

**Changes to Consider in the  
Federal Motor Carrier Safety Regulations and  
North American Standard Inspection Procedures  
to Accommodate Hydrogen as an  
Alternative Fuel**

**Final Report**



**U.S. Department of Transportation  
Federal Motor Carrier Safety Administration**

**November 2007**

# **FOREWORD**

## **PURPOSE**

Today, virtually all commercial trucks are powered by diesel fuel, while private cars are fueled by gasoline. Supported by our National Energy Policy, a new generation of technologies is currently being developed that allow the use of hydrogen as a fuel to power cars and trucks. The purpose of this document is to provide a review of existing Federal Motor Carrier Safety Regulations (FMCSRs) with respect to changes that should be considered to accommodate commercial vehicles that use hydrogen as an alternative fuel. In addition, this document also provides a review of the existing North American Standard (NAS) Inspection Procedures and considers changes in those procedures that should be considered for inspections of commercial vehicles using hydrogen as an alternative fuel.

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## SI\* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
<u>LENGTH</u>					<u>LENGTH</u>				
in	Inches	25.4	millimeters	Mm	mm	millimeters	0.039	inches	in
ft	Feet	0.305	meters	M	m	meters	3.28	feet	ft
yd	Yards	0.914	meters	M	m	meters	1.09	Yards	yd
mi	Miles	1.61	kilometers	Km	km	kilometers	0.621	miles	mi
<u>AREA</u>					<u>AREA</u>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>	mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ac	Acres	0.405	hectares	Ha	ha	hectares	2.47	acres	ac
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>	km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<u>VOLUME</u>					<u>VOLUME</u>				
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	Gallons	3.785	liters	L	l	liters	0.264	gallons	gal
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	35.71	cubic feet	ft <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<u>MASS</u>					<u>MASS</u>				
oz	Ounces	28.35	grams	G	g	grams	0.035	ounces	oz
lb	Pounds	0.454	kilograms	Kg	kg	kilograms	2.202	pounds	lb
T	short tons (2000 lbs)	0.907	megagrams	Mg	Mg	megagrams	1.103	short tons (2000 lbs)	T
<u>TEMPERATURE (exact)</u>					<u>TEMPERATURE (exact)</u>				
°F	Fahrenheit Temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
<u>ILLUMINATION</u>					<u>ILLUMINATION</u>				
fc	foot-candles	10.76	lux	Lx	lx	Lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m2	cd/m2	cd/m2	candela/m2	0.2919	foot-Lamberts	fl
<u>FORCE and PRESSURE or STRESS</u>					<u>FORCE and PRESSURE or STRESS</u>				
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

\* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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## ACRONYMS

CHP	California Highway Patrol
CNG	Compressed Natural Gas
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMVSS	Federal Motor Vehicle Safety Standards
LNG	Liquefied Natural Gas
NAS	North American Standard for commercial vehicle inspections
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
PRD	Pressure Relief Devices
PRV	Pressure relief valve; a device used to protect from overpressure inside a high-pressure storage tank
psi	Pounds per square inch; a unit of measure for pressure
psig	Pounds per square inch gauge; gauge pressure is measured relative to atmospheric air pressure at sea level, so that gauge measurements of atmospheric pressure at sea level are always 0 psig
SAE	Society of Automotive Engineers



## **EXECUTIVE SUMMARY**

Over the next 50 years, hydrogen use is expected to grow dramatically as an automotive and electrical power source fuel. As hydrogen becomes commercially viable, the safety concerns associated with hydrogen systems, equipment, and operation are of concern to the commercial motor vehicle industry. This report provides a review of the existing Federal Motor Carrier Safety Regulations (FMCSRs) that pertain to fueling systems and considers changes in order to accommodate gaseous and liquid hydrogen. In addition, this report considers changes to the current North American Standard (NAS) Inspection Procedures to accommodate gaseous and liquid hydrogen used as an alternative fuel in commercial vehicles.

# 1. INTRODUCTION

This report provides a review of existing Federal Motor Carrier Safety Regulations (FMCSRs) overseen by the FMCSA to determine what, if any, modifications should be considered in existing regulations in order to accommodate the use of hydrogen fuel in the commercial vehicle sector. The primary FMCSR that governs commercial vehicle fuel systems is 49 CFR Part 393.65. This report also considers how commercial vehicle inspections and carrier reviews may need to be modified to address commercial vehicles that use hydrogen as an alternative fuel.

Examples of hydrogen fuel system equipment that are different from traditional fueled vehicles include:

- Pressure relief devices
- Venting stacks
- High-pressure fuel tanks (compressed hydrogen)
- Cryogenic fuel tanks (liquid hydrogen)
- Leak detection systems
- Numerous other special features depending on fuel cell type, reformer technology, fuel storage approach, and other manufacturer-specific design features

A separate report provides information on the types of hydrogen fuel systems and components that could be expected for use in the commercial vehicle sector (see *Guidelines for Use of Hydrogen Fuel in Commercial Vehicles*, FMCSA, dated 2007).

## 2. HYDROGEN FUEL CONSIDERATIONS

In order to promulgate safety regulations for the use of hydrogen as an alternative fuel, one must have a basic understanding of the properties of hydrogen (see Guidelines for Use of Hydrogen Fuel in Commercial Vehicles, FMCSA, dated 2007 for additional details on the properties of hydrogen). Hydrogen as a fuel has unique physical and chemical properties that are different from traditional automotive fuels. These properties have specific hazards associated with them including:

- Hydrogen is not readily detectable by human senses. Hydrogen is colorless, odorless,<sup>1</sup> and tasteless. Therefore, systems and equipment are required to detect the presence of hydrogen in the event of a leak.
- Hydrogen has a high flammability for two reasons. As compared to other automotive fuels, hydrogen has a much wider range of flammable concentrations in air. Second, hydrogen has one of the lowest ignition energy levels of automotive fuels.

These two hazards of hydrogen are the fundamental principles that were considered in reviewing existing safety regulations and identifying the need for modifying or developing new safety regulations.

In addition to the above issues related to the properties of hydrogen, one must also have an understanding of the form in which hydrogen is likely to be stored and used on the vehicle. Due to the low energy content of hydrogen, using hydrogen as a fuel requires onboard storage in compressed gas or liquid form in order to provide sufficient range for vehicle systems. Consequently, the storage of hydrogen onboard vehicles can introduce additional hazards such as:

- High Pressure – Hydrogen is most likely to be stored on the vehicle as a high-pressure gas, at pressures up to 10,000 pounds per square inch.
- Extremely Low Temperature – Hydrogen may also be stored on the vehicle as a cryogenic liquid at temperatures below -423°F.

The understanding and consideration of the hazardous properties discussed thus far form the basis for safely using hydrogen as an alternative fuel, and will shape appropriate considerations for changes in the regulations. Consideration of changes in FMCSA regulations that address hazards related to the form in which hydrogen is stored on the vehicle will be similar if not identical to those by NHTSA in the FMVSS regulations dealing with other high-pressure gases or cryogenic liquids used as automotive fuels (for example, compressed natural gas or liquefied natural gas). Of the fuel properties unique to hydrogen, the most important with respect to safety regulations are those related to detection by human senses (odorless, colorless, invisible flame) and hydrogen's very high flammability.

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<sup>1</sup> Other gases used as automotive fuel, for example natural gas, are also naturally odorless. However, sulfur-based odorants are typically added to pipeline natural gas to aid in detecting a leak. These odorants are incompatible with the catalysts used in automotive fuel cells and substitute odorants have not been developed.

### **3. FMCSR REVIEW**

The FMCSR requirements for “All Fuel Systems” are listed in 49 CFR Parts 392.50, 393.27, 393.28, and 393.65 as shown in section 4.0 of this report. Based on the review of this existing regulation, it is apparent that significant modifications are required for commercial vehicles that use hydrogen as an alternative fuel. Specifically:

- In general, the regulations are written for commercial vehicles using diesel fuel and do not address alternative fuels.

In particular, the regulations do not consider safety systems and equipment regulations required for commercial vehicles using hydrogen as an alternative fuel (e.g., requirements for grounding and bonding fueling connections).

## 4. 49 CFR PARTS 392.50, 393.27, 393.28, AND 393.65

### 49 CFR 392.50, Ignition of fuel; prevention.

No driver or any employee of a motor carrier shall:

- (a) Fuel a commercial motor vehicle with the engine running, except when it is necessary to run the engine to fuel the commercial motor vehicle;
- (b) Smoke or expose any open flame in the vicinity of a commercial motor vehicle being fueled;
- (c) Fuel a commercial motor vehicle unless the nozzle of the fuel hose is continuously in contact with the intake pipe of the fuel tank;
- (d) Permit, insofar as practicable, any other person to engage in such activities as would be likely to result in fire or explosion.

### 49 CFR 393.27, Wiring specifications.

(a) Wiring for both low voltage (tension) and high voltage (tension) circuits shall be constructed and installed so as to meet design requirements. Wiring shall meet or exceed, both mechanically and electrically, the following SAE Standards as found in the 1985 edition of the SAE Handbook:

- (1) Commercial vehicle engine ignition systems-SAE J557-High Tension Ignition Cable.
- (2) Commercial vehicle battery cable-SAE J1127-Jan 80-Battery Cable.
- (3) Other commercial vehicle wiring-SAE J1128-Low Tension Primary Cable.

(b) The source of power and the electrical wiring shall be of such size and characteristics as to provide the necessary voltage as the design requires to comply with FMVSS 571.108.

(c) Lamps shall be properly grounded.

NOTE: This shall not prohibit the use of the frame or other metal parts of a motor vehicle as a return ground system provided truck-tractor semitrailer/full trailer combinations are electrically connected.

### 49 CFR 393.28

Electrical wiring shall be installed and maintained to conform to SAE J1292-Automobile, Truck, Truck-Tractor, Trailer, and Motor Coach Wiring, October 1981, except the jumper cable plug and receptacle need not conform to SAE J560. The reference to SAE J1292 shall not be construed to require circuit protection on trailers. (See §393.7(b) for information on the incorporation by reference and availability of this document.)

### 49 CFR 393.65

(a) *Application of the rules in this section.* The rules in this section apply to systems for containing and supplying fuel for the operation of motor vehicles or for the operation of auxiliary equipment installed on, or used in connection with, motor vehicles.

(b) *Location.* Each fuel system must be located on the motor vehicle so that --

- (b)(1) No part of the system extends beyond the widest part of the vehicle;
- (b)(2) No part of a fuel tank is forward of the front axle of a power unit;
- (b)(3) Fuel spilled vertically from a fuel tank while it is being filled will not contact any part of the exhaust or electrical systems of the vehicle, except the fuel level indicator assembly;
- (b)(4) Fill pipe openings are located outside the vehicle's passenger compartment and its cargo compartment;
- (b)(5) A fuel line does not extend between a towed vehicle and the vehicle that is towing it while the combination of vehicles is in motion; and
- (b)(6) No part of the fuel system of a bus manufactured on or after January 1, 1973, is located within or above the passenger compartment.

(c) *Fuel tank installation.* Each fuel tank must be securely attached to the motor vehicle in a workmanlike manner.

(d) *Gravity or syphon feed prohibited.* A fuel system must not supply fuel by gravity or syphon feed directly to the carburetor or injector.

(e) *Selection control valve location.* If a fuel system includes a selection control valve which is operable by the driver to regulate the flow of fuel from two or more fuel tanks, the valve must be installed so that either --

- (e)(1) The driver may operate it while watching the roadway and without leaving his/her driving position; or
- (e)(2) The driver must stop the vehicle and leave his/her seat in order to operate the valve.

**49 CFR 393.65 (continued)**

(f) *Fuel lines.* A fuel line which is not completely enclosed in a protective housing must not extend more than 2 inches below the fuel tank or its sump. Diesel fuel crossover, return, and withdrawal lines which extend below the bottom of the tank or sump must be protected against damage from impact. Every fuel line must be --

(f)(1) Long enough and flexible enough to accommodate normal movements of the parts to which it is attached without incurring damage; and

(f)(2) Secured against chafing, kinking, or other causes of mechanical damage.

(g) *Excess flow valve.* When pressure devices are used to force fuel from a fuel tank, a device which prevents the flow of fuel from the fuel tank if the fuel feed line is broken must be installed in the fuel system.

[36 FR 15445, Aug. 14, 1971, as amended at 37 FR 4341, Mar. 2, 1972; 37 FR 28752, Dec. 29, 1972]

## **5. BASES FOR CONSIDERING CHANGES TO FMCSRs AND NAS INSPECTION PROCEDURES**

The consideration of changes to the Federal Motor Carrier Safety Regulations and North American Standard Inspection Procedures to accommodate hydrogen as an alternative fuel contained in this report are based on three factors:

- The wide flammability range of hydrogen and inability of the unaided human senses to detect hydrogen leaks require more stringent measures than those currently being taken with diesel fuel.
- Gaps identified in existing Federal Motor Carrier Safety Regulations (FMCSRs) with respect to pressurized gaseous and cryogenic liquid fuel systems.
- Current practices identified to inspect alternative-fueled vehicles.

Each of these factors is discussed below.

### **5.1 GAPS IN EXISTING FMCSRs WITH RESPECT TO FUELS THAT ARE LESS DETECTABLE AND MORE FLAMMABLE THAN DIESEL FUEL**

As compared to diesel, hydrogen has properties that should be considered in the FMCSRs, mainly:

- Hydrogen leaks onboard a commercial vehicle using hydrogen as an alternative fuel cannot be detected by human senses. The inability to detect hydrogen leaks means that other measures are required for commercial vehicle using hydrogen as an alternative fuel.
- A hydrogen flame has very low luminosity and is nearly invisible or undetectable in daylight conditions.
- Hydrogen has a wider flammability range than diesel. A wider flammability range means that hydrogen poses a greater fire hazard than diesel.
- Hydrogen has a lower ignition energy than diesel. A lower ignition energy means that hydrogen can be ignited easier than diesel.

As a result of these differences, more stringent requirements should be added to the existing FMCSRs to accommodate the use of hydrogen as an alternative fuel in commercial vehicles. Specific changes discussed in the following sections of this report include the need for the requirement for hydrogen leak detection systems, grounding and bonding, and prohibition against the use of cell phones during fueling.

## **5.2 GAPS IN EXISTING FMCSRs WITH RESPECT TO PRESSURIZED GASEOUS AND CRYOGENIC LIQUID FUELS**

Based on current hydrogen fuel technology, there are two ways that hydrogen that may be stored as an alternative fuel:

- Compressed hydrogen—The most common form of hydrogen fuel stored onboard vehicles today is compressed hydrogen. In order to get enough fuel onto a vehicle to be able to go several hundred miles between fill-ups, but without taking up too much space, the hydrogen must be stored at very high pressure. Most current vehicle systems store hydrogen at a pressure of 5,000 pounds per square inch (psi).
- Liquefied hydrogen—In order to increase a vehicle’s range, some manufacturers of hydrogen systems are considering storing hydrogen onboard in liquefied form. The boiling point of hydrogen at atmospheric pressure is -423°F; above that temperature, hydrogen exists as a gas, and it will only liquefy if the temperature drops below the boiling point. Compressors and heat exchangers can be used to lower the temperature of hydrogen gas to produce liquid hydrogen, which must then be kept at this very low temperature or it will “boil off” again as a gas. To maintain its temperature, liquid hydrogen is stored in specialized, heavily insulated, containers called “dewars,” “cryotanks,” or “cryogenic vessels.”

A detailed discussion of hydrogen onboard storage can be found in the FMCSA report entitled “Guidelines for Use of Hydrogen Fuel in Commercial Vehicles.”

These two forms of hydrogen fuel are considered the most common forms of hydrogen that are used as an alternative fuel and form one of the bases for considering revisions in the FMCSRs for accommodating hydrogen as an alternative fuel.

Based on a review of the existing regulations, several key elements are missing with respect to hydrogen and gaseous fuels in general.

- There are currently no FMCSRs for compressed gaseous fuels.
- Currently, there are no FMCSRs that pertain to cryogenic or super-cooled liquid fuels.

Based on increased environmental considerations to operate cleaner commercial vehicles, some fleet operators are investigating hydrogen and natural gas as an alternative to diesel. It is readily apparent from a review of the existing regulations that new regulations need to be developed for the vehicles using these types of alternative fuels.



### **5.3 CURRENT PRACTICES IDENTIFIED TO INSPECT ALTERNATIVE-FUELED VEHICLES**

Another important factor that contributed to the consideration of regulatory changes contained in this report was a review of inspection practices currently deployed to regulate and inspect alternative-fueled vehicles. As part of this project, a site visit was made to the California Highway Patrol (CHP), Commercial Vehicle Section, located in Sacramento, California. The CHP has developed a comprehensive program to inspect compressed natural gas (CNG) and liquefied natural gas (LNG) commercial vehicles operating in California. The CHP inspection program includes developing detailed CNG and LNG inspection checklists from NFPA 52 and 57 fire codes, and providing on-the-job training for field inspectors. Based on this review, the CHP inspection procedures for vehicles using natural gas, either liquefied or compressed, could serve as a model for inspection of commercial vehicles using hydrogen as an alternative fuel (note: The CHP had not updated its checklist to conform to the most recent NFPA edition [NFPA 52] at the time of our visit). A copy of the CHP's inspection procedures is contained in appendix A of this report.

## 6. CONSIDERING CHANGES TO FMCSRs FOR GASEOUS HYDROGEN

To properly regulate gaseous hydrogen-fueled commercial vehicles, specific regulations should be considered for gaseous hydrogen. The following areas should be considered for inclusion into updated regulations:

1. Vehicle Labeling
  - a. Requirement for “diamond “ type labeling of commercial vehicle as a gaseous hydrogen fueled vehicle:
    - Label (consistent with Society of Automotive Engineer [SAE] J2578, Recommended Practice for Hydrogen Vehicles)
    - Location (suggested in tow locations on opposing sides of vehicle cab)
    - Label Size (suggested readable at 50 ft)
2. Fuel Components and Tank Labeling (e.g., similar to requirements of 49 CFR 571.304 for compressed natural gas (CNG) tanks but applied to gaseous hydrogen tanks):
  - a. Manufacturer’s name
  - b. Model/serial number
  - c. Design service pressure
  - d. Direction of flow
  - e. Capacity
  - f. Fuel type (i.e., label “gaseous hydrogen”)
3. Fuel Tank Certification and Recertification (e.g., similar to requirements of 49 CFR 571.304 for CNG tanks but applied to gaseous hydrogen tanks)
  - a. Design Certification Test
  - b. Maintenance Personnel Certification<sup>2</sup>
  - c. Periodic retesting and labeling (per Pamphlet C6)<sup>3</sup>
  - d. Record of last defects visual inspection

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<sup>2</sup> “CSA America is the only known standards development organization in the U.S. that provides testing and certification for qualified compressed natural gas (CNG) cylinder inspections and maintains a National Registry of Certified inspectors. To qualify for a new certification, or to renew an existing certification, candidates must successfully pass a certification exam. To maintain their status without re-examination, certified CNG Inspectors must perform and submit reports on 10 vehicle or 50 cylinder inspections per year.”

<sup>3</sup> Compressed Gas Association, Inc., Pamphlet C-6: Standards for Visual Inspection of Compressed Gas Cylinders, 1984.

4. Pressure Relief Devices (PRDs) installed on fuel tanks in direct contact with fuel (e.g., similar to requirements of 49 CFR 571.304 for CNG tanks but applied to gaseous hydrogen tanks)
5. Fueling Connection
  - a. Grounding and bonding requirements
  - b. Dust cap
  - c. Labeling the fueling compartment or fueling door with “gaseous hydrogen,” service pressure, and installer or company name because all the information may not fit on the fueling compartment door; therefore, some of the information for Item 5 may be placed on the back panel of the fueling compartment so that it can be seen when the fueling door is opened.
  - d. Support for fueling connector
6. Fuel Tank System Installation
  - a. Protection and shielding from road hazards
  - b. Mounted to minimize damage from collision
  - c. Mounting racks are secured
  - d. Clearance from road to storage tank container
  - e. Shielded against heat sources
  - f. Fuel system components electrically bonded and grounded (specific for hydrogen)
7. Venting System
  - a. Hydrogen venting or purging does not vent to hazardous location (i.e., not to engine compartment or wheel well)
  - b. Vent piping system shall be metallic
  - c. Hydrogen does not vent or purge to restrict PRD safety devices
  - d. Venting system contains protective cap or cover
  - e. Secured at outer end
  - f. Venting of enclosed spaces where leaked gaseous fuel might collect
  - g. Not blocked by ice, snow, or debris
8. Piping and valves
  - a. Provide automatic shutoff valve for fuel tanks in response to system fault.
  - b. Provide manual shutoff valve.
9. Installation of Fuel Pressure Gauge

10. Wiring
  - a. High voltage labeling is properly labeled and color coded.
  - b. Do not route through passenger compartment.
  - c. Ground fault detection system shall be provided.
  - d. Live components behind cover/enclosure labeled with high-voltage symbols.
  - e. Connectors are not loose, broken, cracked, or otherwise defective.
11. Post Accident Precautions – Inspection and replacement following an accident (e.g., similar to requirements of 49 CFR 571.304 S7.4(g) for CNG tanks but applied to gaseous hydrogen tanks)
12. Gas Leak Detection System (e.g., regulation should require a hydrogen leak detection system)
13. Shutoff Valve - Turning off main on/off switch isolates fuel to storage tank
14. Driver Awareness Training Program – Suggest vehicle operator attend hydrogen hazard awareness training and compressed gas hazards.
15. Activities – The use of cellular phones during fueling in the fueling area should be prohibited.

## **7. CONSIDERING CHANGES TO FMCSRs FOR LIQUID HYDROGEN**

To properly regulate liquid hydrogen fueled commercial vehicles, specific regulations should be considered for liquid hydrogen. The following areas should be considered for inclusion into updated regulations:

1. Vehicle Labeling
  - a. Requirement for “diamond” type labeling of commercial vehicle as a liquid hydrogen vehicle
    - Label (consistent with Society of Automotive Engineer [SAE] J2578, Recommended Practice for Hydrogen Vehicles)
    - Location (suggested in tow locations on opposing sides of vehicle cab)
    - Size (suggested readable at 50 ft)
2. Fuel Components and Tank Labeling (similar to the requirements of 49 CFR 571.304 requirements but applied to liquid hydrogen tanks)
  - a. Fuel type (i.e., liquid hydrogen)
  - b. Manufacturer’s name
  - c. Model number/serial number
  - d. Design service pressure
  - e. Direction of flow
3. Fuel Tank Certification and Recertification (similar to the requirements of SAE standard J2343 for liquefied natural gas (LNG) tanks but applied to liquid hydrogen tanks)
  - a. Design Certification Test
  - b. Periodic retesting and labeling
4. Pressure Relief Valves (PRVs) installed on fuel tanks
5. Fueling Connection
  - a. Grounding and bonding requirements
  - b. Dust cap
  - c. Labeling the fueling compartment or fueling door “liquid hydrogen” with service pressure, and installer or company
6. Fuel Tank System Installation
  - a. Protection and shielding
  - b. Mounted to minimize damage from collision
  - c. Mounting racks are secured

- d. Clearance from road to storage tank container
  - e. Shielded against heat sources
  - f. Fuel system components electrically bonded and grounded (specific to hydrogen)
  - g. Fuel system components insulated, vapor sealed, and protected from casual contact
7. Venting System
- a. Venting diffuser output to less than 20% of the lower flammable limit
  - b. Hydrogen venting or purging does not vent to hazardous location (i.e., not to engine compartment or wheel well)
  - c. Vent piping system shall be metallic
  - d. Hydrogen does not vent or purge to restrict PRD safety devices
  - e. Venting of enclosed spaces where leaked gaseous fuel might collect
  - f. Venting system contains protective cap or cover
  - g. Secured at outer end
  - h. Not blocked by ice, snow, or debris
8. Piping and valves
- a. Provide automatic shutoff valve for fuel tanks
  - b. Provide manual shutoff valve
9. Installation of fuel liquid level gauge
10. Wiring
- a. High voltage labeling is properly labeled and color coded
  - b. Do not route through passenger compartment
  - c. Ground fault detection system shall be provided
  - d. Live components behind cover/enclosure labeled with high voltage symbols
  - e. Connectors are not loose, broken, cracked, or otherwise defective
11. Post Accident Precautions – Inspection and replacement (similar to requirements of 49 CFR 571.304 S7.4g for CNG tanks but applied to liquid hydrogen tanks)
12. Leak Detection
13. Shutoff Valve - Turning off main on/off switch isolates fuel to storage tank.
14. Driver Awareness Training Program – Suggest vehicle operator attend hydrogen hazard awareness training including a module on cryogenic hazards.
15. Activities – The use of cellular phones during fueling in the fueling area should be prohibited.

## **8. NORTH AMERICAN STANDARD (NAS) INSPECTION PROCEDURES**

The North American Standard (NAS) Inspection program has five levels of inspections, established by CVSA:

- Level I: Detailed driver and vehicle inspection
- Level II: Driver inspection and walk-around vehicle inspection
- Level III: Driver only inspection
- Level IV: Special one-time inspections of a particular item
- Level V: Vehicle only inspection without a driver present (typically conducted at a carrier facility/terminal)
- Level VI: Enhanced Level I inspection for radioactive shipments (includes additional checks for vehicles carrying radioactive hazardous materials).

Table 1 below shows the various inspection levels and what is typically performed.

Three types of inspections are generally implemented by inspection oversight agencies:

- Annual
- Trip
- “Random” roadside

Certainly, everything that has been specified for consideration in sections 10 and 11 apply to the more thorough, comprehensive annual inspections, which generally occur at the owner/operator’s facilities or at an inspection facility. The comprehensive annual inspections would make use of a checklist similar to the CHP checklists for LNG and CNG, except that these would be for liquid hydrogen and compressed hydrogen. Only certain parts of sections 10 and 11 apply to both the trip and “random” roadside inspections.

The trip and “random” roadside inspections may be discussed together at the same time because whatever the driver can do, the inspector can, and vice versa. Those parts of sections 10 and 11 that would apply to both the trip and “random” roadside inspections should include the following:

- Verifying that the annual inspection was performed,
- Ensuring that the appropriate labels are affixed properly for hydrogen,
- Checking for certification/recertification of the hydrogen storage tanks,
- Observing for any visible damage to the hydrogen storage tanks,
- Checking for properly functioning leak detection system as well as for leaks, and
- Confirming that the operator (if present) has had hydrogen awareness training.

**Table 1. Inspection Levels**

Inspection Item	Level I	Level II	Level III	Level IV	Level V	Level VI
Driver's License	✓	✓	✓			✓
Medical Examiner's Certificate and Waiver	✓	✓	✓			✓
Alcohol and Drugs	✓	✓	✓			✓
Driver's Log (HOS and Duty Status)	✓	✓	✓			✓
Seatbelt System	✓	✓	✓		✓	✓
Vehicle Inspection Report	✓	✓	✓		✓	✓
Brake System	✓	✓			✓	✓
Coupling Devices	✓	✓			✓	✓
Exhaust System	✓	✓			✓	✓
Frame	✓	✓			✓	✓
<b>Fuel System *</b>	✓	✓			✓	✓
Lights/Lamps	✓	✓			✓	✓
Safe Loading of Cargo	✓	✓			✓	✓
Steering Mechanism	✓	✓			✓	✓
Suspension	✓	✓			✓	✓
Tires	✓	✓			✓	✓
Wheels, Rims, Hubs	✓	✓			✓	✓
Van and Open Top Trailer Bodies	✓	✓			✓	✓
Windshield Wipers	✓	✓			✓	✓
Emergency Exits (buses)	✓	✓			✓	✓
Hazardous Materials Requirements	✓	✓			✓	✓
One Time Special Inspection of an Item				✓		
Radiological Requirements						✓

\* Highly pertinent to hydrogen-fueled vehicles.

## 8.1 BASIS FOR CONSIDERING CHANGES TO NAS INSPECTION PROCEDURES

For commercial vehicles that use hydrogen as an alternative fuel, it is clear that procedures for examining the integrity of the fuel system will need to be modified. Specifically, the fuel system inspection requirements for Levels I, II, V, and VI need to be modified for commercial vehicles that use hydrogen as an alternative fuel. The basis for identifying changes to the inspection procedures are based on the current practices developed by the California Highway Patrol for inspection of natural gas vehicles (see attached inspection checklists for CNG and LNG in appendix A).



## **9. CONSIDERING CHANGES TO INSPECTION PROCEDURES FOR GASEOUS HYDROGEN**

Since commercial vehicle inspectors are enforcing regulations, the inspection procedures for commercial vehicles that use hydrogen as an alternative fuel should also be considered for modification. It is important to note that not all changes to the FMCSRs specified for consideration in section 6.0 have associated inspection procedures. In particular, FMCSRs associated with wiring have not been included in the consideration of changes to inspection procedures that are listed below. Wiring is not included because it is not listed as a safety-critical inspection item. Based on the review, Level I and Level V procedures should be considered for modification, including the following inspection areas of commercial vehicles that use hydrogen as an alternative fuel:

1. Verify and Inspect Vehicle Labeling
  - a. Requirement for labeling commercial vehicle as a gaseous hydrogen fueled vehicle:
    - Label (consistent with Society of Automotive Engineer [SAE] J2578, Recommended Practice for Hydrogen Vehicles)
    - Location (suggested in tow locations on opposing sides of vehicle cab)
    - Size (suggested readable at 50 ft)
2. Verify and Inspect Fuel Components and Tank Labeling (e.g., similar to requirements of 49 CFR 571.304 for compressed natural gas (CNG) tanks but applied to gaseous hydrogen tanks):
  - a. Manufacturer's name
  - b. Model/serial number
  - c. Design service pressure
  - d. Direction of flow
  - e. Capacity
  - f. Fuel type (i.e., "gaseous hydrogen")
3. Verify and Inspect Fuel Tank Certification and Recertification (e.g., similar to requirements of 49 CFR 571.304 for CNG tanks but applied to gaseous hydrogen tanks)
  - a. Design Certification Test
  - b. Periodic retesting and labeling
  - c. Record of last visual inspection
4. Verify and Inspect Pressure Relief Devices (PRDs) installed on fuel tanks (e.g., similar to requirements of 49 CFR 571.304 for CNG tanks but applied to gaseous hydrogen tanks)

5. Verify and Inspect Fuel Connection
  - a. Grounding and bonding requirements
  - b. Dust cap
  - c. Labeling the fueling compartment or fueling door with “gaseous hydrogen,” service pressure, and installer or company name
  - d. Support for fueling connector
6. Verify and Inspect Fuel Tank System Installation
  - a. Protection and shielding from road hazards
  - b. Mounted to minimize damage from collision
  - c. Mounting racks are secured
  - d. Clearance from road to storage tank container
  - e. Shielded against heat sources
  - f. Fuel system components electrically bonded and grounded (specific for hydrogen)
7. Verify and Inspect Venting System
  - a. Venting diffuser output to less than 20% of the lower flammable limit
  - b. Hydrogen venting or purging does not vent to hazardous location (i.e., not to engine compartment or wheel well)
  - c. Vent piping system shall be metallic
  - d. Hydrogen does not vent or purge to restrict PRD safety devices
  - e. Venting system contains protective cap or cover
  - f. Secured at outer end
  - g. Venting of enclosed spaces where leaked gaseous fuel might collect
  - h. Not blocked by ice, snow, or debris
8. Verify and Inspect piping and valves integrity
  - a. Provide automatic shutoff valve for fuel tanks in response to system fault
  - b. Provide manual shutoff valve
9. Verify and Inspect Installation of Fuel Pressure Gauge
10. Verify and Inspect Post Accident Precautions – Inspection and replacement following an accident (e.g., similar to the requirements of 49 CFR 571.304 S7.4(g) for CNG tanks but applied to gaseous hydrogen tanks)
11. Verify and Inspect Gas Leak Detection System (e.g., regulation should require a hydrogen leak detection system and that it should be functioning properly)

12. Verify and Inspect main on/off switch isolates fuel to storage tank.

13. Verify operator has attended hazard training. (Note: This does not apply to Level V inspections where the operator is not present.)

The consideration of changes to procedures specified in this section pertain to the required commercial vehicle inspections. Safety procedures, training, and guidance should be provided to vehicle inspectors or enforcement officers with respect to hydrogen system safety. For example, inspectors or enforcement officers should not be smoking or using radios or cell phones while detecting for leaks or checking any lines or connections that carry high-pressure gas (usually identifiable by stainless steel tubing).

## **10. CONSIDERING CHANGES TO INSPECTION PROCEDURES FOR LIQUID HYDROGEN**

Since commercial vehicle inspectors are enforcing regulations, the inspection procedures for commercial vehicles that use liquid hydrogen as an alternative fuel should also be considered for modification. It is important to note that not all changes to the FMCSRs specified for consideration in section 7.0 have associated inspection procedures. In particular, FMCSRs associated with wiring have not been included in the consideration of changes to inspection procedures that are listed below. Wiring is not included because it is not listed as a safety-critical inspection item. Based on the review, Level I and Level V procedures should be considered for modification, including the following inspection areas of commercial vehicles that use hydrogen as an alternative fuel:

1. Verify Vehicle Labeling
  - a. Requirement for “diamond” type labeling of commercial vehicle as a liquid hydrogen vehicle
    - Label (consistent with Society of Automotive Engineer [SAE] J2578, Recommended Practice for Hydrogen Vehicles)
    - Location (suggested in tow locations on opposing sides of vehicle cab)
    - Size (suggested to be readable at 50 ft)
2. Verify Fuel Components and Tank Labeling (similar to the requirements of 49 CFR 571.304 for CNG tanks but applied to liquid hydrogen tanks)
  - a. Fuel type (i.e., liquid hydrogen)
  - b. Manufacturer’s name
  - c. Model number/serial number
  - d. Design service pressure
  - e. Direction of flow
3. Verify Fuel Tank Certification and Recertification (similar to the requirements of SAE standard J2343)<sup>4</sup> for LNG tanks but applied to liquid hydrogen tanks
  - a. Design Certification Test
  - b. Periodic retesting and labeling
4. Verify Pressure Relief Valves (PRVs) installed on fuel tanks

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<sup>4</sup> Society of Automotive Engineers [SAE J2343], J2343 – Recommended Practices for LNG Powered Heavy-Duty Trucks, January 1997.

5. Verify and Inspect Fueling Connection
  - a. Grounding and bonding requirements
  - b. Dust cap
  - c. Labeling the fueling compartment or fueling door “liquid hydrogen” with service pressure and installer or company
6. Verify and Inspect Fuel Tank System Installation
  - a. Protection and shielding
  - b. Mounted to minimize damage from collision
  - c. Mounting racks are secured
  - d. Clearance from road to storage tank container
  - e. Shielded against heat sources
  - f. Fuel system components electrically bonded and grounded (specific to hydrogen)
  - g. Fuel system components insulated, vapor sealed, and protected from casual contact
7. Verify and Inspect Venting System
  - a. Venting diffuser output to less than 20% of the lower flammable limit
  - b. Hydrogen venting or purging does not vent to hazardous location (i.e., not to engine compartment or wheel well)
  - c. Vent piping system shall be metallic
  - d. Hydrogen does not vent or purge to restrict PRD safety devices
  - e. Venting of enclosed spaces where leaked gaseous fuel might collect
  - f. Venting system contains protective cap or cover
  - g. Secured at outer end
  - h. Not blocked by ice, snow, or debris
8. Verify and Inspect Piping and valves
  - a. Provide automatic shutoff valve for fuel tanks
  - b. Provide manual shutoff valve
9. Verify Installation of fuel liquid level gauge
10. Verify Post Accident Precautions – Inspection and Replacement (similar to requirements of 49 CFR 571.304 for CNG tanks but applied to liquid hydrogen tanks)
11. Verify and Inspect Leak Detection System

12. Verify Shutoff Valve - Turning off main on/off switch isolates fuel to storage tank
13. Verify Driver Awareness Training Program – Suggest all vehicle operators attend hydrogen hazard awareness training including cryogenic hazard. (Note: This does not apply to Level V inspections where the operator is not present.)

The consideration of changes to procedures specified in this section pertain to the required commercial vehicle inspections. Safety procedures, training, and guidance should be provided to vehicle inspectors or enforcement officers with respect to hydrogen system safety. For example, inspectors or enforcement officers should not be smoking, using radios or cell phones while detecting for leaks or observing any lines or connections that carry high-pressure gas (usually identifiable by stainless steel tubing).

## 11. CONSIDERING CHANGES TO NAS OUT OF SERVICE ORDERS

In addition to modifying NAS inspection procedures for commercial vehicles that use hydrogen as an alternative fuel, changes should be considered to the NAS Out of Service Criteria (dated January 1, 2004). The Out of Service Criteria provides guidance to commercial vehicle inspectors for placing commercial vehicles out of service as a result of inspection findings. Just as a leak in a diesel fuel system serves as a basis for placing a commercial vehicle out of service, likewise, a leak in a system using hydrogen as an alternative fuel on a commercial vehicle should serve as a basis for placing such a commercial vehicle out of service. For commercial vehicles that use hydrogen as an alternative fuel, the following out of service criteria should be considered for addition to the existing NAS criteria:

- Any fuel system leak detected by an onboard leak detection system
- Any fuel system leak detected by an audible noise, or detected by a hand-held hydrogen detector and confirmed by a “soap bubble test”<sup>5</sup>
- Any fuel system leak that vaporizes in the air
- Any such commercial vehicle operating without a hydrogen leak detection system or operating with a defective hydrogen leak detection system

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<sup>5</sup> Hand held hydrogen detectors indicate the presence of hydrogen, but can not generally confirm the existence, or pinpoint the location of, an active leak. The general procedure for leak checking is as follows: (1) Use a hand held hydrogen detector to sample the air in the vicinity of all major hydrogen bearing components (tanks, valves, pressure regulators), especially near connections and piping joints, where leaks are most likely to occur, and (2) if the hand held detector senses a hydrogen concentration greater than 25% of the lower flammable limit, conduct a “soap bubble test” in that area to confirm/pinpoint the leak. For the soap bubble test, pour or spray a non-ammonia, non-corrosive soap solution onto each connection/joint in the area where hydrogen was detected and observe for several minutes. If small bubbles appear and multiply in the soap solution, it is an indication that hydrogen gas is leaking through the joint.

## **12. SUMMARY/CONCLUSION**

Based on a review of existing Federal Motor Carrier Safety Regulations and the North American Standard Inspection Procedures, additional regulations and inspections procedures are needed to accommodate commercial vehicles that use hydrogen as an alternative fuel. Specifically, the FMCSRs need to be updated to accommodate gaseous and cryogenic liquefied hydrogen fuel. The regulation updates need to consider the hazards associated with gaseous and liquid hydrogen including the properties of hydrogen, operating pressures, cryogenic hazards, safety devices, and hydrogen hazard awareness training. The inspection procedures for these vehicles also need to be updated accordingly. As the result of an inspection, any hydrogen leak that is detected should serve as an additional criterion for placing a commercial vehicle out of service.



# APPENDIX A: California Highway Patrol Inspection Procedures for Compressed Natural Gas and Liquefied Natural Gas

STATE OF CALIFORNIA DEPARTMENT OF CALIFORNIA HIGHWAY PATROL <b>COMPRESSED NATURAL GAS (CNG) VEHICLE                  NFPA (95) FUEL SYSTEM INSPECTION CHECKLIST</b> CHP 353A (New 11-00) OPI 062	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2">CA Number</td> <td colspan="2">FCN</td> </tr> <tr> <td>Vehicle Make</td> <td>Year</td> <td>License Number</td> <td>Unit Number</td> </tr> <tr> <td colspan="4"> <input type="checkbox"/> Bus   <input type="checkbox"/> School Bus   <input type="checkbox"/> SPAB   <input type="checkbox"/> GPPV   <input type="checkbox"/> Youth Bus   <input type="checkbox"/> FLV   <input type="checkbox"/> Truck   <input type="checkbox"/> Tractor                 </td> </tr> <tr> <td colspan="2">Manufactured/Converted Date</td> <td>Month</td> <td>Day</td> </tr> <tr> <td colspan="2"></td> <td>Year</td> <td></td> </tr> </table>	CA Number		FCN		Vehicle Make	Year	License Number	Unit Number	<input type="checkbox"/> Bus <input type="checkbox"/> School Bus <input type="checkbox"/> SPAB <input type="checkbox"/> GPPV <input type="checkbox"/> Youth Bus <input type="checkbox"/> FLV <input type="checkbox"/> Truck <input type="checkbox"/> Tractor				Manufactured/Converted Date		Month	Day			Year	
CA Number		FCN																			
Vehicle Make	Year	License Number	Unit Number																		
<input type="checkbox"/> Bus <input type="checkbox"/> School Bus <input type="checkbox"/> SPAB <input type="checkbox"/> GPPV <input type="checkbox"/> Youth Bus <input type="checkbox"/> FLV <input type="checkbox"/> Truck <input type="checkbox"/> Tractor																					
Manufactured/Converted Date		Month	Day																		
		Year																			
<b>COMPLIANCE WITH NATIONAL FIRE PROTECTION ASSOCIATION CODE 52 (NFPA 52) 1995 Edition</b>																					
COMPLIES WITH NFPA 52 (August 11, 1995 to August 4, 1998)    SECTION    ✓		COMPLIES WITH NFPA 52 (August 11, 1995 to August 4, 1998)    SECTION    ✓																			
<b>DESIGN/CONSTRUCTION OF CONTAINERS</b>		<b>INSTALLATION OF VENTING SYSTEMS (cont.)</b>																			
Cylinder permanently marked "CNG" by Mfr.	2-4.2	Vent outlets: <input type="checkbox"/> Protected by caps, covers or other means																			
* Cylinders (Containers): <input type="checkbox"/> Exempt <input type="checkbox"/> Special permit <input type="checkbox"/> DOT <input type="checkbox"/> TC		<input type="checkbox"/> Protective device does not restrict the flow of gas	3-4.5																		
<input type="checkbox"/> ANSI/IAS NGV2    Type: <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4	2-4.4	Neck of container and all CNG fittings: <input type="checkbox"/> In gastight enclosure																			
<b>PRESSURE RELIEF DEVICES (PRD)</b>		<input type="checkbox"/> Gastight enclosure is vented directly to outside of vehicle	3-4.6																		
Each cylinder fitted with one or more PRD(s)	2-5.1	<b>INSTALLATION OF PIPING</b>																			
PRD: <input type="checkbox"/> In direct communication with the fuel		Manifolds fabricated to minimize vibration and shielded	3-5.1																		
<input type="checkbox"/> Vented to atmosphere	2-5.1(b)	Fuel lines passing through panel protected by grommets where necessary	3-5.4																		
External adjustments provided with means for sealing	2-5.2.2	Fuel lines have maximum practical clearance from exhaust system	3-5.5																		
<b>FUEL LINES</b>		Fuel lines braced to protect against damage due to strain/wear	3-5.6																		
Piping components permanently marked	2-8.5	No incorrect bends in piping and/or tubing	3-5.7																		
<b>VALVES</b>		<b>INSTALLATION OF VALVES</b>																			
Rated service pressure not less than CNG system pressure	2-9.1	Every container equipped with a shutoff valve: <input type="checkbox"/> Manual valve, or																			
Permanently marked service ratings (see exception)	2-9.4	<input type="checkbox"/> Normally closed automatically controlled valve w/manual bleed	3-6.1																		
<b>HOSES AND HOSE CONNECTIONS</b>		In addition to the shutoff valve required by 3-6.1: <input type="checkbox"/> Manual valve 1/4-turn maximum																			
Hose and metallic hose connectors distinctly marked	2-10.4	<input type="checkbox"/> Access to manual valve, or an <input type="checkbox"/> Automatically controlled shutoff valve	3-6.2																		
<b>VEHICLE FUELING CONNECTION</b>		Valve securely mounted and shielded or in protected location	3-6.2.1																		
No fueling adapters needed	2-11	Valve location marked: "MANUAL SHUTOFF VALVE" (if valve is manual)	3-6.2.2																		
<b>ENGINE FUEL SYSTEMS</b>		Additional valve to automatically prevent flow of gaseous fuel to engine	3-6.3																		
No prohibited pipe/tubing/fittings between fuel container and first stage pressure regulator	3-2.3	Automatic valve(s) for multiple fuel systems	3-6.4																		
* Fuel components labeled/stamped with the following:		Fueling system equipped with a back-flow check valve	3-6.5																		
Manufacturer's name or symbol	3-2.4(a)	<b>INSTALLATION OF PRESSURE GAUGES</b>																			
Model designation	3-2.4(b)	Mounted, shielded, installed to prevent damage from vibration	3-7.3																		
Design service pressure	3-2.4(c)	<b>WIRING INSTALLATION</b>																			
Direction of flow (when necessary)	3-2.4(d)	Secured and protected from abrasion and corrosion	3-10.1																		
Capacity or electrical rating	3-2.4(e)	<b>LABELING</b>																			
* Exception: Not applicable to container valves/tubing/fittings		Label located in the engine compartment includes:																			
<b>INSTALLATION OF FUEL SUPPLY CONTAINERS</b>		Identification as a CNG-fueled vehicle	3-11.1(a)(1)																		
Located: <input type="checkbox"/> Within <input type="checkbox"/> Below <input type="checkbox"/> Above driver/pass. compartment		System service pressure	3-11.1(a)(2)																		
<input type="checkbox"/> Protected or shielded <input type="checkbox"/> Shield not contacting container		Installer's name or company	3-11.1(a)(3)																		
<input type="checkbox"/> No trapped materials/liquids <input type="checkbox"/> Not contacting components	3-3.1	Container retest date(s) or expiration date	3-11.1(a)(4)																		
Mounted to minimize damage from collision	3-3.3	Total container water volume in gallons (liters)	3-11.1(a)(5)																		
Container not mounted ahead of front axle/behind rear bumper	3-3.2.2	Label located at fueling connection receptacle includes:																			
Container racks secure to vehicle body, bed or frame	3-3.3	Identification as a CNG-fueled vehicle	3-11.1(b)(1)																		
Weight of container not supported by fuel connections	3-3.5	System working pressure	3-11.1(b)(2)																		
Shielded against direct exhaust heat (if less than 8 inches)	3-3.6	Container retest date(s) or expiration date	3-11.1(b)(3)																		
Gasket installed between clamping bands, supports, container	3-3.9	<b>Exception: If both labels are located in one of the above areas, they may be combined into a single label, which includes the system working pressure.</b>																			
If container is located in a compartment capable of accumulating natural gas:		Vehicle identified with a weather-resistant label	3-11.2																		
<input type="checkbox"/> PRD in same compartment <input type="checkbox"/> Vented to outside by tube or hose		<b>SYSTEM TESTING</b>																			
<input type="checkbox"/> Discharge line secured <input type="checkbox"/> Vent not blocked	3-3.10	Owner advised that containers must be replaced or removed, inspected and retested if vehicle is involved in accident/fire causing damage to container																			
<b>Containers installed above operator/passenger compartment protected by:</b>		<b>MAINTENANCE AND REPAIR</b>																			
Guard rail or similar device	3-3.11(a)(1)	Damaged fuel lines replaced not repaired																			
Shield designed to absorb impacts/free of projections	3-3.11(a)(2)	Fuel system maintained: <input type="checkbox"/> In safe condition																			
Container protected from contact with overhead electrical wiring	3-3.11(c)	<input type="checkbox"/> Container retest date or expiration date is current																			
Minimum clearance from the road to a container, housing, or fitting is:		3-13.2																			
<input type="checkbox"/> 7 inches - wheelbase less than/equal to 127 inches		<b>Vehicles and fuel supply containers complying with FMVSS 303 and 304 covering the installation of CNG fuel systems on vehicles and certified by the respective manufacturer as meeting these standards are not required to comply with NFPA-52, 2-4, 2-4.8, and Chapter 3 (except 3-11).</b>																			
<input type="checkbox"/> 9 inches - wheelbase greater than 127 inches	3-3.12	* DOT = U.S. Department of Transportation    TC = Transport Canada																			
Container behind rear axle installed transversely (see exception)	3-3.13	ANSI/IAS = American National Standards Institute/International Approval Standards																			
<b>INSTALLATION OF VENTING SYSTEMS</b>		NGV2 = Basic Requirements of Type 3NG Fuel Containers																			
If Pressure Relief Devices (PRD) installed in closed compartment:		Type 1 = Non-composite metallic container    Type 2 = Composite metallic hoop-wrapped container																			
Vented to the outside of compartment	3-4.1	Type 3 = Composite metallic full-wrapped container																			
Vent system secured at the outer end	3-4.2	Type 4 = Composite non-metallic full-wrapped container																			
Vent does not exit into wheel well	3-4.3																				
Vent does not restrict operation of pressure relief device/channel	3-4.4																				
INSPECTED BY		I.D. NUMBER	DATE																		

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Figure 1. California Highway Patrol Inspection Checklist—Form CHP 353A

STATE OF CALIFORNIA  
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL  
**LIQUEFIED NATURAL GAS (LNG) VEHICLE**  
**NFPA FUEL SYSTEM INSPECTION CHECKLIST**  
CHP 354 (New 11-00) OPI 062

CA Number	FCN		
Vehicle Make	Year	License Number	Unit Number
<input type="checkbox"/> Bus <input type="checkbox"/> School Bus <input type="checkbox"/> SPAB <input type="checkbox"/> GPPV <input type="checkbox"/> Youth Bus <input type="checkbox"/> FLV <input type="checkbox"/> Truck <input type="checkbox"/> Tractor			
Manufactured/Converted Date	Month	Day	Year

**COMPLIANCE WITH NATIONAL FIRE PROTECTION ASSOCIATION CODE 57 (NFPA 57) 1996 Edition**

Note: This checklist does not cover all items regarding the installation of LNG fuel systems found in NFPA 57. It covers only those items that can be inspected without disassembly of the fuel system.

COMPLIES WITH NFPA 57 (January 1, 2000 to Present)	SECTION	✓	COMPLIES WITH NFPA 57 (January 1, 2000 to Present)	SECTION	✓
<b>VEHICLE FUEL CONTAINERS</b>					
*Container Design: <input type="checkbox"/> DOT 4L <input type="checkbox"/> ASME	2-3.1		Fueling receptacle located outside passenger compartment	2-12.2.2	
Equipped with a device that indicates maximum liquid level	2-3.2		Gas detection system (Continuous operation)	2-12.2.4	
Container shutoff valve installed directly on the tank vapor outlet	2-3.4		<b>PIPE, TUBING AND FITTINGS</b>		
<i>Container shutoff valves marked:</i>			Manifolds fabricated and shielded to minimize vibration	2-12.3.1	
<input type="checkbox"/> "VAPOR SHUTOFF VALVE" (for container vapor outlet)	2-3.4		Piping/tubing supported, protected and secured	2-12.3.2	
<input type="checkbox"/> "LIQUID SHUTOFF VALVE" (for container liquid outlet)			Piping/tubing passing through panel is protected by grommets	2-12.3.3	
<i>Container permanent identification markings (decals or stencils):</i>			Piping/tubing passing through floor is installed properly	2-12.3.4	
Total water capacity of the container in gallons	2-3.8(a)		No fuel connection between vehicles in combination	2-12.3.5	
"FOR LNG ONLY" in letters not less than 1-inch high, visible	2-3.8(b)		PRD installed in each section of piping or tubing (isolated)	2-12.3.6	
<i>Inlets and outlets marked to designate whether they communicate with:</i>			<b>VALVES</b>		
Vapor or Liquid space	2-3.8(c)		Valves securely mounted and shielded or in protected location	2-12.4.1	
Markings not obscured by "frosting"	2-3.8(c)		Valve weight not placed on, or supported by, attached lines	2-12.4.2	
<b>PRESSURE RELIEF DEVICES (PRD)</b>			Automatic shutoff valve installed in supply line at inlet of regulator	2-12.4.3	
PRD and pressure control valves (PCV) communicate directly with vapor space of container	2-4.2		Automatic shutoff valves for multiple fuel systems	2-12.4.4	
Safety relief devices vented outside of vehicle	2-4.3		Backflow check valve installed	2-12.4.5	
PRD lines are metallic	2-4.3(a)		<b>PRESSURE REGULATORS</b>		
Discharge lines/adapters secured	2-4.3(b)		Installed so weight is not placed on, or supported by, fuel lines	2-12.5.2	
Vent outlets protected by caps, covers or other means	2-4.3(d)		<b>PRESSURE GAUGES</b>		
Vent outlets fitted with device to prevent icing	2-4.3(e)		Mounted securely, shielded and installed in protected location	2-12.6.2	
PRD directed upward or downward within 45 degrees of vertical and not directed toward the exhaust, vehicle or interior of vehicle	2-4.3(f)		<b>ELECTRICAL WIRING</b>		
Discharge line on bus located at: <input type="checkbox"/> Rear of vehicle <input type="checkbox"/> Directed upward	2-4.3(g)		Supported, secured and protected from wear or corrosion	2-12.7.1	
<input type="checkbox"/> Extended to top of vehicle roof			<b>LABELING</b>		
External or adjustable PRD/PCV valves sealed	2-4.4		<i>Label located at fueling connection receptacle includes:</i>		
<b>PRESSURE GAUGES</b>			Identification as LNG-fueled vehicle	2-12.8.1(a)	
Connected to container above the maximum liquid level	2-5.1		Maximum allowable working pressure of container	2-12.8.1(b)	
<b>VALVES</b>			Each vehicle identified with a weather-resistant label	2-12.8.2	
Container shutoff valves are stainless steel, brass or copper	2-8.2		<b>FUELING RECEPTACLE</b>		
Extended bonnet valves installed to prevent leakage or malfunction	2-8.3		Firmly supported	2-12.9.1	
<b>PUMPS AND COMPRESSORS</b>			Incorporates a means to minimize entry of dust, water, etc.	2-12.9.1(b)	
Pump provided with vent or relief valve	2-9.2		Not corroded	2-12.9.1(c)	
<b>VARORIZER</b>			<b>SYSTEM TESTING</b>		
Marked to indicate maximum allowable working pressure	2-10.2		Owner advised that fuel system (including container) must be inspected & retested if vehicle is involved in accident or fire causing damage to LNG system	2-13.2	
Direct exhaust gases not used as a source of heat	2-10.6		<b>TITLE 13, CALIFORNIA CODE OF REGULATIONS</b>		
<b>INSTALLATION OF FUEL SUPPLY CONTAINERS</b>			In addition to the requirements of NFPA 57, 1996 edition, LNG fuel systems must also comply with the following:		
Located: <input type="checkbox"/> Within <input type="checkbox"/> Below <input type="checkbox"/> Above driver/passenger comp.	2-12.1.2		<i>Vehicle equipped with methane gas detection system which shall:</i>		
Shielded against direct exhaust heat (less than 8 inches)	2-12.1.3		<input type="checkbox"/> Warn of presence of methane in the engine compartment, driver's compartment and any passenger compartments	935(b)(2)	
Container markings visible after installation (mirror use OK)	2-12.1.4		<input type="checkbox"/> Give plainly audible and visible warning to driver before entering driver's compartment and while seated in driving position		
Not mounted forward of front axle or rear of the rear bumper (Between rear axle and rear bumper is acceptable)	2-12.1.6		<input type="checkbox"/> Function continuously, engine on or off	935(b)(2)	
<i>Container road clearance (installed between axles) measures as follows:</i>			<input type="checkbox"/> Fuel tank mounting and orientation	935(b)(4)	
<input type="checkbox"/> In compliance with 2-12.1.7(c), or <input type="checkbox"/> not lower than lowest point on structural component of body, frame, engine, etc.	2-12.1.7(a)		<input type="checkbox"/> Spill pan installed if tank is mounted above driver or passenger compartment		
<i>Container road clearance (installed behind rear axle) extending below frame measured as follows:</i>			<input type="checkbox"/> Spill pan does not retain rain water		
<input type="checkbox"/> In compliance with 2-12.1.7(b), or <input type="checkbox"/> In compliance with 2-12.1.7(b)(1) and (2)	2-12.1.7(b)		<i>Label located at or near fueling connection includes:</i>		
Installation of substituted fuel container (Conversion)	2-12.1.7(c)		Identification as LNG-fueled vehicle	935(b)(5)(A)	
Containers securely mounted to vehicle body, bed or frame	2-12.1.8		Maximum allowable working pressure of vehicle fuel container	935(b)(5)(B)	
Container weight not supported by fuel connections	2-12.1.9		Note: Use CHP 354A for inspection of fuel systems installed in compliance with Society of Automotive Engineers (SAE) Standard J2343, Recommended Practices for LNG Powered Heavy-Duty Trucks, January 1997.		
No corrosion between container and mounting system	2-12.1.10		Vehicles that are required to comply with Federal Motor Vehicle Safety Standards (FMVSS) covering the installation of LNG fuel systems on vehicles and that are certified by the manufacturer as meeting these standards shall not be required to comply with NFPA-57, Chapter 2, (except 2-12.8).		
Valve location marked "MANUAL SHUTOFF VALVE"	2-12.1.12		* DOT = U.S. Department of Transportation ASME = American Society of Mechanical Engineers (Boiler and Pressure Vessel Code) SAE = Society of Automotive Engineers J2343, Recommended Practices for LNG Powered Heavy-Duty Trucks, January 1997		
<b>CONTAINERS MOUNTED IN THE INTERIOR OF VEHICLES</b>			INSPECTED BY		
Enclosure is gas tight from: <input type="checkbox"/> Driver/passenger compartment	2-12.2.1(a) or (b)		ID. NUMBER		
<input type="checkbox"/> Radio transmitter <input type="checkbox"/> Spark producing equipment			DATE		
<input type="checkbox"/> Enclosure is vented to outside of vehicle					

Figure 2. California Highway Patrol Inspection Checklist—Form CHP 354

## REFERENCES

- Compressed Gas Association, Inc., Pamphlet C-6: Standards for Visual Inspection of Compressed Gas Cylinders, 1984
- Federal Motor Carrier Safety Administration (FMCSA), *Guidelines for use of Hydrogen Fuel in Commercial Vehicles*, 2007
- National Fire Protection Association, NFPA 52 – Vehicle Fuel Systems Code – 2006 Edition.
- Society of Automotive Engineers (SAE), J2343 – Recommended Practices for LNG Powered Heavy-Duty Trucks, January 1997
- Society of Automotive Engineers (SAE), J2578 - Recommended Practice for Hydrogen Vehicles, December 2004