

CNG Codes & Standards Considerations and EOL Tank Testing

Lauren Lynch
Senior Mechanical Engineer
National Renewable Energy Laboratory

NGVTF 2021

May 11, 2021

AGENDA

- CNG Codes & Standards Considerations
 - Project Background & Objectives
 - Proposed Considerations to DOT
 - Discussion
- CNG Fuel Tank End of Life Testing
 - Project Background & Objectives
 - Testing Results
 - Recommendations
 - Discussion

ICF supported NREL on the study.
Lou Browning presented during
NGVTF 2020.

Aaron Williams presented during
NGVTF 2020.
Test results from subcontractor
Hexagon (previously Digital Wave)
were presented by Brian Burks.

CNG Codes & Standards Considerations

NREL's Evaluation of Alternative Fuel Systems & Alternative Fuel Container Safety Standards

Federal Motor Vehicle Safety Standards (FMVSS) specify requirements for integrity of the fuel system and fuel container on CNG fueled vehicles.

- FMVSS 303 “Fuel System Integrity of Compressed Natural Gas Vehicles”
 - Light-duty CNG vehicle focused:
 - “Passenger cars, multipurpose passenger vehicles, trucks, and buses < 10,001 lbs GVWR”
 - “School buses regardless of weight that use CNG as a motor fuel”
- FMVSS 304 “Compressed Natural Gas Fuel Container Integrity”
 - Light-duty CNG vehicle focused:
 - “Passenger cars, multipurpose passenger vehicles, trucks, and buses (regardless of weight) that use CNG as a motor fuel”
 - CNG Fuel Systems Only

Despite the increasing number of CNG heavy-duty vehicles on the road, there are no Federal fuel system integrity requirements for CNG (and LNG) heavy vehicles.

CNG Codes & Standards Considerations

Objective

- NREL conducted a study to provide applicable and accurate recommendations to ensure the standards address relevant safety issues, are practical, and do not produce future barriers.

Scope

- Fuel system and fuel container integrity requirements for CNG & LNG vehicles.
 - Light-, medium-, and heavy-duty.

Key Deliverable

- Recommendations of **performance requirements and specifications** for CNG & LNG fuel systems and fuel containers.
 - Justified by literature review, relevant research and technical forum's feedback.
 - Provide relevant research/test data where available.
 - Recommend test procedures to evaluate compliance with the recommended performance requirements.

Proposed Considerations to DOT NHTSA

- In Summary, the considerations presented to DOT were to:
 - Update FMVSS to include fuel system integrity assessment of medium- and heavy-duty vehicles
 - Update FMVSS to include fuel system integrity requirements for propane vehicles and tanks
 - Add additional CNG fuel tank integrity tests
 - Incorporate more repeatable fire test procedure for fuel tank integrity.

Proposed Considerations to DOT NHTSA

- Considerations for Minimum Safety Standards:
 - Consider expanding the applicability of FMVSS No. 303 to medium- and heavy-duty CNG fuel vehicles to address.
 - Consider modifying FMVSS No. 304 test requirements to include chemical test specifications that subject CNG containers to various chemical agents, as described in NGV 2, to better represent the external container environment of real-world applications.
 - Consider modifying FMVSS No. 304 to effectively represent container failures experienced in field CNG vehicle fires and to improve repeatability and reproducibility of the fire test for efficient compliance verification.
- Link to the full report: <https://www.nrel.gov/docs/fy21osti/77455.pdf>

Proposed Considerations to DOT NHTSA

- Considerations to Reflect Industry Best Practices:
 - Consider modifying FMVSS No. 303 to define acceleration tests, instead of barrier crash tests, to evaluate the integrity of tank mounts to ensure applicability and ease of verification across the large variety of medium- and heavy-duty vehicle configurations.
 - Consider modifying FMVSS to include PRD venting requirements for medium- and heavy-duty vehicles that align with NGV 6.1 and NFPA codes that require venting of the PRD and manifold upwards, above the vehicle to prevent injuries from PRD venting.
 - Consider modifying FMVSS No. 304 test requirements to include a drop test, notch test, and impact test, as defined in NGV 2, to better represent the external container environment of real-world applications, harmonize with North American standards, and ensure compliance with tank manufacturer design requirements.
 - Consider modifying FMVSS No. 304 test to harmonize with a newly developed test procedure in Phase 2 of UN GTR No. 13.
- Link to the full report: <https://www.nrel.gov/docs/fy21osti/77455.pdf>

CNG Codes & Standards Considerations

Questions and Discussion

CNG Fuel Tank End of Life Testing

Evaluating safety concerns of CNG fuel tanks at the end of their defined useful life.

Fuel Tanks that have reached their labeled expiration date/end of life (EOL) or have been condemned by inspection shall be removed from service (and destroyed).

- Natural Gas Vehicles tend to last longer than their fuel tanks
- Not economical to replace tanks
- Vehicle have been known to continue operation with expired tanks
 - No consistent method to track expired tanks
- Replacing tanks has potential to introduce acute hazards
 - Improper installation of fittings and mounting components compared to original
- Safety challenges of visual inspection
 - Human error
 - Qualitative and subjective measure
 - Non-visible damage
 - Non-conservative

CNG Fuel Tank End of Life Testing

Objective

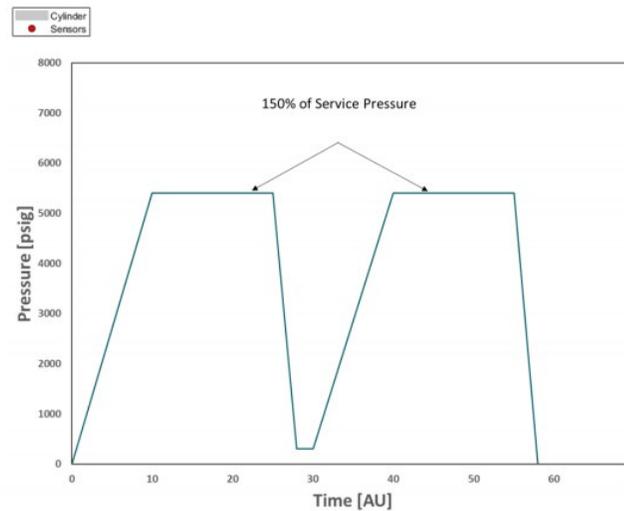
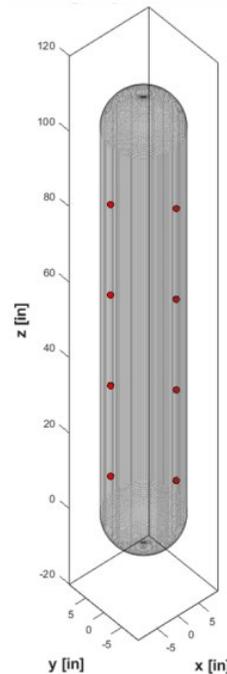
- Characterize tank conditions at the end of their defined useful life
- Characterize the remaining functional life of expired tanks
- Determine how fuel tanks might fail under routine operating conditions
- Understand alternative methods for inspecting tanks

Project History

- Started 2016
- Paused 2017-2018
- Concluded Testing 2019
- Final Report 2020

CNG Fuel Tank End of Life Testing

- High-level Test Outline:
 - 101 Tanks sourced from LA Metro
 - Visual Inspection and Modal Acoustic Emission (MAE) Evaluation
 - Burst Pressure Testing
 - Artificial Damage
 - Notching or Impact
 - Fatigue Cycle
 - Burst Pressure Testing
 - MAE Evaluation



(Left) MAE sensor placement
(Right) MAE inspection pressure schedule



CNG Fuel Tank End of Life Testing

- Potential opportunity of continued use of tanks
- Additional research and development with an expanded CNG fuel tank sample size to characterize tank integrity after experiencing a full service
- Life in a variety of applications could further verify such potential
- Visual inspection was not sufficient in identifying damage inflicted by a localized impact test on Type III and Type IV CNG fuel tanks
- A nondestructive evaluation method successfully assessed the structural integrity of the tanks and would not have compromised the original installation

60 of 101 Tanks Initial Visual and MAE Inspection 60 Passed

20 of 60 Tanks Burst Pressurized as Received 20 Passed

Number of Tanks Tested	Minimum Burst Pressure Test Pass/Fail	
	20 of 20 Tanks as Received from LA County Metro Transportation Authority	20 Tested 20 Passed

20 of 60 Tanks Artificially Damaged and Burst Pressurized 14 Passed, 6 Failed

Number of Tanks Tested	Hydraulic Fatigue Tested to 15,000 Cycles Pass/Fail		Minimum Burst Pressure Test Pass/Fail	
	8 of 20 Tanks Notch Damaged	4 Tested 4 Passed	2 Type III 2 Type IV	8 Tested 8 Passed
4 of 20 Tanks Impact Damaged	2 Tested 2 Passed	1 Type III 1 Type IV	4 Tested 4 Passed	2 Type III 2 Type IV
4 of 8 Tanks Local Impact Damaged at Standard Height	2 Tested 2 Passed	1 Type III 1 Type IV	4 Tested 2 Passed 2 Failed	2 Type III 2 Type IV
4 of 8 Tanks Local Impact Damaged at Double Height	2 Tested 2 Passed	1 Type III 1 Type IV	4 Tested 4 Failed	2 Type III 2 Type IV

20 of 60 Tanks Hydraulically Fatigued to 18,000 Cycles 20 Passed

Number of Tanks Tested	Hydraulic Fatigue Tested to 18,000 Cycles Pass/Fail		Minimum Burst Pressure Test Pass/Fail	
	2 of 20 Tanks Leak-Tested	2 Tested 2 Passed	1 Type III 1 Type IV	None Tested
20 of 20 Tanks Burst Pressurized	20 Tested 20 Passed	10 Type III 10 Type IV	20 Tested 20 Passed	10 Type III 10 Type IV

CNG Fuel Tank End of Life Testing

Questions and Discussion