RESULTS: FINDINGS & CONCLUSIONS
Critical Issues Workshop
CNG & LNG Safety: Perception & Reality
8-9 October 2014
Brussels, Belgium

This sixth in the series of Clean Fuels Consulting *Critical Issues Workshops* since 2008 gathered 56 experts from 16 countries on four continents representing natural gas vehicle (NGV) stakeholders, including equipment manufacturers and suppliers, vehicle manufacturers, government policy makers and others to identify and address the most critical safety issues related to compressed natural gas (CNG) and liquefied natural gas (LNG) as vehicle fuels. The presentations and discussion focused on the current standards and regulatory state-of-play related to CNG and LNG fuel storage systems, vehicle technologies, and fuelling options. The workshop participants addressed existing gaps as well as some of the opportunities to fill the gaps in order to facilitate further market development and commercialization of NGVs.

Four informative panels followed by a discussion session helped formulate the findings, conclusions and some 'next steps' that will be required to improve the safety outlook for CNG and LNG. Sessions included:

- Understanding the Critical Elements in the NGV Safety Chain;
- Technical Issues for CNG Safety;
- LNG Safety for Road, Rail and Sea; and
- Design and Safety of CNG and LNG Fuelling Systems.

Some of the key findings from the presentation and discussions, as well as conclusions drawn, indicated that the safety of CNG and LNG equipment and systems is an on-going concern. Despite the best efforts of the industry to learn from accidents and incidents, safety issues – some real and some perceived – will be a continued topic of concern, analysis and on-going improvement.

Understanding the Critical Elements in the NGV Safety Chain

The NGV industry faces two separate but related challenges to ensure that, on a global basis, NGV customers receive the safest and most reliable equipment: 1) dealing responsibly and professionally to improve technology and safety through legitimate standards and regulatory channels that are supported by effective industry and government oversight; and 2) that those in the NGV value chain do not jeopardize NGV safety due to inferior materials, poorly made equipment, or lax enforcement of existing standards and regulations.

As the market for NGVs has developed, certain issues within the 'safety chain' seem to have remained constant over time:

- *Perception is reality and NGV safety remains an issue.* Consumer research of commercial fleet operators in the United States dating back to 1991 showed that safety is one of the top issues, although different types of operators put it at different priority levels

related to performance and economics. Likewise, consumer research of commercial fleet operators and the driving public in Italy over the past two decades shows that, despite the familiarity with the fuel and technology, NGVs are perceived to be less safe than gasoline and diesel vehicles by a large margin.

- *NGVs are safe….if you handle them safely.* Most failures of NGV systems are due to human error, often due to a lack of knowledge. Industry advocates, for example, tout the strength and integrity of CNG cylinders and LNG tanks typically shown in 'severe abuse testing', however, proper care and handling of fuel storage systems is required because damage inflicted through *human* abuse makes them less safe.
- *The safety ethic and the concept of 'quality' vary widely from country-to-country.* Safety, quality, and reliability of equipment and systems are sacrificed when a manufacturer or customer's driving motivation is to have low cost products. In the long run, the cost of equipment to customers will go up because of poor quality. *Buyers beware* of NGV systems coming from locations where 'cheap' is a priority over safety and quality.
- *Equipment installers at the workshop-level seem to be the weakest point of the NGV value chain, mainly because of the lack of certified competence.* This begins to highlight the differences between OEM quality and retrofit quality control.

Technical Issues for CNG Safety

Despite having one of the best safety records in the transportation sector, the steady growth of NGVs has resulted in a constant learning process through accidents, incidents and understanding 'best practices.' Increasingly rigorous testing and certification requirements have resulted but, unfortunately, implementation continues to be a challenge.

- *Installers need to follow appropriate installation codes.* Handling pressurized fuels like CNG requires installers and mechanics who have received training and, at best, certification and licensing. In-depth training is required especially if the 'train-the-trainer' model is to be effective.
- *Clear installation requirements should be specified.* Problems associated with premature PRD activation or non-activation in fire can result in vent down and a possible fire hazard. Cylinder rupture can be mitigated also through localized fire testing and "smarter" fueling stations that include temperature compensation.
- *Periodic inspections and cylinder recertification are weak links in the safety chain.* Visual inspections of external cylinder surfaces are the only practical way to detect certain damage that might occur during normal use. This includes things such as moisture trapped in CNG cylinder shields that can create external corrosion or mechanically induced damage due to improperly installed rubber gaskets on mounting brackets. Enforcement inspectors frequently do not have the knowledge required for thorough cylinder inspections. Additionally, the manufacturers' manuals, which are essential to understand different inspection procedures for different types of cylinders, are not regularly provided to inspection agencies. ISO 19078 and other standards have requirements for inspection but, ultimately inspection quality relies on the manufacturers' recommendations and these frequently are not forthcoming.
- *An automotive-grade corrosion performance test is required in NGV industry standards.* External corrosion is an ongoing concern – sometimes made worse by installation practices (trapping water in contact with the cylinder; installation in proximity to hot exhaust systems). Standards allow for the application of coatings, but this has not been sufficient. North American standards may adopt the General Motors (GM) corrosion test

so that eventually every design will have to comply with automotive corrosion performance.

- *The NGV industry must continue to understand the causes of NGV incidents in order to effect changes in codes/standards, resulting in safer products.* Incidents that occur should be explored, analyzed and not ignored (or concealed).
- *The NGV industry should learn from the hydrogen industry and consider adopting hydrogen vehicle industry practices*. The hydrogen industry in its infancy first looked to the CNG sector to guide the development of its standards and regulations. The hydrogen/fuel cell industry has received massive funding from government and private sector sources enabling the fuel cell vehicle (FCV) industry to do research and development that could also be applicable for NGVs.

LNG Safety for Road, Sea and Rail

Cryogenic natural gas in the form of LNG brings a new dimension to NGV markets and technologies for trucks, marine vessels and railway trains. Safety in the design of vehicles, fuelling and fuel storage for large and very large scale systems pose new practical and regulatory challenges that must be addressed and resolved.

- *There are potential hazards as well as safeguards at each stage of the LNG supply chain.* Fixed parts of the supply chain (e.g. 'small scale' fuelling) and mobile suppliers in the fuel chain (e.g. virtual pipelines via truck) require different measures to ensure safety.
- *Lessons learned from industrial LNG applications are applied to transport sectors.* There is extensive experience with LNG for industrial applications and these have been carried through to vehicular use of LNG and expanded/refined to help ensure safety of handling LNG in the trucking and marine sectors.
- *Marine sector NGV standards are emanating from the top down.* Unlike the road transport sector where standards and regulations have grown 'bottom up' as the technology and need arises, marine NGV stakeholders are defining some basic 'principles' (e.g. in ISO). Creating specifications for marine LNG applications before completely understanding and experiencing the details of LNG fuelling and operating procedures is very challenging. Gas propulsion is at different levels of maturity between road, marine and rail applications but quality control still must remain a goal.
- *The rail sector use of LNG is in its infancy and mostly is prohibited except through exemptions and for purposes of 'proof of concept.'* The railway regulatory framework for LNG is unclear, with no specific LNG regulations and standards for locomotives, tender (tank) cars, or fuelling. Leadership and advocacy for natural gas is needed in the railway industry to determine what standards and regulations *should* be developed and which ones *must* be created.

Design and Safety of CNG and LNG Fuelling Systems

While the traditional CNG fuel station represents the largest share of NGV fuelling, LNG and liquefied-to-compressed (L-CNG) stations represent a new dynamic in building the market simultaneously for both CNG and LNG vehicles. Mobile fuel transport and mobile fuel stations also are important in fuelling NGVs where the gas infrastructure is limited. The lack of worldwide fuel station standards has complicated the job of fuel station installers and local code officials in assuring best safety practices of fuelling vehicles, although this should improve with the introduction of new ISO fuel station standards for CNG and LNG.

- *Development of natural gas as a marine fuel will depend on the development of robust safety standards and regulations for bunkering (fuelling ships) and related activities.* One of the early and on-going challenges for the marine application of natural gas will be to maintain the high standards formulated by the Society of International Gas Tanker and Terminal Operators (SIGTTO), the International Maritime Organization (IMO), ISO and others in the bunkering industry. This will be separate from any other gas-related standards with respect to other non-fuelling marine activities such as travel on inland waterways; passenger and cargo loading; training and qualification of personnel; and further integration of gas usage with normal port activities.
- *Proving safety through hazardous operations studies (HAZOP) is being done on a case-by-case, location-by-location basis, which is very expensive and time-consuming.* It is not yet clear whether 'generic' safety studies can replace individual point-of-use safety studies. If possible, this could help speed the use of natural gas as a marine fuel.
- *There are no standards or regulations for mobile fuelling stations*. Without specific requirements, existing standards and regulations for stationary fuelling, moveable high pressure equipment TPED *(Transportable Pressure Equipment Directive)* and ADR (dangerous good transport) are being applied.

CONCLUSIONS

Changing perceptions into reality is a necessary and on-going process that needs continued attention and effort.

- *Perception vs reality: The perception of natural gas as a vehicle fuel is that potential dangers remain*. The reality that NGVs (CNG and LNG) are safe requires a concerted and sustained communications effort via all channels to reach the widest audience of policy makers, regulators, and customers.
- *A process to systematically track CNG incidents internationally would promote continued learning and safety.* A small group of industry stakeholders have been tracking CNG incidents and sharing information on an informal but coordinated basis internationally. The challenge is to create a formal process within a yet-to-be-determined institution that can record incidents, identify causes (likely from other investigations) in order to continue amassing technical information designed to improve the safety knowledge base of NGV technology.
- *'Best practices', sharing experiences of various stakeholders and preparing the proper documentation for broad dissemination could be a good way to introduce safety concepts that are not necessarily in the context of legal regulations or even standards.* It is a method that also might encourage equipment suppliers, who are cautious about liability and sharing what they consider their 'intellectual property, to provide data or experiences that contribute to an overall safety consciousness. This is a role for equipment suppliers and the various associations.

Harmonization of standards and regulations as well as vigilant implementation and enforcement within each industry sector dealing with gas (road, marine and, in future, rail) will continue to be a challenge but should be a long-term priority that will promote safety, reliability, and reduce costs for manufacturers and customers.

- *The NGV industry must police itself to ensure safe system designs and safe products.* Implementation of the standards/regulations differs widely in different parts of the world. Enforcement of regulations also differs in different places, especially in those countries that do not have a robust 'safety culture'. If equipment emanates from countries where

safety and safe practices are not well enforced, then all customers/recipients must be cautious to ensure that the equipment conforms to the proper standards and regulations.

- *Countries entering the NGV market should look to the highest level of international standards and regulations – ISO and UNECE – as the best models to guide the safe adoption of equipment, whether it is for the road, marine or rail sectors.* Countries should **not** 'borrow' regulations from other countries.
- *NGV stakeholders should strengthen their cooperation through active participation in the regulatory and standards forums like the UNECE Working Parties and ISO.* The joint participation of government experts, industry and standardization organizations make it possible to improve harmonization and safety by developing regulations also on the basis of updated available standards.

Training is critical, desired and available but costly. The NGV and safety expertise needs to reach more people throughout the NGV value chain who need it the most in order to help provide safe equipment and practices to all NGV markets.

- *Expertise and training is available for a broad range of needs (conversions, vehicle and fuelling station operation, maintenance, inspection, fire mitigation) but the cost frequently is something the stakeholders are not willing to pay for.* Without legal obligations for certification or training, safety can be compromised throughout the NGV value chain. Manufacturers often provide training for specific technologies and associations can assist. Disseminating knowledge (i.e. training) to the right stakeholders will continue to be a challenge and should receive more attention in order to maximize the reach to the most stakeholders for a reasonable price.

Expanding cooperation between the advocates and stakeholders supporting the different NGV technologies and fuel sectors – CNG, LNG & biomethane for road, off-road, marine and rail applications -- will speed the market entry and commercialization of methane throughout all the transportation sectors.

- *Cross fertilization of knowledge, expertise and experience between the transport sectors (road, marine and rail) is possible but it likely will involve cooperation via industry associations and standards organizations at the various levels, international, regional and national.* But this must be a goal first embraced by the industry organizations before such knowledge-sharing can realistically take place. Thereafter, the 'A2A', association-to-association contacts could be an effective and important method to create the relationships needed to move NGVs and methane forward across all of the transportation sectors.