UNITED
NATIONS

E

Economic and Social Council

Distr.
GENERAL

TRANS/WP.15/1999/51
27 August 1999

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

Working Party on the Transport
of Dangerous Goods
(Sixty-seventh session,
Geneva, 8-12 November 1999)

PROPOSAL FOR AMENDMENTS TO ANNEXES A AND B OF ADR

Introduction of Alternative Arrangements in Connection with Protection against Damage

ADR Marginals 21x 100 and 21x 127 (5)

Transmitted by the Government of Germany

Proposal

1. Add the following text after the first sentence of marginal 21x 100:

   In recognition of scientific and technological advances, the technical requirements of this Appendix may be varied by alternative arrangements. These alternative arrangements shall offer a level of safety not less than that given by the requirements of this Appendix with respect to the compatibility with substances transported and the ability of the fixed tank (tank vehicle), demountable tank or battery-vehicle [tank-container] to withstand [impact, loading and fire] conditions. Alternative arrangement tanks shall be approved by the applicable competent authorities.

2. Delete paragraph 1. and 4. of marginal 211 127 (5) (b).

3. As a consequential amendment former paragraph 2. of marginal 211 127 (5) (b) shall be paragraph 1. and former paragraph 3. shall be paragraph 2., now.

4. Add a new paragraph to marginal 211 127 (5) (b) as follows:

   3. these shells or tanks (shells fitted with service and structural equipment) offer otherwise a level of safety not less than that given by the requirements of marginal 211 127 (3) referring to marginal 211 100. The assessment of the level of safety shall refer to a tank having basic properties as follows:

- Material: Reference mild steel,
- Wall thickness: 6 mm,
- Design pressure: 0.4 MPa,
- Capacity: $ 30 000 l,

- No strengthening members like partitions, surge plates, stiffening rings a.s.o.

and it shall result in a level of safety not less then 1.5 times the level of safety of the above-mentioned tank. This assessment shall be approved by the applicable competent authorities [or be related to standard EN XXXX:XXXX].

5. The last sentence in the present marginal 211 127 (5) (b) – “For demountable tanks this protection is not required when they are protected on all sides by the drop sides of the carrier vehicles.” – remains the last sentence in the new-worded marginal 211 127 (5) (b), too.

6. Add a new paragraph to marginal 212 127 (5) before 212 127 (6) as follows:

The protection referred to under (4) may also consist of shell or tank related measures leading to a level of safety not less than that given by the requirements of marginal 212 127 (3) referring to marginal 212 100. The assessment of the level of safety shall refer to a tank having basic properties as follows:

- Material: Reference mild steel,
- Wall thickness: 6 mm,
- Design pressure: 0.4 MPa,
- Capacity: $ 30 000 l,
- No strengthening members like partitions, surge plates, stiffening rings a.s.o.

and it shall result in a level of safety not less then 1.5 times the level of safety of the above-mentioned tank. This assessment shall be approved by the applicable competent authorities[or be related to standard EN XXXX:XXXX].

Justification

Where protection of the shell is provided, the required basic wall thickness of 6 or 5 mm related to mild steel may be reduced in the proportion to the protection provided (up to a maximum reduction of 2 mm related to mild steel - see marginal 21x 127 (3) and (4)). So, reduction of the wall thickness is permitted only if the remaining wall thickness and the protection added will reach an equivalent level of safety with regard to the safety level of the shell wall not being reduced, in principle. In other words, the combination of the remaining wall thickness with the protection added shall offer a level of safety not less than that given by the wall thickness not being reduced.

The decrease of the level of safety caused by the reduction of the wall thickness for tank-vehicles can be compensated completely only by double-wall designs of certain characteristics (vacuum-insulation or intermediate layer of solid materials - see marginal 211 127 (5) (b) 2. and 3. of the present ADR e.g.).

But, the material/wall thickness combination is only one important detail of the totality of measures influencing the overall level of safety of a certain kind of tank, as long as no real accident-proof tank is required, however. Among other things the level of safety depends as well on the

- choice of material and wall thickness,

- kind of additional protection

as on the

- accidental behaviour of the whole structure,
- effects of details of the design (equipment e.g.),

- quantity of the substances being released during an accident, probably,
- hazardous properties/characteristics of the substances being released

and even the

- level of safety of the vehicle (concerning tilt stability e.g.).

Therefore, the decrease of the level of safety caused by the reduction of the wall thickness may be compensated not only by tank wall related measures but also by measures increasing the structure of the whole tank, eliminating the effects of bad design and weak service equipment, completed by knowledge about the accidental behaviour of the whole tank and its components.

For tank containers some of these ideas had been taken up along time ago, already. For tank containers the loss of properties by the reduction of wall thickness may be compensated completely by double wall design on one hand, but by a certain level of the properties of the external structural equipment on the other hand. By means of this structural additional protection it will be avoided that global impact will affect the shell wall of the tank container severely (see marginal 212 127 (5)).

The basic principles of the above-mentioned solution have been taken over later on for tank-vehicles, also, but in contrast to the structural reinforcement of tank containers which is arranged separately from the tank shell itself, the structural protection of tank-vehicles is arranged inside or outside the tank shell, but in direct connection to it in any case. So, impact will affect the tank shell directly (see marginal 211 127 (5) (b) 1.). Insofar, the structural reinforcement of tank-vehicles does not work as good as the structural reinforcement of tankcontainers. Not only therefore the structural protection of tank-vehicles does not compensate the loss of properties of the shell wall by reduction of wall thickness completely.

Another kind of additional protection of tank vehicles is just as incomplete as the above-mentioned solution. The longitudinal additional protection (belly-belt) required in marginal 211 127 (5) (b) 4. leads only for a certain percentage of the shell area to a compensation of the loss of properties of the tank shell caused by the reduction of wall thickness. In this case, no additional structural protection has to be applied, in principle.

For tank-vehicles intended for the transport of similar quantities of dangerous goods showing identical hazards the application of the above mentioned different measures concerning additional protection result in different levels of safety of these tank-vehicles.

Against this background it is advisable to introduce a system which comprises all possibilities of compensation with regard to the reduction of wall thicknesses

- directly by increasing the properties of the tank shell,
- indirectly by increasing the level of safety of the whole tank.

Above-mentioned solutions which do not compensate the loss of properties of the shell wall concerning the reduction of the wall thickness completely may become part of measures to increase the level of safety of the whole tank.

The level of safety of the tank in a whole should be the directional aspect for safety evaluations of tanks in the future.

The basic level of safety should be indirectly defined by fixing a set of characteristics of a reference tank which could be looked at as a solution safe enough to be intended for the transport of a certain quantity of dangerous goods with certain hazardous properties.

The German proposal contains a solution, how the characteristics of a tank (showing a sufficient level of safety) could be fixed.

Thus follows, tanks may be put into service only, if they represent the same or a multiple level of safety like the level of safety of the reference tank, depending on the hazards of the substances to be transported and so on.

For the application of this procedure a method of assessment for levels of safety of transport tanks would be needed; a proposal for such a method can be found in the annex to this document.

As a consequence, furthermore the appendices B.1a and B.1b should contain only examples of fully compensating measures on one hand, and a new general requirement concerning the application of safety level related solutions based on the level of safety of a certain kind of reference tank on the other hand; all insufficient compensating measures should be deleted.

The German proposal has been worded bearing in mind all the above-mentioned aspects.

By the way, the procedure enclosed as annex to this document and based on a reference tank as defined in the German proposal has been applied already in Germany, successfully, for many years, so, the procedure really is applicable ensuring any kind of safety level required.

Based on the German proposal and the explanations given in the justification, a brief comment on the Italian document TRANS/WP.15/1999/33 shall be given:

The Italian proposal concerning additional protection of tanks with polycentric shape does not lead to complete compensation of the loss of properties of polycentric tanks caused by a reduction of wall thickness. Therefore, the Italian solution cannot be added to the remaining examples for additional protection in Appendix B.1a in the opinion of Germany. So, the Italian polycentric tanks should be subjected to an evaluation of their safety level by the method described in the annex to this document. If the result of this evaluation will show a sufficient level of safety, the requirements of the Appendix B.1a are fulfilled in the opinion of Germany and these tanks may be used unrestricted. No amendment to the Appendix B.1a will be necessary.

The presented method of assessment of the safety levels of transport tanks had been discussed during several meetings of the CEN/TC 296/WG 2. No decision on the matter was taken there. As a result of the discussions in CEN/TC 296/WG 2 it had been recommended to bring the proposed method to the audience of the WP.15 to decide on, in principle.

Therefore, Germany is asking WP.15 for a decision on the German basic proposal. In regard of the details of the method of evaluation respectively assessment of the safety levels of transport tanks the CEN/TC 296 shall decide on as before in the opinion of Germany. Besides, if the German proposals concerning the equivalent wall thickness formula, absolute minimum wall thickness and rear protection will be adopted by the WP.15, it may be necessary to revise the present details of the method, but this should be done by CEN/TC 296.

Annex

Safety levels of transport tanks
A method of assessment -

Summary presentation

1. Introduction

In the ADR, Annex B, Appendix B.1a and B.1b, Rn 21x 121 requires that tanks must withstand without loss of contents the static and dynamic stresses appearing under normal conditions encountered during transportation. No additional safety is required for stresses in excess of the ones specified (e.g. stresses under accident conditions). From this it is possible to derive a certain probability of tank failure in accident conditions. This is confirmed in practice.
In some cases the ADR may, for example, apply a higher calculation pressure in compliance with the special requirements for different classes (Part II of Appendix B.1a and B.1b) to provide for increased wall thicknesses that are suitable for accommodating increased stresses that exceed those encountered during normal operation. The protective measures used in conjunction with wall-thickness reduced tanks also have this purpose. Due to the various design requirements placed on differently applied ADR tanks, different tank categories also have different safety margins against real dangers and/or stresses. In this context, the various design types and - for wall-thickness reduced tanks - the alternative additional protective measures must be assessed in a correspondingly differentiated manner.

2. Principle of assessment

One method for making comparative, quantitative assessments of the enclosure safety of tanks is presented in the BAM "Research Report 203" under the heading of "Safety Levels of Transport Tanks". The principle of this concept will be presented here; for details please refer to the enclosure.

Commencing with the concept of the term "risk of the transport of dangerous goods" - which can be defined as the relationship between the frequency H with which a damage occurs (here tank failure) and the consequence K of the damage occurrence (here the extent of damage in correlation with the amount of hazardous material released) - risk can be generally expressed as:

$$R = H \cdot K.$$

The tank risk level with respect to design type and equipment are determine by the following influencing quantities to which the characteristic quantities f_x are assigned:

For factor H:

the specific energy absorption capacity of the tank wall = f_1
the global energy absorption capacity of the tank structure = f_2
the pressure-engineering tank design = f_3

For factor K: :

the probable amount of dangerous goods released during tank destruction, corresponding to the mean tank-compartment volume = f_4.

The principle upon which the assessment of tanks is based is a comparison of the respective risk values, whereby the reference or base level taken is the risk level of the so-called ADR reference tank, a cylindrical tank made of mild steel with a wall thickness of 6 mm.

3. Determining the risk values

In order to determine the characteristic quantities f_1, f_2, f_3 and f_4, safety-relevant properties of the tank to be assessed are compared with the properties of specially selected ADR-tanks. The ADR-tanks mentioned above determine the respective base or reference value used in this methodology (for example, the comparative quantity for characteristic quantity f_1 - the specific energy absorption capacity - is derived from the corresponding property of the base tank, 6 mm mild-steel tank, cylindrical form).

The dimensionless characteristic quantities f_1 through f_4 are inserted into the risk equation instead of H and K as follows:

$$R = H \cdot K = (f_1 + f_2 + f_3) \cdot f_4$$

The individual characteristic quantities are determined as follows:

Characteristic quantity $f_{1:}$

A comparative quantity is derived from the product of wall thickness, tensile strength and elongation at fracture; this quantity is then used to determine the energy absorption capacity.

For the reference tank is W^{++} = 60000:

$$f_1 = \frac{\text{comparative quantity } W^{++} \text{ of the tank}}{\text{comparative quantity } W^{++} \text{ of the reference tank}}$$

$$f_1 = \frac{e \cdot Rm \cdot A}{60\,000}$$

Where there are different wall thickness on a single shell element, f_1 is determined by means of a fictitious overall wall thickness derived by means of a superimposition method.

Characteristic quantity $f_{2:}$

The global energy absorption capacity of the tank is brought into a relationship with the existing global energy absorption capacity of the reference tank, the structurally reinforced cylindrical tank, the so-called "French tank“. The reference tank has a global energy absorption capacity of 70 kNm.

$$f_2 = \frac{\text{Global energy absorption capacity of tank}}{\text{Global energy absorption capacity of reference tank}}$$

$$f_2 = \frac{W_{glob}}{70}$$

The characteristic quantity f_2 is limited by an upper value of 1.4. At higher values the tank would be too rigid so that, for example, in an accident condition resulting in a tank overturn, the tank would be subjected to overly high local stresses.

Characteristic quantity $f_{3:}$

The characteristic quantity for the pressure-engineering design of the tank comprises 2 elements (summands). The summand f_{3Shape} takes into account the designed shape of the tank; because of its stress-optimised design, a cylindrical tank is assigned the value 0.5 while other tank design shapes get the value 0. The summand $f_{3Pressure}$ takes into account either the test pressure of the tank - from 4 bar onwards, $f_{3Pressure}$ = 0.5 - or the optimised design of the manhole covers under certain boundary conditions (e.g. leak-tightness after an overturn in conjunction with other requirements).

$$f_3 = f_{3Shape} + f_{3Pressure}$$

The maximum value of f_3 consequently calculates to 1.0. No comparison with another tank is made for characteristic quantity f_3.

Characteristic quantity $f_{4:}$

The mean tank-compartment volume (arithmetic mean of the gross volumina of all compartments) is used as a basis for evaluating the consequence. The mean compartments volume of the tank is placed in relation to the optimised tank-compartment volume of 7500 l. Because of its volume-dependence (x^3), the cube root of the quotient is calculated so that f_4 is determined directly:

$$f_4 = \sqrt[3]{\frac{\text{7500 litres}}{\text{Mean compartment volume of tank}}}$$

The above determined characteristic quantities f_1 through f_4 can now be inserted into the risk equation as follows:

$$R = (f_1 + f_2 + f_3) \cdot f_4$$

Due to the differing safety-engineering effectiveness of the individual tank engineering measures, which finally lead up to the characteristic quantities f_1 through f_4, the characteristic quantities are "weighted" separately.

Characteristic quantity	**Weighting factor**
f_1	4
f_2	2
f_3	1

Characteristic quantity f_4 requires no weighting because it solely and absolutely represents the consequence for the release of dangerous goods from the tank being assessed.
The above specified weighting factors are assigned to the characteristic quantities so that R_g is derived:

$$R_g = (4f_1 + 2f_2 + 1f_3) \cdot f_4$$

The final division by the sum of the weighting factors (equal to 7) delivers the normalised risk respectively safety level R_N:

$$R_N = \frac{R_g}{7}.$$

This risk level facilitates a safety-engineering comparison of the tanks with each other without absolutely determining the measure of acceptability of accident-like actions. Both

- the design types and
- the protective measures

of tanks are assessed in particular with respect to their function of securing the enclosure.

4. Example

The risk level R_N is to be determined for the base tank in compliance with ADR, Appendix B.1a, Rn 211 127 (3).

Tank form: Cylinder, without compartment partitioning,
Volume: 30,000 litres
Wall thickness e = 6 mm, test pressure 4 bar
Material: mild steel, Rm = 360 N/mm^2, A = 27 %
Global energy absorption capacity W_{glob}= 30 kNm

$$R_g = (4f_1 + 2f_2 + 1f_3) \cdot f_4$$

$$f_1 = \frac{e \cdot Rm \cdot A}{60000} = \frac{6 \cdot 360 \cdot 27}{60000} = 1$$

$$f_2 = \frac{W_{glob}}{70} = \frac{30}{70} = 0,4$$

$$f_3 = f_{3shape} + f_{3pressure} = 0,5 + 0,5 =$$

$$f_4 = \sqrt[3]{\frac{7500}{30000}} = 0,63$$

$$R_g = (4 \cdot 1 + 2 \cdot 0,4 + 1) \cdot 0,63$$

Rg = 3,65

$$R_N = \frac{Rg}{7} = \frac{3,65}{7} = 0,5$$

The comparable risk level of the base tank made of mild steel is 0.5.