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Recommendation of Future Standardisation

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Executive Summary

The LNG Blue Corridor project is focused on demonstrating the use of LNG as truck fuel and to define a road map for future large scale development of the market. This report is the third deliverable of the Work Package 4.

Work Package 4 – Harmonization and Standardisation is focused on the further improvement and development of common standards and regulations related to LNG HD vehicles and fuel stations.

This report – 4.3 Recommendation to a future common standardisation – is written with the objective of identify and analyses those uncovered issues in the current EU standards and regulations or those that generate controversy and propose possible recommendations looking for their solution and clarification.

Analysis and recommendations have been focused on topics summarised in Table 0-1. This table also include an overview of the provided recommendations, indicating the subject, the suitable recipients and the status of the respective harmonisation actions. In the body of the document further justifications and support to each recommendation are provided.

Table 0-1 Summary of standardisation issues and respective recommendations

Standardisation issue	Recommendation	Subject	Main recipients	Status
LNG nozzles and receptacles compatibility	To form a technical group to specify a single universal mechanism suitable across the whole market, and document this in an applicable existing standard.	Stations / Vehicles	The 3 major manufacturers (JC Carter, Macrotech, and Parker) CEN/TC 326	There is ongoing work for the standardisation of LNG receptacle dimensions (upcoming ISO Standard ISO/DIS 12617). This work does not cover the compatibility between nozzles and receptacles
Drivers training	A drivers training should be mandatory. The training/education has to be local, but we should also make sure that the information contains all relevant issues.	Vehicles	Natural & bio Gas Vehicle Association (NGVA)	A document about the future recommendation for LNG drivers approved by LNG trucks manufacturers has been developed by NGVA.
Consumer information about LNG price	Price should be displayed in the station and price is recommended.to be in €/litre. BIO Methane content and Methane Number should be provided and should be refreshed constantly. An agreed and reliable method of determination is needed.	Stations	CEN/TC 326	To be proposed
Compliance to weights and measures	To include an adequate measure system for gas that is vented back from a vehicle to the station at point of refuelling.	Stations	CEN/TC 326	To be proposed
Weights and dimensions for LNG vehicles	To adopt a common European exception for LNG trucks. The British model would be an example.	Vehicles	European Shippers council (ESC) Estate Members	Revision of the Directive 96/53/EC

Maintenance facilities	Heating/cooling systems and gas detectors are required.	Stations / Workshops	CEN/TC 326	There are specific regulations in United States: NFPA 88B and NFPA 30A.
Parking structures	Underground garages: - Installation of methane leak detectors or justification that the ventilation system is good enough to vent out any possible methane emissions. - Piping of the relief stack outside the building structure. Tunnels: - Acceptance of LNG vehicles and LNG tankers by tunnel or bridge operators.	Parking structures	CEN/TC 326 UNECE Inland Transport Committee	In the majority of the European counties there is currently no restriction for parking of LNG trucks in underground garages. Harmonization is possible.
Fuel quality	To ensure a common MN calculation method. Main LNG quality specification in order to meeting the demands from the automotive industry: Suphur: max. 10mg/m^3; Net Wobbe Index between 44.7 and 49 MJ/m^3; Methane number, high grade min. 80MWM; Methane number, regular grade min. 70MWM; siloxanes max. 0.1 mg/m^3; H_2S + COS max. 5 mg/m^3	Stations / Vehicles	European Commission – Climate action	Quality specifications have been proposed inside LNG BC framework.
Lower LNG tank mounting height	Investigation in tank protection systems and the homologation of 559 mm diameter tank and its inclusion in R110.	Vehicles	Working Party on General Safety Provisions (GRSG)	LNG TF (GRPE) is already working on this issue.
Type approval of dual fuel retrofit systems at Euro VI	A common in Europe provisional position should be adopted regarding the approval process for retrofit systems.	Vehicles	Gaseous Fuelled Vehicles (GFV) informal group from Working Party on Pollution and Energy (GRPE)	Postures from different European countries are different.
Refuelling pressure and temperature	Refuelling pressures and temperature limitations should be established and harmonized.	Stations / Vehicles	Working Party on General Safety Provisions (GRSG)	An in-depth analysis of this issue is currently under development in Deliverable 3.5 Market harmonization proposal.
Safety distances	Internal safety distances are recommended regarding LNG installation, LNG dispenser/truck refuelling with LNG, shop and other vulnerable components of the establishment, LNG filling point/ parking space for LNG tanker or boundary limit.	Stations	CEN/TC 326	• PGS 33-1 Natural gas – Liquefied natural gas (LNG) delivery installations set out internal and external safety distances. Under development. • Swedish Guidelines for LNG stations under development. This work will be fully finished in 2015; a draft will be available soon.
Couples (nozzle) between the tank and the thermo trailer	Change to dry cryogenic couple (without drips) should be discussed.	Stations / Vehicles	CEN/TC 326	Working groups (Sweden).
Boil-off in vehicle tank	Vehicle LNG tanks should have a design hold time after being filled net full and at the highest point in the design filling temperature/pressure	Vehicles	Working Party on General Safety Provisions (GRSG)	SAE J2343 takes into account this issue.

	range. Possible strategies In order to minimise the venting of boil-off gas to the atmosphere have been proposed.			
Vehicle interlock system	Inclusion of the vent coupling in the vehicle interlocks system.	Vehicles	Working Party on General Safety Provisions (GRSG)	To be proposed

Some of these issues are deeply analysed in additional reports within this project. Examples of current or future deliverables with relevance to this report are D3.2 *Gas Quality* or D3.5 *Market harmonization proposal*.

Taking into account that some of these issues are still under development in different national and international working groups and they require further analysis, and that other outstanding issues may appear while the project progress, in coming months updated versions of this deliverable are expected.

Contents

1 Introduction

1.1 LNG Blue Corridors project

The LNG Blue Corridors project's aim is to establish LNG as a real alternative for medium- and long-distance transport—first as a complementary fuel and later as an adequate substitute for diesel. Up to now the common use of gas as fuel has been for heavy vehicles running on natural gas (NG) only for municipal use, such as urban buses and garbage collection trucks. In both types of application, engine performance and autonomy are good with present technologies, as they are well adapted to this alternative cleaner fuel.

However, analysing the consumption data, the equivalence in energy of 1 litre of diesel oil is 5.8 litres of CNG (Compressed Natural Gas), compressed to 200 bar. Over five times more volume of fuel prevents the use of CNG in some heavy road transport, because its volume and weight would be too great for a long-distance truck. This opens the way for LNG (Liquefied Natural Gas), which is the way natural gas is transported by ship to any point of the globe. NG liquefies at 162º C below zero, and the cost of liquefaction in energy terms is only 5% of the original gas. This state of NG gives LNG the advantage of very high energy density. Only 1.8 litres of LNG are needed to meet the equivalent energy of 1 litre of diesel oil. A 40-ton road tractor in Europe needs a tank of 300 to 400 litres for a 1,000 km trip (based 32 litres / 100 km); its equivalent volume with liquid gas would be 600 to 700 litres of LNG. An LNG tank volume of 550 litres can be fitted to the side of the 4 x 2 semi-tractor (category N3) truck chassis and some rigid truck chassis (category N3 and N2). For 6 x 2 semi-tractor truck chassis around 275 litres of LNG can be fitted. This opens the way for the use of LNG for medium distance road transport, and in dual fuel form for longer distance transport. As a point of reference the largest commercially available LNG tank, (where chassis dimensions allow a larger 28" diameter tank may be allowable), is 144 USG (555 litres), this application on a 4 x 2 semi-tractor based on 32 litre / 100km fuel consumption with a dual fuel engine operating at 60% gas substitution would give that vehicle a range of 1170 km, typically 2 days driving, (Intervals of refill of no more than 2 days for LNG should be considered best practice. A variety of chassis configurations and heights may restrict the maximum size of LNG tank that can be installed.

LNG has huge potential for contributing to achieving Europe's policy objectives, such as the Commission's targets for greenhouse gas reduction and improving air quality, while at the same time reducing dependency on crude oil and guaranteeing supply security. Natural gas mono fuel and dual fuel heavy-duty vehicles already comply with Euro V emission standards and have enormous potential to reach future Euro VI emission standards, some without complex exhaust gas after-treatment technologies, which have increased procurement and maintenance costs.

Figure 1-1. Impression of the LNG Blue Corridors

To meet the objectives, a series of LNG refuelling points have been defined along the four corridors covering the Atlantic area (green line), the Mediterranean region (red line) and connecting Europe's South with the North (blue line) and its West and East (yellow line) accordingly. In order to implement a sustainable transport network for Europe, the project has set the goal to build approximately 14 new LNG stations, both permanent and mobile, on critical locations along the Blue Corridors whilst building up a fleet of approximately 100 Heavy-Duty Vehicles powered by LNG.

This European project is financed by the Seventh Framework Programme (FP7), with the amount of €7.96 M (total investments amounting to €14.33 M), involving 27 partners from 11 countries.

This document corresponds to the 3rd deliverable within Work Package 4. It is a document describing limitations and missing aspects of current regulations applicable to LNG vehicles and infrastructure (stations). This document will be available at the project website: http://www.lngbluecorridors.eu/.

1.2 Aim of this deliverable

Experience has shown that the lack of common standards within the European Union is the main obstacle for a wide deployment of heavy-duty vehicles powered by liquefied natural gas (LNG) as well as the related infrastructure of LNG fuelling stations. Furthermore, in some European countries there are no local normatives for LNG vehicles and stations and none are foreseen.

Experience with LNG heavy-duty vehicles has come after years of experience with CNG vehicles, thus all regulations and standards affecting the construction and approval of specific LNG components have been developed taking into consideration the already existing legal framework for CNG vehicles and their components.

Up to now, all on-board CNG related aspects were approved according to ECE Regulation 110, but LNG was missing in its scope. Thus the Heavy-Duty vehicle manufacturers have been experiencing certain issues regarding the deployment of L-NGVs in most European markets, where they have had to rely on national approvals to-date. This has certainly set a barrier as those vehicles were only recognized by those countries granting the approval, causing problems for most fleet operators willing to travel across the European Union.

After years of experience in the use of this vehicle technology, the European NGV industry addressed the need to solve the above-mentioned lack of harmonization, and this was partially carried out through the work of the UNECE LNG Task Force. This Task Force, with the cooperation of several European LNG vehicle and component manufacturers, has worked for more than two years to update ECE R110 in order to include all the necessary amendments for LNG components & systems to be approved.

Technical subcommittee *ISO/TC 22/SC 25 Vehicles using gaseous fuels*, is working on ISO Standards regarding components and GNL vehicles: *ISO 12614 - Liquefied natural gas (LNG) fuel system components*, or *ISO/DIS 12617.2 - Liquefied natural gas (LNG) refuelling connector*. On the another hand, Technical committee *ISO/PC 252 - Natural gas fuelling stations for vehicles*, is working on ISO Standards regarding GNL stations: *ISO 16924 - LNG stations for fuelling vehicles*.

Although the aforementioned regulations provide enough detail to construct an LNG fuelling station in line with existing standards, they are fully separate from ECE R110, which focuses on on-board vehicle equipment. Therefore, technical features that require synergy between fuelling stations and on-board equipment must consider input from both aspects in order to achieve standardisation targets. Aspects such as fuel storage/delivery pressure, temperature or composition and coupling devices are especially crucial.

The aim of this deliverable is to summarize the safety, security and environmental limitations and missing aspects of current and forthcoming European regulations and standards applicable to LNG vehicles and infrastructure (stations) including the new version of Regulation ECE R110 regarding the type-approval provisions for vehicles equipped with LNG propulsion system - expected to come into force in July 2014 - and addressing in more detail the gaps and creating a more comprehensive scenario on which recommendations for improvements and future standard developments are provided.

2 Definitions

For a complete understanding of this document, some definitions are offered (arranged in alphabetical order):

Anti driveaway switch: safety switch that prevents the vehicle from starting when it is connected to the refuelling system.

Approval of a vehicle: means the approval of a vehicle type of categories M and N (see Table 2-1) with regard to its LNG system as original equipment for the use in its propulsion system.

Table 2-1 Categories M and N

Category **M**	Power-driven vehicles having at least four wheels and used for the **carriage of passengers**	Category **N**	Power-driven vehicles having at least four wheels and used for the **carriage of goods**
M1	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat - **Passenger car**	**N1**	Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes - **Pick-up Truck**
M2	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes - **Bus**	**N2**	Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes - **Commercial Truck**
M3	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes - **Bus**	**N3**	Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes - **Commercial Truck**

Automatic valve: valve that is actuated by either electrical solenoid or pneumatics

Boil-off gas: gas produced from evaporation of LNG in the storage tank and in other parts of the station. It also includes the gas return from the vehicle tank, due to heat leak into the tank.

Break-away device: device on the fuelling hose that disconnects the hose when a tension limit is exceeded and stops flow (for example, if the vehicle moves away with the fuelling hose connected). (See yellow device in Figure 2-1).

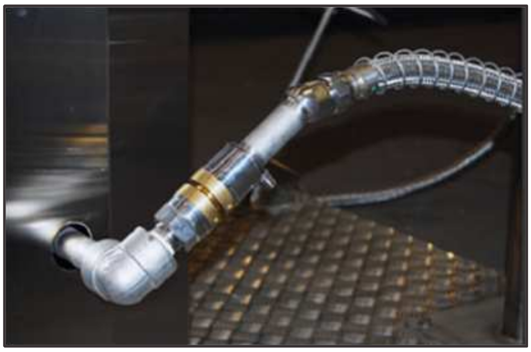


Figure 2-1 Break-away devices. Source: HAM

Compressed Natural Gas (CNG): natural gas that has been compressed and stored for use as a vehicle fuel.

Cryogenic: cryogenics is the study of production of extremely cold temperatures, how to produce them, and how materials behave at those temperatures.

Cryogenic pump: pump which raises LNG to a higher pressure, typically a centrifugal (used preferably for delivery of LNG to the LNG dispenser) or reciprocating piston pump (used preferably for delivery of high-pressure liquid into the high-pressure vaporizer for buffer storage and/or direct dispensing CNG – see Figure 2-2).

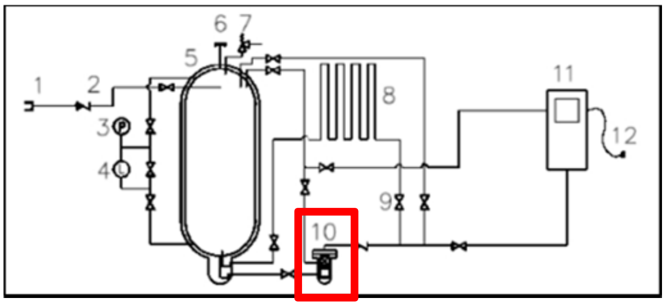


Figure 2-2 LNG Station scheme and location of the cryo-pump. Source: GNVERT

Cryogenic temperature: those temperatures below -40 °C.

Delivery pressure or fuelling pressure: pressure at which the gas is delivered to the vehicle.

Figure 2-3 NG delivery operation. Source: NGVA

Electronic control unit (ECU): device that controls the fuel demands of the engine, and other engine parameters, and cuts off automatically the automatic valve, required for safety reasons.

Excess flow valve (excess flow limiting device): device that automatically shuts off or limits the gas or liquid flow when the flow exceeds a set design value.

Filling: operation consisting of transfer of LNG from an LNG tanker to the LNG storage tank.

Filling unit or receptacle: device fitted in the vehicle used to fill the container or tank in the fuelling station.

Filter: protective screen that removes foreign debris from the gas or liquid stream.

Fitting: connector used in a piping, tubing, or hose system.

Fuel rail: the pipe or conduit that connects the fuel injection devices.

Fuelling: operation which involves the transfer of LNG from the station dispenser to the fuel tank of a vehicle.

Fuelling pressure or delivery pressure: pressure at which the gas is delivered to the vehicle.

Gas /air mixer: device for mixing the gaseous fuel and intake air for the engine.

Gas flow adjuster: gas flow restricting device, installed downstream of a pressure regulator, controlling gas flow to the engine.

Gas injector: device for introducing gaseous fuel into the engine or associated intake system.

Gas supply device: device for introducing gaseous fuel into the engine intake manifold (carburettor or injector).

Gas-tight housing: device that prevents gas leakage to outside the vehicle including the gas ventilation hose.

Heat exchanger/Vaporizer: device used to change the state of LNG into CNG.

Inner vessel or inner tank: part of the fuel tank that contains LNG and is insulated from the outer vessel by vacuum or insulation material.

Isolation switch: devices designed to avoid the complete loss of liquid in accidental situations.

Liquefied Natural Gas (LNG): also called "Liquid Natural Gas". It is a cryogenic liquid produced by reducing the temperature of natural gas to about -161.7 ºC at atmospheric pressure and stored for use as a vehicle fuel.

LNG and LCNG station: a fuelling station that is capable of fuelling LNG vehicles.

LNG dispenser: equipment through which the liquefied natural gas is supplied to the vehicle (Figure 2-4 shows an example).

Figure 2-4 LNG dispenser. Source: NGVA

LNG filling receptacle: device connected to a vehicle or storage system which receives the LNG fuelling nozzle and permits safe transfer of fuel. The receptacle consists as minimum of a receptacle body and of a check valve mounted inside the body.

LNG fuelling nozzle: device that permits quick connection and disconnection of fuel supply hose to the LNG receptacle in a safe manner (Figure 2-5 shows an example of these devices).

Figure 2-5 LNG fuelling nozzle. Source: NGVA

LNG fuel pump: device to establish the supply of LNG to the engine by increasing the pressure of the fluid (liquid or vapour).

LNG fuelling receptacle: device connected to a vehicle fuel storage system that receives the LNG fuelling nozzle and permits safe transfer of fuel.

LNG nozzle: device which permits quick connection and disconnection of fuel supply hose to the LNG receptacle in a safe manner.

LNG station: station that delivers LNG from a storage tank to the LNG vehicle fuel tank in liquid phase. Figure 2-6 shows LNG BC project station from *Eni* (Italy).

Figure 2-6 LNG station. Source: Eni

LNG storage tank: cryogenic vessel used for the purposes of storing liquefied natural gas (Figure 2-7 shows an example of these tanks).

Figure 2-7 Storage tank. Source: Eni

LNG system: means an assembly of components (tanks, valves, flexible fuel lines, etc.) and connecting parts (fuel lines, fittings, etc.) fitted on motor vehicles using LNG in their propulsion system and related components up to and including the vaporizer. Other parts downstream from the vaporizer shall be considered as CNG components.

LNG tanker: vehicle that delivers LNG for offloading to the station storage tank.

LNG trapping: operation which involves the containment of LNG in an enclosure of constant volume.

LNG vehicle tank: cryogenic tank mounted on a vehicle for the storage of LNG as a fuel for that vehicle (see Figure 2-8).

Figure 2-8 LNG truck: Iveco Stralis. Source: Iveco

LCNG station: A fuelling station that delivers LNG from a storage tank to the vaporizer, and then as compressed natural gas (CNG), to CNG vehicle high-pressure cylinders in gaseous phase. The station can be encountered in literature under the abbreviations 'L-CNG' or 'L/CNG' station. Figure 2-9 shows a scheme of a LCNG station.

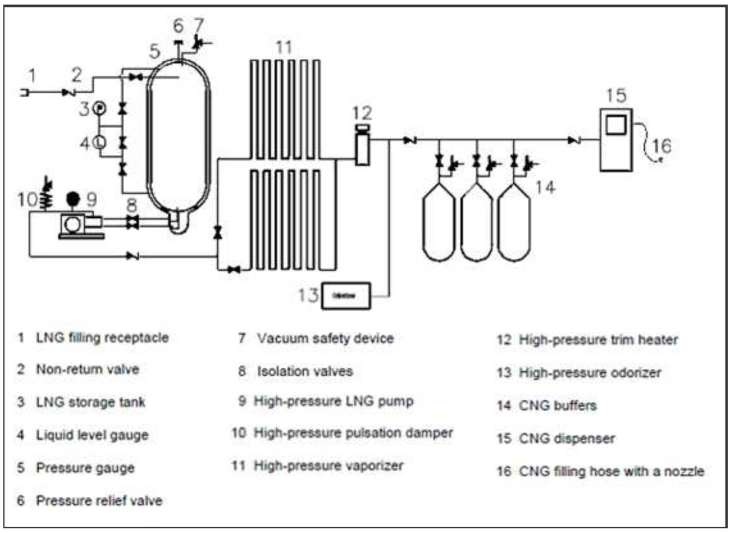


Figure 2-9 LCNG Station. Source: GNVERT

Manual valve: valve rigidly fixed to the cylinder or tank which is operated manually.

Natural gas: gaseous fuel containing a mixture of hydrocarbons, primarily methane, but sometimes including ethane, propane and other hydrocarbons. It generally also includes some inert gases, such as nitrogen and carbon dioxide, plus trace constituents, e.g. from its storage/transport in pipelines or wells.

Non-return valve or check valve: automatic valve that allows gas/fluid to flow in only one direction.

Operating temperatures: means maximum values of the temperature ranges, at which safe and good functioning of the specific component is ensured and for which it has been designed and approved.

Outer vessel or outer jacket: part of the fuel tank that encases the inner vessel or inner tank(s) and its insulation system.

Pressure: means relative pressure versus atmospheric pressure, unless otherwise stated.

Pressure regulator: device used to control the pressure of CNG or LNG.

Pressure relief valve (discharge valve): device that prevents a predetermined upstream pressure being exceeded.

Pressure sensor/indicator: pressurized device which indicates the gas or liquid pressure.

Pressurization: a phenomenon that occurs when cryogenic liquid vaporizes, creating increased pressure when trapped between valves or other liquid lock elements.

Rigid fuel lines: tubing that has not been designed to flex in normal operation and through which natural gas flows.

Safety distance: minimum separation between a hazard source and an object that will mitigate the effect of a likely foreseeable incident and prevent a minor incident from escalating into a larger incident.

Saturation pressure: pressure at which the liquid of certain thermal state (certain temperature) boils. Saturation pressure is used as an expression of thermal state of LNG. LNG of different compositions will be at a different temperature at the same saturation pressure.

Service pressure or Operating pressure: it means the settled pressure at a uniform gas temperature of 15 ºC. Service pressure for LNG means the intended settled pressure of the tank in use –as declared by the manufacturer.

Service valve: isolation valve that is closed only when servicing the vehicle.

Specific component:

- Tank;
- Accessories fitted to the container;
- Pressure regulator;
- Automatic valve;
- Manual valve;
- Gas supply device;
- Gas flow adjuster;
- Rigid fuel line;
- Filling unit or receptacle;
- Non-return valve or check valve;
- Pressure relief valve (discharge valve) primary and secondary;
- Filter;
- Pressure or temperature sensor / indicator;
- Excess flow valve;
- Service valve;
- Electronic control unit;
- Gas-tight housing;
- Fitting;
- Ventilation hose;

- Fuel rail;
- Heat exchanger/vaporizer;
- Natural gas detector;
- Fuel pump for LNG.

Tank (or vessel): any storage system used for liquefied natural gas.

Type of tank: those tanks that do not differ in respect of the dimensional and material characteristics.

Valve: device by which the flow of a fluid may be controlled.

Vehicle type: means vehicles fitted with specific components for the use of LNG in their propulsion systems which do not differ with respect to the following conditions:

- the manufacturer;
- the type designation established by the manufacturer;
- the essential aspects of design and construction:
    - Chassis/floor pan (obvious and fundamental differences)
    - The installation of the LNG equipment (obvious and fundamental differences)

Venting: the release of gas that has boiled from a liquid to a gaseous phase. This can occur from a LNG station or a truck mounted LNG storage tank.

Venting system: system that controls the release of natural gas from the LNG storage system, or from a truck mounted LNG storage tank.

3 Abbreviations

°C Degrees Celsius

CNG Compressed natural gas

ECU Electronic Control Unit

ESD Emergency shut-down

GRPE Working Party on Pollution and Energy (UNECE)

HDDF Heavy-Duty Dual Fuel

HDV Heavy-Duty Vehicles

LCNG Compressed natural gas, sourced from LNG

LNG Liquefied natural gas

LNG TF Task force regarding Liquefied natural gas (GRPE)

OEM Original Equipment Manufacturer

SD Spill detection

4 Uncovered aspects in the current regulations and standards

4.1 LNG nozzles and receptacles

There is no European or International standard that ensures the compatibility of LNG nozzles and receptacles. There is ongoing work for the standardisation of a given LNG receptacle dimension (upcoming ISO Standard ISO/DIS 12617, which will then be incorporated in the UNECE R110 regulation), but this work does not cover the compatibility between nozzles and receptacles (the ISO standard only refers to receptacle geometry; not nozzle).

There are three main types of nozzles and receptacles: *JC Carter*, *Parker Kodiak* and *Macrotech*.

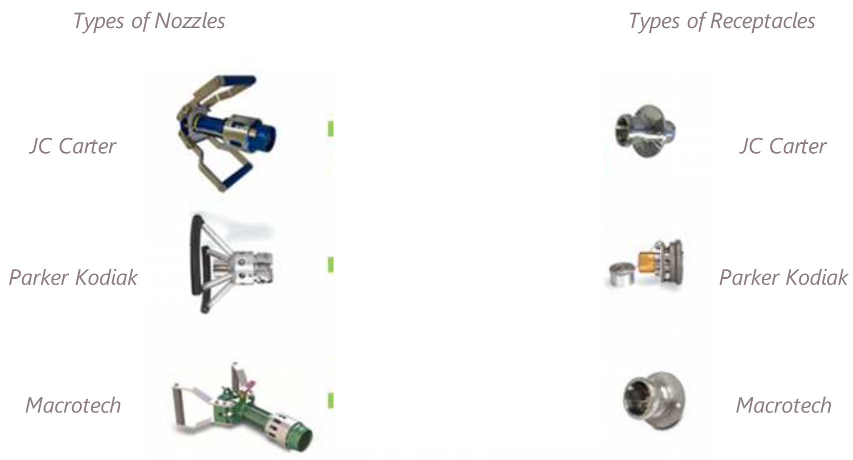


Figure 4-1 Main types of nozzles and receptacles. Source: JC Carter, Parker Kodiac and Macrotech

There are compatibility issues in two cases:

- Between *Parker Kodiak* nozzles and *JC Carter* receptacles; and
- Between *Parker Kodiak* nozzles and *Macrotech* receptacles.

On one hand, a *Parker Kodiak* nozzle requires a *Parker Kodiak* receptacle because it relies on *Parker's* unique twist clamping, whereas a JC Carter or a *Macrotech* nozzle can fill any receptacle, however most current receptacles do not comply with ISO 12617, and therefore durability issues may be prevalent. On the other hand, any nozzle can fill the Parker receptacle; whereas *JC Carter* and *Macrotech* receptacles can only be filled by *JC Carter* or *Macrotech* nozzles (*JC Carter* nozzles and *Macrotech* receptacles are compatible, as well as *Macrotech* nozzles and *JC Carter* receptacles). It is also important to note that "adaptors" between different types of nozzles and receptacles are illegal in the EU for safety reasons.

JC Carter nozzle is the de facto standard in North America and China. There are hundreds of *JC Carter* nozzles in service across the world. *Macrotech* and *JC Carter* receptacles (which are fully compatible with *JC Carter* nozzles) are the most common in North America and China. There is a lot of experience globally with the *JC Carter* nozzles connecting to the *Macrotech* receptacle. Due to the widespread use of Parker receptacles in the EU, not much is known about the compatibility between JC/Macrotech nozzles and the Kodiak receptacle.

Nearly all the LNG stations built in Europe in recent years use *JC Carter* nozzles (and *Macrotech* for gas return). *Parker Kodiak* nozzles are used in some stations, almost exclusively in the UK and the Netherlands. These stations will not be able to fill most international trucks.

A recommendation to develop a standard receptacle for adoption by the market should be considered. The aim of LNG Blue Corridors Project is that all LNG stations/vehicles are compatible. It is not acceptable for either existing or new vehicles to present at a filling station and be unable to complete a refuelling of LNG. There is some preference for *Parker Kodiak* nozzles in certain regions which may not change, so the objective should be to approach these individual stations and make them see the harmonization should be a must and find out if they would be interested in adapting.

For instance, *Chive* stations are all *Parker Kodiak* nozzles meaning they prevent the use of *Macrotech* or *JC Carter* equipped vehicles. One option is to get *Chive* installations changed to *Macrotech* or *JC Carter* nozzles.

4.1.1 Recommendations

An alternative would be for the 3 major manufacturers (*JC Carter, Macrotech*, and *Parker*), to form a technical group to specify a single universal mechanism suitable across the whole market, and document this in an applicable existing standard.

4.2 Fuelling infrastructure operations

Fuelling infrastructure operations covers the following topics: shutting off the vehicle, grounding the vehicle, ensuring that vehicle is not moved with the fuel hose connected to the vehicle, fuel connector operation, fuel connector spillage, cold metal contact and required personal safety aspects in the refuelling operation of LNG vehicles.

The Dutch PGS 33: Part 1 LNG truck fuelling - still under development - Establishes guidelines about these issues.

4.2.1 Recommendations

A drivers training should be mandatory. The training/education has to be local, but we should also make sure that the information contains all relevant issues.

An accurate document about the future recommendation for LNG drivers approved by LNG trucks manufacturers has been developed.

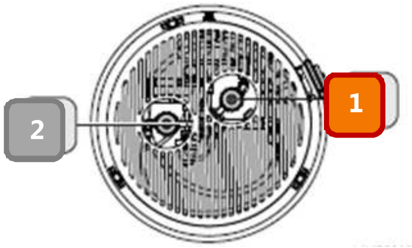
4.2.1.1 Recommendations for drivers of LNG trucks

Before delivering a LNG truck, some aspects have to be taken into account. These aspects are considered like a training process for drivers and folks who will participate in the refuelling process of LNG tank and be in charge of truck maintenance. The following aspects should be covered properly:

4.2.1.1.1 During the engine starting

Before starting the engine, these recommendations should be born in mind:

1. Close the general contact power.
2. Check the valves 1 and 2 on the picture below, in red and grey colour, are opened and closed respectively.



3. Check the pressure on the manometer. This should indicate upper 8.5 bar.
4. After these verifications, press brake, select gear in neutral and insert the key turning to +15 position. This last step must be followed up as a conventional diesel truck.

Before starting the engine in an enclosed area, make sure that it is properly ventilated. After start-up, maintain the engine idle for a few minutes. In this way the control unit stores the optimum setting during the first few minutes.

4.2.1.1.2 During driving

Vehicle performance. Level indicator

Special attention has to be paid during driving regarding the fuel indicator showed on the display. Since the combination state of natural gas between liquid and gas, sometimes the cluster fuel indicator doesn't show the real gas remainder. In addition to this, the tank shape also contributes the eventually non-linear progression of the indicator level. Therefore, a brief clarification about its performance is recommended for a complete understanding.

4.2.1.1.3 During refuelling process

- Technical aspects

Normal refuelling:

The refuelling point is situated on the right lateral of the vehicle, at the upper side of the tank. It is recommended:

- o Connect a mass wire from the station to the cryogenic tank in order to avoid electric shocks. This ensures that any static charge is taken down to earth to avoid the potential of fire / explosion if there is an LNG leakage

Figure 4-2 Earth cable / clip. Source: BOC

- Unscrew the tap of the nozzle.
- Ensure fuel receptacle is clean and not damaged. Use air gun to clear it prior to refuelling.
- Connect the nozzle to the fuel receptacle. It is necessary to explain how the nozzle is connected in a safety and proper way (different procedures according JC-Carter, Macro Tech, Kodiak, etc.):

a) Macro Tech:

Pre-fuel:

1. Clean Nozzle and Receptacle.
2. Press Safety Button and pull back handle.
3. Slide Nozzle onto Receptacle.
4. Push handles forward.

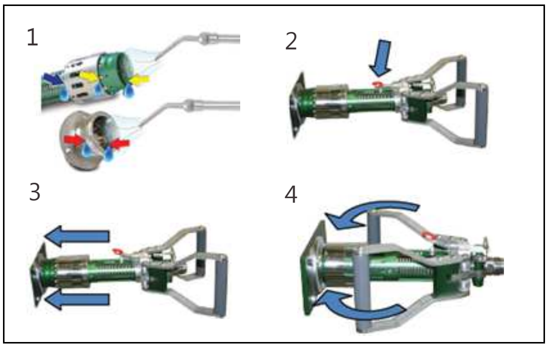


Figure 4-3 Macro Tech nozzle connection. Source: BOC

Post-fuel:

1. Pull handles back.
2. Allow Nozzle to vent.
3. Press Safety Button and pull back handle.
4. Pull handles back and remove.

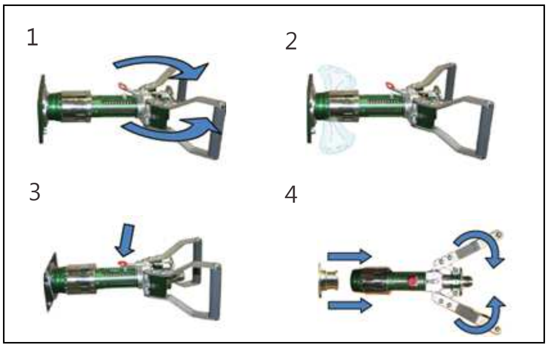


Figure 4-4 Macro Tech nozzle disconnection. Source: BOC

b) JC Carter:

Pre-fuel:

1. Clean Nozzle with Airgun.
2. Slide onto the Receptacle.
3. Push handles forward into fuelling position.

Post-fuel:

1. Pull handles back and allow nozzle to vent.
2. Slide off the Receptacle.
3. Clean Nozzle with Airgun.

Figure 4-5 JC Carter nozzle. Source: JC Carter

c) Parker – Kodiak:

Pre-fuel:

1. Clean nozzle and receptacle with airgun.
2. Line up receptacle studs with nozzle.
3. Twist nozzle right until locked into position.

Post-fuel:

1. Twist nozzle left.
2. Allow to vent then remove from receptacle.
3. Clean nozzle with airgun.

Figure 4-6 Parker-Kodiac nozzle. Source: Parker Kodiac

- Apply vent return line (subject to vehicle). This lie returns gas to prevent waste.
- Open the valve on the dispenser to refuel the tank. Once the refuel process is over, close it. The dispenser stops automatically.
- Finally remove the dispenser and screw the tap as last step. Always replace the dust cap after refuelling to protect the receptacle from damage and free from debris/dirt/moisture.

On the cryogenic tank is situated a limit valve at 16 bar. In this point is important to note that, the pressure right after refuelling process inside the tank must be 8.5 bar in saturation. That means the temperature after refuelling must be the temperature in saturation according 8.5 bar. Therefore it is necessary to adapt in the refuelling process the temperature at the service point, in order to guarantee a right performance. Otherwise, if the temperature was lower, even though getting the right pressure by means of a pump, after some kilometres the pressure would decrease below the minimum level, not having the normal performance engine and would stop the vehicle.

First refuelling. Fuelling a warm tank

A LNG tank just installed is considered like a high temperature tank. The pressure inside increases rapidly during refuelling process meanwhile the recipient itself is getting cooler and cooler. This process is interrupted prematurely. In order to avoid this, the recommended procedure is refuelling the tank with 40-80 litres of LNG. Once done this, natural gas pipelines should be checked in case of eventually leakages. After that, drive the vehicle during 10-15 minutes is required in order to decrease the pressure tank to the normal one as well as cool the tank. Check again possible gas leakages after driving test. Unless some anomaly is detected, continue refuelling the tank as normal process explained on the previous point.

The same procedure is advised with those tanks which have remained out of service more than 10 days.

- Safety aspects

Refuelling site

The eventual drop of cryogenic liquid can create atmosphere with low oxygen content. For that, it is quite important always guarantee refuelling at non-confined place with enough ventilation. This avoids accumulating natural gas. (This aspect is already covered according the requirements of building a LNG station).

LNG is a flammable gas, so fire may result if an ignition source is present. Smoking, naked flames and mobile phones are forbidden.

PPE (Personal protective equipment)

Due to the really low LNG temperatures, any contact with the skin could create severe burns. Therefore it is recommended to wear:

- Full-face shield: to protect from liquid Splashes/sprays and venting gas.
- Thermal gloves approved for cryogenic use: to protect hands from cold-burns.
- Cryogenic smock: long sleeves and trousers (not shorts) are recommended.
- Sturdy shoes capable of withstanding cryogenic spill.

4.2.1.1.4 During maintenance interventions

General recommendations of use:

- Before carrying out maintenance interventions isolate the fuel tank and release the pressure system.
- Never use direct fire or strong heat sources in order to increase the pressure. In absolute terms, is not allowed approaching to the pipelines and tank with temperatures above 650ºC.
- The ventilation valves are used in order to remove the gas remained in the pipelines if it is necessary during the maintenance operations. On the tank itself, the fuel shutoff valves, which are open during normal operation of the vehicle, have the function of closing the fuel line to allow maintenance operations.

- o The manometer shows the pressure on the tank. This value should be checked periodically by the driver or the person in charge of refilling the tank. The right range of working pressure is between 8.5 bar and 15.5 bar.

4.3 Consumer information about LNG price

Information provided by stations regarding LNG price and specific features should be normalized.

BIO methane content will be on interest to some operators where sustainability is important. It is also correct to highlight the bio content of gas stored in LNG stations as this will drive and improve market awareness.

Like with diesel and petrol fuels a rating should be given to LNG representing the energy value or a performance indicator for any particular gas at any particular item. A common method of determining this quantitatively is to adopt a reference to its Methane number. The consumer should also be advised against which standard that figure has been calculated as several different methods exist.

These two features of the LNG available at any specific station will vary from time to time as fresh supplies are delivered.

4.3.1 Recommendations

Price should be displayed in the station and it should be decided if price is given in €/kg or €/litre. €/litre is recommended.

BIO Methane content and Methane Number should be provided in the station in a dynamic way and will need refreshing constantly by station operators. The Methane Number also requires an agreed and reliable method of determination.

4.4 Compliance to weights and measures

Currently the measurement of the dispensed LNG is less than optimised at the point of refuelling a vehicle. Compliance to weights and measures standards needs to be facilitated by the inclusion of LNG within these regulations.

It is still common for gas to be vented back from a vehicle tank to the station at point of refuelling. Many LNG stations do not deduct this gas from the amount of LNG added to the truck. Currently vented gas is not adequately measured and systems do not always therefore correctly advice operators of the correct amount of gas consumed by the truck. This affects the fuel economy statistics that are calculated to monitor fuel efficiency. This also potentially overcharges the truck operator for gas which has been taking from a truck back to the station. All of these losses are currently costed against the operating costs of the truck which negatively affects the business case for the adoption of LNG-powered trucks and may influence take up on a wide scale.

4.4.1 Recommendations

It is proposed to include an adequate measure system for gas that is vented back from a vehicle to the station at point of refuelling.

The issue regarding who assumes these overcharges, and in which proportion, needs further development.

4.5 Weights and dimensions for LNG vehicles

Current situation:

- Dir 96/53/EC regulates weight restrictions in the EU Member States.
- Derogations to Dir 96/53/EC are currently only proposed for electric battery trucks and hybrids, which are primarily focused on urban applications.
- Some countries, regions and municipalities have their own rules and exemptions for LNG vehicles and NGVs more generally, but these rules and exemptions only apply in the territories themselves.
- The UK currently has an action plan for this and it will be based on the law which currently exists. This states that a vehicle can exceed its gross allowable weight by 3% so long as it does not exceed the design weights of the axles and infringe on braking performance. For example a 40,000kg truck could in-fact carry 41,200 kg so long as axle design weights are not exceeded.

4.5.1 Recommendations

It is recommended to adopt a common European exception for LNG truck in this issue, supporting the use of this technology. The British model would be an example.

4.6 Maintenance facilities

There are a number of special requirements that should apply to workshops servicing LNG or CNG vehicles. The recommendation is that consideration is given to the revision of ECE R115 to document these requirements. This may include the provision of regulations covering external safe areas of work for the drain down of LNG containment, and the inclusion of methane detection in roof areas of workshops, which is the obvious mitigation to any risk assessment which any company might carry out.

Specific regulation in United States: NFPA 88B: Standard for Repair Garages. This regulation is applicable throughout all kinds of vehicle workshops.

The specific requirements for NGV workshops are presented on issues related to ventilation, electrical installations on the roof and temperature of heaters exposed surfaces. It specifically indicates that in the case of LNG vehicle repairs, the use of open flame heaters or heating equipment is not allowed with surfaces exposed to a temperature higher than 399 °C.

United States regulation NFPA 30A offers fire code regulations for fuel dispensing facilities and repair garages. This regulation focuses especially on climate (heating/cooling systems); e.g. it is critical that repair garages that may contain hazardous or explosive gases have heat/ventilation systems that do not recirculate dangerous gases.

In practice, though, safety requirements for shop modifications vary greatly by country, province and even by town and are usually controlled by the local authorities (i.e. fire marshals, health & safety government agencies, etc.). Each maintenance facility must verify the requirements with its local authorities, but in general, modifications should include a list similar to this one:

The shop in this example is equipped with three roll-up service bay doors and takes up to five trucks at the same time:

- *Six sensors spread around the shop:*
  - *Two NO_2 sensors about 5′ off the floor on the wall*
  - *Two CO sensors about 5′ off the floor on the wall*
  - *Two CH_4 sensors mounted under the roof*
- *One control panel mounted close to the entrance door monitors the six sensors*
- *Two red alarm lights (mounted on opposite inside shop wall)*
- *Center roll-up service bay door is equipped with explosion-proof electric overhead door opener*
- *Electric disconnect panel mounted on back wall beside main breaker panel*
- *Exhaust fan mounted on roof top in center of shop*

Should sensors register a dangerous level of NO_2/CO/CH_4, the power to the main breaker panel in the shop will be disconnected (everything is shut off). The red warning light is activated and the emergency lights come on, while simultaneously, the center roll-up door opens and the roof exhaust fan starts up.

Often, a basic precautionary procedure provides enough safety to complete simple LNG truck maintenance and inspections. This procedure can consist, for example, of isolating the LNG fuel tanks and purging the high-pressure gas lines that feed the engine. Each vehicle manufacturer will have specific recommendations; however, local authorities will still need to be consulted to verify what minimal shop modifications are needed, if any.

If the only available facility for maintenance work is not specially equipped for NGVs, work should be done outdoors.

4.6.1 Recommendations

Proposed requirements for maintenance facilities are focused on heating/cooling systems and gas detectors and are the same as proposed above.

An in-depth analysis of this issue is under development in Deliverable 5.12, where the support to the LNG vehicles during the demonstration phase is addressed. Conclusions and recommendations from this deliverable will be included in future reports.

4.7 Parking structures

This section of the document discusses issues related to parking structures receiving LNG vehicles and other restrictions when LNG vehicles circulate in other particular areas.

4.7.1 Use of underground public parking

While there is no common Europe-wide regulation on LNG or other gas vehicles regarding the use of underground car parks, there are some regulations at the national level. The current situation in some European countries is:

Belgium: CNG vehicles are not forbidden in Belgian's underground garages. Currently the objective is to add an article in the legislation to have an official document which can be presented for instance to insurance companies, owners of car parks, etc.

Czech Republic: There are very strict rules for underground parking of NGVs. Underground parking rules do not distinguish between different NGs (CNG and LNG). Leak detectors and efficient ventilation systems are mandatory according to Bill n.268/2011 on the conditions of fire protection in buildings.

Germany: there are not any legislative restrictions for NGV's in underground parking. This standard is defined in the law for regional building. It is regulated by law on the level of each German Federal State.

Italy: there is no restriction to NGVs having a relative density lower than 0.8 (lighter than air).

Since 2002 (Decr. 22/11/2002) the prohibition for vehicles fuelled with gas having a relative density greater than 0.8 has been abolished, only for the 1st underground floor (not deeper), provided that the on-board gas system is made to the European Regulation R67. In particular concerning PRD and automatic receptacle (filling is limited to 80%).

Portugal: currently there are no special restrictions about closed underground parking for GN vehicles. The mandatory legislation is found in: Lei nº 13/2013 from 31st January and Portaria nº 207-A/2013 from 25th July.

Slovenia: there is currently no regulation for parking of LNG trucks.

Spain: there is not any specific regulation in this regard. CNG vehicles can be parked in any underground place if these places fulfil the CTE (national technical building code) prescriptions.

Sweden: there are no regulations, since it is not necessary – the ventilation requirements for underground garages are good enough to vent out any possible methane emissions.

United Kingdom: according to British rules, where NGVs are parked in enclosed areas, there should be suitable ventilation to prevent the hazardous accumulation of gas. The Road Vehicles (Construction and Use) Regulation 1986, however makes no reference to special provisions for gaseous fuelled vehicles when parked or stored.

Outside Europe, the following regulations stand out:

United Estates: NFPA 57: Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code (2002). According to *chapter 7: fire protection and safety*, the use of underground garages by liquefied natural gas vehicles is enabled, as long as such facilities or vehicles are equipped to prevent the accumulation of gas in a combustible mixture, or the LNG supply system and on-board fuel tank are drained and purged with inert gas or without pressure.

China: there is no specific regulation for parking LNG trucks. However, there are some recommendations for LNG truck manufacturers:

When parking a truck, the engine should be left working at idle speed for at least 3 minutes, then the engine power shut off; if the LNG truck is going to be parked for more than 20 days, all LNG fuel should be run out of the cylinders and the remains expelled into the air.

As the gas could be expelled into the air through the vent on the cylinders; there is the possibility for the natural gas to be burnt accidentally, so the LNG trucks should be parked far from fire sources, inflammables and explosives. It is better to avoid closed areas for parking LNG trucks for long periods, as the gas vented from the cylinders does not dissipate easily, if the density of gas reaches critical levels, it could explode. An open area is a better place for long-term parking.

It is recommended to inform the security staff about the gas venting phenomenon, in order to avoid any incident.

4.7.1.1 Recommendations

The following recommendations for underground garages are suggested:

- Installation of methane leak detectors or justification that the ventilation system is good enough to vent out any possible methane emissions.
- Piping of the relief stack outside the building structure.

4.7.2 Other restrictions

When a natural gas vehicle is to be transported by road, rail or ferry, or a tunnel is to be used, it should be checked whether there are any specific restrictions.

Considering UK restrictions for LNG/CNG, currently LNG is not listed as a road fuel in the road vehicles construction and use act (RCV&U). This directly contradicts type-approval documentation for LNG vehicles which forbids member states prohibiting the use of the vehicle on the roads.

4.7.2.1 Circulation through tunnels

National regulation must been taken into account. For example, in the case of France, the Ministerial Order of 2007 set the technical conditions to ensure safety in road tunnels. Guidelines for proper protection, evacuation are established. It is applicable to any fuel vehicle (*Circulaire Interministerielle N° 200-63 du 25 aout 2000 relative à la sécurité dans les tunnels du réseau routier national*).

4.7.2.2 Circulation through the Eurotunnel Le Shuttle

Eurotunnel's policy is not to permit gas-powered vehicles to use euro Le Shuttle (see Table 4-1). This is a major barrier to the use of LNG dedicated or dual-fuelled vehicles on international routes between UK and Ireland and the rest of Europe; therefore the connection between UK and France is by ferry.

LNG and dual-powered vehicles fitted with a LNG or equivalent tank as an alternative fuel cannot be accepted for transport by Eurotunnel Le Shuttle, even though:

- The LNG or equivalent tank is empty;
- The LNG or equivalent mode of the vehicle is not selected.

Table 4-1 Acceptability of vehicles according to their fuel type / power source by Eurotunnel

		PRIMARY FUEL TYPE / POWER SOURCE			
		Petrol / Diesel	Electric (battery & plug-in)	LPG / LNG / CNG (and all other flammable gas)	Biofuel (including Bio Ethanol & Bio Diesel)
SECONDARY FUEL TYPE / POWER SOURCE	Petrol / Diesel	OK	OK	NO	OK
	Electric (battery & plug-in)	OK	OK	NO	OK
	LPG / LNG / CNG (and all other flammable gas)	NO	NO	NO	NO
	Biofuel (including Bio Ethanol & Bio Diesel)	OK	OK	NO	OK

4.7.2.3 Recommendations

National Grid in the UK has an existing working party looking at this issue. It is recommended to constitute a working group to discuss and formulate the correct best practice.

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) is exempt for vehicles that use the dangerous good as propulsion fuel. However, according to the International Maritime Dangerous Goods (IMDG) code, the maritime industry will accept LNG vehicles and LNG tankers on ventilated decks. The acceptance of this by the tunnel or bridge operators will facilitate the LNG technology deployment.

4.8 Fuel quality

Gas quality will vary depending on the source of LNG, the production of LBG and the handling of the fuel along the distribution chain up to the delivery of the truck. The variation of the gas quality is not an impediment to progress, but could affect the possibility of optimising truck engines and will also continue to be an issue of interest after the launch of trucks on the market. Therefore, continuous focus on gas quality will remain a critical area to keep track of.

In the LNG supply chain most BOG is generated by the LNG ships themselves. The used LNG cargo or losses of LNG cargo due to boil-off reduce the amount of cargo delivered by LNG tankers to the receiving terminal while the ageing process steadily changes the composition, quality and properties of LNG cargo during a ship's voyage. Therefore, the quantity and quality of unloaded LNG are the key factors for the economic assessment of the LNG supply chain. As described below; geopolitical relations can make a country use rich or lean gas.

Despite these differences, each country has its own way to manage gas quality. Japan and the USA are able to keep a similar gas quality over the country thanks to different management processes. From the other side, Europe shows a high diversity between the different countries. Due to different gas specifications, each member imports its gas from several parts of the world so the quality at each terminal differs on the composition (Methane Number, Wobbe Index…). To get a similar quality on Europe, several measures have to be applied starting by introducing quality standards. To establish these standards different processes can be used such as:

- Ballasting (N_2 injection to reduce the Wobbe Index)
- Propane / Butane injection or removal (for small Wobbe Index corrections)
- CO_2 or N_2 removal (only applicable for pipeline gas)
- Blending (Blend of LNG coming from different sources)

These measures can help to make the LNG available throughout Europe more interchangeable.

Different topics related to LNG vehicle technology could be affected by gas quality. New design parameters depending on the technology platform might be found or highlighted during the demonstrations. This needs consideration regarding benefits of the amount of increased efficiency in vehicle technology vs. possibilities to provide specific gas quality at competitive price for customers.

The test method of taking samples of gas quality at the LNG filling station will have to be further developed. The increased ability to follow-up the gas quality at the filling station will lead to improved fact-based knowledge that in turn will facilitate defining potential causes of quality problems, thereby improving the LNG market for trucks as a whole.

Euromot recommend a methane number to 80, but this number would endanger the safety of natural gas supply to the European market.

Another important aspect to consider is that there is no commonly agreed Methane Number calculation method and one would need to be agreed, or even developed and made available in the public domain.

Including the Methane Number in the European Standard requires an agreed and reliable method of determination and should incur minimum costs.

The Methane Number cannot directly be used to optimise engine operation as there is no guarantee that the Methane Number at the point of measurement will correspond to the gas quality at the engine. Automation of engine emissions monitoring and automatic optimisation is the best method of ensuring optimum operation over a range of gas qualities.

The influence of hydrocarbons from biomass gasification on the fuel quality is not that different from that corresponding to hydrocarbons from NG. It is not worth having a fuel production line different from that of LNG, as the gas from gasification should be cracked to syngas and converted to the final fuel.

However the CO_2 and H_2 removal in the final upgrade should be optimised to meet specific value of MN and LFL (Lower Flammable Limit) instead of Wobbe Index, used for injection in the NG grid.

Regarding reducing the effect of silicon dioxide deposits, in the engine, various methods have been employed. Fluid injection systems do allow the silicon matrix to soften making removal easier, however in the long term it is preferable to remove the siloxanes from the gas before they reach the engine preventing the formation of deposits. This aspect is very important in order to ensure the engine life.

Active carbon filtration systems are available; they filter the contaminants for a finite period. These can be long installations (Requiring planning permissions) and need manual removal of spent activated carbon and disposal of the contaminated medium. Recently derivatives of the active carbon principal have been developed which offer a cartridge / silo replacement and removal service of the spent carbon. Although this avoids some of the disposal and safety issues, it is costly and requires constant maintenance. Normally these installations have a large footprint and require site planning before commissioning and a costly chiller to remove the water from the gas.

Work to develop a European fuel quality standard has been carried out by CEN/TC 408 and resulted in a draft "Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network - Part 2: Automotive fuel specifications". The draft version was published for CEN Enquiry end on March 2014 and comments will be collected during a 5-month period from CEN National Members.

In parallel, a draft European Standard "Gas infrastructure - Quality of gas - Group H" has been developed by CEN/TC 234 and submitted to CEN members for enquiry. The latter standard deals with gases classified as group H, as in EN 437:2003+A1:2009 and is applicable to gases in transmission and distribution networks. For filling stations connected to the gas network it is difficult to change the quality of the gas and most of the parameters in the automotive fuel specification are limited by values set in the network standard. For LNG filling stations the situation is less limited since they are typically not connected to the gas network.

For some parameters, such as total sulphur content, it has not been possible to reach consensus. Currently, there is a difference between the automotive industry needs for sulphur content below 10 mg/Sm3 and the values the gas industry can provide, 30 mg/m^3.

The fuel standard does not distinguish CNG from LNG, however, in an informative annex it is stated that, with regard to sulphur content on natural gas, CEN/TC 408 takes the decision on an approach how to handle the different opinions about the maximum permitted sulphur content, and agrees that: "as a processed product, LNG used as fuel for engines can typically meet a low average sulphur value (e.g. 10mg/m^3)"

Several other parameters will typically be in a narrower range for LNG than for CNG, as the Wobbe Index interval.

In some cases the lack of standardised test methods limits the value stated in the standard, such as the limit for compressor oil. Limiting values for compressor oil might, however, not be relevant for LNG.

4.8.1 Recommendations

The LNG Blue Corridors project pays continuous attention to the issue of gas qualities by keeping the dialogue open between the actors. This discussion is going to be developed through the trials developed during the project. The importance of the gas quality is going to be analysed.

In order to ensure the European import/export market it is necessary to create, or develop gas quality standardisation. Progress in gas interchangeability is vital for market development and work in the study of vehicle technology.

One important topic recommended about the LNG quality is to ensure a common MN calculation method for the standardisation in the European market and to have a reliably criteria. It is important to know the MN and LFL index in order to optimise engines, instead of Wobbe Index which is used to in injection to grid gas.

In order to ensure long engine durability, it is important to reduce the siloxanes in the fuel. For this reason it is necessary to study the best way to perform the cleaning or filtration. The utilization of active carbon is a possible solution. It should also be incumbent on bio gas processors (providing bio gas which is upgraded through the removal on non-methane gases for use as a road fuel), to remove any agents from the final product which are used in the upgrading process, in particular Zeolite compounds, which can have a significant impact on gas system component life.

Regarding the discussions on how to find market and technology solutions to handle varying gas qualities, below is a list containing details currently being worked on by another area of the project:

- Sourcing of gas.
- Fuel management solutions throughout the delivery chain.
- Solutions to secure gas quality are kept within agreed specification.
- Measuring of gas quality in small scale LNG facilities
- Evaluation regarding design criteria and possibilities for different engine technologies to be optimised toward different gas qualities in terms of robustness, engine efficiency and emission control. The project consortium is recommended to monitor and report accordingly during the demonstration period to what extent gas quality will effectively influence engine performance, setting through substantiated observations the range of quality indicators and parameters jointly with target range values to be met to ensure proper functioning of engines.

4.8.1.1 Parameters of most relevance for LNG and values suggested by LNG Blue Corridors

The LNG quality specification set in Table 4-2 is meeting the demands from the automotive industry and it is believed that the specification is met by essentially all LNG qualities presently available in Europe.

Table 4-2 Suggested values for parameters of most relevance for LNG. All units calculated using ISO Standard Reference conditions of 15 °C and 1.01325 bar and using EN ISO 6976 for Wobbe Index.

Parameter	Unit	Min	Max	Comment
Sulphur total	mg/m^3	-	10	As required by the automotive industry. Gas industry can supply < 30 mg/m^3 in CNG
Net Wobbe Index	MJ/m^3	44.7	49.0	Min: CH_4 with 1.5% N_2 (No CO_2 in LNG) Max: Same as CEN/TC408 and CEN/TC 234
Methane number, high grade	MWM	80	-	Required for the dual fuel technology
Methane number, regular grade	MWM	70	-	Required by the automotive industry for all engines. Gas industry can supply > 65 in CNG
Total siloxanes (calculated as Si)	mg/m^3	-	0.1	Required for switching type of lambda sensor
H_2S + COS	mg/m^3	-	5	

For further information please see *D.3.2 Fuel quality thorough the whole chain*.

Where bio methane is also in the supply chain a limit for Zeolite compounds should also be determined.

4.9 Lower LNG tank mounting height

Fleet operators request LNG-powered trucks that are compatible with mega-trailers, and therefore use a 95 cm 5th wheel height - a lower mounting height requirement. At the present, in case of mega-trailers, the truck's chassis sits lower to the ground, which in turn means that the diameter of the LNG tanks needs to be smaller.

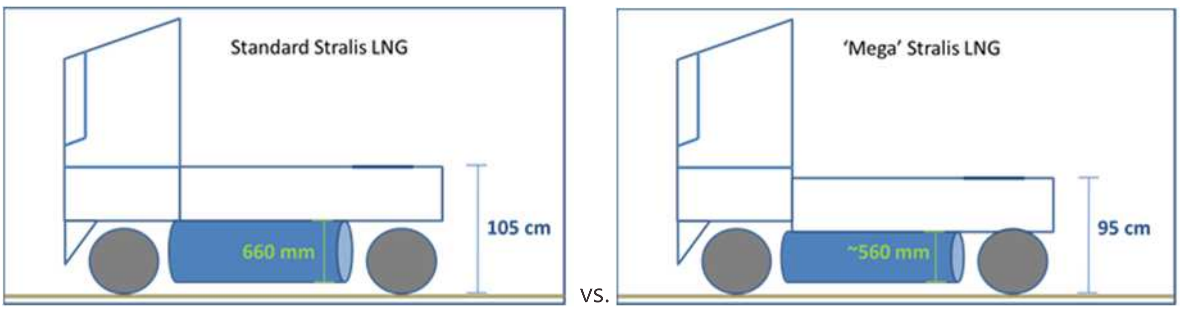


Figure 4-7 Standard stralisLNG vs. Mega stralis LNG

It is an especially important setup for air cargo companies (who have great potential as an industry to use LNG).

Manufacturing a smaller diameter LNG tank for this purpose is possible; the issue is the cost, time, and extra development/homologation. This will change if a large enough order for smaller diameter LNG tanks is made. *Chart Inc.*, the manufacturer of the standard LNG storage tank that is used on the *Iveco Stralis*, is already capable of manufacturing a 559mm diameter tank. However, this particular setup is not R-110 approved. Investigation into this issue and the requirements for homologation are ongoing.

Current legal framework is the next:

According to current Regulation No. 110, Revision 1 (30 May 2008):

17.4.3. When the vehicle is ready for use the fuel container shall not be less than 200 mm above the road surface.

17.4.3.1. The provisions of paragraph 17.4.3. shall not apply if the container is adequately protected, at the front and the sides and no part of the container is located lower than this protective structure.

In the new proposal for supplement 1, the same statements appear, but in this case in Regulation section 18.4.3 and 18.4.3.1 respectively.

On the other hand, LNG TF (GRPE) is already working on this issue, and the current position is that the fuel tank cannot, under any condition during driving or when stationary, touch the ground. According to this, they have proposed the next corrections:

18.4.3: "When the vehicle is ready for use, the fuel container and/or tank shall not be less than 200 mm above the road surface and the container shall not touch the ground if any tire or tires are deflated."

18.4.3.2: "Where the vehicle has "kneeling" or variable suspension height, the fuel tank shall not touch the ground in the kneeling or lowest suspension position. To avoid puncture or other damage, the tank shall be adequately protected from touching the ground when the truck is kneeling or if the suspension set to lowest position." (For consideration of vehicles with hydraulic systems capable of lowering and raising the vehicle).

There is further discussion about the protective structure around the tank:

18.4.3.3. "For a double skinned, insulated LNG tank, if the inner vessel is adequately protected by the outer vessel at the front and the sides and no part of the inner vessel is located lower than this protective structure, the provisions of paragraph 18.4.3 shall not apply".

In case of 18.4.3.1 (17.4.3.1), the language leaves it to the manufacturer to persuade the Type-Approval Inspector what "adequately protected" means, so the same could apply to LNG tanks. This would prevent tanks with very light outer vessels being approved, but still allow some flexibility.

4.9.1 Recommendations

Currently all the possibilities are covered by Regulation No 110. LNG tank height should be enough to ensure safety.

It is recommended the investigation in tank protection systems and the homologation of 559 mm diameter tank and its inclusion in R110.

4.10 Type approval of dual fuel retrofit systems at Euro VI

Supplement 1 to the 06 series of amendments of Regulation No. 49 defines the approval process for dual-fuel engines.

The Informal Group on Gaseous Fuelled Vehicles (GFV) from GRPE is working on a draft regarding a new regulation on uniform provisions concerning the approval of specific LPG (liquefied petroleum gases) or NG (compressed natural gas/bio-methane/liquefied natural gas) dual fuel retrofit systems and dual fuel retrofitted engines to be installed in heavy-duty applications, that is foreseen to be adopted in June 2015 (an informal document is foreseen next June 2014). May 2014 will start a Task Force HDDF retrofit which will be responsible for developing this Regulation.

In this draft, the proposal is that for Euro stage in force (Euro VI) limits and procedures for HDDF retrofit systems will be the same as OEM DF. This will be a challenging level of emissions to attain with an engine not specifically designed to combust gaseous fuels, (as is the case for retrofit dual fuel systems). This may also in turn reduce the take up of dual fuel vehicles before OEM dual fuel systems are available. These OEM systems may not however offer the same flexibility as the current retrofit systems on the market. In turn the reduced availability of flexible, (with full diesel only operating mode), dual fuel HD trucks may negatively affect the adoption of LNG fuelled HD trucks for long and medium distance transport and also negatively affect the increase in LNG infrastructure to support the growth desired by the EU.

In addition to that, according to last conversations regarding this issue with the Spanish Ministry, its position is in line with the requirements for dual fuel systems according to R49.06. Up to now there are no specifications about the required tests and in which conditions such tests must be performed, so a possible solution was an analysis of the contents of R49.06 contents regarding dual fuel systems and prepare a testing proposal compatible with R115. It is also unclear if there is a forecast for changes in R115 regarding these requirements, and clarification on this point is required.

Some member states have national regulations which control the standards of retrofit systems installed on trucks registered within their region. The UK and Belgium are examples of this. Figure 4-8 below represents the UK position regarding the retrofit systems before and after vehicle registration.

For Euro VI vehicles a regulator could exercise discretion under Article 20 of 2007/46/EC and apply R49-05 which includes emissions limits for Euro V only for dual fuel. This could a small series approval on a Euro VI engine complying with Euro V dual fuel limits only (until Euro VI DF limits for retrofit Euro VI dual fuel systems are included in R49).

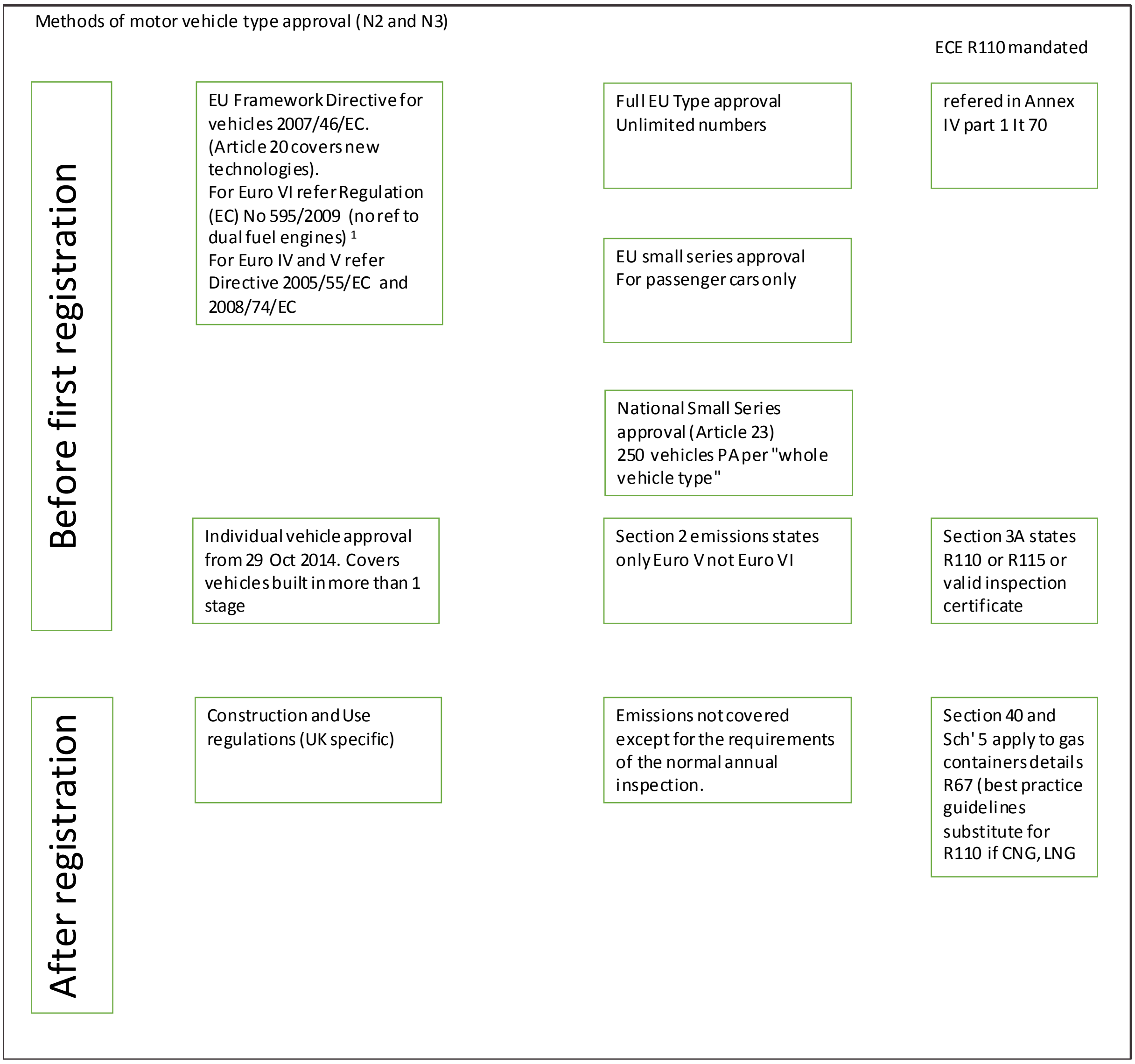


Figure 4-8 Methods of motor vehicle type approval (N2 and N3) from Hardstaff

4.10.1 Recommendations

Until the new Regulation on uniform provisions concerning the approval of NG dual fuel retrofit systems and dual fuel retrofitted engines to be installed in heavy-duty applications is adopted, a common in Europe provisional position should be adopted regarding the approval process for retrofit systems.

Up to now, postures from different European countries are not the same, so further development is required in this aspect.

4.11 Refuelling pressure and temperature

Refuelling pressure is not harmonized in Europe; limitations are not established in any regulation. Main delivery pressure in practice is 8 bar, but there are some special cases; for instance, in Portugal and

Spain, 16 bar is also possible and delivery pressure in Sweden is from 6 bar to 12.5 bar and in The Netherlands is 3.7 and 18 bar.

An in-depth analysis of this issue is currently under development in Deliverable 3.5 *Market harmonization proposal*. Conclusions and recommendations from this deliverable will be included in future reports.

4.12 Safety distances

Safety distances to objects (such as buildings) outside of the station as well as components inside the station including the refuelling truck are required.

PGS 33-1 *Natural gas – Liquefied natural gas (LNG) delivery installations* set out internal and external safety distances.

There is also a work going on in Sweden with Swedish Guidelines for LNG stations. This work will be fully finished in 2015, but a draft will be available soon. Proposed distances are based on fire tests.

4.12.1 Recommendations

According to PGS 33-1, safety distances shown in Table 4-3 are recommended.

Table 4-3 Internal safety distances for the different scenarios

Accident scenario	Scenario 1 (35 kW/m^2)	Scenario 2 (10 kW/m^2)	Scenario 3 (35 kW/m^2)	Scenario 4 (10 kW/m^2)
Risk source **Risk victim**	**LNG installation, except for LNG filling point/parking space for LNG tanker**	**LNG installation, except for LNG filling point/parking space for LNG tanker**	**LNG filling point/parking space for LNG tanker**	**LNG filling point/parking space for LNG tanker**
LNG installation	0 m	N/A	10 m	N/A
LNG dispenser/truck refuelling with LNG	N/A	0 m	N/A	0 m
Sales premises/shop within establishment	N/A	3 m	N/A	15 m
Other vulnerable components of the establishment	N/A	3 m	N/A	15 m
LNG filling point/ parking space for LNG tanker	Is determined by accident scenario 3 from LNG filling point to LNG installation component	N/A	N/A a	N/A
Boundary limit	N/A	3 m	N/A	3 m

Scenarios are defined in Table 4-4:

Table 4-4 Considerations for internal safety distances

	Accident scenario	Decisive effect	Protection	Protection value	Condition(s)
Scenario 1	**1 mm leak in flange, piping or stationary vessel (perceptible, no pool formation). This corresponds to 10 g/s source strength at 18 bar** **Direct ignition. Flare fire**	Heat radiation due to flare fire.	Prevent failure of neighbouring installation/ domino effect.	Max 35 kW/m^2 heat radiation to neighbouring LNG installation (protected by twin-walled design).	Use of technical measures to minimise the chance of the accident scenario. Use of self-closing filler coupling, break-away coupling delivery hose. Twin-walled design and insulation material offer extra protection against heat radiation.
Scenario 2	**1 mm leak in flange, piping or stationary vessel (perceptible, no pool formation). This corresponds to 10 g/s source strength at 18 bar.** **Direct ignition. Flare fire**	Heat radiation due to flare fire.	Prevent failure of neighbouring installation/ domino effect.	Max. 10 kW/m^2 for other neighbouring (unprotected) installations.	Use of technical measures to minimise the chance of the accident scenario. Use of self-closing filler coupling, break-away coupling delivery hose. Twin-walled design and insulation material offer extra protection against heat radiation.
Scenario 3	**5 mm leak from offloading hose (10% of 2 inch diameter) at 18 bar during LNG transfer at filling point/ parking space LNG tanker** **Direct ignition. Flare fire**	Heat radiation due to flare fire.	Prevent failure of neighbouring installation/ domino effect.	Max 35 kW/m^2 heat radiation flux to neighbouring LNG installation (protected by twin-walled design).	Use steel or composite hoses.
Scenario 4	**5 mm leak from offloading hose (10% of 2 inch diameter) at 18 bar during LNG transfer at filling point/ parking space LNG tanker** **Direct ignition. Flare fire**	Heat radiation due to flare fire.	Prevent failure of neighbouring installation/ domino effect.	Max. 10 kW/m^2 for other neighbouring (unprotected) installations.	Use steel or composite hoses.

Additional regulations for safety distances:

- The LNG delivery installation shall be at least 10 m away from the closest high voltage line, according to NEN-EN 13458-3. In addition it may not be positioned under high-voltage masts and/or lines.
- The LNG delivery installation may not be positioned within 5 m of a pipeline route for hazardous substances.

- Suitable measures shall be taken to prevent damage that may be caused in the direct vicinity of the LNG delivery installation by planting and/or other objects.

Nevertheless, guidelines set by the Swedish working group will be considered as soon as the first draft becomes available.

4.13 Couples (nozzle) between the tank and the thermo trailer

In Sweden there is currently a discussion on whether it should all change to dry cryogenic couple (without drips).

This topic is under discussion in specific working groups (Sweden). It will be further developed and included in the work done in the future.

4.14 Boil-off in vehicle tank

The design and operation of the station and vehicle shall minimise the venting of boil-off gas to the atmosphere.

When the boil-off effect is produced due to heat leak into the LNG storage tank (for instance when a vehicle is parked for a long period of time) an overpressure in the tank is produced so the release of the gas is required in order to avoid a possible accident.

ECE R110 does not define specific guidelines that provide solutions to this problem. However, there are other standards, such as SAE J2343, which establish minimum requirements.

4.14.1 Recommendations

It is recommended that vehicle LNG tanks have a design hold time (build pressure without relieving) after being filled net full and at the highest point in the design filling temperature/pressure range. According to SAE J2343, 5 days are suggested.

In order to minimise the venting of boil-off gas to the atmosphere, possible strategies would be the following:

- Burning the gas before being released into the atmosphere.
- Utilize the gas for the vehicle heating system (according to ECE R122, it is possible only for M2 and M3 categories).
- Process the gas through a reforming process for use in a fuel cell. Such a project, called "SAFARI", is currently funded by the EU.
- Store the gas in other different tank.

In this case of the release gas that exists in the tank in the refuelling process, if the last suggestion is selected, it would be needed standardise this process: a storage tank for this purpose should be mandatory in all refuelling stations and coupling between these nozzles and receptacles should be normalized. This coupling system should be different that main LNG coupling system with the objective of avoids mistakes and dangerous situations.

4.15 Vehicle interlock system

The fill nozzle is included in the vehicle interlock system to not allow the engine to start, but the vent coupling on the tank is outside the interlock flap thus allowing the engine to start and the truck to be driven away. It could cause an incident if only the refuelling line is pulled off.

4.15.1 Recommendations

It is recommended to include the vent coupling in the vehicle interlock system.

5 Conclusions

In order to ensure and stimulate the LNG technology deployment in Europe it is necessary to standardise those uncovered issues that have been identified in the current EU standards and regulations.

Currently, in Europe there are different working groups developing national or international standards and normatives trying to solve these issues, but efforts should be joined in order to achieve harmonized solutions.

Table 5. 1 summarises the issues which have been considered and it includes an overview of the provided recommendations, indicating the subject, the suitable recipients, the partner in charge of convey each recommendation and the status of the respective harmonisation actions.

Table 5-1 Summary of standardisation issues and respective recommendations and expected actions

Standardisation issue	Recommendation	Subject	Main recipients	Partner	Status
LNG nozzles and receptacles compatibility	To form a technical group to specify a single universal mechanism suitable across the whole market, and document this in an applicable existing standard.	Stations / Vehicles	The 3 major manufacturers (JC Carter, Macrotech, and Parker) CEN/TC 326	BOC	There is ongoing work for the standardisation of LNG receptacle dimensions (upcoming ISO Standard ISO/DIS 12617). This work does not cover the compatibility between nozzles and receptacles
Drivers training	A drivers training should be mandatory. The training/education has to be local, but we should also make sure that the information contains all relevant issues.	Vehicles	Natural & bio Gas Vehicle Association (NGVA)	NGVA	A document about the future recommendation for LNG drivers approved by LNG trucks manufacturers has been developed by NGVA.
Consumer information about LNG price	Price should be displayed in the station and price is recommended.to be in €/litre. BIO Methane content and Methane Number should be provided and should be refreshed constantly. An agreed and reliable method of determination is needed.	Stations	CEN/TC 326	ENI	To be proposed
Compliance to weights and measures	To include an adequate measure system for gas that is vented back from a vehicle to the station at point of refuelling.	Stations	CEN/TC 326	HARDSTAFF	To be proposed
Weights and dimensions for LNG vehicles	To adopt a common European exception for LNG trucks. The British model would be an example.	Vehicles	European Shippers council (ESC) Estate Members	VOLVO	Revision of the Directive 96/53/EC
Maintenance facilities	Heating/cooling systems and gas detectors are required.	Stations / Workshops	CEN/TC 326	ERDGAS	There are specific regulations in United States: NFPA 88B and NFPA

					30A.
Parking structures	Underground garages: - Installation of methane leak detectors or justification that the ventilation system is good enough to vent out any possible methane emissions. - Piping of the relief stack outside the building structure. Tunnels: - Acceptance of LNG vehicles and LNG tankers by tunnel or bridge operators.	Parking structures	CEN/TC 326 UNECE Inland Transport Committee	NGVA	In the majority of the European counties there is currently no restriction for parking of LNG trucks in underground garages. Harmonization is possible.
Fuel quality	To ensure a common MN calculation method. Main LNG quality specification in order to meeting the demands from the automotive industry: Suphur: max. 10mg/m^3; Net Wobbe Index between 44.7 and 49 MJ/m^3; Methane number, high grade min. 80MWM; Methane number, regular grade min. 70MWM; siloxanes max. 0.1 mg/m^3; H_2S + COS max. 5 mg/m^3	Stations / Vehicles	European Commission – Climate action	VOLVO	Quality specifications have been proposed inside LNG BC framework.
Lower LNG tank mounting height	Investigation in tank protection systems and the homologation of 559 mm diameter tank and its inclusion in R110.	Vehicles	Working Party on General Safety Provisions (GRSG)	ERDGAS	LNG TF (GRPE) is already working on this issue.
Type approval of dual fuel retrofit systems at Euro VI	A common in Europe provisional position should be adopted regarding the approval process for retrofit systems.	Vehicles	Gaseous Fuelled Vehicles (GFV) informal group from Working Party on Pollution and Energy (GRPE)	HARDSTAFF	Postures from different European countries are different.
Refuelling pressure and temperature	Refuelling pressures and temperature limitations should be established and harmonized.	Stations / Vehicles	Working Party on General Safety Provisions (GRSG)	ECOPLAN	An in-depth analysis of this issue is currently under development in Deliverable 3.5 Market harmonization proposal.
Safety distances	Internal safety distances are recommended regarding LNG installation, LNG dispenser/truck refuelling with LNG, shop and other vulnerable components of the establishment, LNG filling point/ parking space for LNG tanker or boundary limit.	Stations	CEN/TC 326	ERDGAS	• PGS 33-1 Natural gas – Liquefied natural gas (LNG) delivery installations set out internal and external safety distances. Under development. • Swedish Guidelines for LNG stations under development. This work will be fully finished in 2015; a draft will be available soon.
Couples (nozzle) between the	Change to dry cryogenic couple (without drips) should	Stations / Vehicles	CEN/TC 326	ECOPLAN	Working groups (Sweden).

tank and the thermo trailer	be discussed.				
Boil-off in vehicle tank	Vehicle LNG tanks should have a design hold time after being filled net full and at the highest point in the design filling temperature/pressure range. Possible strategies In order to minimise the venting of boil-off gas to the atmosphere have been proposed.	Vehicles	Working Party on General Safety Provisions (GRSG)	WESTPORT	SAE J2343 takes into account this issue.
Vehicle interlock system	Inclusion of the vent coupling in the vehicle interlocks system.	Vehicles	Working Party on General Safety Provisions (GRSG)	VOLVO	To be proposed

Sharing each recommendation and message to the respective standardization committee, working group or association is responsibility of partners in charge (according to Table 5. 1). Partners have the support of the work package coordinator (IDIADA) in this communication task. Responsible partners are subjected to change depending on the different meeting opportunities with the right recipient that may arise along the project.

The action protocol is first to contact with the respective recipients (in case of those issues related to LNG vehicles safety, the LNG Task Force from Working Party on General Safety Provisions (GRSG)), then, to send comments regarding current regulations (in this case Regulation No 110) and finally to participate, if possible, in the group meetings.

Communication labor will happen within the LNG BC project timeframe when possible, according to standardization issue development along the project and availability, taking into account that meetings of the different working groups take place a couple of times per year.

In case those issues which are being further developed inside other deliverables of this project, action time frames are based in activities developed in these deliverables (*D3.2. Fuel quality; D3.5. Refuelling pressure and temperature; D5.12. Maintenance facilities*).

It is recommended that the LNG Blue Corridor Project continues paying attention to these uncovered issues in the current EU standards and regulations by keeping the dialogue open among the actors. This discussion is going to be developed through the project demonstrations at the same time as other outstanding issues may appear as the project progresses.

6 References

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