Links and Gaps in the NGV Safety Chain: An Overview of NGV Safety Perceptions & Realities

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CNG & LNG Safety: Perception & Reality
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Scope of the presentation

• Common perceptions of natural gas safety: CNG & LNG
• The realities of natural gas safety: CNG & LNG
• Safety along the NGV supply chain
• Global NGV safety: Tying up the loose ends
COMMON PERCEPTIONS OF NATURAL GAS AS A VEHICLE FUEL
Past & Present

Perception is Reality
Safety: the most important operations issue for fleet operators (in the U.S.) 1991

Different types of U.S. fleet operators rated their concerns about NGVs (2012)
safety - range - weight/space - performance

Despite being world market leaders amongst alternative fuels, in the U.S., NGVs and LPG-Vs are least appealing.

Individuals were asked by Maritz which alternative fuel vehicle they would prefer out of 11 choices. Credit: Maritz Automotive Research Group, 2011. telephone survey of 1,207 licensed American drivers 18 years of age or older.
U.S. Alternative Fuel Vehicles
1995-2011

2011: 1.2 million AFVs

2011: 269,000 Hybrids

140,000 LPG-Vs

118,000 NGVs

3,436 L-NGVs

863,000 E85-Vs

Alternative Fuels Data Center, U.S. Energy Information Administration,
http://www.afdc.energy.gov/data/10300
1999 Italian NGV Campaign
surveyed 800 people, representative of the Italian drivers population
(Eurisko marketing survey)

Media Campaign: 3 main newspapers; 8 weekly magazines; 25 monthly magazines (car, science, environment, life style)

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
Do you think CNG is an attractive motor fuel?

1999 survey

- Not at all: 4
- Not much: 5
- Neutral: 16
- Much: 46
- Very much: 29

75% Yes
16% neutral
9% No

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
Why do you think CNG is attractive?

- **ENVIRONMENT**: 72%
- **COST SAVINGS**: 60%

1999 survey results:
- Energy saving: 3
- Alternative fuel: 2
- Good performance: 1
- Praticable: 1
- Other: 3
- I don't know: 2

(More than one answer allowed)

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
### Why do you think CNG is **NOT** attractive?

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>It's dangerous</td>
<td>18</td>
</tr>
<tr>
<td>Not enough filling station</td>
<td>7</td>
</tr>
<tr>
<td>Poor performance</td>
<td>7</td>
</tr>
<tr>
<td>Not interested</td>
<td>6</td>
</tr>
<tr>
<td>It's polluting</td>
<td>5</td>
</tr>
<tr>
<td>Too much space demanding</td>
<td>4</td>
</tr>
<tr>
<td>High conversion costs</td>
<td>3</td>
</tr>
<tr>
<td>Price not competitive</td>
<td>2</td>
</tr>
<tr>
<td>Lack of advertising</td>
<td>2</td>
</tr>
<tr>
<td>I run too few km/y</td>
<td>2</td>
</tr>
<tr>
<td>I'm not accustomed</td>
<td>1</td>
</tr>
<tr>
<td>It ruins the engine</td>
<td>1</td>
</tr>
<tr>
<td>Bad experience with NG at home</td>
<td>1</td>
</tr>
<tr>
<td>It increases fuel consumption</td>
<td>1</td>
</tr>
<tr>
<td>My car is too small</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
</tr>
<tr>
<td>I'm not enough informed about it</td>
<td>42</td>
</tr>
</tbody>
</table>

(More than one answer allowed)

1999 survey

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
Would you be interested in CNG for your own car?

1999 survey

- **64% Yes**
- **20% No**
- **16% neutral**

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
If not, why?

1999 survey

- It's dangerous: 19
- I run too few km/y: 15
- I'm not interested: 7
- Not enough fuelling station: 7
- Too much space demanding: 6
- My car is too small: 4
- Poor performance: 4
- Price not competitive: 4
- High conversion costs: 4
- It's polluting: 4
- Lack of advertising: 1
- Bad experience with NG at home: 1
- It increases fuel consumption: 1
- My car is too old: 1
- It ruins the engine: 1
- Other: 6
- I'm not enough informed about it: 30

(More than one answer allowed)

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
What’s your fuel now?

1999 survey

- Gasoline: 85
- Diesel: 8
- LPG: 5
- CNG: 2

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
Would you be interested in converting your car to CNG?

1999 survey

- I don't know: 8
- No: 54
- Yes: 38

Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium
Italian customers’ appreciation of NGVs: Safety was a perceived issue in 2005

Source: Italian NGV Scenario 2005, Flavio Mariani, Metauto-ENI Divisione Gas & Power, Cattolica, September 20-21, 2005
Fleet operators opinion survey
Perception of CNG features vs gasoline and diesel

POSSIBILITY OF CIRCULATION IN PERIODS OF TRAFFIC BLOCK
ENVIRONMENTALLY FRIENDLY
THRIFTINESS
SUITABLE TO ALL VEHICLES
PERFORMANCES
AVAILABILITY OF CAR MODELS
AVAILABILITY OF REFUELLING STATIONS

NEGATIVE    SCARCE    ACCEPTABLE    GOOD

Source: Italian NGV Scenario 2005, Flavio Mariani, Metauto-ENI Divsione Gas & Power, Cattolica, September 20-21, 2005
What is the regulators’ perception of NGVs?: Tunnels

- After May 1949 gaseous fuel trucks were illegal in New York tunnels (also Boston)
- A tank truck carrying highly flammable carbon disulfide was in a 10 truck accident in the Holland Tunnel linking New York City and New Jersey. 69 people injured; 1 death;
What is the regulators’ perception of NGVs?: Underground Parking

REGULATIONS EXIST

Parking Allowed
- Italy
- Ukraine
- U.S.A

Parking Forbidden
- Hungary
- Slovakia

No Regulations

Parking Allowed
- Austria
- France
- Germany
- Sweden
- UK

Parking not forbidden
- Croatia
- Belgium
- Netherlands
- Spain
NATURAL GAS SAFETY
## Properties of Natural Gas

<table>
<thead>
<tr>
<th>Property</th>
<th>Natural Gas</th>
<th>Gasoline</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical State</td>
<td>Vapor</td>
<td>Liquid</td>
<td>Liquid</td>
</tr>
<tr>
<td>Ignition Temperature</td>
<td>1,080 °F</td>
<td>540 °F</td>
<td>410 °F</td>
</tr>
<tr>
<td>Density</td>
<td>22 Grams/Cubic Foot (Lighter Than Air)</td>
<td>2,800 Grams/Gallon (lighter than water)</td>
<td>3,200 Grams/Gallon (lighter than water)</td>
</tr>
<tr>
<td>Spill Behavior</td>
<td>Evaporates and Disperses</td>
<td>Pools on Surface</td>
<td>Pools on Surface</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>CNG: Ambient Temperature LNG: Below –200 °F</td>
<td>Ambient Temperature</td>
<td>Ambient Temperature</td>
</tr>
<tr>
<td>Strong Pressure</td>
<td>CNG: 3,000–3,600 psi LNG: Varies</td>
<td>Ambient Pressure</td>
<td>Ambient Pressure</td>
</tr>
</tbody>
</table>
CNG storage technology has been a focus of safety.

Scottish Motor Traction Bus, Edinburgh 1914-1918

Citroen 1941

Dedicated Ford Ranger: 1st Type II Cylinder - 1983

Chinese buses 1988

The Wikov NGV, Czechoslovakia 1936

CNG Cylinder Severe Abuse Test 1983
The reality is that, when there is a failure of a high pressure fuel cylinder (or LNG tank) the results can be dramatic.

Bus fire in Montbéliard, France (2005) resulted in cylinder melt-down & launching one through the roof of a home

LNG tanker accident Zarzalico, Spain 2011

Dutch bus with ‘flame thrower effect’ Wassenaar, NL Oct. 2012
NGV safety has been proven in many situations.

Fire in a bus garage in Utrecht, Netherlands, 6th July 1990.

Remains of the natural gas bus. All cylinders are intact; no explosions occurred.

The meltable fuse did its job.

The valve melted away.
Norm Fawley, President CNG Cylinder Corporation (Long Beach, CA) created the 12 minute ‘Severe Abuse Test’ safety video 1983

The Rally for Fuel Savings crossed America in 1984 and 1986 publicizing NGVs and the safety of CNG (American Gas Association)
CNG CYLINDER SEVERE ABUSE TEST

Only an armour-piercing bullet shot from a NATO-style assault rifle can penetrate a metal cylinder.
NGV SAFETY: SEVERE ABUSE TESTING OF CNG CYLINDERS

Dropped Cars

10 ...17....23...30m drops ...no leakage!!

Gunshot Test

Dynamite Test

Structural composites industry, fire proof cylinders

CNG cylinders remain intact under the most rigorous conditions
SEVERE ABUSE TESTING

Car drops from...
10 ...17....23...30 metres and no leakage
U.S. DOT study systematically characterized NGV/CNG accidents, equipment failures & fires from 1976-2010

- **138 incidents**: 56% U.S.; 44% Europe, Asia, S.America
- **All vehicles included**: 51% LDV/Trucks; 38% buses; 11% other commercial vehicles
- Most problems were with individual NGVs
- Some systemic problems identified, especially with Pressure Relief Devices (PRDs)
- 12% involved fire but most not attributed to CNG systems or NGVs (leaking petroleum liquids)

*Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures*, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation
**135 CNG incidents characterized**

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Number of Incidents</th>
<th>Percentage of Total (135)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder ruptures</td>
<td>50</td>
<td>37%</td>
</tr>
<tr>
<td>PRD release (no fire)</td>
<td>14</td>
<td>10%</td>
</tr>
<tr>
<td>Vehicle fire (no cylinder rupture)</td>
<td>17</td>
<td>13%</td>
</tr>
<tr>
<td>Accident w/another vehicle</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Single vehicle accident</td>
<td>6*</td>
<td>4%</td>
</tr>
<tr>
<td>Cylinder or fuel tank leak</td>
<td>14</td>
<td>10%</td>
</tr>
<tr>
<td>Other</td>
<td>7**</td>
<td>5%</td>
</tr>
<tr>
<td>Unknown cause</td>
<td>15+</td>
<td>11%</td>
</tr>
</tbody>
</table>

*5 of these were at low underpasses
**5 related to operational/maintenance
†12 outside the U.S.

*Source: Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation*
Many PRD-related incidents but many were not design-related or due to failures

- PRDs worked properly in 42% of incidents involving fire
- In half of these the gas ignited but was attributed to poor installation or PRD
- 35% of fires PRDs did not release but mostly because fire did not reach location of PRD so storage system was compromised
- Two-thirds of NGV accidents w/vehicles no gas was released.

Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation
(U.S.) Clean Vehicle Education Foundation has created specific stakeholder working groups to resolve these critical issues

1. SANDIA Phase II modeling on indoor gas releases
2. Over pressure filling of CNG cylinders (short term) (related to temperature compensation at the fuelling station) Technical Bulletin has been published.
3. Over pressure filling of CNG Cylinders (mid term) will explore possible pressure control by the vehicle vs. the fuel dispenser
5. Pressure activated PRD use and issues
6. PRD installation and venting
Reality: CNG vehicles are safer than gasoline vehicles in tunnels.

• in 1989, several natural gas utilities and the New York State Energy Research and Development Authority jointly funded an comprehensive, $1.2 million safety analysis of fuel-related accidents in tunnels.

• Conclusion: modern tunnel environments, fanned by high-powered ventilation systems, would quickly remove and disperse gaseous fuels safely above ground in the event of an accident.

Reality: CNG vehicles are safer than gasoline vehicles in tunnels.

- Report done to overcome prohibitions of NGVs in tunnels in Boston, Massachusetts (1994)
- The comparison of the gasoline and CNG dispersion calculations demonstrates that the size of the flammable region from an incident involving a CNG fueled van is significantly smaller than the flammable region from a comparable incident involving a gasoline fueled van as long as the effective ventilation velocity is on the order of 0.10 m/s or higher.

Reality: NGVs pose no risk in underground parking garages

- “A CNG vehicle poses no extraordinary risk in a typical parking garage; that is, the risk of the CNG vehicle is equal to or less than the risk posed by a gasoline fuelled vehicle. The conclusion is valid for both forced and natural circulation type garage designs and should cover every type of public parking garage normally encountered. Overall, parking in public garages is not a major CNG safety concern.” (Caveat: Special cases, where the analysis cannot be extended, include a garage with no ventilation, or a garage with no ceiling registers [ventilation outlets]).

Reality: Home fuelling appliances pose minimal risks in garages*

The potential for a hazardous fire due to accidents (non-misuse failures) and even mis-use of the fuelling appliance are 1 in 10.7 million over one year.

On the sea with LNG has some strong supporters…and for inland waterways

• "We support the steps taken to develop the use of liquefied natural gas (LNG) as fuel in European inland navigation because we are convinced of its advantages.

• The use of LNG by vessels into a transport system meets the highest level of security and fully meets the criteria of the CCNR on this point. **LNG-powered vessels are just as safe as others.**“

Hans van der Werf, Secretary General of the Central Commission for the Navigation of the Rhine (CCNR)


Photo: © Dance

Eiger-Nordwand is the first retrofitted LNG river container ship with funding from the EU Ten-T project. CO2 reduced by 40%; NOx & particulates by 90%
SAFETY in the NGV
‘VALUE CHAIN’

From ‘mine-mouth’ to tailpipe…and beyond
Safety requirements are imposed along each link in the NGV value chain
Small Scale LNG Value Chain

Small Scale LNG, TNO Vision on Innovation, Bas van den Beemt, IEA Gas & Oil Technologies Implementing Agreement, 2014 09 16. Adapted from Shell graphic.
Weak links along the Safety Chain

- Low quality raw materials
- Inferior components or ‘knock-offs’
- Single unit certification – no batch testing
- Untrained certification officials
- Bribed certification officials
- Human errors
Making weak links stronger

• Identifying the problem;
• Who is responsible? (buyer beware?);
• How to rectify the problem?
• What can be done to prevent a recurrence?
• Who is liable?
• Penalties? (enforcement)

‘He did it!” (Thomas Nast)
Global NGV Safety
Tying up the loose ends
Overview of total energy consumption for transportation markets suitable for small scale LNG.

By 2025 worldwide LNG consumption anticipated:
- 74% = trucks
- 20% = marine
- 6% = rail

Source: Global Potential of Small Scale LNG Production, A quick scan study, TNO, 2014, report 10447.
Trucks, Rail and Maritime volumes are based on the estimations from the ExxonMobil graph, 2014.
More than 300 members from industries and associations are working together creating a global team

- NGVA Europe
- ANGVA – Asia/Pacific
- ARPEL – Latin America

**Regional NGVs Associations**

- Argentina, Austria, Belgium, Bolivia, Brasil, Canada, Caribbean, China, Croatia, Cz.Republic, Denmark, Ecuador, Finalnd, France, Hungary, India, Indonesia, Italy, Japan, Malaysia, Netherlands, Norway, Pakistan, Portugal, Russia, South Korea, Spain, Sweden, Thailand, Turkey, Ukraine, USA, Uzbekistan

**NGV Global**

- The NGV Stakeholders
  - Equipment & service suppliers
  - Energy industries
  - Vehicle-makers

**National NGVs Associations**
Associations supporting gaseous fuel propulsion – NGVs, marine, rail -- must work together

NGV Stakeholders

Regional Associations

International Industry Associations

National Associations

Standards Institutions
ISO – CEN Etc.

Regulatory Institutions
UNECE-IMO Etc.
Strategic vision to promote safe technology & best practices (and, by the way, *market growth*)

- Cross-fertilized, harmonization of international standards and regulations that *recognize the common safety attributes* (and risks) of natural gas as fuel alternative to petroleum fuels (*to the best extent possible*….)
- Cross-fertilization of industry associations (road-off-road/marine/rail) and their members’ knowledge, skills and experiences.
- Integration of NGV global markets for all applications – road/off-road, marine, & rail
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