 150 kJ which the rear protection or the tank is to withstand without leakage, only two out of eight tanks would not be damaged.

In five of the eight tests cargo was released. Joint features of these vehicles were the tank material AIMg4.5Mn and a wall thickness of 4-5mm (see THESEUS, 1995, p. 117 and p. 161).

Three vehicles did not release cargo (see THESEUS, 1995, p. 121).

- Vehicle A04 (test SH 92.12): <u>Stainless steel</u> cylinder tank (wall thickness 4.6 mm, insulation removed)
- Vehicle A18 (test SH 93.13): Coffer tank from AIMg4.5Mn and <u>double bottom</u> (wall thickness 2x5.12 mm)
- Vehicle A20 (test SH 93.03): Drawbar tank trailer with a coffer tank from AIMg4.5Mn (wall thickness 4.6 mm)
  Here, the <u>rear overhang was very short</u> so that the frame ends and the rear-axle suspensions provided a certain protection for the tank, thus essentially reducing the strain on the rear tank bottom.

It is clear from these findings, that simple measures may already prevent the release of hazardous materials at collision speeds of up to 25 km/h. The old THESEUS results are in the majority of cases today challenged by new aluminium tank materials and modified minimum wall thicknesses, the properties of which significantly outperform those of the "old" tank vehicle tanks. Irrespective of this, the kinetic energy shares of the vehicles involved in the accident remain the same.

We will analyze this fact in the following.

9.2 Calculation

When calculating the collision energy, it has to be taken into account that the energy is not only absorbed by the rear end of the vehicle driving ahead or a stationary vehicle ahead, but also by the driver's cab of the impacting vehicle according to the in each case relevant deformation distance. 50% of the total energy is assumed as an approximate value for the deformation work of the tank (cf. THESEUS, 1995, p. 126). The driver's cab of the impacting HGV is not considered in more detail since the task here is to protect the tank and not the driver.

By way of example, the following calculation can be made (cf. test SH 92.13, THESEUS, 1995, p. 123 ff.):

From the distribution of the velocities of the centres of gravity of the vehicles involved over time it ensues that both vehicles have about 350 ms after the start of the collision the same speed (v = 6.3 km/h). Then they begin to drift apart from each other, i.e. the main deformation phase ends here (see THESEUS, 1995, Fig. 4.12, p. 123).

Accordingly, the following speed changes can be determined for both vehicles:

HGV	Δv_L	= 27 km/h -6.3 km/h = 20.7 km/h	= 5.75 m/s
Tank-vehicle	Δv_T	= 6.3 km/h	= 1.75 m/s
fictitious impact time	Δt		= 350 ms

The average impetuses for the HGV and the tank vehicle can be calculated as follows:

F	$= m * a$	
with a_L	$= \Delta v_L / \Delta t$	= 16.4 m/s²
and a_T	$= \Delta v_T / \Delta t$	= 5.0 m/s²

$\Rightarrow \quad F_{St,L} = m_L * a_L = 15900 \text{ kg} * 16.4 \text{ m/s}^2 = 261 \text{ kN}$

And

$\Rightarrow \quad F_{St,T} = m_T * a_T = 37{,}600 \text{ kg} * 5 \text{ m/s}^2 = 188 \text{ kN}$

where:

F:	force
F_{St}:	impetus
m:	mass
a:	acceleration
L	HGV
T	tank-vehicle
v:	velocity
t	time

The two impetuses deviate by 16% from their average value. Actually, they would have to be equal if one starts out from the assumption of a straight and central impact of two rigid masses. This deviation is deemed to be acceptable in view of the simple model representation and the accuracies of the measurement and evaluation procedures (see THESEUS 1995, p. 124).

Taking the high-speed recording as a basis, it can be determined that the main deformation phase ends approximately 350 ms after the beginning of the impact. At this moment, the sum of the deformation and frictional work amounts to about 360 kJ. Since the deformation work of the tank is assumed to account for 50% of the total energy, the value for the tank deformation work thus resulting is $W_{def,T} = 180$ kJ.

A different calculation method leads to the same result:

$$W_{def} + W_{reib} = E_{kin,0} - E_{kin,LKW} - E_{kin,TF}$$

where:

W_{def}:	deformation work
W_{reib}:	frictional work
$E_{kin,0}$:	kinetic energy prior to the impact
$E_{kin,LKW}$:	kinetic energy of the HGV at t = 350 ms
$E_{kin,0}$:	kinetic energy of the tank vehicle at t = 350 ms

This means for the example described above (test SH 92.13):

$W_{def} + W_{reib} = 447 \text{ kJ} - 26 \text{ kJ} - 61 \text{ kJ} = 360 \text{ kJ}$

Assuming that the value of the frictional work is low as compared with that of the deformation work and that the deformation energy is equally distributed between both vehicles, meaning that the deformation distances of both vehicles are the same, the values may be halved in order to obtain the deformation work for one of the two vehicles. This results in an energy absorption of 180 kJ for the rear end of the tank vehicle travelling ahead.

Considering the deformation energy of the rear protection in the form of an exemplary square tube (see Fig. 8), a similar energy absorption capability is obtained (see Erhard, presentation on the occasion of the International Motor Show, 2008):

Fig.8: Rear protection in the form of a square tube

$$W_{Ver} = F \cdot l \approx \frac{\sigma_{max}(A^4 - a^4)}{6 \cdot A \cdot L} \cdot l$$

where,

W_{Ver}:	deformation work
F:	force
l:	distance (elongation)
σ_{max}:	max. compression strain
A:	length of the outer edge
a:	length of the inner edge
L:	length of the lever arm (displacement of the centre of gravity of the colliding vehicles)

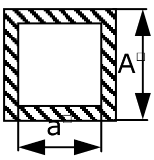

Fig.9: Cross-section of a square tube

With A = 80 mm and a wall thickness of 4 mm (see Fig. 9), σ_{max} = 700 N/mm²,
l = 40 mm and a displacement of the centre of gravity of the colliding vehicles of
L = 5 mm the result of the deformation work is

$$W_{Ver} \approx 165\,\text{kJ}\,.$$

It has, however, to be indicated that if this energy absorption capability is exceeded, the geometry of the square tube may lead to the laceration of the tank bottom. Moreover, the maximum energy absorbing capability of the square tube can only be achieved if a sufficient rigidity is ensured and the tube is mounted to the vehicle in a constructionally useful way. Plastic deformation reserves of the tank bottom or other component parts were not taken into consideration in the above analysis.

9.3 Interim summary

The objective of rear protection is to minimize the probability of a leakage of hazardous materials for the major percentage of the expected rear-end collisions. This would be achieved for a certain percentage of accidents by a rear protection capable of absorbing 150 kJ. Since former WP.15 proposals already mentioned a limit value of 150 kJ which was justified with the results of the THESEUS study, the recognition factor should be borne in mind if a further proposal to this effect is to be submitted.

Indeed, a higher deformation absorbing capacity would be desirable in order to avoid the leakage of hazardous materials for a great number of rear-end collisions. But in order to justify a higher limit value, reliable statistics from all the states involved which may provide information about the impact speeds for rear-end collisions with commercial vehicles are lacking (see Chapter 6: “Accidents").

And with the assumption that the impact speeds are today higher due to an increased average speed as a consequence of excessive speeds driven by HGV, a shorter safety distance or the failure to brake before the impact owing to inattention, it might be desirable to request a more resistant rear protection with a higher energy absorption capability than 150 kJ (see table 4).

It seems, however, also to be conceivable that by means of active safety measures such as the driver assistance systems ESC (electronic stability control), ACC (adaptive cruise control), SLD (speed limiting device) and LDW (lane keeping assistance) the average impact speed decreased as compared with 1990-1993 (see table 4).

Table 4: Exemplary scenarios concerning the possible development of the impact speed from 1995 to 2008 with contradictory results:

1995→2008:	- HGV performance - average speed within built-up areas / outside built-up areas / motorways	→impact speed ?
1995→2008:	- improved / more active safety systems in vehicles (e.g. due to driver assistance systems)	→impact speed ↓?

The issue concerning the realistic vehicle masses involved in collisions cannot be neglected, either. The impacting test vehicles within the framework of the THESEUS study weighed between 15.9 and 22.1 tonnes. The maximum permissible weight of HGV in Germany is 40 tonnes, so that in the case of an accident involving a 40-tonne HGV the energy absorbing capability of the rear protection would have to be essentially higher than 150 kJ (namely about 500 kJ) in order to effectively protect the tank. A stronger intrusion may also be caused by an offset or an unfavourable impact angle of the accident opponents.
What seems, however, more important than the question of the „right“ limit value appears to be the general introduction of a rear protection device with a defined energy absorbing capability. As already mentioned, the rear protection does not claim to protect the dangerous goods vehicle safely against *all* rear-end collisions. The ADR anyway only provides for the safety necessary for normal operational stresses (see ADR 2009 Subsection 1.4.3.4 b) and/or that the tank bodies are so designed that they can withstand the defined stresses (see ADR 2009, Subsection 6.8.2.1.1) without any loss of cargo in normal conditions of carriage.
During the last ten years, the safety of aluminium mineral oil tanks has been improved due to the prescribed higher wall thicknesses. This is to be considered as an additional protection measure for the tank.
In order to make an assessment of the overall design of a tank, the Summary Report of the THESEUS study recommends to introduce a drop test with a representative tank section (see THESEUS, 1995, p. 229 and p. 231).

Another possibility is the penetration test as is also carried out at tank bottoms for the stress test in the case of point loads. Here, a part of the tank is placed into a holding fixture and a defined force is applied by means of rams.
The advantage compared with the drop test would be the lower effort. In contrast to this, there is, however, the transferability to a real rear-end collision which would be imitated in a more realistic form by a drop test. Moreover, the penetration test cannot simulate large-scale stresses but it is well suited to represent the behaviour of form aggressive parts. If it can be assumed that the impact speed has not changed since 1995, the limit value of 150 kJ should be maintained in proposals submitted to the WP.15 because of its recognition value among the Member States.

10. The EU underrun protection

In Germany, the EU underrun protection is regulated in section 32b of the German Road Traffic Registration Regulations and is referred to in Directive 2006/20/EC of 17 February 2006 for the adaptation of Directive 70/221/EEC. Since 11 July 2008, the UNECE Regulation 58, Rev. 2 has been applying to underrun protection. It covers vehicles of the categories N2, N3, O3 and O4, thus vehicles for the carriage of goods of more than 3.5 tonnes.
The purpose of the underrun protection is to provide effective protection against underrunning to an impacting passenger car or caravan (category M1) and vehicles for the carriage of goods with a maximum authorized mass of not more than 3.5 tonnes (category N1).

10.1 Composition of the underrun protection device

An underrun protection device generally consists of a cross-member and linking components connected to the chassis side-members or to whatever replaces them. There is some margin of discretion as regards the design, moments of inertia etc. The section height of the cross-member must not be less than 100 mm. The lateral extremities of the cross-member must not bend to the rear or have a sharp outer edge. This condition is fulfilled when the lateral extremities are rounded on the outside and have a radius of curvature of not less than 2.5 mm. The individual components of the underrun protection device must have an effective surface of at least 350 cm² each.

10.2 Test method

The test method is described in Directives 70/221/EEC or 70/156/EEC and Regulation 58. A practical test is generally not required if it can be proved by calculation that the rules in force are complied with. It can be performed at the vehicle or at a section of the chassis or on a rigid test bed.

The underrun protection device must offer adequate resistance to forces applied parallel to the longitudinal axis of the vehicle, and be connected, when in the service position, with the chassis side-members or whatever replaces them. It has to be proved that both during and after the application of the force as defined the horizontal distance between the rear of the device (of the underrun protection) and the rear extremity of the vehicle does not exceed 400 mm at any of the points P1, P2, P3 (see Fig. 10).

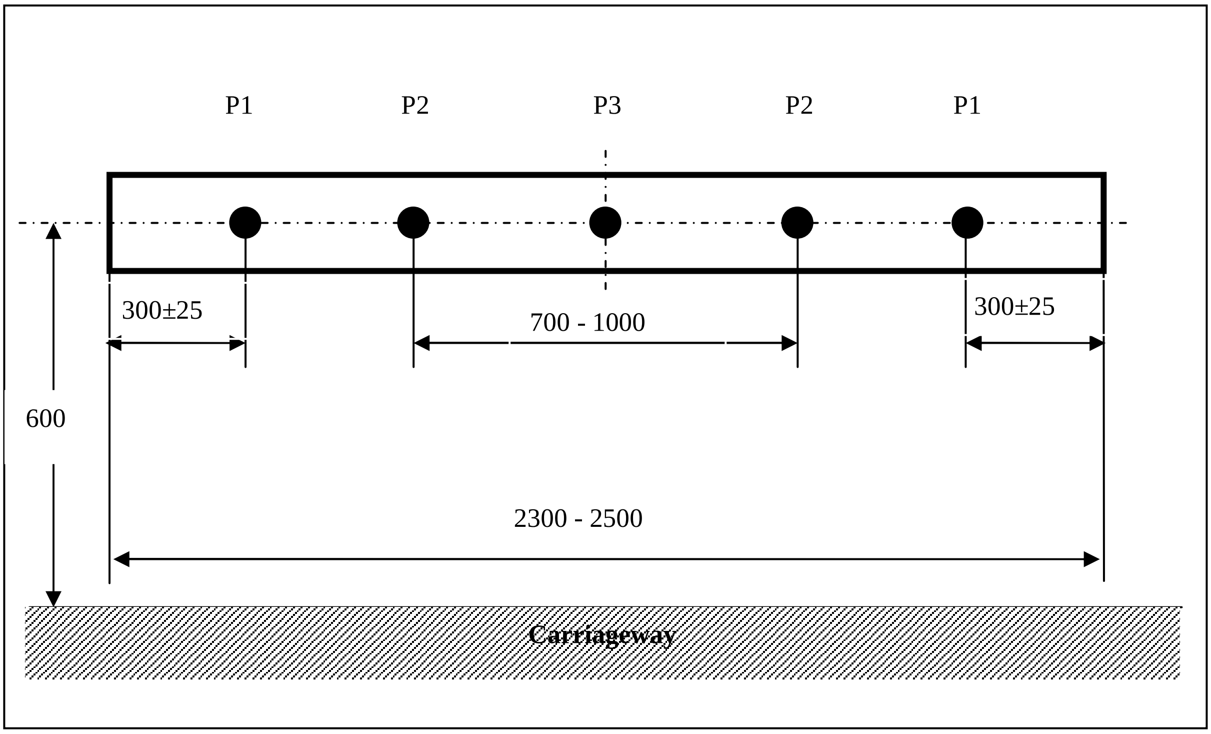

Fig.10: Arrangement of the points to be tested at the underrun protection device (in mm)

This has direct consequences for the installation of the underrun protection if this device has to be mounted under the vehicle. It the device bends by 60 mm during the test it has to be mounted at 400 mm – 60 mm = 340 mm from the rear end of the vehicle.

The position of the underrun protection has in an accident a considerable effect on the consequence for the impacting vehicle. Especially in the case of aerodynamically constructed passenger cars for which clearly the tendency to a wedge shape can be seen and whose front area is flat, passive safety systems cannot use their full potential if the protection is installed too low or too high under the HGV. Therefore, in view of this aspect, the underrun protection device is, if possible, to be flush-mounted to the rear part.

For a test, points P1 are located 300 ± 25 mm from the longitudinal planes tangential to the outer edges of the wheels of the rear axle, points P2 which are located on the line joining points P1, are symmetrical to the median longitudinal plane of the vehicle at a distance from each other of 700 to 1000 mm inclusive, the exact position being specified by the manufacturer. The height above the carriageway of points P1 and P2 must be defined by the vehicle manufacturer within the lines that bound the underrun protection device. The height must not, however, exceed 600 mm when the vehicle is unloaded, point P3 is the centre-point of the line joining P2-P2.

10.3 Test forces

The following section describes in which way and at what point the forces are applied to the vehicle during the test.

Since the adoption of the Ordinance of 17 February 2006, it is necessary to successively induce a horizontal force in the two points P1 and in point P3, corresponding to 25% of the technically permissible total weight of the vehicle but not exceeding 5×10^4 N (50 kN). For point 2, the value is 50% of the total permissible weight or 100 kN. The forces must be applied separately and the order of their application may be specified by the manufacturer. Whenever a practical test is performed to verify compliance with the above-mentioned requirements, the following conditions must be fulfilled:

The rear underrun protection must be connected to the chassis side-members of the vehicle or to whatever replaces them; the specified forces must be applied by rams which are suitably articulated (e.g. by means of universal joints) and must be parallel to the median longitudinal plane of the vehicle via a surface not more than 25 cm in height (the exact height must be indicated by the manufacturer) and 20 cm wide with a radius of curvature of 5 ± 1 mm at the vertical edges; the centre of the surface is placed successive at points P1, P2 and P3.

When performing the test on a test bed, a horizontal force of 50 kN or 25% of the total weight has to be applied at two points at the choice of the manufacturer and a precisely defined third point.

Currently, a discussion is being held on the rear underrun protection with regard to its installation at the vehicle. This may result in restrictions of the energy absorbing capability.

11. Next steps

From the above statements concerning the underrun protection its detailed representation in the sets of regulations becomes apparent. In contrast to this, ADR does not contain the requirement and definition of a test for rear protection; it is, therefore, necessary to make an amendment to this effect.

In the course of further works, especially new findings for the following issues are to be compiled:

- Elaboration and proof of a test method for rear protection
- Design type of rear protection

11.1 General possible procedures

Tests

The tests are intended to demonstrate whether a rear protection with a conventional design in accordance with ADR on the one hand and a rear protection which simultaneously serves the purpose of underrun protection on the other can ensure an energy absorption capability of 150 kJ without failure of the tank. In order to solve these issues it is necessary to hypothesize (see 11.1.2) so as to enable a scientific analysis.

11.1.1 Hypotheses

Hypotheses as justifiable assumptions are popular with scientific works in order to describe vague cases, thus, making them the subject of discussions. Hypotheses must be drafted in such a way that they can be generalized, i.e. they must be universally valid and be falsifiable on the basis of observational data (see Bortz, 2003. p. 7 f.).

Potential hypotheses are:

a) The more extensive the protection device at the rear tank end is, the less the rear tank end will be damaged or leaky as the consequence of an impact.

b) The thicker the rear tank end is, the less it will be damaged or leaky as the consequence of an impact.
c) The higher the impact energy, the greater the damage to the rear tank end, even including leakage (impact energy depends on the mass and the speed difference of the impacting vehicle).
d) The less the overlapping in an impact, the greater the damage to the rear tank end, even including leakage.
e) The lower the rear protection is mounted (e.g. only as an underrun protection) the less effective it is against damage to the rear tank end, even including leakage as a consequence of an impacting HGV.
f) The more selective the deformation work is applied (with the same energy volume) the higher is the probability of penetration.

The data observed during the analysis are compared with the previously defined hypotheses to find out to what extent the results expected correspond to the findings actually made. If the results correspond with each other the hypotheses are deemed to be confirmed.

A further key element must be the assessment of the influence of dynamic load application at the rear protection in order to make the testing of the rear protection as realistic as possible.

11.1.3 Test design as defined by the hypotheses established

The following test arrangements as defined by the hypotheses might be possible:

a) Individual components
   - rear protection in accordance with ADR
   - combined rear and underrun protection
b) whole vehicle
c) tank only

Potential test methods:

1) crash test
2) drop test
3) quasi-stationary test (mandrel but also a more large-scale test element)

4) dynamic test

The following table 5 shows conceivable combination possibilities of the test arrangements mentioned together with possible test methods:

Table 5 Possible combinations of test arrangements with test methods

		1)	1)	2)	3)	4)	5)
test arrangement	**test methods**	crash test (tank vehicle/HGV)	crash test (tank vehicle / barrier)	drop test	quasi-stationary test (mandrel but also a more large-scale test element)	dynamic test (mandrel but also a more large-scale test element)	crash simulation (f. ex. with FEM, MKS)
	components tested						
a)	rear protection in accordance with ADR				x	x	x
a)	“combined” rear and underrun protection				x	x	x
b)	rear protection in accordance with ADR	x	x	x	x	x	x
b)	“combined” rear and underrun protection	x	x	x	x	x	x
b)	whole vehicle with improved rear protection	x	x	x	x	x	x
c)	tank test only		x	x	x	x	x

Possible useful combinations are marked with a cross in table 5. The possibility of only testing the vehicle without the tank to be protected was not taken into consideration since it does not seem to be useful to exclude the object to be protected from the tests.

Tables 6 and 7 set out the advantages and disadvantages of possible test arrangements and/or test methods. It becomes apparent here that with an increased test effort the reality of accident scenarios is better reflected which in turn leads to more analysis work.

Table 6: Advantages and disadvantages of the test arrangements

	Test arrangements	**Advantages**	**Disadvantages**
a)	testing of individual components (rear protection in accordance with ADR, “combined” rear and underrun protection)	lower test effort	only measures at the protection element itself can be assessed: energy absorbing capability of the vehicle structure and stability of the connection between rear protection and vehicle structure is not measured
b)	whole vehicle	leaves all design possibilities open reflects the accident details for rear-end collisions more realistically than tank test	test procedure for the energy absorbing capability of 150 kJ has to be newly defined; higher test effort
c)	tank test only	might be developed on the basis of already existing tests (penetration tests with mandrel, dynamic penetration tests) low effort conceivable option: later on approval according to comparative tables (material, wall thickness) even without a test	restricts design possibilities since only measures to the tank are effective

Table 7: Advantages and disadvantages of potential test methods

	Potential test methods:	**Advantages**	**Disadvantages**
1)	crash test	realistic accident picture	complex
2)	drop test	relatively realistic accident picture	complex especially in the case of complete vehicles
3)	quasi-stationary test (mandrel but also a more large-scale test element)	low effort, experience already gained by tank bottom test	not as realistic as crash test: validity/comparability with crash test would have to be tested
4)	dynamic test (mandrel but also a more large-scale test element)	low effort, experience already gained by tank bottom test	not as realistic as crash test: validity/comparability with crash test would have to be tested
5)	crash simulation	after a one-time manufacturing of a model cost-effective and flexible (modification of the basic	HGV and component models would first have to be manufactured

	Potential test methods:	Advantages	Disadvantages
		parameters possible without problem), tests are reproducable	

During the development phase, tests to assess the energy absorbing capability of the protection device should be performed at the complete vehicle. In order to also convince the other ADR Member States of the significance of improving the rear protection, tests which are as realistic as possible, should be performed for reasons of better clearness. These might be crashes involving two HGV, HGV crash tests against barriers or as an alternative also drop tests. The comparison of the damage situation and the relevant analysis is to provide the safety-related bases for the requirements specification for the rear protection. Moreover, on the basis of these tests, simpler tests (e.g. quasi-stationary, dynamic tests at individual components) or suitable numerical procedures (e.g. FEM, MKS) are validated for later series tests / approval tests for inclusion in the ADR.

11.2 Future investigations

It is endeavoured to gain experience as a result of practical tests to achieve an improvement of the rear protection of tank vehicles. In this connection, account should be taken of the proportionality of the work required for the tests and the benefits to be derived from them.

A test procedure for rear protection is to be developed which is to be realized following the test arrangement prescribed for underrun protection.

In this respect, it is proposed to perform the test in quasi-stationary test conditions as an EU test of individual components (as compared with the test of the underrun protection in accordance with the above-mentioned EU Directive 70/221/EEC) in order to obtain an effective protection by the rear protection device.

Parallel to this it will be useful, with a view to technological progress, to combine the rear protection by design with energy absorbing elements, for example with the support strap absorbers already described in THESEUS (see THESEUS, 1995, p. 164 ff.). Comparable energy-absorbing elements are already used for the same purpose in the case of dangerous goods movements in accordance with RID at certain railway tank wagons (see ADR/RID 2009: Section 6.8.4 b) Items of Equipment: TE 22). The buffers designated there as “crash elements“ ensure that the tank wagon only experiences plastic deformation at a very high energy influx. These

crash buffers have proven their effectiveness already in the course of real railway accidents e.g. with tank wagons carrying chlorine in Sweden.
By means of practical tests, data are to be determined to support the subsequent design shape of the vehicle rear protection. Furthermore, tests by applying quasi-stationary loads as well as crash tests are to be carried out to simulate rear-end collisions. It is proposed to use these tests, by selecting suitable absorbing elements, to comply with the requirement stated above, i.e. to provide for a minimum distance between the rear wall of the tank and the rear of the bumper. For this purpose, the distance should be clearly defined. In addition, in order to adjust the results obtained from the tests of the individual components, drop tests with vehicles seem to be imaginable.
The objective is to reflect rear-end collisions close to reality, with the impact speed being determined by the drop height.
In the medium run, it might be endeavoured to improve the passive safety of vehicles by using airbag systems. Such systems are already providing valuable services in the sector of passenger protection. The analysis of the possibilities of using this technology to solve the problems in connection with the accident consequences in the case of colliding heavy commercial vehicles or at least to mitigate them might be ground-breaking.

12. Summary

The report sets forth the current situation of the rear protection of tank vehicles for the carriage of dangerous goods. It has to be stated that previous attempts undertaken by Germany to amend the provisions of the ADR, in special consideration of the results of the THESEUS study, failed due to the rejection of other ADR states.
Owing to the rear-end collisions involving tank vehicles carrying dangerous goods which have occurred during the last ten years in Germany and the accident situation described in Chapter 6 “Accidents“ for rear-end collisions in Europe, the installation of special rear protection devices at these vehicles is still considered to be a safety-enhancing requirement.
This report stresses the necessity of once again dealing with the subject of "rear protection" in a new quality.

For reasons of the complex technological character of possible design solutions concerning rear protection (key word: unit consisting of the vehicle and the tank) a systematic approach is proposed to reach this objective. This approach consists of an analytical and experimental procedure (see Chapter 11). The design of the rear protection can be performed as an EU investigation of individual components which provides the bases for the subsequent approval test of the individual component "rear protection".

The intended rear protection is to be constructed as a prototype in order to show, by means of crash tests to be carried out, the higher protection effect as compared with the current situation. It is to be expected that these results may substantiate the justification of a future proposal submitted to the WP.15 by Germany.

The aim here is to obtain the acceptance of the other ADR Member States of a relevant development of the law in the ADR if the results prove the effect of the rear protection and if a suitable test method can be developed for this purpose.

The prerequisite to achieve this aim is the timely and practical implementation of the feasibility study.

12200 Berlin, 19 March 2009

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13. Abbreviations

ABS	Anti-Lock System
ACC	Adaptive Cruise Control
ADR	Accord Européen Relatif au Transport International des Marchandises Dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road including the special arrangements signed by all states involved in the carriage)
AGGB	Standing Committee on the Transport of Dangerous Goods of the Advisory Council on the Transport of Dangerous Goods with the Federal Ministry of Transport, Building and Urban Development
ASR	Antislip Control
ATT	Committee on Tanks and Technology (today: AGGB)
BAG	Federal Office for Goods Transport
BAS	Brake Assistant System
BASt	Federal Highway Research Institute
BMVBS	Federal Ministry of Transport, Building and Urban Development
CFC	Coupling Force Control
DGMK	German Scientific Society for Petroleum, Natural Gas and Coal
EBA	Federal Railway Office
EBS	Electronic brake system
ECE	Economic Commission for Europe
EG	European Community
ESC	Electronic Stability Control
ESP	Electronic Stability Programme
EU	European Union
EWG	European Economic Community (today: European Union)
FEM	Finite Elements Method
FZV	Regulations for the Licensing of Road Vehicles (Vehicle Licensing Regulations)
GUNDI	Internet Database for Accidents involving Dangerous Goods Vehicles
LDW	Lane Departure Warning System
MEGC	Multiple-element gas container
MEMU	Mobile Explosives Manufacturing Unit

MKS	Multibody Simulation
RID	Règlement internationale concernent le transport des marchandises dangereuses par chemin de fer (Regulations concerning the International Carriage of Dangerous Goods by Rail)
Rn	Marginal
SLD	Speed Limiting Device
StVZO	German Road Traffic Registration Regulations
TC	Tank-container
TF	Tank-vehicle
THESEUS	Tank vehicles mit maximum attainable safety through experimental accident stimulation
tkm	Tonne-kilometre
TOPAS	Tank vehicle with optimized passive and active safety devices
UDS	Accident Recorder
UNECE	United Nations Economic Commission for Europe
WP.15	Working Party on the Transport of Dangerous Goods
WP.29	Working Party on the Construction of Vehicles

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15. Annex

Encl.: 1	ADR 2009, Part 6, Requirements for the construction and testing of packages, intermediate bulk containers (IBCs), large packagings and tanks, Subsections 6.8.2.1.17 to 6.8.2.1.19
Encl.: 2	ADR 2009, Part 9, Requirements concerning the construction and approval of vehicles, Section 9.7.6 Rear protection of vehicles
Encl: 3	ADR 1993, marginal 10 220
Encl: 4	TRANS/WP.15/R.430
Encl.: 5	TRANS/WP.15/1999/15/REV.1
Encl.: 6	TRANS/WP.15/2002/11
Encl.: 7	TRANS/WP.15/2007/XXX
Encl.: 8	ADR 2009, Subsection 1.8.5.4 Model for report on occurrences during the carriage of dangerous goods

Enclosure 1

ADR 2007

Part 6

Requirements fort he construction and testing of packagings, intermediate bulk containers (IBCs), large packagings, tanks and bulk containers

Sub-sections 6.8.2.1.17 to 6.8.2.1.19

The values of Re and Rm to be used shall be specified minimum values according to material standards. If no material standard exists for the metal or alloy in question, the values of Re and Rm used shall be approved by the competent authority or by a body designated by that authority.

When austenitic steels are used, the specified minimum values according to the material standards may be exceeded by up to 15% if these higher values are attested in the inspection certificate. The minimum values shall, however, not be exceeded when the formula given in 6.8.2.1.18 is applied.

Minimum shell thickness

6.8.2.1.17 The shell thickness shall not be less than the greater of the values determined by the following formulae:

$$e = \frac{P_T D}{2\sigma\lambda} \qquad\qquad e = \frac{P_C D}{2\sigma}$$

where:

e = minimum shell thickness in mm

P_T = test pressure in MPa

P_C = calculation pressure in MPa as specified in 6.8.2.1.14

D = internal diameter of shell in mm

σ = permissible stress, as defined in 6.8.2.1.16, in N/mm²

λ = a coefficient not exceeding 1, allowing for any weakening due to welds, and linked to the inspection methods defined in 6.8.2.1.23.

The thickness shall in no case be less than that defined in

	6.8.2.1.18 to 6.8.2.1.21.	~~6.8.2.1.18 to 6.8.2.1.20.~~
6.8.2.1.18	Shells of circular cross-section [2] not more than 1.80 m in diameter other than those referred to in 6.8.2.1.21, shall not be less than 5 mm thick if of mild steel [3], or of equivalent thickness if of another metal.	~~Shells shall be not less than 5 mm thick if of mild steel [3] (in conformity with the requirements of 6.8.2.1.11 and 6.8.2.1.12) or of equivalent thickness if of another metal.~~
	Where the diameter is more than 1.80 m, this thickness shall be increased to 6 mm except in the case of shells intended for the carriage of powdery or granular substances, if the shell is of mild steel [3], or to an equivalent thickness if of another metal.	~~Where the diameter is more than 1.80 m, this thickness shall be increased to 6 mm except in the case of tanks intended for the carriage of powdery or granular substances, if the shell is of mild steel [3] or to an equivalent thickness if of another metal.~~
		~~Whatever the metal used, the shell thickness shall in no case be less than 3 mm.~~

[2] *For shells not of a circular cross-section, for example box-shaped or elliptical shells, the indicated diameters shall correspond to those calculated on the basis of a circular cross-section of the same area. For such shapes of cross-section the radius of convexity of the shell wall shall not exceed 2 000 mm at the sides or 3 000 mm at the top and bottom.*

[3] *For the definitions of "mild steel" and "reference steel" see 1 2 1.*

"Equivalent thickness" means the thickness obtained by the following formula[4]:

$$e_1 = \frac{464e_0}{\sqrt[3]{(R_{m1}A_1)^2}}$$

6.8.2.1.19	Where protection of the tank against damage through lateral impact or overturning is provided according to 6.8.2.1.20, the competent authority may allow the aforesaid minimum thicknesses to be reduced in proportion to the protection provided; however, the said thicknesses shall not be less than 3 mm in the case of mild steel[3], or than an equivalent thickness in the case of other materials, for shells not more than 1.80 m in diameter. For shells with a diameter exceeding 1.80 m the aforesaid minimum thickness shall be increased to 4 mm in the case of mild steel[3] and to an equivalent thickness in the case of other metals.	~~Where protection of the tank against damage is provided according to 6.8.2.1.20, the competent authority may allow the aforesaid minimum thicknesses to be reduced in proportion to the protection provided; however, the said thicknesses shall be not less than 3 mm in the case of mild steel[3], or than an equivalent thickness in the case of other materials, for shells not more than 1.80 m in diameter. For shells of a diameter exceeding 1.80 m this minimum thickness shall be increased to 4 mm in the case of mild steel[3], and to an equivalent thickness in the case of other metals.~~
	Equivalent thickness means the thickness given by the formula in 6.8.2.1.18.	~~Equivalent thickness means the thickness given by the formula in 6.8.2.1.18.~~
	Except in cases for which 6.8.2.1.21 provide, the thickness of shells with protection against damage in accordance with 6.8.2.1.20 (a) or (b) shall not be less than the values given in the table below.	~~The thickness of shells with protection against damage in accordance with 6.8.2.1.20 shall not be less than the values given in the table below.~~

	Diameter of shell	≤ 1.80 m	> 1.80 m
Minimum thickness of shells	Stainless austenitic steels	2.5 mm	3 mm
	Other steels	3 mm	4 mm
	Aluminium alloys	4 mm	5 mm
	Pure aluminium of 99.80%	6 mm	8 mm

3 *For the definitions of "mild steel" and "reference steel" see 1 2 1*

4 *This formula is derived from the general formula:*

$$e_1 = e_0 \sqrt[3]{\left(\frac{R_{m0}A_0}{R_{m1}A1}\right)^2}$$

where

e_1 = *minimum shell thickness for the metal chosen, in mm;*

e_0 = *minimum shell thickness for mild steel, in mm, according to 6.8.2.1.18 and 6.8.2.1.19,*

Rm_0 = *370 (tensile strength for reference steel, see definition 1 2 1, in N/mm²),*

A_0 = *27 (elongation at fracture for reference steel, in %);*

Rm_1 = *minimum tensile strength of the metal chosen, in N/mm², and*

A_1 = *minimum elongation at fracture of the metal chosen under tensile stress, in %.*

Enclosure 2

ADR 2007

Part 9

Requirements concerning the construction and approval of vehicles

Section 9.7.6 Rear protection of vehicles

9.7.5 Stability of tank-vehicles

9.7.5.1 The overall width of the ground-level bearing surface (distance between the outer points of contact with the ground of the right-hand tyre and the left-hand tyre of the same axle) shall be at least equal to 90% of the height of the centre of gravity of the laden tank-vehicle. In an articulated vehicle the mass on the axles of the load-carrying unit of the laden semi-trailer shall not exceed 60% of the nominal total laden mass of the complete articulated vehicle.

9.7.5.2 In addition, tank-vehicles with fixed tanks with a capacity of more than 3 m^3 intended for the carriage of dangerous goods in the liquid or molten state tested with a pressure of less than 4 bar, shall comply with the technical requirements of ECE Regulation No. 111 [1] for lateral stability, as amended, in accordance with the dates of application specified therein. The requirements are applicable to tank-vehicles which are first registered as from 1 July 2003.

9.7.6 Rear protection of vehicles

A bumper sufficiently resistant to rear impact shall be fitted over the full width of the tank at the rear of the vehicle. There shall be a clearance of at least 100 mm between the rear wall of the tank and the rear of the bumper (this clearance being measured from the rearmost point of the tank wall or from projecting fittings or accessories in contact with the substance being carried). Vehicles with a tilting shell for the carriage of powdery or granular substances and a vacuum-operated waste tank with a tilting shell with rear discharge do not require a bumper if the rear fittings of the shell are provided with a means of protection which protects the shell in the same way as a bumper.

NOTE 1: *This provision does not apply to vehicles used for the carriage of dangerous goods in tank-containers, MEGCs or portable tanks.*

NOTE 2: *For the protection of tanks against damage by lateral impact or overturning, see 6.8.2.1.20 and 6.8.2.1 21 or, for portable tanks, 6.7 2.4.3 and 6.7 2.4.5*

9.7.7 Combustion heaters

9.7.7.1 Combustion heaters shall meet the requirements of 9.2.4.7.1, 9.2.4.7.2, 9.2.4.7.5 and the following:

(a) The switch may be installed outside the driver's cab;

(b) The device may be switched off from outside the load compartment; and

(c) It is not necessary to prove that the heat exchanger is resistant to the reduced afterrunning cycle.

In addition for FL vehicles, they shall meet the requirements of 9.2.4.7.3 and 9.2.4.7.4.

9.7.7.2 If the vehicle is intended for the carriage of dangerous goods for which a label conforming to models Nos. 1.5, 3, 4.1, 4.3, 5.1 or 5.2 is prescribed, no fuel tanks, power sources, combustion air or heating air intakes as well as exhaust tube outlets required for the operation of the combustion heater shall be installed in the load compartment. It shall be ensured that the heating air outlet cannot be blocked by cargo. The temperature to which the load is heated shall not exceed 50 °C. Heating devices installed inside the load compartments shall be designed so as to prevent the ignition of an explosive atmosphere under operating conditions.

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[1] *ECE Regulation No. 111. Uniform provisions concerning the approval of tank-vehicles of categories N and O with regard to rollover stability.*

Enclosure 3

ADR 1993

Marginal 10 220

10 220 (1) Rear protection of vehicls: A bumper sufficently resistant to rear impact shall be fitted over the full width of the tank at the rear of the vehicle. There shall be an clearance of at least 100 mm between the rear wall of the tank and the rear of the bumper (this clearance being measured from the rearmost point of the tank wall or from projecting fittings or accessoirs in the contact with the substance beeing carried). Vehicles with a tilling tank for the carriage of powdery or granular substances with rear discharge do not require a bumper if the rear fittings of the tank are provided with a means of protection wich protects the tank in the same way as a bumper.

NOTE 1: This provision does not apply to vehicles used for the carriage of dangerous goods in tank-containers.

NOTE 2: For the protection of tanks against damage by lateral impact or overturning, see marginal 211 127 (4) and (5).

(2) Vehicles transporting liquids having flash-point of 55°C or below or the inflammable substances of Class 2 as defined in marginal 2200 (3) shall, in addition, comply with the following requirements:

(a) Engines and exhaust systems

The engine propelling the vehicle and where applicable, the discharge pump, shall be so equipped and situated and the exhaust pipes so directed or protected as to avoid any danger to the load through heating or ignition.

(b) Fuel tanks

The fuel tanks for supplying the engine shall be so placed as to be protected so far as possible against any collision, and so that in the event of any leakage the fuel may drain directly to the ground. Fuel tanks shall in no case be placed immediatly above the exhaust pipe and tanks containing petrol shall be equipped with an effective flame-trap fitting the filler opening or with a closure with wich the opening can be kept hermetically closed.

Enclosure 4

TRANS/WP.15/R.430

Encl. 4

UNITED
NATIONS

E

Economic and Social Council

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TRANS/WP.15/R.430
6 March 1997

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ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

Working Party on the Transport
of Dangerous Goods
(Sixty-second session, agenda item 5 (b),
Geneva, 12-16 May 1997)

MARGINAL 10 220 (1)

Transmitted by the Government of Germany

Proposal: Amend marginal 10 220(1) to read as follows:

"(1) Rear protection of tanks

To protect tanks in rear-end collisions, the rear side of tanks must be provided with an adequately rigid bumper extending across the entire width and located above the underside of the tank. The distance between the rear end of the tank and the rear end of the bumper must be at least 100 mm (measured from the most rearward point of the tank end or the protruding accessory equipment that is in contact with the substance being transported). Vehicles equipped with rearwardly dischargable, tiltable containers for powdery or granular materials must not be provided with a bumper bar if the rear equipment of the container has protective facilities that protect the tank to the same extent as a bumper bar would.

GE.97-20587

Alternatively, tank protection could consist of a full-surface reinforced tank end, which could also be embodied as a double wall. The effect of this protective measure must correspond to at least that provided by a doubled wall thickness as per Marginal 211 127 (4). This can be verified by determining the specific work absorption capacity.

A combination of reinforced tank end and a bumper is possible following approval by the relevant authority."

Justification:

In its final summary report, the THESEUS research project refers to the extensive analyses performed and indicates that the rear tank ends of semitrailers are the main impact points in accidents (approx. 30%). Protection for this tank area was hitherto provided on the basis of the currently valid regulation which requires an "adequately rigid bumper". Because of the characteristic of tank ends, this measure does not provide complete protection because the bumper does not cover the complete end area so that it does not prevent impacting vehicles from coming into direct contact with the rear end of the tank.

In European practice this ADR requirement is interpreted differently. In some cases the rear underdrive protection required in Directive RL 70/221/EEC designed, for example, to protect passenger cars from underdriving tank vehicles in rear-end accidents, is considered to be a rear-end protection for tank vehicles as required by ADR.

The THESEUS study showed that for rear-end accidents at speeds of 10-30 km/h and realistic impact masses of 16-22 t, the rear-end impact protection is not always able to prevent tank failure. For example, in one rear-end collision the shaft of the windscreen wiper of the impacting vehicle penetrated the rear tank end. In order to improve the enclosing function of the tank, it is thus considered appropriate for safety reasons to directly protect the entire surface of the rear end of the tank. Particularly in the case of wall-thickness reduced tanks, this protective aim can be best achieved by means of a double wall. A large number of tests performed in Germany have shown the effectiveness of double walls in providing resistance against accident-like effects. A double wall provides protection for the whole surface of the tank end while a protective bumper together with a longitudinal reinforcement (reinforcement band) only provides zonal protection or serves as a (yielding) spacer

A double wall can absorb impact energy and keep away aggressively formed parts from the (inner) tank wall better than the bumper that has previously been required as a sole means of protection.

At this point reference is made to a rear-end accident that occurred on a German Autobahn. A double-decker bus impacted against the rear end of a semitrailer tank vehicle and its intermediate deck penetrated the rear tank end. A large number of passengers died. Even if this impact may have represented an extreme load for the tank, and it cannot be guaranteed that the enclosing function of the tank could have been maintained if the tank end had had a double wall, this incident does provide an indication of the real loads to which tank walls may be subjected. When a tank equipped with a double wall is subjected to such or similar loads it is better protected than a tank that is equipped with impact protection placed at the height of the lower tank area

For this reason it is recommended to have alternative approval for impact protection or double walls for tank ends.

Enclosure 5

TRANS/WP.15/1999/15/REV.1

Encl. 5

ECONOMIC COMMISSION FOR EUROPE
INLAND TRANSPORT COMMITTEE

Working Party on the Transport of Dangerous Goods
(Seventy-second session, Geneva, 13 - 17 May 2002)

TRANS/WP.15/1999/15/REV.1
Original: ENGLISH

PART 9 OF ADR

9.7.6 Rear Protection Of The Tank

Transmitted by the Government of Germany

SUMMARY	
Executive Summary:	Proposal for improvement of the rear protection of tanks
Action to be taken:	Amendment of section 9.7.6 (ADR)
Related documents:	TRANS/WP.15/1999/15, TRANS/WP.15/1999/48

Introduction

In some of the former sessions of ECE WP.15 amendments of the requirements for the rear protection of tanks have been discussed in order to achieve a better protection of the rear end of the tank. After that Germany announced a review of the discussed documents.

Proposal

Delete ~~Amend~~ Section 9.7.6 ~~to read as follows:~~
Amend new Section 6.8.2.1.29 to read as follows:

"Rear protection of tanks

The rear side of the tank shall be sufficiently protected against rear impact by a bumper, by other means of protection or by protection provided by the design of the tank.

The protective means shall provide protection over the full width of the tanks and shall be capable of absorbing a collision energy of at least 150 kNm without the tank sustaining any damage which would cause leakage. For the determination of the energy absorption capacity, the impact energy specified above shall be assumed as being equally distributed over the entire surface of the protective means.

Examples for appropriate protection by the design of the tank are

1.) Shell with a minimum thickness according to 6.8.2.1.17 respectively 6.8.2.1.18 (not reduced thickness) multiplied by factor 1.2.

or

2.) A double rear endwall consisting of an inner shell of at least the reduced thickness according to, the table in 6.8.2.1.19 and an outer shell with a thickness of at least 2 mm Steel respectively 3 mm Aluminium alloy. The distance between the two shells of a double wall should be at least 50 mm. [If in the final edition of EN 13094 a measure will be required for the distance between the two shells of a double wall reference should be made to this standard.]"

Justification

In its final summary report the THESEUS research project refers to the extensive analyses performed and indicates that the rear tank ends of semi-trailers are the main impact points in accidents (approx. 30 %). Protection for this tank area was hitherto provided on the basis of the currently valid regulation, which requires an "adequately rigid bumper". Because of the characteristic features of tank ends, this measure does not provide complete protection. Because the bumper does not cover the entire end area, it does not prevent impacting vehicles from coming into direct contact with the rear end of the tank

In European practice this ADR requirement is interpreted differently. In some cases the rear underdrive protection required in Directive RL 70/221/EEC, which is designed, for example, to prevent passenger cars from underdriving tank vehicles in rear-end accidents, is considered to be a rear-end protection for tank vehicles as required by ADR.

The THESEUS study showed that for rear-end accidents at a speed of 10-30 km/h and a realistic impact mass of 16-22 t the rear-end impact protection cannot always prevent tank failure. For example, in one rear-end collision the shaft of the windscreen wiper of the impacting vehicle penetrated the rear tank end.

The THESEUS summary report includes the results of an extensive analysis of a large number of accidents that have actually taken place. A figure under item 2,8 shows the distribution of impact points on a tank semi-trailer. The side impacting vehicles hit most frequently appears to be the rear tank end.

The purpose of the rear protection is to protect the tank from rear impact, so the right place for this requirement is not chapter 9.7 but chapter 6.8.

To underline the significance of this problem concerning the safety of tank transportation, we refer to a tragic accident on a German motorway several years ago. A double-decker coach hit the rear end of a tank semi-trailer loaded with fuel oil. The plate between the lower and the upper deck of the passenger compartment damaged the rear side of the tank. Parts of the tank contents reacted to form an aerosol and were distributed within the coach. The aerosol was ignited and the coach burnt out. Twenty members of a British military orchestra died.

It appears from the analysis results of the eight real vehicle/vehicle collisions involving a rear-end impact which were investigated within the framework of the THESEUS study that the entire rear-end wall is always endangered.

An evaluation of these eight tests was carried out to determine the energy absorption capacity of the tanks only. The respective values are given in table 4.9 of the final summary report. These values varying from 125 kNm to 185 kNm were determined at precise conditions (certain mass of the car, velocity etc.). The average value was approx. 150 kNm.

A special bumper, other means of protection or the design of the rear side of the tank itself should have an energy absorption capacity of 150 kNm to sufficiently protect the tank in a rear-end accident. The examples for appropriate protection by the design of the tank shall be deemed having an energy absorption capacity of at least 150 kNm.

In the case of a single not reduced wall (example 1.)) the factor 1.2 should be seen as an equivalent for the better absorption capacity of the double wall(example 2.)), where the space between the two walls is able to absorb energy and in addition by means of a certain redundancy with the second wall a higher safety can be achieved even if the total thickness of the double wall is the same as the thickness of the single wall .

It cannot be guaranteed, however, that the containment function of tanks capable of withstanding 150 kNm always remains unaffected, but many of the normal rear-end collisions would be covered.

For this reason and particularly with regard to standardization, it is recommended to have alternative means of impact protection for tank ends.

For constructions other than those of examples 1 or 2 efficiency of the rear protection may be proved by calculation or by performing a test.

Forces resulting from a crash onto the rear endwall will be led into the cylindrical part of the shell. This part has proved in several accidents to withstand this stress without failure (it may be deformed).

This proposal cannot be justified with a scientific cost-benefit analysis

However, Germany would like to point out that during a serious collision on a motorway near Munich in 1985, 25 people were killed and others seriously injured. A coach hit the rear end of a tank semi-trailer, which was driving more slowly. The rear end of the tank failed, the tank contents (kerosene) were spilled into the coach and ignited. This accident could have been avoided with better rear-end protection

Enclosure 6

TRANS/WP.15/2002/11

Encl. 6

E

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NATIONS

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27 February 2002

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INLAND TRANSPORT COMMITTEE

Working Party on the Transport
of Dangerous Goods
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Geneva, 13-17 May 2002)

PROPOSALS OF AMENDMENTS TO ANNEXES A AND B OF ADR

Part 9 of ADR

9.7.6 Rear Protection of the Tank

Submitted by the Government of Germany

SUMMARY

Executive Summary:	Proposal for improvement of the rear protection of tanks
Action to be taken:	Amendment of section 9.7.6 (ADR)
Related documents:	TRANS/WP.15/1999/15, TRANS/WP.15/1999/48

Introduction

In some of the former sessions of the Working Party, amendments to the requirements for the rear protection of tanks have been discussed in order to achieve a better protection of the rear end of the tank. After that, Germany announced a review of the discussed documents.

GE.02-

Proposal

Amend section 9.7.6. to read as follows:

"Rear protection of tanks

The rear side of the tank shall be sufficiently protected against rear impact by a bumper, by other means of protection or by protection provided by the design of the tank.

The protective means shall provide protection over the full width of the tanks and shall be capable of absorbing a collision energy of at least 150 kNm without the tank sustaining any damage which would cause leakage. For the determination of the energy absorption capacity, the impact energy specified above shall be assumed as being equally distributed over the entire surface of the protective means.

Examples for appropriate protection by the design of the tank are

1.) Shell with a minimum thickness according to 6.8.2.1.17 respectively 6.8.2.1.18 (not reduced thickness) multiplied by factor 1.2.

or

2.) A double rear endwall consisting of an inner shell of at least the reduced thickness according to, the table in 6.8.2.1.19 and an outer shell with a thickness of at least 2 mm Steel respectively 3 mm Aluminium alloy. The distance between the two shells of a double wall should be at least 50 mm. [If in the final edition of EN 13094 a measure will be required for the distance between the two shells of a double wall reference should be made to this standard.]"

Justification

In its final summary report the THESEUS research project refers to the extensive analyses performed and indicates that the rear tank ends of semi-trailers are the main impact points in accidents (approx. 30 %). Protection for this tank area was hitherto provided on the basis of the currently valid regulation, which requires an "adequately rigid bumper". Because of the characteristic features of tank ends, this measure does not provide complete protection. Because the bumper does not cover the entire end area, it does not prevent impacting vehicles from coming into direct contact with the rear end of the tank.

In European practice this ADR requirement is interpreted differently. In some cases the rear underdrive protection required in Directive RL 70/221/EEC, which is designed, for example, to prevent passenger cars from underdriving tank vehicles in rear-end accidents, is considered to be a rear-end protection for tank vehicles as required by ADR.

The THESEUS study showed that for rear-end accidents at a speed of 10-30 km/h and a realistic impact mass of 16-22 t the rear-end impact protection cannot always prevent tank failure. For example, in one rear-end collision the shaft of the windscreen wiper of the impacting vehicle penetrated the rear tank end.

Enclosure 7

TRANS/WP.15/2007/XXX

UNITED NATIONS

E

Economic and Social Council

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ECE/TRANS/WP.15/2007/XXX
xxxx August 2007

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ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

Working Party on the Transport of Dangerous Goods

Eighty-third session
Geneva, 5-9 November 2007

PROPOSALS FOR AMENDMENTS TO ANNEXES A AND B OF ADR

Sub-section 6.8.2.1.19

Rear End-Wall of Tanks

Transmitted by the Government of Germany

SUMMARY	
Executive Summary:	To ensure a sufficient protection of the tank contents, the rear end of tanks should not be designed in reduced wall thickness.
Action to be taken:	Amend 6.8.2.1.19 Delete 9.7.6

Introduction

9.7.6 of ADR requires a bumper for the protection of the tank. Various discussions about this provision have shown that there are many different interpretations and designs resulting from this requirement in the various contracting parties of ADR.

A broad consensus however exists on the purpose of the rear protection: It has to protect the tank respectively its contents. Consequently a provision concerning the tank should be placed in chapter 6.8 of ADR.

More over the requirement of a linear bumper prevents more protective designs as e.g. double end-walls or reinforced end-walls.

GE.07

Proposal

1. Delete 9.7.6

2. Amend at the end of 6.8.2.1.19:

Rear End-Wall
The rear end-wall of a shell shall have a minimum thickness according to 6.8.2.1.17 respectively 6.8.2.1.18 in any case.
Alternatively the rear end of a shell may be designed as a double rear end-wall consisting of an inner shell of at least the reduced thickness according to the table in 6.8.2.1.19 and an outer shell with a thickness of at least 2 mm steel respectively 3 mm aluminium alloy. The distance between the two shells of a double wall should be at least 50 mm.

NOTE 1: This provision (concerning rear end-walls) does not apply to vehicles used for the carriage of dangerous goods in tank-containers, MEGCs.

[NOTE 2: For the protection of tanks against damage by lateral impact or overturning, see 6.8.2.1.20 and 6.8.2.1.21.]

3. Amend a new transitional measure 1.6.3.22:

Fixed Tanks (tank vehicles) and demountable tanks not in conformity with the requirements of 6.8.2.1.19 applicable as from 1 January 2009 may continue to be used if they conform to the requirements of 9.7.6 of ADR applicable until 31 December 2008.

Justification
In its final summary report the THESEUS research project performed in Germany in the 1990th refers to the extensive analyses performed and indicates that the rear tank ends of semi-trailers are the main impact points in accidents (approx. 30 %). Protection for this tank area was hitherto provided on the basis of the currently valid regulation, which requires an "adequately rigid bumper". Because of the characteristic features of tank ends, this measure does not provide complete protection. Because the bumper does not cover the entire end area, it does not prevent impacting vehicles from coming into direct contact with the rear end of the tank.

In European practice this ADR requirement is interpreted differently. In some cases the rear underrun protection required in Directive 70/221/EEC, which is designed, for example, to prevent passenger cars from underrunning tank vehicles in rear-end accidents, is considered to be a rear-end protection for tank vehicles as required by ADR.

Therefore Germany proposes a requirement in chapter 6.8 of ADR that rear end-walls of shells must not be designed in reduced thickness.
Following this proposal to amend chapter 6.8, the provision in 9.7.6 may be deleted.

Safety: Safety will increase when the rear end-wall of tanks is build in non reduced thickness because the end of the tank is reinforced over its hole surface and not only in the region where a bumper is placed. Especially in those cases where the underrun protection according Directive 70/221/EEC is interpreted as to fulfill the requirement of 9.7.6 safety will increase because these protection is installed below the contour of the tank.

Feasibility: No problems.

Enforceability: Tanks and vehicles designed in conformity with the existing provision of 9.7.6 may continue to be used. However where an old tank with reduced thickness of the rear end-wall is fixed on a new vehicle, it has to be verified that the new vehicle is also in conformity with the requirements in 9.7.6 applicable until 31 December 2008.

Enclosure 8

ADR 2007

Sub-paragraph 1.8.5.4
Model for report on occurrences during the carriage of dangerous goods

In occurrences involving Class 7 material, the criteria for loss of product are:

(a) Any release of radioactive material from the packages;

(b) Exposure leading to a breach of the limits set out in the regulations for protection of workers and members of the public against ionizing radiation (Schedule II of IAEA Safety Series No. 115 – "International Basic Safety Standards for Protection Against Ionizing Radiation and for Safety of Radiation Sources"); or

(c) Where there is reason to believe that there has been a significant degradation in any package safety function (containment, shielding, thermal protection or criticality) that may have rendered the package unsuitable for continued carriage without additional safety measures.

NOTE: *See the requirements of 7.5.11 CV33 (6) for undeliverable consignments.*

Material damage or environmental damage means the release of dangerous goods, irrespective of the quantity, where the estimated amount of damage exceeds 50,000 Euros. Damage to any directly involved means of carriage containing dangerous goods and to the modal infrastructure shall not be taken into account for this purpose.

Involvement of authorities means the direct involvement of the authorities or emergency services during the occurrence involving dangerous goods and the evacuation of persons or closure of public traffic routes (roads/railways) for at least three hours owing to the danger posed by the dangerous goods.

If necessary, the competent authority may request further relevant information.

1.8.5.4 ***Model for report on occurrences during the carriage of dangerous goods***

Report on occurrences during the carriage of dangerous goods
in accordance with RID/ADR section 1.8.5

Carrier/Railway infrastructure operator: ....
Address: ....
Contact name: .... Telephone: .... Fax: ....

(The competent authority shall remove this cover sheet before forwarding the report)

1. Mode	
□ Rail Wagon number (optional)	□ Road Vehicle registration (optional) ....
2. Date and location of occurrence	
Year: .... Month:	Day: .... Time: ....
<u>Rail</u> □ Station □ Shunting/marshalling yard □ Loading/unloading/transhipment site Location / Country: .... or □ Open line: Description of line: .... Kilometres:	<u>Road</u> □ Built-up area □ Loading/unloading/transhipment site □ Open road Location / Country: ....
3. Topography	
□ Gradient/incline □ Tunnel □ Bridge/Underpass □ Crossing	
4. Particular weather conditions	
□ Rain □ Snow □ Ice □ Fog □ Thunderstorm □ Storm Temperature: ..... °C	
5. Description of occurrence	
□ Derailment/Leaving the road □ Collision □ Overturning/Rolling over □ Fire □ Explosion □ Loss □ Technical fault Additional description of occurrence:	

6. Dangerous goods involved						
UN Number [(1)]	Class	Packing Group	Estimated quantity of loss of products (kg or *l*) [(2)]	Means of containment [(3)]	Means of containment material	Type of failure of means of containment [(4)]

[(1)] For dangerous goods assigned to collective entries to which special provision 274 applies, also the technical name shall be indicated.

[(2)] For Class 7, indicate values according to the criteria in 1.8.5.3.

[(3)] Indicate the appropriate number
1 Packaging
2 IBC
3 Large packaging
4 Small container
5 Wagon
6 Vehicle
7 Tank-wagon
8 Tank-vehicle
9 Battery-wagon
10 Battery-vehicle
11 Wagon with demountable tanks
12 Demountable tank
13 Large container
14 Tank-container
15 MEGC
16 Portable tank

[(4)] Indicate the appropriate number
1 Loss
2 Fire
3 Explosion
4 Structural failure

7. Cause of occurrence (if clearly known)

□ Technical fault
□ Faulty load securing
□ Operational cause (rail operation)
□ Other:
....
....
....

8. Consequences of occurrence

Personal injury in connection with the dangerous goods involved:
□ Deaths (number: ......)
□ Injured (number: ......)

Loss of product:
□ Yes
□ No
□ Imminent risk of loss of product

Material/Environmental damage:
□ Estimated level of damage ≤ 50,000 Euros
□ Estimated level of damage > 50,000 Euros

Involvement of authorities:
□ Yes
  □ Evacuation of persons for a duration of at least three hours caused by the dangerous goods involved
  □ Closure of public traffic routes for a duration of at least three hours caused by the dangerous goods involved
□ No

If necessary, the competent authority may request further relevant information.