Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Dangerous Goods

Ninety-eighth session
Geneva, 4-7 May 2015
Item 6 (a) of the provisional agenda
Proposals for amendments to annexes A and B of ADR: construction and approval of vehicles

30 April 2015

Safety considerations in the use of liquefied petroleum gas (LPG) as fuel for vehicles carrying dangerous goods: Response ECE/TRANS/WP.15/2015/INF.4 (Germany)

Transmitted by AEGPL

Summary

Executive summary: AEGPL advocates the use of LPG (liquefied petroleum gas) as a fuel in vehicles for the transport of dangerous goods and the inclusion of suitable provisions in the text of ADR. The detailed concerns of Germany and Sweden shall be addressed to support its additional effort with NGV Global to allow CNG and LPG as per TRANS/WP.15/2015/6. This document addresses the questions for LPG only.

Action to be taken: consider.

Related documents: ECE/TRANS/WP.15/2014/2 and related informal documents
ECE/TRANS/WP.15/2015/6
ECE/TRANS/WP.15/224, paragraphs 31 to 35
ECE/TRANS/WP.15/226, paragraphs 27 and 29

Introduction

1. In the past two sessions the introduction of gaseous fuels has been discussed. Notwithstanding the information already provided by the associations advocating the use of these fuels, some questions arose during the discussion.

2. The interaction of the fuel with the load or the structure of the tank and vehicle both in leakage and fire conditions were of concern. It was also wished that the behaviour of pressure relief mechanisms and their protection against failure are explained in more detail.

3. In the following the subjects as identified through the questions brought forward by the representatives of the contracting parties are addressed and the information provided.

Detailed Justification

General

4. The term container is used to create consistency with UN/ECE Regulation Nr. 67-01 and to avoid confusion with the terms tank and cylinder as enclosures for the transport of dangerous goods.

5. As ADR does not consider accidents, “normal operation conditions of the vehicle” shall be assumed. This takes into account normal driving conditions and inclination angles up to those specified as stability requirements in ECE Regulation No. 111. Nevertheless, accident induced stresses such as impact and fire shall be taken into account for the fuel system.

6. The applicability of LPG as a fuel for the transport of dangerous goods shall be limited to FL and OX vehicles leaving out EX classes.

Pressure relief valve and routing of efflux

7. The pressure relief valve (PRV) is of central importance for the safety of the gaseous fuel container. Its function needs to be ensured even in the event of an accident. The positioning of the PRV itself as well as the routing of the efflux are two essential items in order to successfully dissipate the energy absorbed through an external fire.

8. In those cases where the orientation of the PRV opening is such that a direction toward the load or hot parts of the vehicle cannot be excluded, a gas tight housing according to 6.15.12 ECE Regulation No. 67-01 and corresponding discharge piping shall be used in order to direct the discharge efflux from the PRV to a safe position on the vehicle.

- Opening of the gas tight housing and the inner diameter of the discharge pipe shall have a free cross section of at least 450 mm^2.
- Gas tightness is tested at 10 kpa to prevent leakage in case of discharge and maintain desired routing through discharge pipe.
- The gas tight housing is designed to withstand a pressure of 50 kpa granting it gas tight even under demanding discharge conditions but letting it fail in case of blockage of the discharge pipe and subsequent blockage of flow.

9. As ECE Regulation No. 67-01 does not contain specific requirements regarding the interaction with dangerous goods, the correct orientation respective the suitability of the discharge piping shall be evaluated when approving the entire vehicle.

Mitigation of the influence of fire on LPG fuel container

10. In order to correctly mitigate the risks associated when pressure vessels containing liquefied gases under pressure, the fuel tank designs are tested in fire conditions. The requirements for this external fire (bonfire) test are laid down in Annex 10, R.67-01 as follows:

- The container - filled to 80 % - is subject to direct flame impingement from a uniform fire source of at 1.65 m length with a temperature of at least 590 °C.
- The tank shall not burst. The tank shall relieve internal pressure by discharging in a controlled manner as described by the manufacturer. Composite containers may discharge through their surface in a controlled manner.
- The pressure shall never rise above 136 % of the PRV set pressure (2,700 kpa).

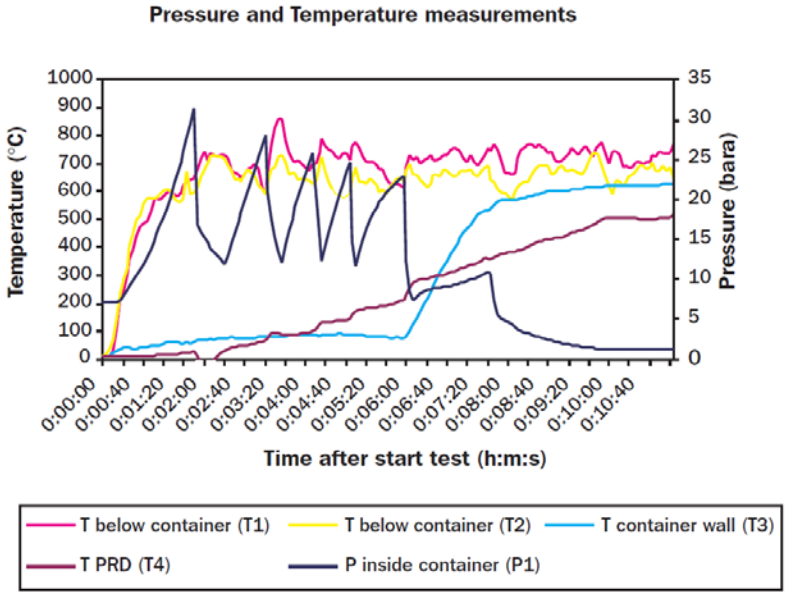

Fig. 1 Pressure and temperature measurements

11. The bonfire test is performed for each container type approval. Only similar containers are gathered under one type approval. The test results therefor always remain relevant.

12. Tests performed by TNO for 10 different container manufacturers1 indicate that the design criteria in R.67-01 Annex 10 are sufficient to successfully prevent the bursting of containers even in fully engulfing pool fires. The following charted values indicate how the efflux of the evaporating fuel cools the container sufficiently until nearly no more liquid phase is left. After reaching a set temperature, the PRD (pressure release device, usually a

[1] Bonfire test LPG automotive container (R67-01), TNO
http://www.wvm.nl/phocadownload/LPG/2010-02-en-tno-bonfiretest%20lpg%20automotive%20container.pdf

fusible plug) irreversibly opens a passage to the interior, thereby preventing bursting of the container after all liquid phase has been expended.

Fig. 2 Activation of PRV in four steps

13. The intensity of the test covers the possible scenarios

- Pool fire (liquid fuel under vehicle)
- Engine fire
- Tire fire

and therefore most possible fire related incidents.

Impact resistance

14. In order to prove resilience to collisions, tanks are fastened to the vehicle to withstand accelerations of at least 6.6 g in the direction of travel and 5 g horizontally perpendicular to the direction of travel. For lighter vehicle classes higher accelerations must be

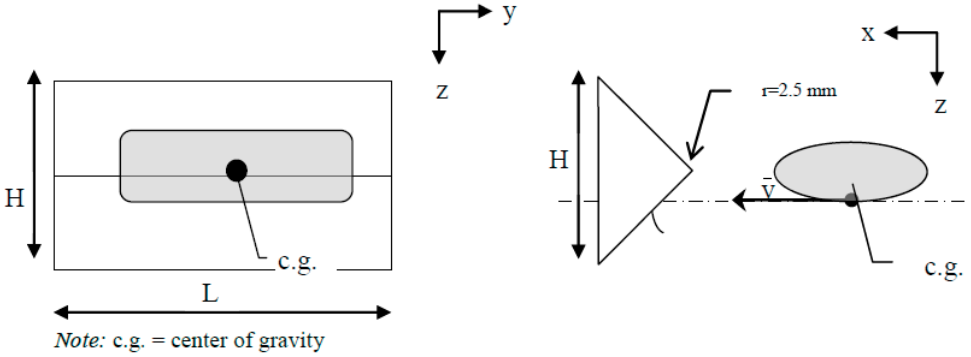

Fig. 3 Impact test arrangement

demonstrated.

15. The container shall be subject to an impact test in which the container filled to its nominal capacity with a fluid of similar density impacts a wedge shaped barrier at 50 km/h. The test is performed for each position in which the container is installed in the vehicle as to be representative.

16. The container must preserve its leak tightness after the impact test in order to prevent leaks from occurring after collisions.

17. The fastening requirements in combination with the impact and drop test (with subsequent pressure cycling) ensure that the container is built to withstand extreme loads and stresses from possible accidents like collisions or explosions. This resilience is necessary to obtain approval.

Interaction with the load (chemical reaction and cooling)

18. When leaking in gaseous state, LPG quickly arrives at ambient temperature having little to no cooling effect due to the relatively low specific heat capacity in gaseous state. The Joule-Thomson effect is not pronounced as the initial gas pressure is low.

19. The gaseous phase will show no reactivity with other chemicals. Saturated aliphatic hydrocarbons, contained in LPG, may be incompatible with strong oxidizing agents like nitric acid. Charring may occur followed by ignition of unreacted hydrocarbon and other nearby combustibles. In other settings, mostly unreactive. Not affected by aqueous solutions of acids, alkalis, most oxidizing agents, and most reducing agents.2

20. The container is subject to an acid environment test3 in which a finished container is exposed for 100 hours to a 30 % sulphuric acid solution (battery acid) while pressurized to 3,000 kPa. During the test, a minimum of 20 per cent of the total area of the container has to be covered by the sulphuric acid solution. After which it must still reach 85 % of the original burst pressure.

21. For the very unlikely event of the rupture of an LPG fuel container with subsequent large leakage of LPG in its liquid phase, the effects of it coming directly in contact with other substances and the structure of the vehicle and the enclosure of the load need to be taken into account.

22. For the impinging of the structure and the enclosure of the dangerous goods, the cooling effect the cryogenic liquid has, must be taken into account.

23. The rapid cooling of metals, most prominently steel lead to an embrittlement of the material and may severely reduce the amount of stress the structure made of this material may support. This applies to structural elements as well as pressure vessels. The general behaviour of the

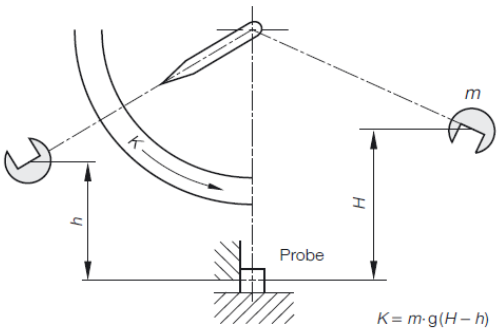

Fig. 4 Charpy test rig

[2] Source http://cameochemicals.noaa.gov/chemical/987

[3] 2.10 Annex 10 ECE Regulation No. 67-01

materials is tested with a Charpy test rig (see fig. 4[4]), in which a pivoted weight impacts a specimen at the lowest point of its path. After impact the weight completes its swing and its maximum deflection indicates how much energy absorption potential the specimen had remaining after impact at a given temperature tested.

24. Charpy tests for traditional welding steels indicate a pronounced drop at a transition temperature below which only a fraction of the original resilience can be expected from the material. (fig. 5)

25. The transition temperature for ductile steel materials is found around -50 °C at a sufficient temperature distance to the evaporation temperature for LPG. Most materials suited for temperatures up to -20 °C will show sufficient residual resilience at -40 °C.

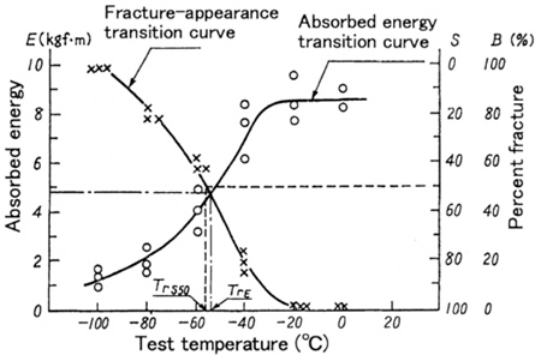

Fig. 5 Typical transition temperature curves of a carbon or low alloy weld metal

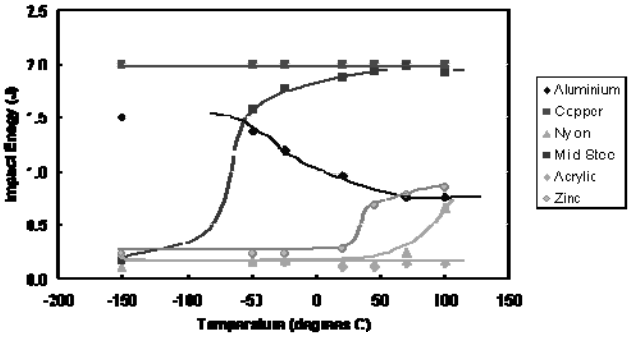

Fig. 6 Charpy test results for different materials

Mitigation of the effects of leakages in the fuel system

26. Fuel systems may consist of

- Tank (one or more tanks or tank bundles)
- Single fuel line (some cases return line)
- Vaporiser / regulator with shutoff solenoids
- (in some cases separate shutoff solenoids are used)
- Injectors (or other methods of metering / needlevalve)

[4] Bargel/Schulze Werkstoffkunde

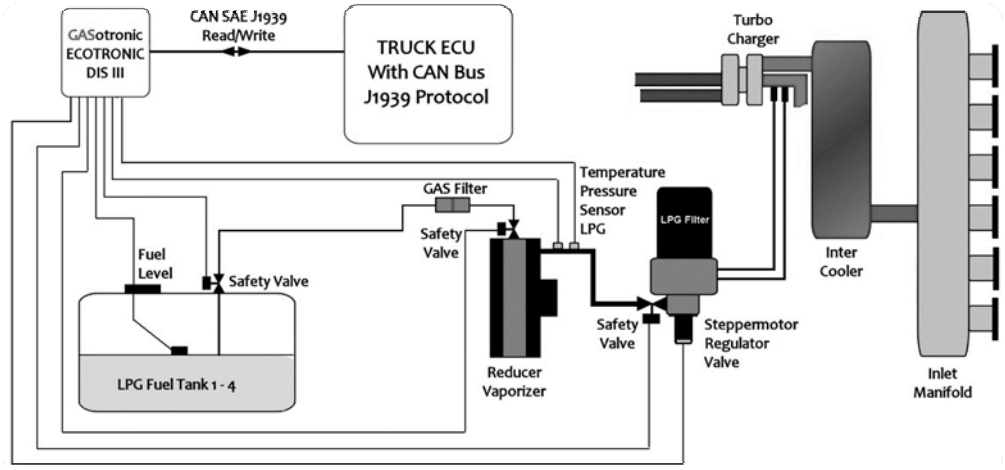

Fig. 7 Schematic of a dual fuel system

- Electronic controls (ECU, sensors etc.)

27. Fuel systems and engine injection system have safety barriers such as a remote shut off valve combined with an excess flow valve to prevent outflow of gas from the tank when system integrity is compromised. Further safety valves are located at the inflow of the vaporiser/regulator and of the metering system.

28. The total content of gaseous fuel downstream of the remote shut off valve in the tank is very small, usually less than 1.5 litres in total. The risk from the fuel contained in equipment beside the fuel container itself is relatively low. Special measures are not needed.

29. Prescriptions made in 9.2.2 ADR for electrical equipment apply to all electric and electronic equipment in an LPG system. As a type approval according to ECE Regulation No.67-01 does not encompass the requirements out of 9.2.2, a separate test according to these requirements is needed.

Additional Requirements (refuelling / firefighting / marking)

30. Refuelling is simple and can be performed with much lower venting losses as the gaseous fuel system is closed and pressurised. Refuelling systems for LPG are standardised according to CEN standards for LPG dispensers (EN 14678-1), LPG fuel stations (EN 14678-3) and refuelling nozzles for LPG (EN 13760). Although different connector contours are possible depending on the market (as specified in ECE-Regulation No. 67-01, Annex 9), each contour is unique and cannot be mistakenly connected to another fuel. The use of adapters when crossing borders needs to be executed with care.

31. In order to alert firefighting crews of the presence of a gaseous fuel employed on the

Fig. 8 LPG sign

vehicle itself, the vehicle can be marked additionally with signage according to ECE Regulation No. 67-01 (see fig. 6).

32. The sign consists of a sticker which shall be weather resistant. The colour and dimensions of the sticker shall fulfil the following requirements:

Colours:	Dimensions
Background: green	Border width: 4 - 6 mm
Border: white or white reflecting	Character height: ≥ 25 mm
Letters: white or white reflecting	Character thickness: ≥ 4 mm
	Sticker width: 110 - 150 mm
	Sticker height: 80 - 110 mm

The word "LPG" shall be centred in the middle of the sticker.

33. For small fires, CO2 or dry chemical fire extinguishers of small size are enough.5 The equipment found on vehicles for the transport of dangerous goods are deemed sufficient. Larger fires require the assistance of specialist crew. Leaking LPG fires are not to be extinguished unless the leak can be stopped.

34. Larger fires must be treated with special care, refer to specific guidelines (i.e. Guide 115, see Annex)

[5] http://cameochemicals.noaa.gov/erg_guides/Guide_115.pdf

Annex

GUIDE 115 — GASES - FLAMMABLE (INCLUDING REFRIGERATED LIQUIDS) — ERG2012

POTENTIAL HAZARDS

FIRE OR EXPLOSION

- **EXTREMELY FLAMMABLE.**
- Will be easily ignited by heat, sparks or flames.
- Will form explosive mixtures with air.
- Vapors from liquefied gas are initially heavier than air and spread along ground.

CAUTION: Hydrogen (UN1049), Deuterium (UN1957), Hydrogen, refrigerated liquid (UN1966) and Methane (UN1971) are lighter than air and will rise. Hydrogen and Deuterium fires are difficult to detect since they burn with an invisible flame. Use an alternate method of detection (thermal camera, broom handle, etc.)

- Vapors may travel to source of ignition and flash back.
- Cylinders exposed to fire may vent and release flammable gas through pressure relief devices.
- Containers may explode when heated.
- Ruptured cylinders may rocket.

HEALTH

- Vapors may cause dizziness or asphyxiation without warning.
- Some may be irritating if inhaled at high concentrations.
- Contact with gas or liquefied gas may cause burns, severe injury and/or frostbite.
- Fire may produce irritating and/or toxic gases.

PUBLIC SAFETY

- **CALL EMERGENCY RESPONSE Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- As an immediate precautionary measure, isolate spill or leak area for at least 100 meters (330 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind.
- Many gases are heavier than air and will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Keep out of low areas.

PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Structural firefighters' protective clothing will only provide limited protection.
- Always wear thermal protective clothing when handling refrigerated/cryogenic liquids.

EVACUATION

Large Spill

- Consider initial downwind evacuation for at least 800 meters (1/2 mile).

Fire

- If tank, rail car or tank truck is involved in a fire, ISOLATE for 1600 meters (1 mile) in all directions; also, consider initial evacuation for 1600 meters (1 mile) in all directions.

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ERG2012

GASES - FLAMMABLE (INCLUDING REFRIGERATED LIQUIDS)

GUIDE 115

EMERGENCY RESPONSE

FIRE

- **DO NOT EXTINGUISH A LEAKING GAS FIRE UNLESS LEAK CAN BE STOPPED.**

CAUTION: Hydrogen (UN1049), Deuterium (UN1957) and Hydrogen, refrigerated liquid (UN1966) burn with an invisible flame. Hydrogen and Methane mixture, compressed (UN2034) may burn with an invisible flame.

Small Fire

- Dry chemical or CO_2.

Large Fire

- Water spray or fog.
- Move containers from fire area if you can do it without risk.

Fire involving Tanks

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Do not direct water at source of leak or safety devices; icing may occur.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

SPILL OR LEAK

- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- If possible, turn leaking containers so that gas escapes rather than liquid.
- Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material.
- Do not direct water at spill or source of leak.
- Prevent spreading of vapors through sewers, ventilation systems and confined areas.
- Isolate area until gas has dispersed.

CAUTION: When in contact with refrigerated/cryogenic liquids, many materials become brittle and are likely to break without warning.

FIRST AID

- Move victim to fresh air.
- Call 911 or emergency medical service.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Remove and isolate contaminated clothing and shoes.
- Clothing frozen to the skin should be thawed before being removed.
- In case of contact with liquefied gas, thaw frosted parts with lukewarm water.
- In case of burns, immediately cool affected skin for as long as possible with cold water. Do not remove clothing if adhering to skin.
- Keep victim warm and quiet.
- Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves.