CNG Lessons Learned

California Department of Transportation – Caltrans

Division of Equipment

Experiences with Compressed Natural Gas (CNG) powered trucks

Presentation Topics

- Costs
- Legal Requirements - Federal
- Legal Requirements - State
- Emission Issues
- Industry Equipment Issues
- Quality Assurance
- CNG professional resources
- Recommended publications

How much does CNG cost upfront?

- Dollars:
  - $50,000 extra for cab/chassis
  - $80,000 extra for purpose-built sweeper
- Real Estate:
  - 2’ minimum frame space for a 8’x8’x2’ CNG cabinet which replaces 60 diesel gallon equivalent (DGE).
- Payload:
  - 8’x8’x2’ cabinet weighs about 1800 lbs with empty cylinders

Diesel vs CNG

-CNG cabinet adds to wheelbase and consumes payload
-Tandem axle configuration was specified to offset payload loss on some vehicle types

Diesel powered unit

Federal Regulations

Federal Motor Vehicle Safety Standards – FMVSS
Code of Federal Regulations - CFR

FMVSS Requirements

- FMVSS only has two CNG specific requirements:
  - 571.303 Fuel system integrity - applies to
    - applies to school buses
    - vehicles with GVWR of 10,000lbs or less
  - 571.304 CNG fuel container integrity
    - Basically applies to all CNG fuel containers
    - Under section S7.4 Labeling – there is a ‘shall’ requirement for a series of labels including a label with a ‘should requirement’ for Inspection every 36 months or 36,000 miles
      - There is no section requiring a certified inspector or the inspection requirements…however, each state may have a specific regulation addressing this requirement.

CFR 49 includes vehicle certification requirements

- Sections 567 and 568 cover vehicle certification for Incomplete and Intermediate Manufacturers
- The responsibility of meeting FMVSS 303 and 304 falls on either the *engine installer* or the *incomplete vehicle manufacturer* or the *final stage manufacturer*:

  - Option 1: CNG engine installer takes on responsibility for their system by adding an 'Intermediate Vehicle Manufacturer' certification label
  - Option 2: The chassis-cab manufacturer takes on the responsibility for the engine installer through their 'Incomplete Vehicle' certification label
  - Option 3: The Final Stage Manufacturer takes on responsibility for the engine installer through their 'Final Stage Certification Label'

Federal Regulations - Lessons Learned

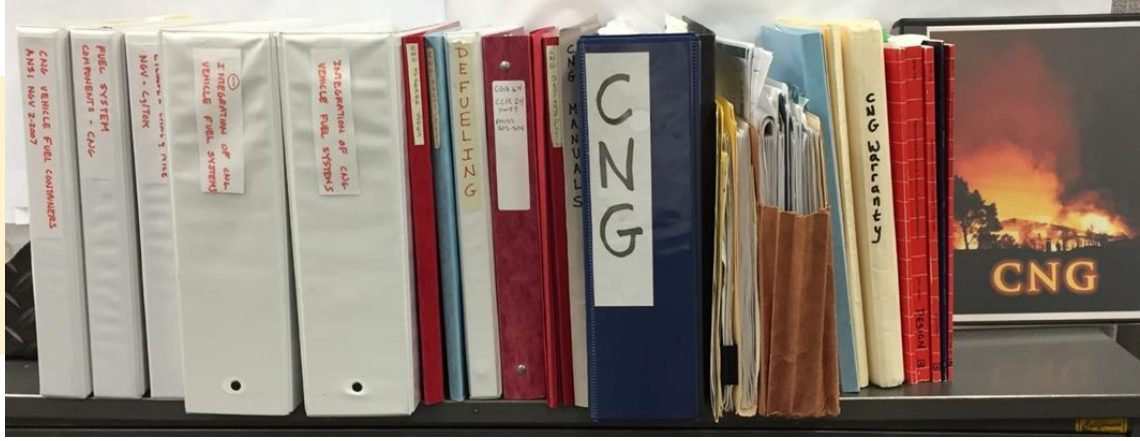
- Minimal Federal Direction

California Regulations

-Vehicles-

What does your state require??

CA Legal Requirements…



- California Code of Regulations Title 13 section 934.1 assigns authority
  - In CA, the authority having jurisdiction is the California Highway Patrol (CHP)
- Section 934.1 . . . CNG fuel systems shall be installed per National Fire Protection Association publication 52, NFPA52, … and any ‘should’ references in NFPA 52 will be interpreted as mandatory.
- NFPA 52 contains, among other things, vehicle requirements for components, installation, labels, testing, maintenance and repair, discharge of CNG from containers and a Tank Inspection Reference.
- NFPA52 references 56 other publications including the Merriam-Webster’s Collegiate Dictionary

California Tank Inspection - path of rules

- NFPA 52 references ANSI NGV 2*
  - Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers and considers it part of the NFPA 52 document
- ANSI NGV2 section 2.1.3 references CGA C-6.4** for inspection procedures
- CGA C-6.4 says the inspection shall be performed by a qualified inspector but . . . it does not cite the section with the requirements for a qualified inspector.
- If you browse . . . CGA C-6.4 does contain guidelines in another section for the Qualifications of an Inspector

*American National Standards Institute Natural Gas Vehicle Publication 2

** Compresses Gas Association Publication C-6.4

California Vehicle Regulations -Lessons Learned

- Majority of regulations and details are at the state level
- Know where the regulations reside
  - Know your ‘Authority Having Jurisdiction’
- You have to dig for the rules
- Recommend developing your own experts
  - In California the user and the installer are both held responsible for the use of correct components as well as the correct installation.

California Regulations
-Repair Facilities-

What does your state require??

California…DOT Repair Facilities…

- A building housing a CNG fueled vehicle is regulated by California Fire Code
  - Section 2211 Repair Garages required to meet one of the following:
    - Approved natural ventilation
    - Continuously running ventilation system meeting more codes
    - CNG detection system that trigger ventilation systems, audible and visible alarms, and deactivation of heating system
    - Restrictions on building heater types – e.g. no open flame

    Caltrans has many older facilities that do not meet these requirements.

- Are there other alternatives? YES

Alternative 1 – Remove CNG Tanks

No building modifications required but:

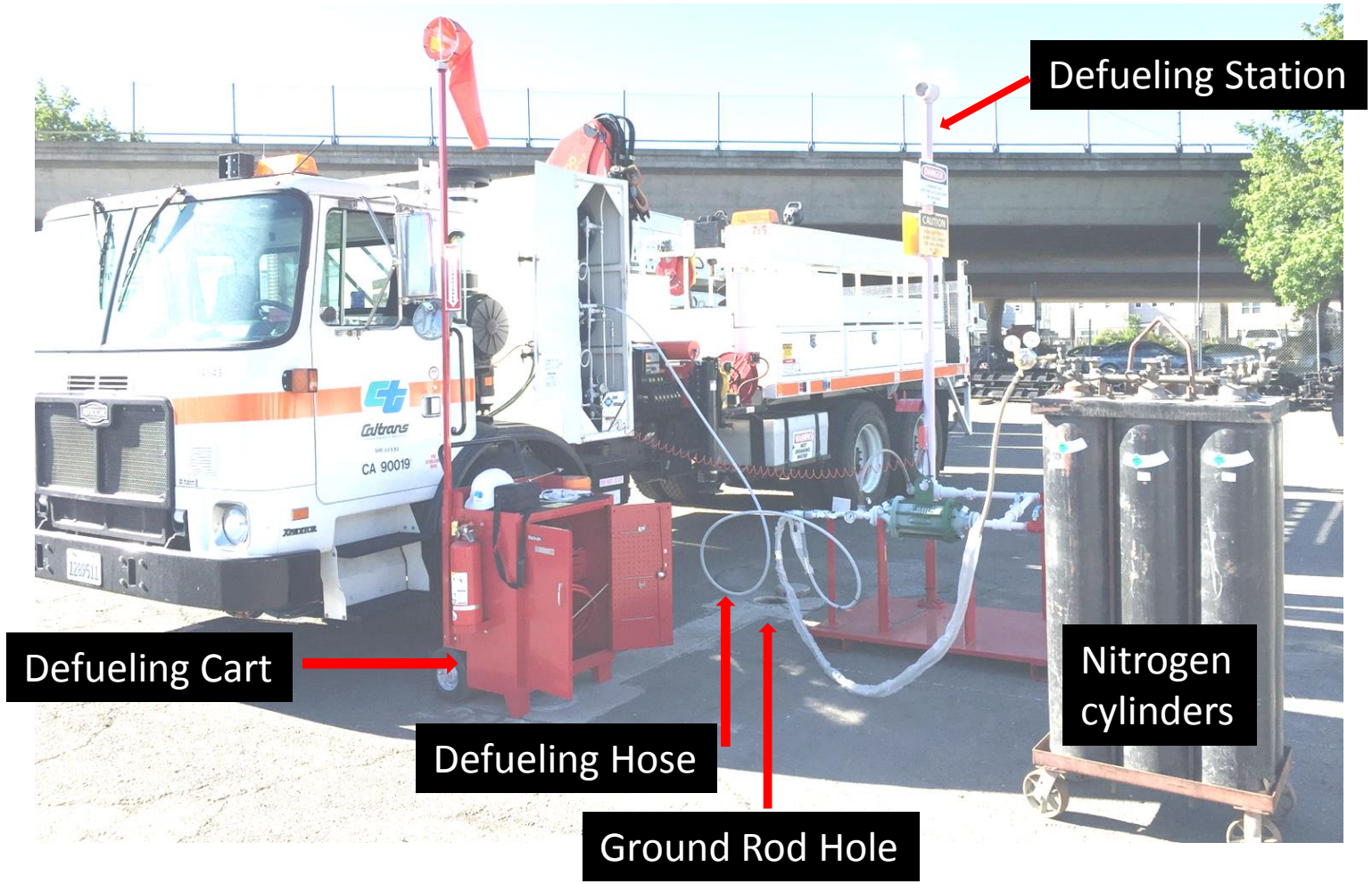
- Requires a permit to store more than 3000 cu ft at Normal Pressure and Temp
  - Typical tank holds 8200 cu ft at NPT
- Bollards are required around the tank storage area
- Secure tanks from tipping – need a rack compatible with different mfgr tanks
- 125F max temp
- No exposure to falling objects – our HQ facilities is under a freeway
- Minimum distances to buildings, public areas, combustible liquids, adjacent storage areas, lot lines – most are 10’ to 20’
- No exposure to corrosive chemicals or fumes
- Not stored below power lines

Alternative 2 – Defueling

- No building modifications required
- In-house design for a defueling station that met California Fire Code requirements in Section 2211.8 and NFPA 52
- Sonic Choke
- Bi-directional detonation flame arrestor
- Added a process to flush the CNG tanks with Nitrogen
- Included a sensor port to check CNG concentration in Nitrogen to ensure below combustible level
- Ground Rod in yard – retest 18 months
- Ca Fire Marshal approved method

Defueling Station

Caltrans CNG Defueling Station

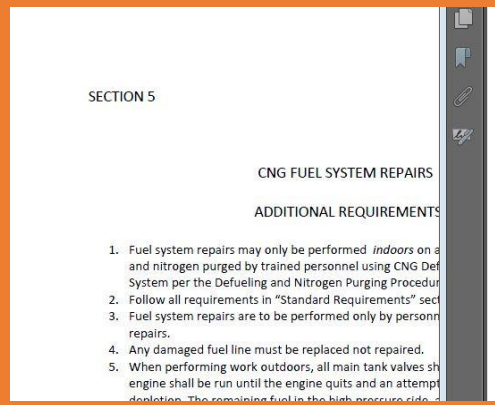


CNG system is grounded to vent stand.
Vent stand is grounded to ground rod.

Before defueling, a call is made to local fire department to notify them of defueling operation. Public may call fire department and report smelling CNG as the odorant is heavier than air.

Repair Shops

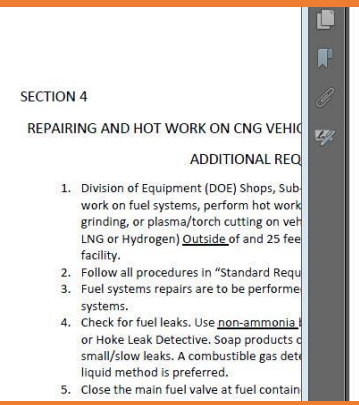
- Code of Safe Operating Practices were developed for:
  - In-shop work that did not involve fuel system or running the vehicle
  - Hot-work – welding performed outdoors – unless defueled
  - Fuel system repairs are performed outdoors


SECTION 5

CNG FUEL SYSTEM REPAIRS

ADDITIONAL REQUIREMENTS

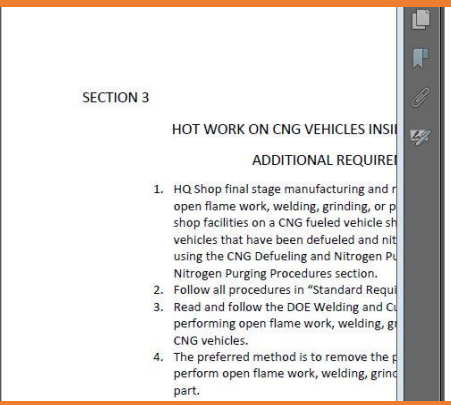
1. Fuel system repairs may only be performed *indoors* on a
and nitrogen purged by trained personnel using CNG Def
System per the Defueling and Nitrogen Purging Procedur
2. Follow all requirements in "Standard Requirements" sec
3. Fuel system repairs are to be performed only by personn
repairs.
4. Any damaged fuel line must be replaced not repaired.
5. When performing work outdoors, all main tank valves sh
engine shall be run until the engine quits and an attempt


SECTION 4

REPAIRING AND HOT WORK ON CNG VEHIC

ADDITIONAL REQ

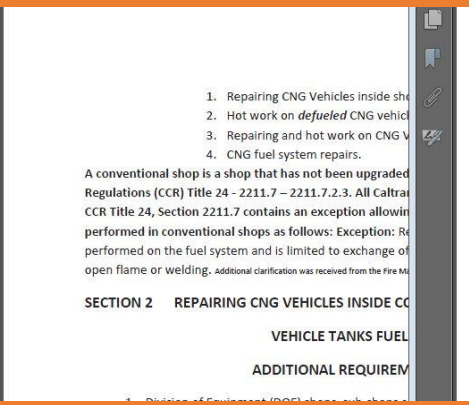
1. Division of Equipment (DOE) Shops, Sub-
work on fuel systems, perform hot work
grinding, or plasma/torch cutting on veh
LNG or Hydrogen) Outside of and 25 fee
facility.
2. Follow all procedures in "Standard Requ
3. Fuel systems repairs are to be performe
systems.
4. Check for fuel leaks. Use non-ammonia
or Hoke Leak Detective. Soap products
small/slow leaks. A combustible gas dete
liquid method is preferred.
5. Close the main fuel valve at fuel contain


SECTION 3

HOT WORK ON CNG VEHICLES INSI

ADDITIONAL REQUIRE

1. HQ Shop final stage manufacturing and r
open flame work, welding, grinding, or p
shop facilities on a CNG fueled vehicle sh
vehicles that have been defueled and nit
using the CNG Defueling and Nitrogen Pu
Nitrogen Purging Procedures section.
2. Follow all procedures in "Standard Requi
3. Read and follow the DOE Welding and C
performing open flame work, welding, g
CNG vehicles.
4. The preferred method is to remove the p
perform open flame work, welding, grind
part.

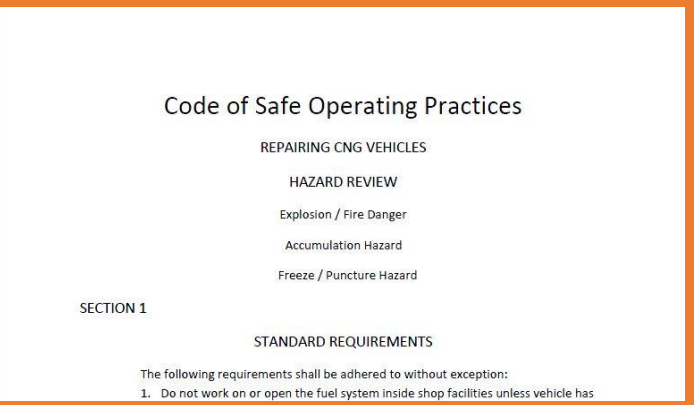

1. Repairing CNG Vehicles inside sh
2. Hot work on *defueled* CNG vehicl
3. Repairing and hot work on CNG V
4. CNG fuel system repairs.

A conventional shop is a shop that has not been upgraded
Regulations (CCR) Title 24 - 2211.7 – 2211.7.2.3. All Caltra
CCR Title 24, Section 2211.7 contains an exception allowin
performed in conventional shops as follows: Exception: R
performed on the fuel system and is limited to exchange of
open flame or welding. Additional clarification was received from the Fire Ma

SECTION 2 REPAIRING CNG VEHICLES INSIDE CO

VEHICLE TANKS FUEL

ADDITIONAL REQUIREM


Code of Safe Operating Practices

REPAIRING CNG VEHICLES

HAZARD REVIEW

Explosion / Fire Danger

Accumulation Hazard

Freeze / Puncture Hazard

SECTION 1

STANDARD REQUIREMENTS

The following requirements shall be adhered to without exception:

1. Do not work on or open the fuel system inside shop facilities unless vehicle has

California Facilities - Lessons Learned

- A Code of Safe Operating Practices should be established to roll-up all rules/codes/recommendations for easy employee access.
  - Caltrans Code of Safe Operating Practices is based on:
    - State Building Codes
    - State Fire Codes
    - Local Codes and Regulations
    - NFPA documents and referenced materials
    - Experience
    - Common sense
    - Previously Developed Safe Practices
- Transit Authorities running CNG are generally a good resource

In-Service Challenges

- Users may be unfamiliar with different requirements for CNG vehicles
  - Hazards for parking in heated barns
- Fueling infrastructure may be limited
  - Be aware of vehicle range and fuel availability
  - Be aware of fuel station pressure differences – compatibility
  - Fill port location may not be compatible with fueling station
- Repair infrastructure may not be fully developed
  - Dealership may have limited support and expertise
  - Develop your own repair experts
  - Certified CNG training is available from private providers

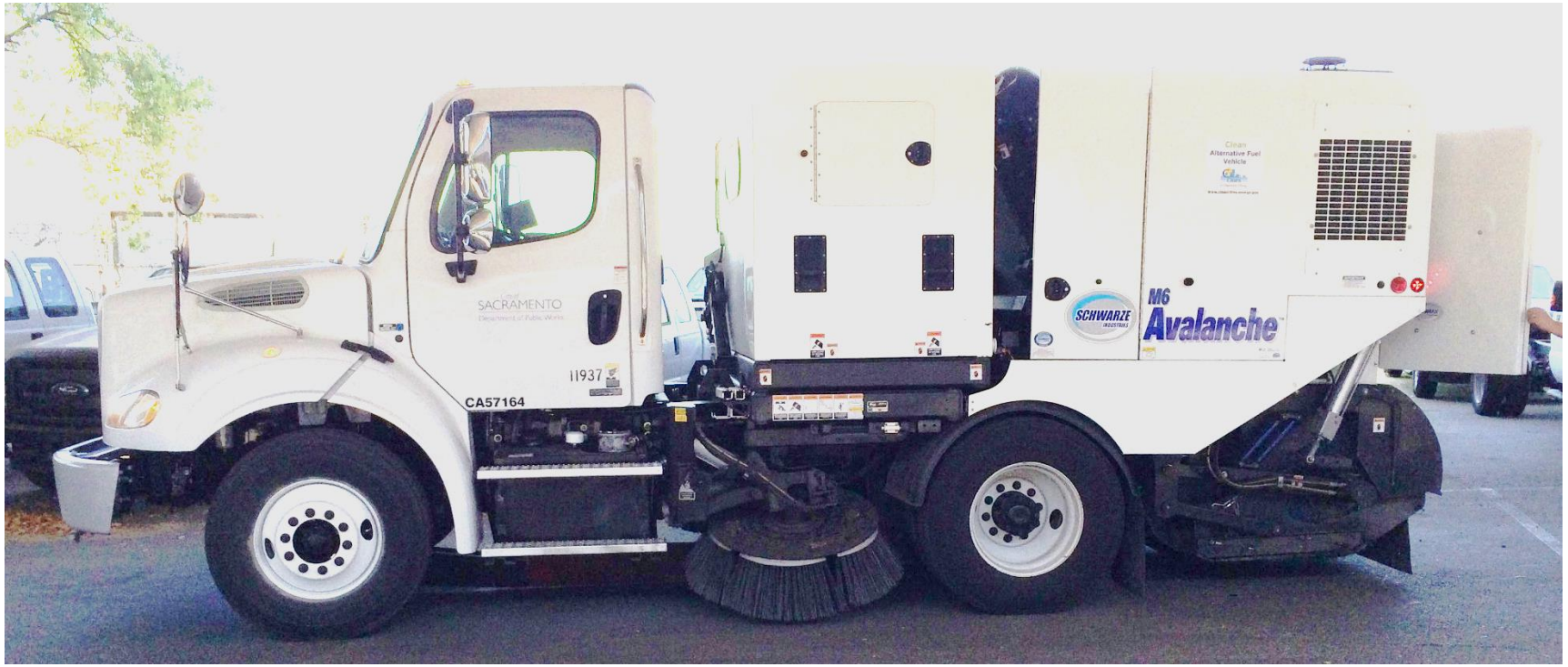
Issues

CNG Trash Compactors -Emission Issues

- Engine Integration in California requires software that has been approved by California Air Resources Board (CARB)
- An order for three Trash Compactor Trucks has had the following issues:
  - Two units on a three unit order were accepted and ran for approximately 1000 miles before a backfire problem was identified on the third unit at the vendor. The third unit was ultimately rejected as the backfire problem could not be solved in the extremely generous amount of time provided: 18 mos.
  - The proposed solution was a new software flash which has never been demonstrated to solve the problem and would require CARB emission testing and approval for engine certification.
- To date there is no resolution.

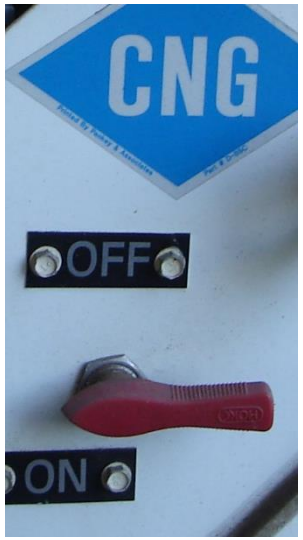
CNG Street Sweeper – overloaded rear axle

- Off-the-shelf, chassis mount, single engine, CNG powered street sweeper may have very limited payload.
- The unit weighed 20,480lb on the rear axle with unknown fuel level, full water
  no driver and
  no debris.
- CA Vehicle Code limits axle to 20,000lb.
  No payload capacity remains.



CNG Cab and Chassis

- Cab/chassis arriving with the original Incomplete Certification label installed and no recognition that the engine has been changed to CNG or fuel system meets FMVSS 571.304
  - CFR Title 49 section 568.5
- Components not rated for CNG – NFPA 52 6.2
- Cylinder labels and other required labels not visible
  - NFPA 52 4.4.4 and 6.11 and CCR Title 13 934(5), 936c
- Missing required second check valve NFPA 52 6.6.5.2
- Fuel lines missing protection from damage, strain, vibration and exhaust heat
  - NFPA 52 6.5.6, 6.5.7 and CCR Title 13 section936
- CNG tank support structure failure – not designed to meet NFPA 52 6.3

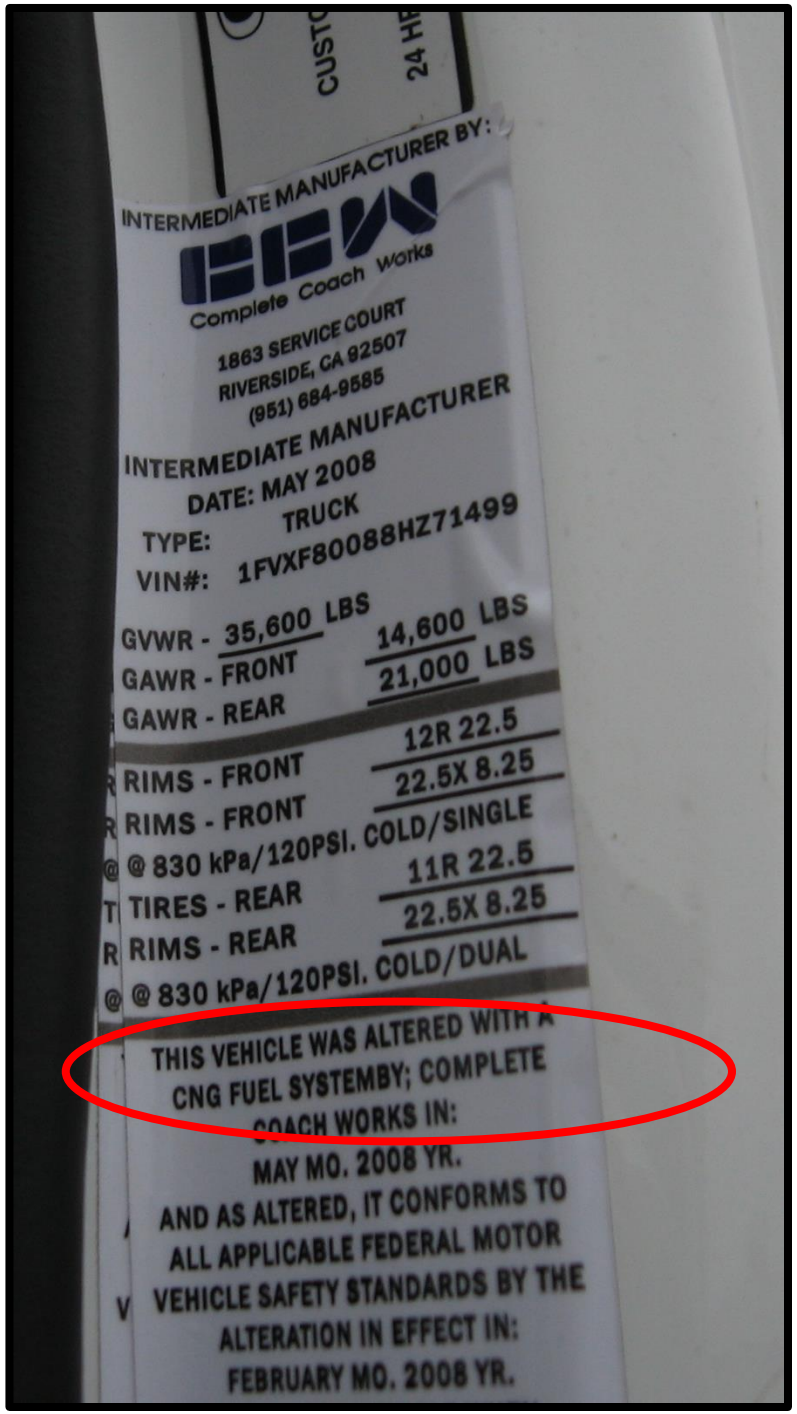


Certification Labels

CFR Title 49 section 568.5

Intermediate Certification Labels were not supplied.

This one took several emails and phone calls as well as a second printing of the label.

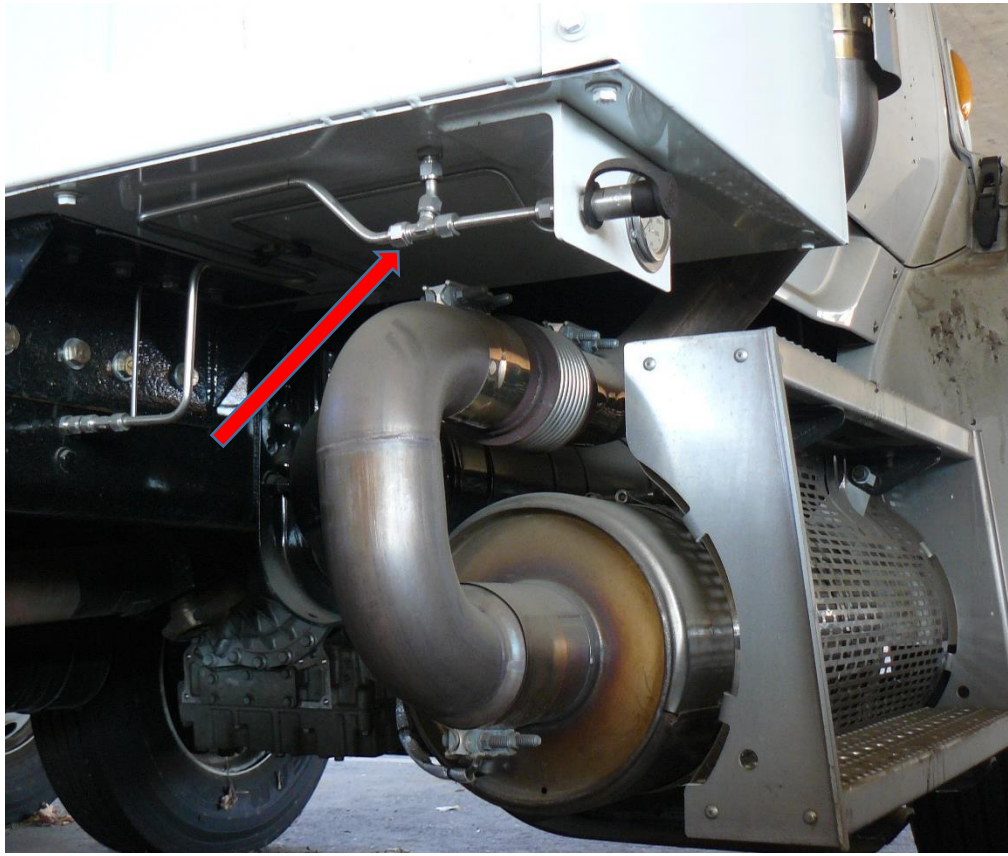


Missing Protection from Damage and Vibration

NFPA 52 6.5.6 and CCR Title 13 section936

Potential Road Debris Damage
-supplier corrected later

UV Damage –supplier installed solid panel



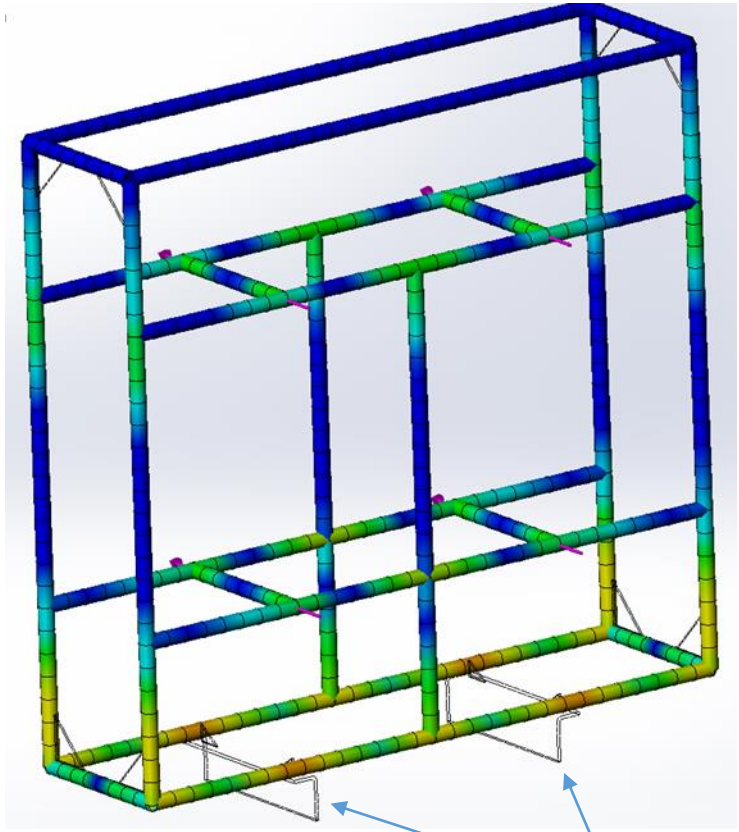
Heat exposure and potential road debris
-supplier added guard

Tank Support Structure Failures

- NFPA52 requires tank support to withstand 8G in 6 principal directions.
- No direct support under saddles.
- Sheetmetal enclosure cracking at welds.

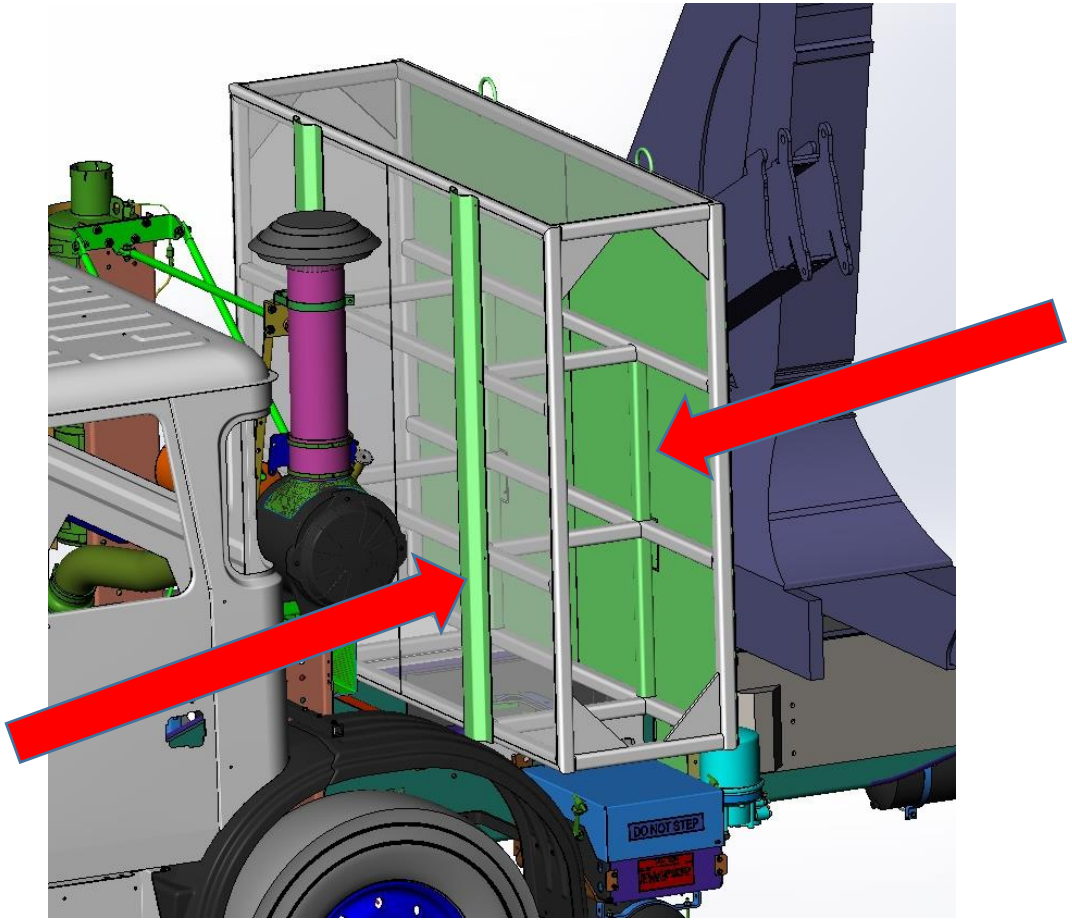
Poor Design – CNG tank cabinet frame

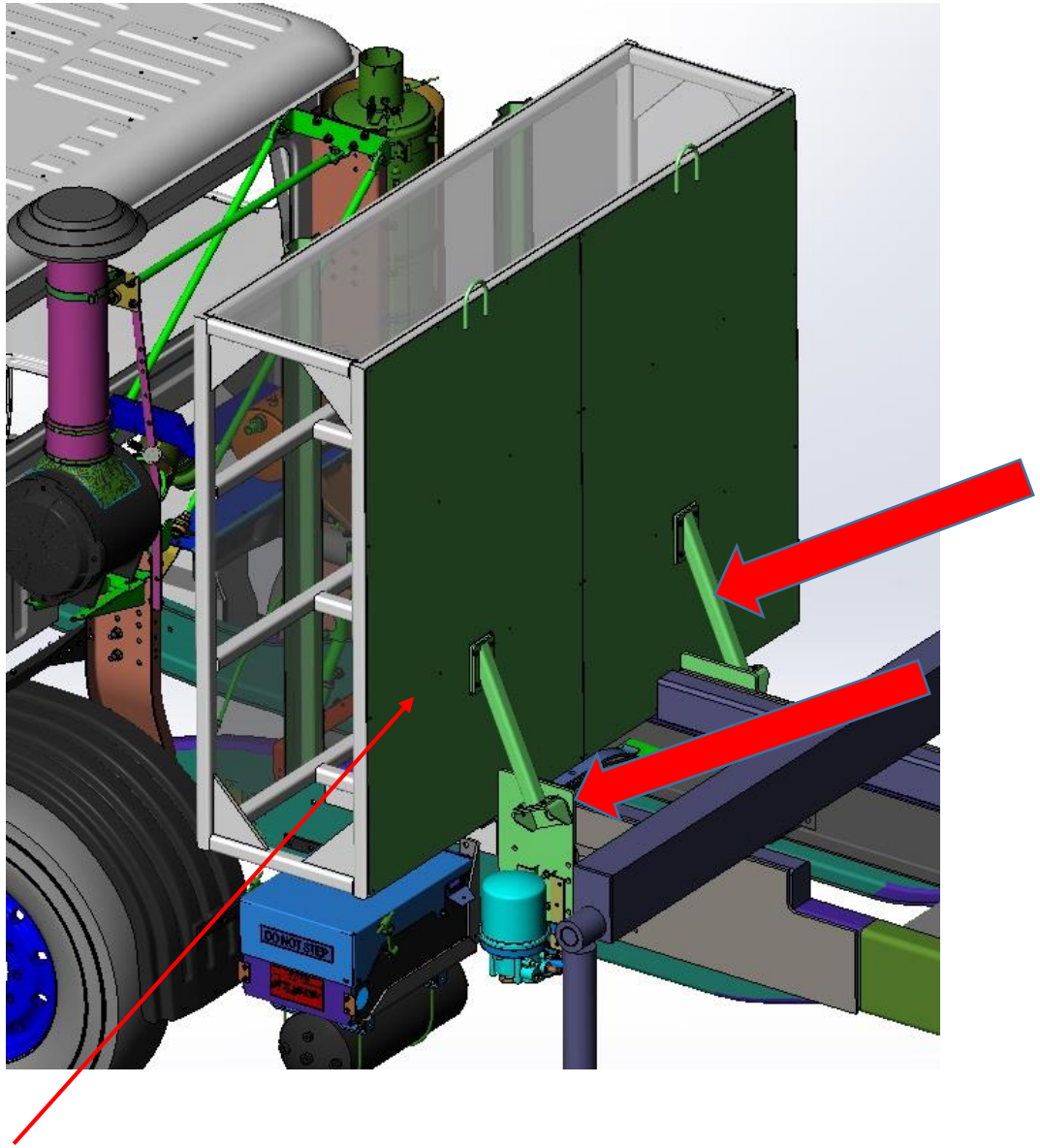
- Safety Factor Analysis
- NFPA 52 6.3.4 requires tank support to withstand 8G in 6 principal directions
- FEA model shows areas meeting requirements as blue



Truck Frame
Mounting hardware

Reinforcements for 8G





Converted panels to a removable type for inspection

Reinforcement for 8G – Finished Product

New rear tubing support

Added vertical sheetmetal support

Anti-Tipping Support

Warranty Correction Timeline – 8 months

Fence and Guardrail Trucks

- Sept 2012 through April 2013 –highlights:

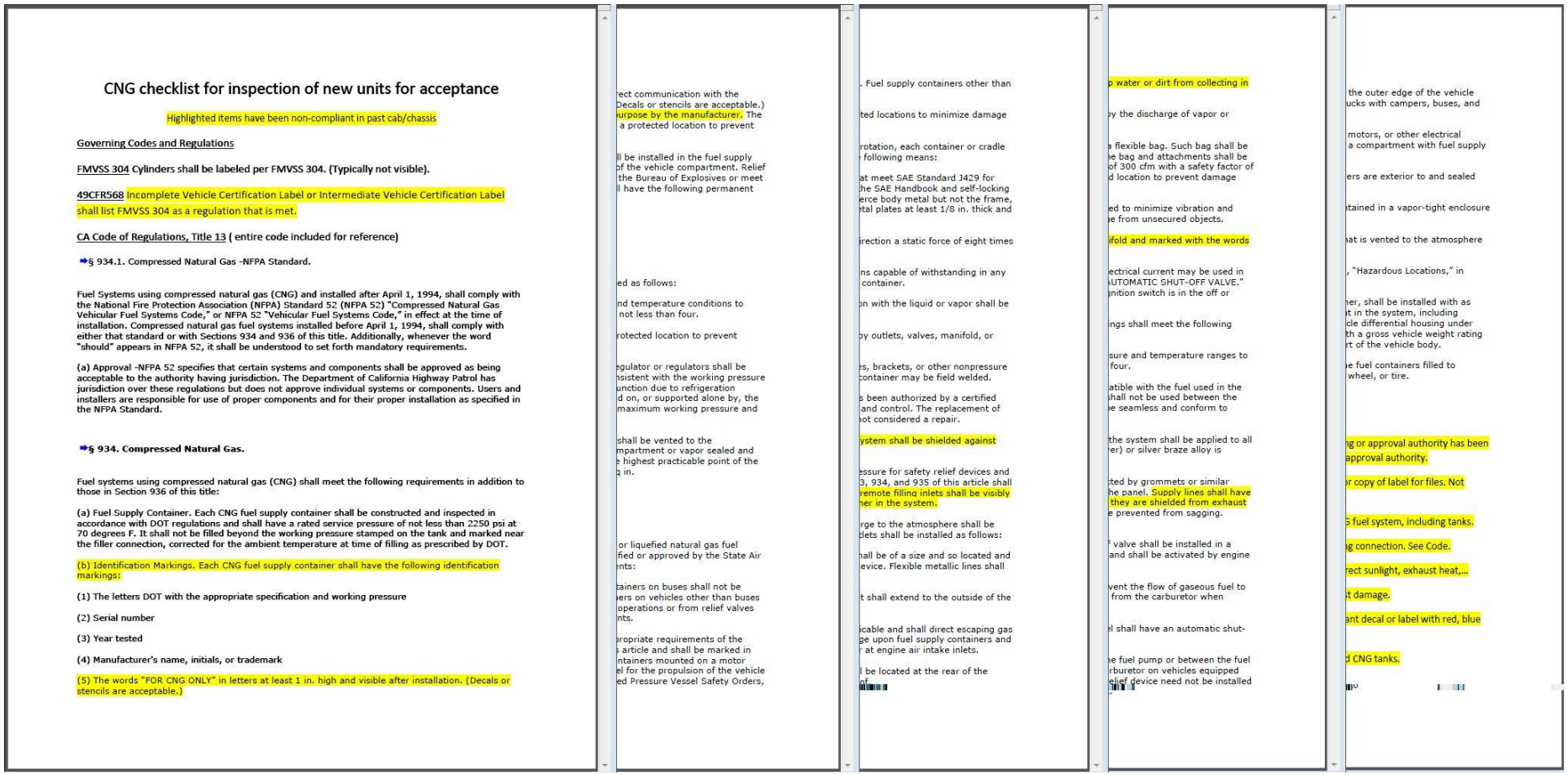
  - Caltrans sent Warranty Letters – included code references for all items
  - Caltrans sent local shop supervisory staff to inspect
  - Caltrans sent Quality Assurance inspection staff on multiple trips
  - Caltrans developed and provided Inspection Reports to vendor
  - Caltrans provided additional detail in emails and phone calls
  - Caltrans sent follow-up warranty letters listing remaining items
  - Caltrans sent additional follow-up letters listing final items

CNG Industry Challenges

-rules are not direct and clear, nor are they in one document-

- NFPA 52 requires components to be listed or approved but does not provide a specific reference to a testing or performance standard such as ANSI/NGV3.1 Fuel System Components for Natural Gas Powered Vehicles.
- Each state may have different rules – manufacturers have to track all of the rules and changes for each state

Develop your own Quality Assurance document



CNG checklist for inspection of new units for acceptance

Highlighted items have been non-compliant in past cab/chassis

Governing Codes and Regulations

FMVSS 304 Cylinders shall be labeled per FMVSS 304. (Typically not visible).

49CFR568 Incomplete Vehicle Certification Label or Intermediate Vehicle Certification Label shall list FMVSS 304 as a regulation that is met.

CA Code of Regulations, Title 13 (entire code included for reference)

➡§ 934.1. Compressed Natural Gas -NFPA Standard.

Fuel Systems using compressed natural gas (CNG) and installed after April 1, 1994, shall comply with the National Fire Protection Association (NFPA) Standard 52 (NFPA 52) "Compressed Natural Gas Vehicular Fuel Systems Code," or NFPA 52 "Vehicular Fuel Systems Code," in effect at the time of installation. Compressed natural gas fuel systems installed before April 1, 1994, shall comply with either that standard or with Sections 934 and 936 of this title. Additionally, whenever the word "should" appears in NFPA 52, it shall be understood to set forth mandatory requirements.

(a) Approval -NFPA 52 specifies that certain systems and components shall be approved as being acceptable to the authority having jurisdiction. The Department of California Highway Patrol has jurisdiction over these regulations but does not approve individual systems or components. Users and installers are responsible for use of proper components and for their proper installation as specified in the NFPA Standard.

➡§ 934. Compressed Natural Gas.

Fuel systems using compressed natural gas (CNG) shall meet the following requirements in addition to those in Section 936 of this title:

(a) Fuel Supply Container. Each CNG fuel supply container shall be constructed and inspected in accordance with DOT regulations and shall have a rated service pressure of not less than 2250 psi at 70 degrees F. It shall not be filled beyond the working pressure stamped on the tank and marked near the filler connection, corrected for the ambient temperature at time of filling as prescribed by DOT.

(b) Identification Markings. Each CNG fuel supply container shall have the following identification markings:

(1) The letters DOT with the appropriate specification and working pressure

(2) Serial number

(3) Year tested

(4) Manufacturer's name, initials, or trademark

(5) The words "FOR CNG ONLY" in letters at least 1 in. high and visible after installation. (Decals or stencils are acceptable.)

Issues -Lessons Learned

- DEVELOP YOUR OWN EXPERTS – rules – repairs – best practices
- Research requirements for your state
- Industry is not necessarily an expert on all laws and regulations
- Caltrans has had the best success when the CNG engine and powertrain management system are provided by the truck manufacturer
- Recommend developing a Quality Assurance Document

RESOURCES

CNG Professional Resources

- SAE- Society of Automotive Engineers –
- ANSI – American National Standards Institute
    - Including NGV3.1 Reference Guide for Integration of Natural Gas Vehicle Fuel Systems
- CGA – Compressed Gas Association
- CSA Group – Canadian Standards Association and CSA America
- NFPA – National Fire Protection Agency – Code 52 and 70
- California Code Of Regulations: Title 8 and Title 13 (ref by SAE)
- NGVI –Natural Gas Vehicle Institute
- NGVC –Natural Gas Vehicle Coalition

Reference Publications

- NFPA 52
- Reference Guide for Integration of Natural Gas Vehicle Fuel Systems
  - Final Report prepared by: Battelle
- Natural Gas Vehicle – Cylinder Care and Maintenance
  - Prepared by: CylTek, Inc
- Fuel system Components for Nautral Gas Powered Vehicles
  - ANSI/AGA NGV3.1 – current publication year
- SAE J2406 contains complete guide to available resources and additional SAE references
- FMVSS 303 and 304
- CFR Title 49 567 and 568 Certification

Summary

- Minimal Federal Guidance
- You need to know what your state requires – can be complicated
- There are CNG professional resources
- **Develop your own experts**

Questions and Comments?