CNG: A SAFE FUEL FOR ADR TRUCKS

presented to
WP15 - Transport of Dangerous Goods
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on behalf of

NGV Global
Building blocks for NGV safety

**EQUIPMENT STANDARDS:**
- Materials Selection
- Factors of Safety
- Verification Testing

**INSTALLATION CODES:**
- Station Siting
- Pressure
- Management
- Cylinder Safety

**QUALIFIED PERSONNEL:**
- Training
- Operating and maintenance procedures

**EDUCATION OF END USERS:**
Drivers, Fleet Managers, Fueling Station Operators, First Responders, General Public

COMMON PERCEPTIONS OF NATURAL GAS AS A VEHICLE FUEL
Past & Present

Perception is Reality
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

- 75% Yes
- 16% neutral
- 9% No
- 4 Not at all
- 5 Not much
- 16 Neutral
- 46 Much
- 29 Very much

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

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

1999 survey

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

(More than one answer allowed)

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

- Not at all: 8
- Not much: 12
- Neutral: 16
- Much: 38
- Very much: 26

64% Yes, 16% neutral, 20% No

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

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

Source: Italian NGV Scenario 2005, Flavio Mariani, Metauto-ENI Divsione Gas & Power, Cattolica, September 20-21, 2005
NATURAL GAS SAFETY
Physical characteristics of natural gas shows that the fuel is as safe or safer than gasoline or diesel

<table>
<thead>
<tr>
<th>Properties</th>
<th>Petrol</th>
<th>Diesel</th>
<th>LPG</th>
<th>CNG</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Explosive Limit (LEL)</strong></td>
<td>1.2%</td>
<td>0.6%</td>
<td>1.8%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td><strong>Upper Explosive Limit (UEL)</strong></td>
<td>7.1%</td>
<td>7.5%</td>
<td>8.5%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td><strong>Auto ignition Temperature</strong></td>
<td>246 °C</td>
<td>210 °C</td>
<td>450 °C</td>
<td>540 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Flash point</strong></td>
<td>-43 °C</td>
<td>55 °C</td>
<td>-104 °C</td>
<td>-188 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Dispersion quality</strong></td>
<td>None</td>
<td>none</td>
<td>medium</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
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
TESTING OF CYLINDERS

- Drop test at 45°
- Drop test vertically
- Drop test horizontally
- Frontal crash test 30g for bus
- Frontal crash test 30g for trucks
- Catapult launching at 50 km/h against a metallic sharp edge
- Bonfire testing
- Gun fire testing bullet 7.62 mm
- Grenade test
- Hydraulic burst test
- Extreme temperature pressure cycling
- Hydraulic test pressure 300 bar

Source: Ullit
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 (1976-2010)

<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.

Details of Incidents
(135 total listed)

Cylinder Ruptures (50 incidents)
- 18 (36%) were due to damage to exterior of cylinder (including, for example, acid leaked from batteries carried in transit) (inspection issue)
- 8 (16%) were due to manufacturer defect

Accidents with other vehicles (12 incidents)
- 8 (47%) had no gas release
- 8 (47%) had controlled release of gas through PRD (1 ignited)

Vehicle Fires (17 incidents or 13% of total incidents [135 of total listed])
- Only 1 attributed to the natural gas system
Fire incidents generally were not related to the CNG system

- “The majority of the vehicle fires included in the list of incidents were not caused by a leaking CNG fuel system and were in light-duty vehicles;

- Most fires were started by an electrical short, stuck brakes (which ignited a tire), or leaking gasoline, diesel fuel, or hydraulic fluid impinging on a hot engine or exhaust components.
NGV Safety in Maintenance Workshops
(HAZOP Study)

1) LNG boil off scenario
2) Venting/bleed CNG/LNG in maintenance scenario
3) Full venting of 700 L CNG tank (high volume)

FINDINGS

1 & 2: “Flammable regions disappeared shortly after leaks; no significant hazard expected”

3: “High volume release had two peaks when gas was flammable with roughly 0.5 kg of natural gas in flammable regions… could produce an overpressure of around 2.2 kPa—enough to break glass, but not much else.”

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 a 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 then gasoline vehicles in tunnels.

- Report done to address 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.

CNG vs Diesel (Buses) in Tunnels

PURPOSE
comparing inherent risks of operating CNG buses in tunnels to the inherent risks of operating diesel buses under the same conditions.

OBJECTIVES
- To identify scenarios of accidents implicating CNG buses being operated in tunnels
- To evaluate the risks of these CNG buses and to compare them to the risks associated to the operation of diesel buses under the same conditions

Two tunnel scenarios evaluated

The tunnel environnement

- Two considered scenarios for the traffic conditions:
  - Dense traffic:
    - 3000 vehicles/hour (average speed: 10 km/h)
    - 100 passengers into the bus
  - Moving freely traffic:
    - 1000 vehicles/hour (average speed: 60 km/h)
    - 40 passengers into the bus

The ventilation evolution in the tunnel following the accident:

Ventilation evolution in the tunnel

Flow stabilization after 4 min
@ 3 m/sec-1

Conclusions CNG vs Diesel in Tunnels

During the first 10 minutes following the accident, the global risk level of a CNG bus is about 3 times inferior to the global risk level of a diesel bus.

During the first hour following the accident, the global risk level of a CNG bus is 1.4 times inferior to the global risk level of a diesel bus.

CNG buses are not more dangerous than diesel buses in tunnels.

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 misuse of the fuelling appliance are 1 in 10.7 million over one year.

CNG cylinder inspections are required every 48 months (UN/ECE R.110)

- Or…after one of the following events occurs:
  - Accident affecting the high pressure system
  - Over pressurization
  - Exposure to corrosive products
  - Other: abnormal gas smell; rapid pressure loss; whistling sound, etc.
  - Installation or replacement of a cylinder

Photo source: CETIM
The inspection process

- **Phase 1: Preparation**
  - Tank detailed visual inspection & leak testing
  - Inspection of environment close to the tank
  - Inspection of tank flanges and gaskets
  - Inspection of complete fuel line from the regulator to the vent line

- **Phase 2: Inspection**

- **Phase 3: recertify / repair / reject**

Source: In-service inspection of high pressure installation using CNG, CETIM, CID Inspection, 2006
What damages are looked for on cylinders?

- labeling inspection
- heat damages
- chemical damages
- UV damages
- Delamination
- leak from the cylinder
- cracks, scratches, dent
- impact
- stress corrosion cracking
- abrasion damages
- generalized corrosion
- galvanic corrosion

Source: In-service inspection of high pressure installation using CNG, CETIM, CID Inspection, 2006
What damages are looked for on the high pressure system?

- the fuel line
- bracket
- PRD
- the valves
- the vent line
- the filling connector
- the regulator

Source: In-service inspection of high pressure installation using CNG, CETIM, CID Inspection, 2006
CONCLUSIONS

- Characteristics of natural gas make it a safe fuel.
- The on-board vehicle fuel system integrity is amongst the most robust of any vehicles.
- CNG fuel storage system safety is outstanding...in theory and practice.
- Natural gas is amongst the safest fuels on the road.
- NGVs are amongst the safest vehicles on the road.....and are suitable to be certified as ADR.
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