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Working Party on the Transport of Dangerous Goods

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

Additional information for ECE/TRANS/WP.15/2014/16 – Use of Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) as fuel for vehicles carrying dangerous goods

Transmitted by AEGPL

Summary

Executive summary:	Gaseous fuels (CNG, LNG and LPG), either in combination with diesel fuel (dual fuel) or used separately are currently being used as alternative fuels for heavy goods vehicles. The operational safety is maintained through the application of the respective ECE Regulations No. 67 and additional requirements taking into account the special conditions applying to the transport of dangerous goods. This document aims to showcase the possible risks associated with the operation of such vehicles and how the regulations aid to mitigate these risks when applied properly.
Action to be taken:	Discussion on the topic, amendment of 9.3.4.4 to include LPG referencing the respective ECE Regulations
Reference documents:	Working Document 16 (ECE/TRANS/WP.15/2014/16)

Introduction

In Working Document 16 – "Use of Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) as fuel for vehicles carrying dangerous goods" AEGPL and NGV Global propose the amending subsection 9.3.4.4 introducing compressed natural gas (CNG) and liquefied petroleum gas (LPG) as fuels alongside liquefied natural gas (LNG) as per the proposal in the working document. This document refers to the safety aspects of LPG.

The introduction of new fuels with different physical and technical characteristics requires an assessment of the different risks associated with the use of the specific fuel. This document will attempt to highlight the differences between LPG and the standard diesel fuel.

Summary of the safety aspects of LPG fuel

LPG is gaseous at ambient pressure and temperature but can be liquefied under moderate pressure. Although it has a relatively low flash point (-104° C), LPG exhibits an auto-ignition temperature of at least 450° C, generally higher. In the absence of a qualified source of ignition, the auto-ignition temperature becomes a more suitable indicator for the probability of a fire as different hot parts of the vehicle may provide a suitable source of ignition. In case of a potential leak the risk of ignition of the gaseous fuels by a hot vehicle part is lower than with diesel.

Because of their physical properties gaseous fuels will be dispersed in the air fairly quickly and the concentration will rapidly drop below the lower explosion limit. Unlike for liquid fuels, no evaporation is necessary which considerably aids the dispersal. Even gases heavier than air disperse quite quickly in a matter of minutes depending on the wind conditions, diluting the mixture below the flammability limit.

An overview of the physical properties of currently used vehicle fuels is shown in Table 1 below.

Table 1: physical properties (indicative) fuels

Properties	*Petrol*	*Diesel*	*LPG*	*CNG*	*LNG*
Lower Explosive Limit (LEL) –	1.2%	0.6%	1.8%	5%	
Upper Explosive Limit (UEL)	7.1%	7.5%	8.5%	15%	
Auto ignition Temperature	246 °C	210 °C	450 °C	540 °C	
Boiling temperature	40°-200°C	180°-360°C	-42.6° C	-161° C	
Flash point	-43 °C	55 °C	-104 °C	-188 °C	
Dispersion quality	none	none	medium	high	medium

Summary of the safety aspects of the LPG fuel system

The systems' components are type approved in accordance with UN/ECE Regulations 67-01, Part I and installed according to the installation requirements included in Part II of the same regulation.

Many safety concerns already have been addressed by a variety of quantitative safety studies over many years. Many of these have been used in the development of standards and regulations worldwide. "Best practices" concerning the design, layout, installation, operation and maintenance of LPG fuel systems for road vehicles are well established based on a long period of experience in practical application.

In addition to the existing requirements applicable for general on-road use, special requirements need to be drafted in order to address the specific risks when transporting dangerous goods. The additional mechanical and electric requirements can be found in the section 9 ADR.

Table 2: additional properties / conditions

Properties	*Petrol*	*Diesel*	*LPG*	*CNG*	*LNG*
ECE-Regulation fuel tank	R.34	R.34	R.67-01	R.110	
Leakage after collision	probable (allowed)	probable (allowed)	improbable	improbable	improbable
Bonfire test of tank	no (only plastic tanks)	no (only plastic tanks)	yes	yes	yes
Bleed (ventilation)	yes	yes	no	no	yes

Description of LPG fuel system

LPG fuel systems exhibit a low level of complexity and usually consist of:

- one or two tanks (tank bundle);
- a single fuel line (in some cases a return line),
- vaporiser/regulator or fuel solenoids,
- injector(s)
- electronic controls.

The total amount of fuel contained beyond the ESD of the tanks is in most cases considerably less than 1.5 litres. The largest imaginable LPG spill could occur if the tank ruptures.

Tank design, installation and isolation from the rest of the system through emergency shut off devices are of prime importance to contain the fuel. Following elements contribute to the resilience of LPG tanks.

- Fuel tanks for LPG are predominantly constructed from steels according to EN 10120 and comply with the requirements of R67-01 Annex 10. For composite fuel tanks specimens are pressure cycled 20,000 times
- Besides pressure tests a fuel tank design undergoes impact and drop testing. The tanks have proven to have a high resistance to accident damage.
- The fuel tank designs are tested in fire conditions, the external fire (bonfire) test. In this test the tank is impinged by fire with a temperature of at least 590 °C. The tank shall not burst. Additionally the tank shall safely relieve internal pressure by discharging in a controlled manner as described by the manufacturer. A high resistance to engulfing fire conditions is thus proven.
- Orientation of a pressure relief valve needs to be taken into account. The discharge from the (emergency) pressure release is of a relatively high pressure. This necessitates that the discharged gas be directed away from the load (as already prescribed for LNG in the ADR regulation).
- When the engine stops, deliberately or in accidental situations an automatic closing device or valve on the cylinder or tank will prevent the outflow of gas. The fuel systems and engine injection system have safety barriers (shut off valve, excess flow valve) to prevent unintended outflow of gas in case the integrity of the system is compromised.

Assessment of risk

It has been suggested that for vehicles carrying dangerous goods fuelled with LPG the following aspects be analysed:

- Interaction between cargo and fuel
- Effect of fuel spillage on the construction
- Effect of cargo fire on fuel system installation
- Different types of hazard posed by using LPG instead of diesel as fuel
- Adequate safety distance during refuelling operation;

The points are derived in analogy to the HAZID study conducted for the use of LNG as a fuel in the carriage of dangerous goods on inland transport waterways (UNECE/TRANS/WP.15/AC2-23-inf2, 22nd session ADN and inf35, 23rd session ADN). In addition the case of an engine fire is looked taken into account.

Interaction between cargo and fuel

LPG is neither oxidant nor corrosive. A chemical interaction with the cargo is unlikely and dependent on the cargo's chemical properties. Physical interaction with the cargo is restricted to chilling (should the cargo come in direct contact with liquid fuel) to temperatures at the lowest of around -40° C. Ignition sources in the cargo need to be taken into account.

Effect of fuel spillage on the construction

Should a leak occur (despite the relatively low probability) two possible scenarios should be analysed.

- 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 gas will show no reactivity except with ignition sources.
- When leaking in a liquid state, the lowest achievable temperature at ambient pressure through evaporation is at around -40 °C. In 6.8.2.1.8 ADR specifies a minimum temperature of -20° C at which the tank shells shall not exhibit brittle fracture and stress corrosion cracking. In addition to this many items of equipment, especially those designed for the carriage of liquefied gases, are required to demonstrate sufficient resilience against cooling during filling operations to temperatures below -40° C.

The construction of vehicles takes dynamic stresses into account. Structural parts are designed to take the multiple static load. In a post-accident leak scenario the structural components would only carry static loads. The risk of a possible brittle fracture of structure components not designed to be exposed to temperatures below -20° C is further reduced.

The fuel system is to be designed as to place tanks in the lower part of the vehicle and route the fuel lines in such a way to minimise fuel spillage onto the load or hot parts of the engine.

Effect of cargo fire on fuel system installation

The fire protection of fuel storage systems for LPG is higher than that for liquid fuel tanks due to the pressure relief devices and valves (PRDs/PRVs) integrated in the tank design. The suitability of each tank-design is verified through bon-fire tests. When in a fire situation the fuel tanks will gradually release fuel in a controlled manner, thereby limiting

the amount of fuel added to the vehicle fire. For the carriage of dangerous goods care shall be taken when placing and orienting the PRD/PRV exit points. The vehicle is to be assumed in a position roughly wheels on the ground.

Different types of hazard posed by using LPG instead of diesel as fuel

Tanks for diesel fuel are thin walled and commonly squared off. The design requirements are limited, only for fuel tanks made of plastic materials a bon-fire test is prescribed. Diesel fuel tanks offer limited protection against mechanical impact or overturning. Leakage of fuel cannot be ruled out in minor collision or overturning scenarios. Several hundred litres of diesel fuel may run out, forming a pool around the vehicle.

Fuel storage systems for LPG will resist much higher puncture loads than liquid fuel tanks. The fastenings of the tanks to the vehicle frame withstand more severe mechanical stresses than tanks for liquid fuels. In case of an accident, the fuel systems automatically isolates cylinders or tanks when the engine stops. As no significant volume of fuel is contained in the fuel lines the release of gas will be limited, making it unlikely to result in a fire. A release of fuel is highly unlikely below the stresses sufficient for considerable diesel leaks.

Adequate safety distance during refuelling operation

Re-fuelling is performed with specially designed dispensing equipment standardised according to EN 14678-1. Employing suitable hoses and connections according to R.67-01 Annex 9. Hoses are limited in length to ensure the enclosed volume does not supersede 1.5 litres. Dispensing operations are initiated and maintained through the use of a dead-man pushbutton. In the event of release, a solenoid closes off the fuel passage from the pump. In the unlikely event of a hose rupture the release of the dead-man pushbutton limits the release of LPG to above mentioned 1.5 litres. The hose is also protected through a breakaway coupling which separates from the dispenser closing off the passage at both ends. In this case no fuel is released. The refuelling system is designed to be operated by private individuals thereby achieving a level of safety comparable to other fuels

Measures to be taken in case of an engine fire

In the event of an engine fire, the engine shut-down will shut off the supply of LPG to the engine subsystem. As previously described the volumes of LPG contained in the componentry beyond the shut-off valve in the tank are minor. The materials used for the manufacture of LPG components can also be found in other automotive components. A different behaviour for engines running on LPG in the event of an engine fire have not been reported. The processes applicable to other types of engines also apply to those fuelled with LPG.

Conclusion

Taking into account the requirements and procedures already in place for the use of LPG as a fuel for road transport, only very few additional requirements are necessary to correctly address the outstanding risks. These requirements can be summed up as:

- fuel tanks and other components shall be positioned with regards to the load or hot parts of the vehicle
- venting and pressure relief valves shall be oriented with regards to the load or hot parts of the vehicle
- electronic components shall be designed in order to conform to the specific requirements laid down in 9.2.2 ADR

Doing so a sufficient level of safety for the use of LPG as a fuel in the transport of dangerous goods can be assumed with a fair degree of safety for FL, OX and AT fixed tank vehicles or dismountable tanks.