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PROPOSALS FOR AMENDMENTS TO ANNEXES A AND B OF ADR

Background document concerning proposals by the Government of Germany for
Adequate Equivalence Minimum Wall Thickness Formula (TRANS/WP.15/1999/49)
Absolute Minimum Wall Thickness(TRANS/WP.15/1999/50)
Rear Protection of Tanks (TRANS/WP.15/1999/15)
Alternative Arrangements/Protection against Damage (TRANS/WP.15/1999/51)

Transmitted by the Government of Germany

1. Present ADR requirements for tanks

For transport of dangerous goods in tanks, especially substances presenting minor hazards, often tanks which do not reach a sufficient level of safety are very often used because of inadequate classification of substances on the one hand and inadequate technical tank requirements - independent from classification problems - on the other hand.

1.1 Classification of petrol (gasoline)

In the present ADR, annex A, marginal 2301 item 3 (b), substances, solutions and mixtures (such as preparations and wastes) having a vapour pressure at 50 °C of not more than 110 kPa (1.10 bar) are listed, inter alia:

1203 motor spirit, 1267 petroleum crude oil, 1863 fuel aviation, turbine engine,
1268 petroleum destillates, n.o.s. or 1268 petroleum products, n.o.s.

A note is added as follows:

While in some climatic conditions petrol (gasoline) may have a vapour pressure at 50 °C of more than 110 kPa (1,10 bar) but not more than 150 kPa (1,50 bar), it is to continue to be classified under this item number.

As far as known, petrol being used nowadays has a vapour pressure of more than 110 kPa (1,10 bar) below 50 °C already in general, sometimes even more than 150 kPa (1,50 bar) during wintertime. In other words, petrol is not classified in accordance with its real characteristics (physical properties); petrol should rather be listed in marginal 2301, item 2 (a) or (b).

Because of the inadequate classification of petrol, the particulars of marginal 21x 123 (1) and (2) have to be taken into account in the design of shells instead of those of marginal 21x 123 (3), subject to special requirements for substances of class 3 supplementing or modifying the general requirements. The wording of the paragraphs (1) and (2) is a follows:

(1) Gravity-discharge shells intended for the carriage of substances having a vapour pressure not exceeding 110 kPa (1,1 bar) (absolute pressure) at 50 °C shall be designed for a calculation pressure of twice the static pressure of the substance to be carried but not less than twice the static pressure of water.

(2) Pressure-filled or pressure-discharge shells intended for the carriage of substances having a vapour pressure not exceeding 110 kPa (1.1 bar) (absolute pressure) at 50 °C shall be designed for a calculation pressure equal to 1.3 times the filling or discharge pressure."

Therefore, substances such as petrol may be transported in “unpressurized” tanks although they should be transported in pressure tanks in accordance with their hazardous characteristics: requirements concerning construction, design and equipment for “unpressurized” tanks are inadequate for substances presenting petrol hazard characteristics.

It should also be mentioned that for sea transport (IMDG-Code) and according to the UN Model Regulations on the Transport of Dangerous Goods” tanks intended for petrol have to be pressure tanks with a minimum test pressure of 2.65 bar.

Therefore, from a safety standpoint, as recommended several times in the past, the Government of Germany considers that ADR requirements in that respect should be aligned on those of the UN Model Regulations.

To sum up the above-mentioned aspects:

Petrol as a substance being carried very frequently in road traffic is allowed to be transported in tanks having a level of safety not adequate for the hazardous characteristics of petrol.

1.2 Determination of minimum wall thicknesses

The determination of minimum wall thicknesses according to the requirements prescribed in marginal 21x 127 (2) results, for test and calculation pressures between 4 and 10 bar, in wall thicknesses of about 3 up to 5 mm and more related to mild steel. Nevertheless, a sufficient level of safety of the tanks against the effects of internal and external (accidental) loads should be ensured. This may be done by fulfilling the requirements laid down in the present marginal 211 127 (3), i.e. by defining absolute minimum thicknesses related to mild steel as follows:

The walls, ends and cover plates of shells of circular cross-section not more than 1,80 m in diameter shall not be less than 5 mm thick if of mild steel, 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, or to an equivalent thickness if the shell is of another metal. “Equivalent thickness” means the thickness obtained by the following formula:

$$e_1 = \frac{21{,}4 \cdot e_0}{\sqrt[3]{Rm_1 \cdot A_1}}$$

The above-mentioned formula - the so called “cubic root formula” - is inadequate in regard of internal or external loads affected to the tank shell (for details see section 2 of this document and the German proposal on the adequate equivalence minimum wall thickness formula, TRANS/WP.15/1999/49). Therefore, the main disadvantages of the cubic root formula are as follows:

Its application to metals with properties inferior to those of mild steel (e.g. aluminium alloys) results in thinner wall thicknesses than needed to cover the same amount of loads the equivalent shell made of mild steel is able to do.

Its application to metals with properties superior to those of mild steel (e.g.austenitic steels) results in thicker wall thicknesses than needed to cover the same amount of loads the equivalent shell made of mild steel is able to do.

This effect leads to a preferential use of aluminium alloys for concerning shells of unpressurized or low pressure tanks to get smaller tare weight tanks. On the other hand, tanks made of austenitic steels which are more suitable for the transport of dangerous goods from a safety standpoint, in principle, will not be used as often as it would be desirable because of their increased weight, as an effect of the application of the inadequate cubic root formula.

1.3 Reduction of wall thickness and additional protection

The above-mentioned figures for minimum wall thickness may be reduced to 2 mm related to mild steel, if additional protection compensating the loss of properties of the tank wall because of reduction of wall thickness is provided. In marginal 211 127 (5) (b) some examples of protectional measures are listed.

The application of these protectional measures does not compensate the loss of properties of the shell wall because of the reduction of the wall thickness completely in any case.

Complete compensation will be achieved if the measures referred to in marginal 211 127 (5) (b) 2. and 3. are applied. If the protectional measures of marginal 211 127 (5) (b) 1. and 4. are applied only partial respectively incomplete protection can be achieved (for details see the German proposal on alternative arrangements in connection with protection against damage, TRANS/WP.15/1999/51).

Because the measures referred to in marginal 211 127 (5) (b) 1. and 4. are easy to apply or part of structural design necessities as well as they are not as heavy as the other compensating measures, they will be applied very often especially for tanks intended for the transport of petroleum destillates and products.

1.4 Conclusion

Thus follows, tanks (shells) intended for the transport of dangerous substances, with test or calculation pressures up to 4 bar or even more

- may be designed on an inadequate basis (cubic root formula), if aluminium alloys instead of mild steels or austenitic steels are used;

- may be fitted with insufficient additional protection, although the reduction of wall thickness should be compensated completely.

Additionally, tanks intended for the transport of petrol

- ought not to be designed in relation to a pressure vessel code (this permits the application of insufficient construction, design and equipment requirements) because of an inadequate classification of the substance.

This evaluation of the present ADR requirements concerning some aspects of the level of safety of the transport of dangerous goods in tanks will be supported by accident statistics and the results of a research project.

2. Accident evaluation and results of investigations

By letter of 17 December 1996, the final report on the research project THESEUS (Tankfahrzeuge mit höchst erreichbarer Sicherheit durch experimentelle Unfallsimulation = Tank-vehicles with maximum attainable safety through experimental accident simulation) was sent in English to Contracting Parties.

A summary of the THESEUS-report was given already in the German documents TRANS/WP.15/R.433 and INF.32 submitted to the 62nd session of the Working Party, starting the discussions on the matter in the meantime. The very interesting results should be repeated, now, because the results of the THESEUS report leads to a confirmation of the matters being described in section 1 of this document on the one hand and possible solutions for some problems the German proposals noted in the headline of this document on the other hand.

Results and conclusions of evaluations and investigations in brief are as follows:

The main kinds of stress on tanks during accidents involve locally and globally caused stresses. Where stresses are caused locally by aggressively shaped parts, the absolute failure limit is determined by the strength parameters of the material. Where stresses are introduced globally, failure mainly occurs where differences in stiffness (e.g. tank ends, internal or external reinforcement rings or welded reinforcement belts) impede deformation. It is only in these areas that stresses comparable with the material-strength parameters occur. Considerable material abrasion through skidding of tank vehicles on the road surface was not observed. Because of their low melting point, aluminium alloys, unlike steel, imply the danger of damage to the tank due to thermal stress through any type of fire.

The test performed show that the “cubic root formula” to be applied for determining wall thicknesses of tanks having material characteristics different to those of mild steel does not lead to tank designs with equivalent safety.

Thus when a liquid filled tank made of mild steel with a wall thickness of 4.4 mm is subjected to an area-type introduction of stress, as used in present tests, it has a failure limit that is 6 times higher than that of a tank with the same design but made of an aluminium alloy with a wall thickness of 6,3 mm. Increased strength parameters and better deformation behaviour of mild steel lead to the above-mentioned result.

A comparison between static impact penetration tests and energy-equivalent drop tests showed that material characteristics basically do not change during a dynamic drop, i.e. it can be assumed a similar failure mechanism. But, under these conditions, the failure force is reached with a much smaller deformation, the energy-absorbing capacities are lower. In the case of local stresses, the energy absorbing capacity determined in static tests is therefore not completely suitable for specifying failure behaviour. Taking into account all results obtained in accident situations, crash simulations, impact penetration and drop tests with tanks and tank components that were evaluated within the framework of the THESEUS project, failures of tanks made of aluminium alloys (additionally protected following marginal 211 127 (5) (b) 4.) were compared with those of a tank made of stainless steel which, according to existing design criteria (see marginal 211 127 (5) (b) 3.), is considered to be equivalent in terms of safety. For this purpose, 23 suitable accidents registered in the documents were selected from the total of all accidents involving a release of dangerous substances. Using a suitable evaluation scale, it was found that, if a 3 mm thick stainless-steel tank had been used, a failure would not have occurred in 8 of these accidents and would probably not have occurred in a further 5 of these accidents. Therefore, a stainless-steel tank with a wall thickness of 3 mm can be considered a safer tank for the transport of class 3 dangerous goods by road, than a 5,2 mm aluminium alloy tank.

An examination performed on a tank internally coated with an elastomeric material showed no improved protection against stresses resulting from aggressively shaped parts.

The failure behaviour of a certain tank design including weld seams, dome lids etc. cannot be expressed in a formula. In order to prove the suitability under these conditions, a representative section of a particular tank should be subjected to a drop test that causes an energy input equivalent to the energy introduced in the crash and rollover simulations that were carried out. Alternatively, a method for the evaluation of the levels of safety of different tank designs should be developed.

According to statistical surveys conducted within the framework of accident analysis and on the basis of experimental accident simulations, in the case of collisions between similar parties an average force of F = 400 kN can be assumed which will affect the tank walls (shells). However, this average force provides no indication of failure under more severe accident conditions (if the vehicle turns over and or encounters an object with a shape aggressive structure e.g.). In this case, the present ADR-values specified for the shell thicknesses of tanks for which the wall thickness may be reduced would be inadequate.

3. Improvement of the current ADR requirements for tanks

In regard of the above-mentioned evaluation of the present regulations and the conclusions drawn from the results of investigations it would be possible to use accident stresses which should be taken into account as penetration loads, bending moments and deformation work up to the failure limits of shells as a basis for determining the minimum wall thickness of shells instead of just using the elastic deformations encountered under service conditions only (which seemed to be the basis for the cubic root formula).

However, the determination of a suitable wall thickness/material relation may be the most important feature to reach a certain level of safety, but, it is not as yet possible to evaluate the overall safety of tanks having complicated designs, completely.

Therefore, it is necessary to introduce a suitable formula, which allows to apply the basic 6 mm/mild steel - requirement e.g. as an adequate level of safety for other metals than mild steel, primarily.

The German proposal concerning an adequate equivalence minimum wall thickness formula (TRANS/WP.15/1999/49) deals with the subject; details of the development of this formula are shown and explained there.

The same amount of attention should be drawn to protectional measures:

Only additional protection which compensates the loss of properties of a shell wall, completely, if its wall thickness is reduced, should be applied. If no complete compensation is obtained, a risk evaluation concerning the overall level of safety of the tank should have to be carried out, which should result in an equal level of safety - compared with a tank representing a basic level of safety - at least. The German proposal (TRANS/WP.15/1999/51) on alternative arrangements in connection with protection against damage deals with the possibilities to proceed in this way. Details and explanatory notes are given in the proposal itself, added by some remarks concerning the Italian proposal on polycentric tanks (see TRANS/WP.15/1999/33).

Nevertheless, although the application of an alternative formula following the laws of mechanics and of suitable alternative arrangements in the above-mentioned sense would ensure a sufficient level of safety, in principle, some aspects of minor importance should be observed.

The use of highly developed materials with increased strength characteristics may lead to very thin wall-thicknesses. Although accidental loads would be covered, some problems concerning service conditions may arise with respect instability problems like buckling or of the effects of fatigue because these problems are not only related to strength parameters. Therefore, absolute minimum wall thicknesses for different materials should be fixed. Insofar, Germany supports the French/Spanish efforts transmitted to the Working Party already with document TRANS/WP.15/1999/13, but, the minimum values (figures) presented in that paper should be increased a little for some materials, in the opinion of Germany. So, Germany transmits a modified proposal on absolute minimum wall thicknesses in the light of the Spanish ideas.

To round up the shell related safety aspects not being dealt with, finally, Germany would like to draw the attention to the proposal concerning rear protection of tanks, again (see TRANS/WP.15/1999/15).

As before, Germany is of the opinion, that rear protection of tanks is needed for the safety reasons explained in the justification to the above-mentioned proposal, in principle. But, if the German proposals on the adequate equivalence minimum wall thickness formula, absolute minimum wall thicknesses and alternative arrangements in connection with protection against damage is adopted by the Working Party, the rear protection problem may be solved partially, at least. So, Germany would like to postpone the decision on the proposal concerning rear protection, at the moment, until decisions on the other proposals are taken.

Final remark:

In the opinion of Germany, an adequate level of safety with respect to the different hazardous properties of the substances being transported in tanks can be ensured by means of a systematic approach, if the above-mentioned German proposals is adopted by the Working Party, bearing in mind that a minimum level of safety concerning release of contents from a tank carrying dangerous goods during an accident is necessary. Many of the problems related to the classification of some products and requirements resulting from the historical background of the transport of dangerous goods in tank-vehicles can be solved. Harmony with the IMO requirements and the UN Recommendations should be achieved, as far as the basic level of safety for tanks intended for the transport of dangerous goods is concerned and, last but not least, scientific and technological progress should be supported.