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RESEARCH FOR THE NFPA MISSION

Alternative Fuel Vehicle Safety Summit

FINAL PROCEEDINGS BY:

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Fire Protection Research Foundation
1 Batterymarch Park, Quincy, MA

Held: 23 June 2016, The Westin Book Cadillac, Detroit, Michigan

August 2016

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Executive Summary

These are the proceedings of the Alternative Fuels Vehicle Safety Summit held in Detroit, Michigan on 23 June 2016. This summit involved a diverse group of stakeholders focused on addressing important and useful review, validation and identification of gaps for emergency responder operational training materials on AFVs. These training materials are used by first and second emergency responders and others handling emergencies with alternative fuel vehicles, with an emphasis on gaseous fuels.

The scope of this effort includes addressing emergency activities such as: fire events, non-fire emergencies (e.g., submersion), fire investigation, crash reconstruction, tow and salvage, extrication practices, refueling and charging infrastructure, etc. The deliverables from this summit provide a summary of prioritized needs and gaps from the perspective of emergency responder stakeholders, and promotes activities to address these needs and gaps through all possible approaches. This includes working with vehicle providers to implement inherent safety design solutions through up-front innovative design.

The key summary observations from this summit address: general hazard concerns; electronic badging; fire fighting tactics; investigation; stranded energy; and other issues and trends. Of particular note, the Summit highlights the following:

- Need to address implementation of electronic badging technologies as soon as possible to enable real-time emergency event size-up and prospective data collection;
- Clarifying the tactical fire fighting approach for the venting of gaseous fuel storage vessels depending on the vessel material (i.e., metal versus composite);
- Addressing the needs of investigators to re-power damaged vehicles to harvest post event data; and
- Continuing to address the problem of stranded energy and its long time frame impact on first and second emergency responders.

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Acknowledgements

This summit was supported by the United States Department of Energy:



This summit proceeding has been prepared by Casey C. Grant, Executive Director at the Fire Protection Research Foundation. The information contained herein is based on the input of numerous professionals and subject-matter-experts. While considerable effort has been taken to accurately document this input, the final interpretation of the information contained herein resides with the report author. The content, opinions and conclusions contained in this report are solely those of the authors and do not necessarily represent the views of the Fire Protection Research Foundation, NFPA, Technical Panel or Sponsors. The Foundation makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

Acknowledgment: "This material is based upon work supported by the Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), under Award Number DE-EE0007020."

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About the Fire Protection Research Foundation

The [Fire Protection Research Foundation](#) plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.



About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. [All NFPA codes and standards can be viewed online for free.](#) NFPA's [membership](#) totals more than 65,000 individuals around the world.



Keywords: Alternative fuel vehicles, LNG, CNG, LPG, lithium-ion batteries, hydrogen fuel cells, emergency responders, Electric vehicles

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1) Background and Overview

The popularity of alternative fuel vehicles (AFVs) has been increasing in recent years based efforts to maximize fuel efficiency and minimize unnecessary environmental waste. There are currently millions of these vehicles on the road today, and that number continues to grow. Figure 1 illustrates the increasing usage trend of these vehicles, for the time period of 1995 through 2011. (Source: *Alternative Fuels Data Center, Energy Efficiency & Renewable Energy, U.S. Department of Energy*, website: <http://www.afdc.energy.gov/data/>, accessed 29 July 2016)

AFVs are those vehicles powered by other than the traditional petroleum-based internal combustion engines, and are using an alternative fuel source such as gaseous fuels (e.g., CNG, LNG, LPG), high voltage electric batteries (e.g., lithium-ion), and hydrogen fuel cells. Specifically, the Energy Policy Act of 1992 defines an alternative fuel as one of the following: Biodiesel (B100); Natural gas and liquid fuels domestically produced from natural gas; Propane (liquefied petroleum gas); Electricity; Hydrogen; Blends of 85% or more of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; Methanol, denatured ethanol, and other alcohols; Coal-derived, domestically produced liquid fuels; Fuels (other than alcohol) derived from biological materials; P-Series fuels. (Source: *H.R. 776 – Energy Policy Act of 1992, Congress.Gov*, website: <https://www.congress.gov/bill/102nd-congress/house-bill/776/text/enr>, accessed 29 July 2016)

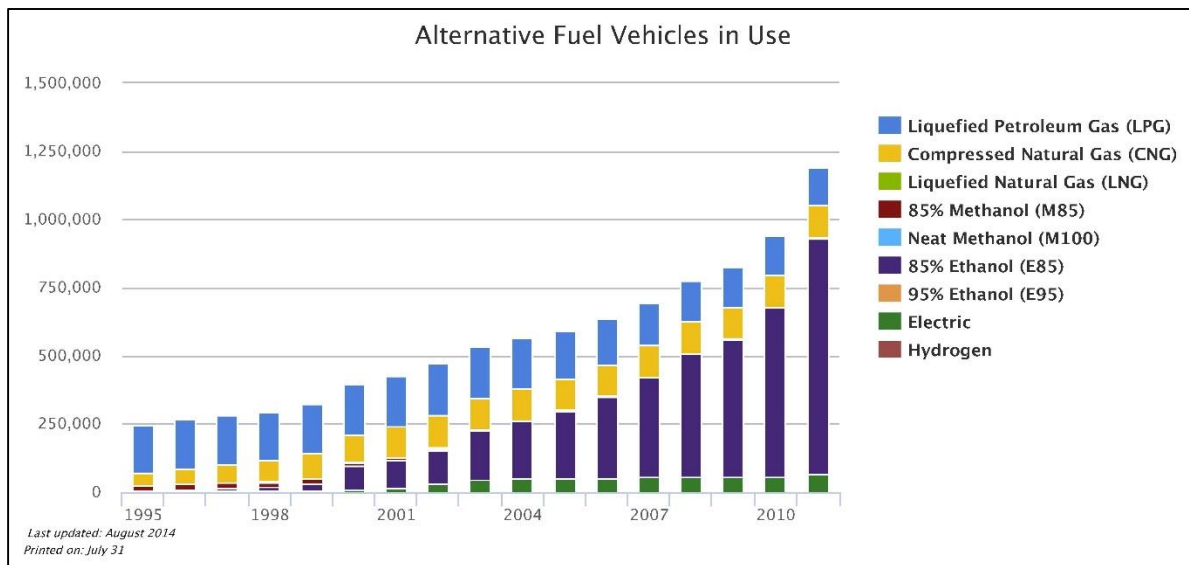


Figure 1: Alternative Fuel Vehicles in Use, 1995-2011

(Source: *Alternative Fuels Data Center, Energy Efficiency & Renewable Energy, U.S. Department of Energy*, website: <http://www.afdc.energy.gov/data/>, accessed 29 July 2016)

While much has been focused on passenger cars, this technology is also proliferating with larger fleet vehicles such as trucks and busses, which have the advantage of uniform and centralized service and maintenance. Cost efficiencies have been attractive for fleet vehicles to be utilized with fleet activities (e.g., bus networks and delivery trucks in local areas). This workshop has been focused on four-wheeled on-road generally includes traditional passenger vehicles as well as larger vehicles such as trucks and busses. However, applications other than four-wheeled on-road vehicles (e.g., motorcycles) are not totally outside the scope of consideration to the extent that similar hazard and safety concepts apply. Figure 2 summarizes the types of vehicles by weight class according to the Federal Highway Administration. (Source: *Alternative Fuels Data*

Center, Energy Efficiency & Renewable Energy, U.S. Department of Energy, website: <http://www.afdc.energy.gov/data/>, accessed 29 July 2016) These illustrate the types of vehicles that are the primary focus of this safety summit.

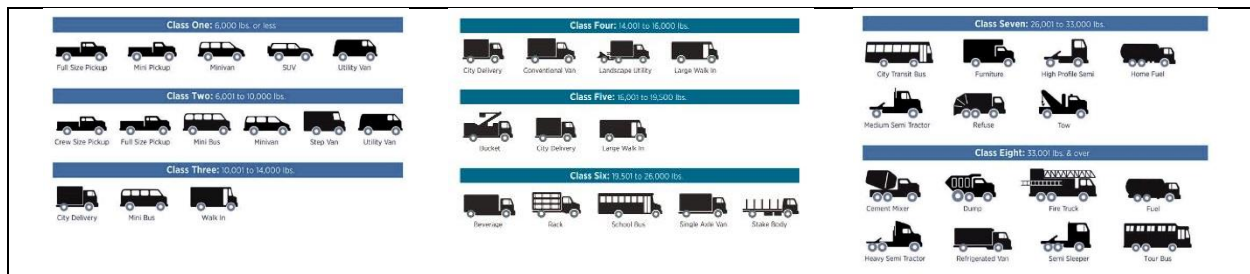


Figure 2: Types of Vehicles by Weight Class (by Federal Highway Administration)
 (Source: Alternative Fuels Data Center, Energy Efficiency & Renewable Energy, U.S. Department of Energy, website: <http://www.afdc.energy.gov/data/>, accessed 29 July 2016)

As new fuels and power sources are introduced, so too does safety considerations associated with them. Paramount to emergency responders is a clear and rapid understanding of all the hazards they are facing, especially in during an emergency when accurate real-time information is critical.

Compared to traditional vehicles with which emergency responders are generally well familiar, the hazards associated with a particular AFV may be greater or less of a concern, but most notably they are often different and require baseline expectations beyond normal training and experience. It is not unusual nor unexpected for emergency responders to arrive at incidents that may involve AFVs (crashes, fires, entrapment, submersion, etc.). Figure 3 illustrates the types of incidents that emergency responder can expect to handle. (Source: Grant, C., “Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Drive Vehicles”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2010) It is essential that emergency responders know how to best handle the hazards presented by these new vehicles.

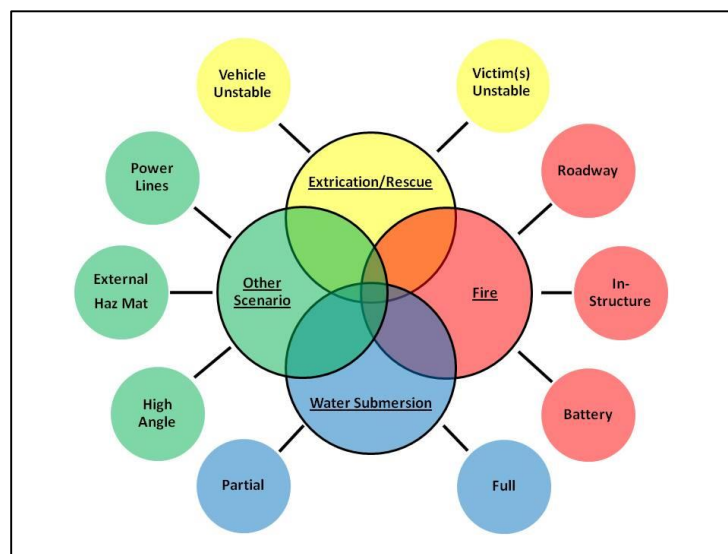


Figure 3: Key Emergency Scenarios for Emergency Responders
 (Source: Grant, C., “Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Drive Vehicles”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2010)

Emergency responders are all the professionals and organizations that respond to an emergency event. There are often two recognized tiers of first responders and second responders. The first responders are generally the organizations in charge of specific aspects of the emergency and include the fire service, emergency medical services (EMS) and law enforcement. Second responders are also critical to handling the event and include groups such as tow/salvage, medical examiner, and follow-up responders from the first tier such as investigators.

Interestingly, first responders are not always first upon an emergency event, such as when tow and salvage arrive at an emergency before any other responders. Figure 4 provides an overview of the details of emergency responders, all of whom are within the scope of this safety summit. (Source: Grant, C., “2nd Annual Electric Vehicle Safety Standards Summit – Summary Report”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2011.)

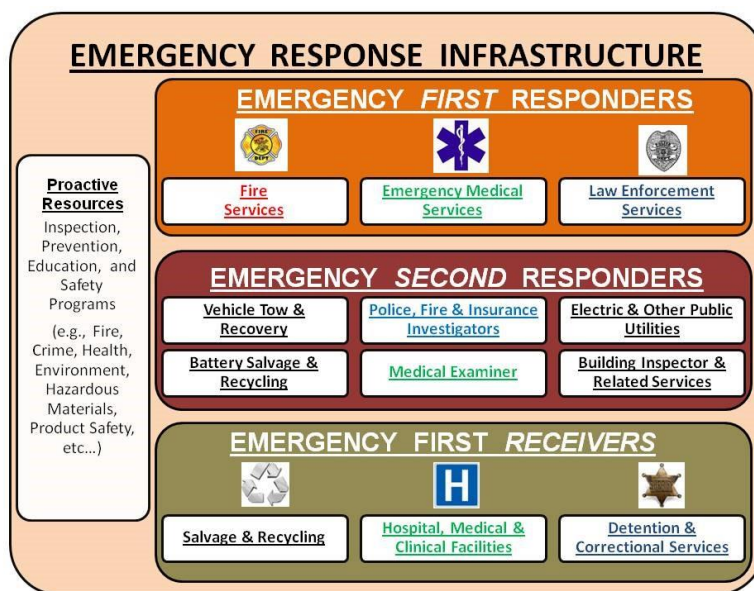


Figure 4: Emergency Responder Infrastructure

(Source: Grant, C., “2nd Annual Electric Vehicle Safety Standards Summit – Summary Report”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2011.)

Several directly applicable projects and workshops were completed prior to this Alternative Fuel Vehicle Safety Summit. The following are the activities, in chronological order, conducted by either the National Fire Protection Association or the Fire Protection Research Foundation:

- **“Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles“:** A background research study that assembled core principle and best practice information for emergency responders to assist in their decision making process at emergencies involving electric drive and hybrid e-vehicles. It included a one-day workshop of applicable subject matter experts to review and evaluate the topic. (Source: Grant, C., “Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Drive Vehicles”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2010)
- **“U.S. National Electric Vehicle Safety Standards Summit Summary Report“:** This was a summit held on 21-22 October 2010 in Detroit, Michigan to address safety related codes and standards issues, with a focus on the fundamental codes and standards centric areas of: vehicles, built

infrastructure, and emergency responders. The intent was to develop the base elements for an action plan for the safe implementation of e-vehicles using safety standards as the primary mechanism for this action plan. (Source: Grant, C., "U.S. National Electric Vehicle Safety Standards Summit Summary Report", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2010)

- "[Lithium Ion Batteries Hazard and Use Assessment](#)": A research study to develop the technical basis for requirements in codes and standards to support the protection requirements for hazards involving lithium ion batteries. This report provides a literature review of battery technology, failure modes and events, usage, codes and standards, and a hazard assessment during the life cycle of storage and distribution. It additionally provides a research approach toward evaluating appropriate facility fire protection strategies for the bulk storage of lithium ion batteries. (Source: Mikolajczak C., Kahn M., White K., and Long R.T., "Lithium-Ion Batteries Hazard and Use Assessment", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, July 2011)
- "[Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards](#)": A research study that facilitated the safe integration of e-vehicles into the electrical safety infrastructure, by reviewing the technologies likely to impact electrical safety, and presenting an assessment of needed changes to codes and standards along with a roadmap for needed additional research. (Source: Simonian, L., et al, "Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2011)
- "[2nd Annual Electric Vehicle Safety Standards Summit – Summary Report](#)": This was a summit held on 27-28 September 2011 in Detroit, Michigan to bring together the appropriate stakeholder groups to further refine a shared implementation plan to ensure that fire and electrical safety standards impacting e-vehicles do not serve as a barrier to their deployment. (Source: Grant, C., "2nd Annual Electric Vehicle Safety Standards Summit – Summary Report", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2011)
- "[Assessment of Powered Rescue Tool Capabilities with High-Strength Alloys and Composite Materials](#)": A research study that assessed the capabilities and existing field inventory of powered rescue tools and their ability to handle high strength steels found in e-vehicles and other new vehicles now proliferating on the highways. (Source: Merrifield, B. and Grant, C., "Assessment of Powered Rescue Tool Capabilities with High-Strength Alloys and Composite Materials", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2011)
- "[Personal Protective Equipment for Hybrid and Electric Vehicles](#)": This workshop was held on 1 May 2012 in Quincy, Massachusetts to bring together emergency responders and other stakeholders to develop guiding principles and recommended action steps to address the proper PPE for emergencies involving hybrid or e-vehicles, with a focus on minimizing the risk to emergency responders due to hazards involving electrically energized equipment. This was driven by the vehicle specific emergency response guides from automakers providing conflicting and sometimes contradictory guidance. (Source: Grant, C., "Personal Protective Equipment for Hybrid and Electric Vehicles", Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, 2012)
- "[Electric/Hybrid Vehicle Safety Training for Emergency Responders](#)": A training materials development project focused on providing comprehensive awareness and emergency response training for fire fighters and other emergency responders to prepare them for widespread implementation of advanced electric drive vehicles, with objectives to enhance

general awareness training and emergency response tactical training, as well as to establish a centralized resource for ongoing technology transfer. (Source: Klock, A., “Electric/Hybrid Vehicle Safety Training for Emergency Responders”, National Fire Protection Association, www.evsaftytraining.org, Quincy MA, 2013)

- [”Lithium Ion Batteries Hazard and Use Assessment Ph. IIB“](#): A research study that provides results of full scale empirical fire tests of high rack storage of common lithium ion batteries, to clarify their flammability characteristics as compared to standard commodities in rack storage. This addressed various sizes of lithium ion batteries, including batteries for electronic devices such as laptops, power tools, cameras, and cell phones. (Source: Long R.T., Sutula J., and Kahn M., “Lithium-Ion Batteries Hazard and Use Assessment Phase IIB - Flammability Characterization of Li-ion Batteries for Storage Protection”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, April 2013)
- [”Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results “](#): A research study involving full scale fire tests of large format lithium ion e-vehicle batteries to develop the technical basis for emergency response best practices, with consideration for certain details such as suppression methods, PPE, and clean-up/overhaul operations. (Source: Long R.T., Blum A., Bress T., and Cotts B., “Emergency Response to Incidents Involving Electric Vehicle Battery Hazards”, Fire Protection Research Foundation, www.nfpa.org/EVBatteryTests, Quincy MA, July 2013)
- [”Alternative Fuel Vehicle Safety Training Program“](#): Training materials development project focused on providing comprehensive awareness and emergency response training for fire fighters and other emergency responders to prepare them for widespread implementation of alternative fuel vehicles, with objectives to enhance general awareness training and emergency response tactical training, as well as to establish a centralized resource for ongoing technology transfer. (Source: Klock, A., “Alternative Fuel Vehicle Safety Training”, National Fire Protection Association, www.evsaftytraining.org, Quincy MA, 2016)
- [”Hazard Assessment of Lithium Ion Battery Energy Storage Systems“](#): This project develops a hazard assessment to address the usage of lithium ion batteries in energy storage systems (ESS), to allow for the development of safe installation requirements and appropriate emergency response tactics. (Source: Blum A.F. and Long R.T., “Hazard Assessment of Lithium Ion Battery Energy Storage Systems”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, February 2016)
- [”Workshop on Energy Storage Systems and the Built Environment“](#): The Research Foundation coordinated with the Fire Department of New York City (FDNY) to host a workshop on 19 November 2015 with all stakeholders to discuss the installation of electrical Energy Storage Systems (ESS) using technologies such as bulk lithium ion batteries and flow batteries, especially in residential occupancies from high-rise buildings to single- and multi-family homes. The purpose was to clarify the potential hazard, review recommended built-in fire protection measures, and inform fire fighting practices. (Source: Gorham D.J., “Workshop on Energy Storage Systems and the Built Environment”, Fire Protection Research Foundation, www.nfpa.org/Foundation, Quincy MA, March 2016)

This summit (the “Alternative Fuel Vehicle Safety Summit”) seeks to review, validate and identify gaps for the operational training materials used by first and second emergency responders and others handling emergencies with alternative fuel vehicles, with an emphasis on gaseous fuels.

To summarize, this includes addressing activities such as: fire events, non-fire emergencies (e.g., submersion), fire investigation, crash reconstruction, tow and salvage, extrication practices,

refueling and charging infrastructure, etc. The deliverables from this summit provide a summary of prioritized needs and gaps from the perspective of emergency responder stakeholders, and promotes activities to address these needs and gaps through all possible approaches. This includes working with vehicle providers to implement inherent safety design solutions through up-front innovative design.

2) Agenda and Presentations

The agenda for the summit is illustrated in Table 1: Summit Agenda. Following welcoming remarks, this is structured to provide an overview of this topic area such as AFV training materials and different fuel types, followed by a dual panel discussion with stakeholders and breakout group discussions, and concluded with a plenary session addressing summary observations.

Table 1 - Summit Agenda

	Item	Time	Speaker
	Registration & Networking	0700-0800	
1)	Introduction & Welcome (<i>10 min</i>)	0800-0810	Casey Grant, FPRF
2)	Overview of NFPA Supporting Materials (<i>15 min</i>)	0810-0825	Michael Gorin, NFPA
3)	Review of AFV Training Materials (<i>120 min</i>)	0825-1000	Jason Emery, WFD
	Morning Break	1000-1015	
3)	Review of AFV Training Materials (<i>Continued</i>)	1015-1040	Jason Emery, WFD
4)	Technical Presentations		
4a)	Natural Gas (CNG / LNG) (<i>20 min</i>)	1040-1100	Dan Bowerson, NGVA
4b)	Propane (LPG) (<i>20 min</i>)	1100-1120	Mike Walters, Superior Energy Systems
4c)	Hydrogen Fuel Cells (<i>20 min</i>)	1120-1140	Will James, DOE Fuel Cell Technologies
4d)	Electric Vehicles (<i>20 min</i>)	1140-1200	Eric Rask, Argonne
	Networking Lunch (<i>opening</i>)	1200-1220	
4e)	AFV Workplace Safety (<i>Lunchtime Speaker, 20 min</i>)	1220-1240	Stephan Yborra, Yborra Assoc.
	Networking Lunch (<i>closing</i>)	1240-0100	
5)	Dual Panel Disc w/ AFV & ER Stakeholders (<i>60 min</i>)	0100-0200	AFV & ER Panelists
6)	Roundtable Breakout Group Discussions		<i>All Attendees</i>
6a)	Roundtable Assignments (<i>15 min</i>)	0200-0215	Casey Grant, FPRF
	Afternoon Break	0215-0230	
6b)	Roundtable Discussions (<i>75 min</i>)	0230-0345	<i>All Attendees</i>
7)	Breakout Group Reports (<i>30 min</i>)	0345-0415	<i>All Attendees</i>
8)	Closing Comments & Conclusion (<i>15 min</i>)	0415-0430	Casey Grant, FPRF

The baseline for this topic was established by the following seven presentations: first by Michael Gorin describing the overall AFV Training effort,, second by Jason Emery on the topic of “Review of AFV Training Materials”; third by Dan Bowerson on the topic of “Natural Gas (CNG/LNG)”; fourth by Mike Walters on the topic of “Propane (LPG)”; fifth by Will James on the topic of “Hydrogen Fuel Cells”, sixth by Eric Rask on the topic of “Electric Vehicles”; and seventh by Stephan Yborra on the topic of “AFV Workplace Safety”. These are illustrated in Annex B.

3) Discussion of Needs – Breakout Session Summary

Following introductory remarks and baseline presentations, breakout group discussions were conducted to clarify the collective consensus perspective on a series of key questions. The questions are summarized in Figure 5: Questions for Breakout Groups. For the following questions, the AFV fuel source includes EVs, fuel cells, gaseous fuels, etc., and emergency events include fire events, non-fire emergencies (e.g., submersion), fire investigation, crash reconstruction, tow and salvage, extrication practices, refueling and charging infrastructure, etc.

- Roundtable Breakout Group Questions
- 1) **Baseline Differences:** Emergency responders deal with emergency events involving traditional ICE (internal combustion engine) vehicles on a regular basis. With this as a baseline, what makes each AFV fuel source different from this baseline? (i.e., what are the primary concerns / hazards that require additional attention? Consider each fuel and each general scenario.
 - 2) **Specific Technical Questions for Fire:**
 - Pressure Relief Design Considerations**
 - a) What is the basis for determining the temperature settings for pressure relief devices?
 - b) What is the basis for determining the venting direction of pressure relief devices?
 - ER Tactical Considerations**
 - c) What consideration should be given to ER water application for the design of the pressure relief device temperature setting?
 - d) What tactical guidance should be provided to ERs for cooling (e.g., water application) of pressure relief devices?
 - e) What are best practices for fire extinguishment?
 - Storage Vessel Design Considerations**
 - f) What methods are being looked at to provide comprehensive real-time sensors (e.g., heat detection) for the entire storage vessel (e.g., along the full length)?
 - g) What methods are being looked at to provide better storage vessel protection against fire exposure (e.g., insulation)?
 - Other?**
 - 3) **Aftermarket and DIY:** How will be the problems and implications with service and other work done by non-qualified people, and how should these be addressed?
 - 4) **Investigations:** Clarify the special challenges for investigators, and what original design considerations are important or needed?
 - 5) **Post Event Handling:** What is the special handling guidance for post event handling (different from baseline)?
 - 6) **High Frequency – Low Severity Events:** What special considerations are important for common events that are not high severity but raise safety questions (partially damaged vehicle with full fuel)?
 - 7) **Research Gaps:** What research is currently needed? What is the priority for this research?
 - 8) **Future Trends:** With continually evolving technologies and materials, what other AFV issues should be considered, now and in the future?
 - 9) **Other issues?** Are there any other issues not addressed elsewhere? For AFV safety, are there any declarative statements on this topic that are important and should be stated?

Figure 5: Roundtable Breakout Group Questions

The breakout groups were evenly balanced with a diverse mix of attendees. They were given a neutral identifier as follows: Yellow Group; Blue Group; Green Group; and Red Group. They collectively reported back during the plenary session with the following:

1) **Baseline Differences: Emergency responders deal with emergency events involving traditional ICE (internal combustion engine) vehicles on a regular basis. With this as a baseline, what makes each AFV fuel source different from this baseline? (i.e., what are the primary concerns / hazards that require additional attention? Consider each fuel and each general scenario.**

- Challenges of AFV hazards are different, but not necessarily more or less hazardous.
- Full EVs have lots of similarities but are less similar to ICE vehicles than gaseous fuels.
- Hybrid EVs have lots of variables with continuing need to be addressed.
- Gaseous fuels are arguably less hazardous. They have greater levels of safety.
- Lack of knowledge at an emergency is a concern. With knowledge the event is straight-forward (i.e., vehicle badging is important).
- Consistent badging and labeling should be promoted (similar to and consistent with ICE vehicles).

2) **Specific Technical Questions for Fire:**

Pressure Relief Design Considerations

a) **What is the basis for determining the temperature settings for pressure relief devices?**

- Temperature thresholds are already well established for certain specific situations and fuels (e.g., based on UL132).
- Important variables need to be considered, such as high pressures, cryogenics, vessel design, etc.
- There is a concern between steel tanks versus composite tanks, and how best to deal with them during a fire.
- This is very fuel dependent, among other important variables.

b) **What is the basis for determining the venting direction of pressure relief devices?**

- Venting direction is a concern.
- Further research, training and education is important on this topic.
- This should be directly addressed by the OEMs and others, via codes (e.g., SAE) and other impactful methods.
- Establish a universal baseline approach, and then deviate from this as appropriate.
- Concern for aftermarket vehicles and designs.

ER Tactical Considerations

c) **What consideration should be given to ER water application for the design of the pressure relief device temperature setting?**

- More research is needed.
- This is a major shift in fire fighting tactics, and thus is a concern and important.
- We need SOPs and tools to address stranded energy of all fuels in the field (including for all first and second emergency responders)

d) **What tactical guidance should be provided to ERs for cooling (e.g., water application) of pressure relief devices? See responses above to 2(c).**

e) What are best practices for fire extinguishment?

- For extinguishing media, more research is needed along with validation of that research.
- One size does not fit all for extinguishing media.
- Tactics also need to be clarified, including when to “let it burn”.

Storage Vessel Design Considerations

f) What methods are being looked at to provide comprehensive real-time sensors (e.g., heat detection) for the entire storage vessel (e.g., along the full length)?

- Consider RFID or similar approaches to address badging and other sensor/knowledge issues.
- Enable on-scene telematics for emergency responders.
- Avoid the difficulties of physical badging which are complicated, and focus on a cyber delivery of information to emergency responders on scene.
- Collect cyber vehicle data at emergency events to populate national data collections going forward.

g) What methods are being looked at to provide better storage vessel protection against fire exposure (e.g., insulation)? See responses above to 2(f).

Other? See responses above to 2(f).

3) **Aftermarket and DIY:** *How will be the problems and implications with service and other work done by non-qualified people, and how should these be addressed?*

- Aftermarket and DIY are a problem.
- The use of qualified and properly credentialed personnel (e.g., service) should be promoted.
- Clarify the need to establish oversight of aftermarket vehicle designs to assure minimal levels of safety.
- Treat all vehicles according to the greatest possible hazard until clarified otherwise.

4) **Investigations:** *Clarify the special challenges for investigators, and what original design considerations are important or needed?*

- Investigators are often re-powering damaged vehicles to harvest vehicle information.
- Harvesting black box information in a post event needs to be considered in the original vehicle designs.

5) **Post Event Handling:** *What is the special handling guidance for post event handling (different from baseline)?*

- Provide support for investigators to harvest black box information.
- Consider other non-technical issues that support the needs of investigators, such as legal, privacy of information, etc.
- Training and education are needed to not activate critical vehicle systems that will re-introduce a hazard.
- Tow and salvage is important, and should be given proper attention so that a potential hazard is properly handling post event.
- Stranded energy of fuels, and especially with electrical energy, is important and not adequately resolved.

- Establish an emergency responder information clearinghouse for real-time emergency responder information.
- 6) **High Frequency – Low Severity Events:** *What special considerations are important for common events that are not high severity but raise safety questions (partially damaged vehicle with full fuel)?*
- Need to clarify and possibly define a “Compromised vehicle”
 - One size does not fit all.
 - Work closely with the OEMs
 - Methods are needed in the field for determining the stability and state of charge of damaged batteries, and to safely dissipate stranded energy.
- 7) **Research Gaps:** *What research is currently needed? What is the priority for this research?*
- Clarification of fire fighting tactics is needed for various gaseous fuel tank designs, to clarify when and when not to apply water.
 - Lithium ion battery fire suppression effectiveness.
 - Ventilation of fuels in confined areas (e.g., garages).
 - SOPs and SOGs for 911 call receivers.
 - Pressure relief devices for gaseous fuels require demonstration tests as proof of concept for emergency responder tactics.
 - Numerous items covered earlier.
 - Develop technology, tools and methods that will monitor the state of health of primary hazards of AFVs.
- 8) **Future Trends:** *With continually evolving technologies and materials, what other AFV issues should be considered, now and in the future?*
- Be aware of proposed 48V systems in vehicles, which are below the threshold of SAE hi-voltage) but arguably still a significant hazard.
 - Consider arc-flash and arc-blast.
 - Monitor and stay involved with the European based standards effort involving ECE R100 for batteries.
 - Express concerns to the ECE R100 arena that their primary criteria of one hour observations after their tests does not consider the thermal runaway concerns of emergency responders when dealing with damaged electrical batteries.
 - Address second life uses of vehicle systems and components, such as with electrical energy storage systems.
 - Consider emerging new technologies, such as low pressure absorption systems and massless batteries (with batteries built into the vehicle structure).
- 9) **Other issues?** *Are there any other issues not addressed elsewhere? For AFV safety, are there any declarative statements on this topic that are important and should be stated?*
- Promote success stories, including the proactive positive approach of this overall effort.
 - Clarify regulations for remote fueling sites and portable charging and re-fueling, such as used for fleets.
 - Consider marine applications.
 - Continue to push for innovative solutions to the stranded electrical energy problem.

4) Summary Observations

This Alternative Fuel Vehicle Safety Summit provides an important and useful review, validation and identification of gaps for emergency responder operational training materials on AFVs. These training materials are used by first and second emergency responders and others handling emergencies with alternative fuel vehicles, with an emphasis on gaseous fuels.

The scope of this effort includes addressing emergency activities such as: fire events, non-fire emergencies (e.g., submersion), fire investigation, crash reconstruction, tow and salvage, extrication practices, refueling and charging infrastructure, etc. The deliverables from this summit provide a summary of prioritized needs and gaps from the perspective of emergency responder stakeholders, and promotes activities to address these needs and gaps through all possible approaches. This includes working with vehicle providers to implement inherent safety design solutions through up-front innovative design.

The key summary observations from this summit are the following:

1) GENERAL HAZARD CONCERNS

- a) **AFV Hazards:** In training materials and tactical approaches, treat all vehicles according to the greatest possible hazard until clarified otherwise. Tactics for offensive and defensive attacks need to be clarified, including when to “let it burn”. The challenges of AFV hazards are different, but not necessarily more or less hazardous.
- b) **Aftermarket Vehicles:** Aftermarket and DIY vehicles continue to be a concern. Generally promote the use of qualified and properly credentialed personnel (e.g., service). Clarify the need to establish oversight of aftermarket vehicle designs to assure minimal levels of safety.
- c) **High Frequency – Low Severity Events:** Need to clarify and possibly define a “Compromised vehicle” to allow development of guidance information for emergency responders on common emergency events that are not severe. One size does not fit all, and need to work closely with the OEMs on this topic due to the implications.

2) ELECTRONIC BADGING

- a) **Badging:** Consider RFID or similar approaches to address badging and other sensor/knowledge issues. Avoid the difficulties of physical badging which are complicated, and focus on a cyber delivery of information to emergency responders on scene. Enable on-scene telematics for emergency responders. Work to implement this sooner rather than later, to take advantage of new vehicle-to-vehicle technologies that are now emerging in the marketplace. The lack of knowledge at an emergency is a pressing concern, since with knowledge the event becomes more straight-forward (i.e., vehicle badging is critically important).
- b) **Data Collection:** Collect cyber and electronic vehicle data at emergency events to populate national data collections going forward.
- c) **Emergency Responder Clearinghouse:** Establish an emergency responder information clearinghouse for real-time emergency responder information. (Note: the establishment of cyber-badging approaches impacts this need).
- d) **Monitoring System Status:** Continue developing technology, tools and methods that will monitor the state of health of primary hazards of AFVs. Provide this information to emergency responders at an emergency in a common, universally recognized format.

3) **FIRE FIGHTING TACTICS**

- a) **Establishing a Baseline Fire Fighting Approach:** Establish a universal baseline approach for AFVs, and then deviate from this as appropriate. Gaseous fuels are perceived to be less hazardous, and they have greater levels of safety. Important variables need to be considered, such as high pressures, cryogenics, vessel design, etc. Temperature thresholds are already well established for certain specific situations and fuels (e.g., based on UL132).
- b) **Fire Extinguishing Media:** For extinguishing media with AFVs, provide more research along with validation of that research. One size does not fit all for extinguishing media. Fresh water is the recognized baseline extinguishing media.
- c) **Gaseous Fire Fighting Water Application:** Clarify when to apply water for a gaseous fuels fires depending on the vessel design. Not applying water in all cases is a major shift in the basic fire fighting tactical approach, and thus a concern and important. There is a concern between steel tanks versus composite tanks, and how best to deal with them during a fire.
- d) **Gaseous Fuel Storage Venting:** Venting direction during a fire event is an on-going concern. Provide further research, training and education on this topic to optimize the best approach to a venting tank during a fire. Provide demonstration tests as proof of concept for emergency responder tactics to clarify the approach for pressure relief devices in a gaseous fuels fire.
- e) **Gaseous Fuel Ventilation in Confined Areas:** Clarify the hazards of ventilation of gaseous fuels in confined areas (e.g., garages) and address in training and education materials.

4) **INVESTIGATIONS**

- a) **Harvesting Data from Damaged Vehicles:** Address the harvesting of black box information in a post emergency event into the original vehicle design. Investigators are often re-powering damaged vehicles to harvest vehicle information, and they need support to safely harvest black box information.
- b) **Non-Technical Data Issues:** Consider other non-technical issues that support the needs of investigators, such as legal, privacy of information, etc., and thus assure that harvesting vehicle data is accomplished by the appropriate professionals.
- c) **Training and Education:** Provide training and education to safely re-activate critical vehicle systems in a manner that will not re-introduce un-anticipated hazards. Clarify details to maintain full control of all re-generated hazards, and establish procedures for returning a damaged vehicle to a safe condition.

5) **STRANDED ENERGY**

- a) **Hazard of Stranded Energy:** Stranded energy of fuels, and especially with electrical energy, is important and not adequately resolved. This significantly impacts when emergency responders can declare an emergency event “safe”. Tow and salvage are especially impacted, and should be given proper attention so that a potential hazard is properly handling post event.
- b) **Procedures and Guidelines:** Develop needed SOPs, SOGs and related tools to address stranded energy of all fuels in the field (including for all first and second emergency responders).

6) **OTHER ISSUES AND TRENDS**

- a) **Emerging Technologies:** Consider emerging new technologies, such as low pressure absorption systems and massless batteries (with batteries built into the vehicle structure).
- b) **Marine Applications:** Consider marine applications.

- c) **Promote Overall Program Success:** Promote success stories, including the proactive positive approach of this overall effort.
- d) **Remote Re-fueling and Re-charging:** Clarify regulations for remote fueling sites and portable charging and re-fueling, such as used for fleets.
- e) **Revised System Voltages:** Be aware of proposed 48V systems in vehicles (which are below the threshold of SAE hi-voltage) but arguably still a significant hazard.
- f) **Telecommunicators:** Develop recommended guidance (via SOPs and SOGs) for 911 call receivers.
- g) **Second Life Uses:** Address second life uses of vehicle systems and components, such as with electrical energy storage systems.
- h) **Standardization:** Monitor and stay involved with the noteworthy European based standards effort involving ECE R100 for batteries. In doing so, express concerns to the ECE R100 arena that their primary criteria of one hour observations after their tests does not consider the thermal runaway concerns of emergency responders when dealing with damaged electrical batteries.

The key summary observations from this summit address: general hazard concerns; electronic badging; fire fighting tactics; investigation; stranded energy; and other issues and trends. Of particular note, the Summit highlights the following:

- Need to address implementation of electronic badging technologies as soon as possible to enable real-time emergency event size-up and prospective data collection;
- Clarifying the tactical fire fighting approach for the venting of gaseous fuel storage vessels depending on the vessel material (i.e., metal versus composite);
- Addressing the needs of investigators to re-power damaged vehicles to harvest post event data; and
- Continuing to address the problem of stranded energy and its long time frame impact on first and second emergency responders.

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Annex A: Summit Participants and Attendees

The Summit was facilitated by Casey Grant of the Fire Protection Research Foundation. The presenters included in Table 2: Summary of Summit Presenters, represent the individuals who made a formal presentation at the “*Alternative Fuel Vehicle Safety Summit*”, held in The Westin Book Cadillac, Detroit, MI on 23 June, 2016. The available slides from these presentations are included in Annex B.

Table 2: Summary of Summit Presenters

Michael Gorin, NFPA
Jason Emery, NFPA (& Emergency Training Solutions and Waterford Fire Dept.)
Dan Bowerson, Natural Gas Vehicles for America (NGVA)
Mike Walters, Superior Energy Systems
Will James, DOE Fuel Cell Technologies
Erick Rask, Argonne National Laboratory
Stephen Yborra, Yborra & Associates

The Summit included a well-balanced cross-sectional mix of attendees. Table 3: Summary of Summit Attendees provides a full list of Summit attendees at the “*Alternative Fuel Vehicle Safety Summit*”, held in The Westin Book Cadillac, Detroit, MI on 23 June, 2016.

Table 3: Summary of Summit Attendees

Daniel Bates, NY State Police
Dan Bowerson, Natural Gas Vehicles for America (NGVA)
Dave Bryson, DOT
Ron Butler, Energy Storage Safety Products International
Jim Carroll, Connecticut Fire Academy / Wallingford Fire Dept.
Victor Chevrette, Washtenaw County Hazardous Materials Response Team
Gregg Cleveland, LaCrosse (WI) Fire Dept.
Ed Conlin, NFPA
John Cunningham, Nova Scotia Firefighter’s School
Jason Emery, NFPA (& Emergency Training Solutions and Waterford Fire Dept.)
Jim Francfort, DOE Idaho National Labs

Gregory Frederick, Louisville Division of Fire

Philip Gonzales, Ford Motor Company

Michael Gorin, NFPA

Gary Graham, General Motors

Casey Grant, FPRF

Will James, DOE Fuel Cell Technologies

John Jordan, Agility Fuel Systems

Dan Kimball, Ypsilanti Fire Dept.

Andrew Klock, NFPA

Todd Macintosh, General Motors

Terence McDonnell, New York State Police

Timothy Morgan, City of Warren (MI)

Larry Munson, BAE Systems

Erick Rask, Argonne

Scott Schmidt, Alliance of Automobile Manufacturers

Kenneth Smith, New York State Police

Q. Sheila Turner, FCA US LLC

Mike Walters, Superior Energy Systems

Jeff Williams, Ford Motor Company

Keith Wilson, Global Ground Vehicle Standards

Stephen Yborra, Yborra & Associates

Annex B: Presentation Slides

NFPA's AFV Safety Summit
June 23, 2016 – Detroit, Michigan

12 million AFV are on US Roads. Are you Prepared to Respond?

Emergency Responder Training Development

Development Progression

- Advanced Electric Drive Safety (EV, Hybrid, Passenger Vehicles)
- EV Trucks & Buses & Fuel Cell (EV, Hybrid, Fuel Cell, & Fleet Vehicles)
- Fire Service EV Tactics (Emergency Response to EV Battery Hazards)
- Stranded Energy (High Voltage Battery Breach Safety & Discharge)
- AFV Safety (Hydrogen, LNG, CNG, LPG, BioDiesel, Ethanol)

Deliverables

- Classroom Training:** Fire Service: EV/Hybrid, Fuel Cell, & Gaseous Fuels; Fire Investigation
- Online Training:** Fire; EMS
- Video Training:** Electric & Hybrid Awareness; Fire Tactics; Stranded Energy; Crash Reconstruction; Tow & Salvage (Update)
- Reference:** Emergency Field Guide; APP; Quick Reference Card

NFPA Alternative Fuel Vehicles Safety Training Program

NFPA Standards Alignment

- NFPA 2: Hydrogen Technologies Code
- NFPA 30A: Motor Fuel Dispensing Facilities
- NFPA 52: Vehicle Gaseous Fuel Systems Code
- NFPA 1500: Occupational Safety & Health Standards for Fire Fighters
- NFPA 1001: Fire Fighter Professional Qualifications Series
- NFPA 1600: Disaster Planning and Emergency Preparedness
- NFPA 472: Competence of Responders to Hazardous Materials
- NFPA 1670: Standards for Technical Rescue Incidents
- NFPA 921: Fire Investigation

National Electrical Code®

- Article 625: Electric Vehicle Charging Stations
- Article 220: Residential power consumption and how EV charging infrastructure will effect power consumption and emergency

Strategic Alliance Partnerships

- NHTSA, SAE, ANSI, NTSB, NREL**
- Fire Service and Law Enforcement**
 - International Association of Fire Chiefs (IAFC)
 - National Volunteer Fire Council (NVFC)
 - International Fire Marshals Association (IFMA)
 - National Association of State Fire Marshals (NASFM)
 - International Association of Fire Fighters (IAFF)
 - Metropolitan Fire Chiefs
 - U.S. Fire Administration (USFA)
 - North American Fire Training Directors (NAFTD)
 - International Association of Chiefs of Police (IACP)
 - National Sheriffs' Association (NSA)
 - Towing and Recovery Association of America (TRAA)
- 12 Fire Service Subject Matter Experts
- NFA Curriculum developer
- Argonne, PNNL, CA Fuel Cell Partnership**
- Alliance of Auto Manufacturers (AAM)**
- 42 Vehicle Manufacturer Partnerships**

NFPA's AFV Safety Online Courses & Website – AFVTechSafety.org

- To reach Emergency Responders who do not have easy access to classroom training programs
- Covers the same content as the classroom course with one for one match to classroom units
- High Quality graphics, animations, video, simulations, and 3D models.
- Includes latest fire tactics from Emergency Response to Incidents Involving Electric Battery and Gaseous Fuel Hazards.
- Includes Learning Management System that will track, record and report on student completions.

2015 NFPA Emergency Field Guide & APP

HOW TO USE THIS GUIDE

Figure 6: Slides from Michael Gorin, NFPA (page 1 of 2)



Figure 7: Slides from Michael Gorin, NFA (page 2 of 2)

GASEOUS FUEL VEHICLES SAFETY TRAINING FOR FIRST RESPONDERS
FIRE SERVICE EDITION

Course Goal
 Gaseous Fuel Vehicle Safety for First Responders

Prepare first responders to operate safely at incidents involving:

- Compressed Natural Gas Vehicles (CNG)
- Liquefied Natural Gas Vehicles (LNG)
- Liquefied Propane Gas Vehicles (LPG)

Course Sections
 Gaseous Fuel Vehicle Safety for First Responders

- Introduction
- Gaseous Fuels Properties
- Vehicle Systems and Operation
- Fueling Stations

Course Sections
 Gaseous Fuel Vehicle Safety for First Responders

- Initial Responses: Identify, Immobilize & Disable
- Emergency Operations
- Course Review

SECTION I
INTRODUCTION TO GASEOUS FUEL VEHICLES

Section I - Introduction
 OBJECTIVES

Following instruction, the student shall be able:

- ✓ Identify the two most commonly used gaseous fuels
- ✓ Identify the typical applications for gaseous fueled vehicles
- ✓ Describe the difference between dual fuel and bi-fuel vehicles

Figure 8: Slides from Jason Emery, NFPA (page 1 of 25)

Why Is This Course Important to Responders?

Introduction

Gaseous fuels are becoming more common in fleets and passenger vehicles



CNG
LNG **PROPANE**

Prevents lack of action or dangerous actions from occurring

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Two Most Common Fuel Types

Introduction

Natural Gas **Propane Gas**

CNG **LNG** **PROPANE**

Compressed Natural Gas Liquefied Natural Gas Liquefied Propane Gas

Both fuels burned in an internal combustion engine

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Vehicle Types & Applications

Introduction

Application **Built By**

MOST COMMON

Commercial (Fleets) **OEM**

Transit **UPFITTER** **MOST COMMON**

Passenger

Takes existing vehicles and adds gaseous fuel components

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Aftermarket Kits

Introduction

Allows individuals to modify their light duty vehicle

Potential Concerns

- Parts may be sub-standard
- Installer may not be qualified
- May not be placarded properly

Only applies to a limited number of vehicles on the road

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Fuel System Types

Introduction

Single Fuel **Multiple Fuels Gaseous and Conventional**

CNG **PROPANE** **LNG**

Dual Fuel **Bi-Fuel**

- Uses both fuels at the same time
- Can switch between fuel systems

Two fuel sources onboard

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Hazards Associated with Gaseous Fuels

Introduction

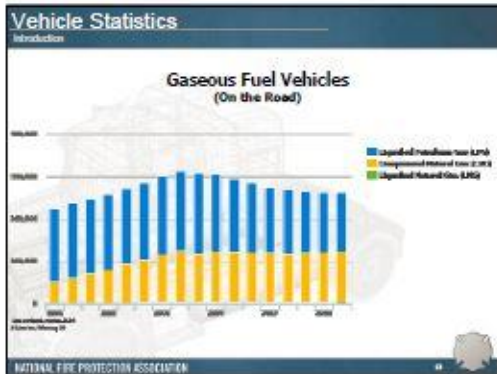
Flammable Gas **High Pressure Storage** **Cryogenic Liquid**

FLAMMABLE GAS 2

-260 °F

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Figure 9: Slides from Jason Emery, NFPA (page 2 of 25)



Review

Introduction

Why is this course important to responders?

What are the two primary types of gaseous fuels used?

Who most commonly installs gaseous systems?

What is the difference between dual fuel and bi-fuel?

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SECTION II

GASEOUS FUELS PROPERTIES

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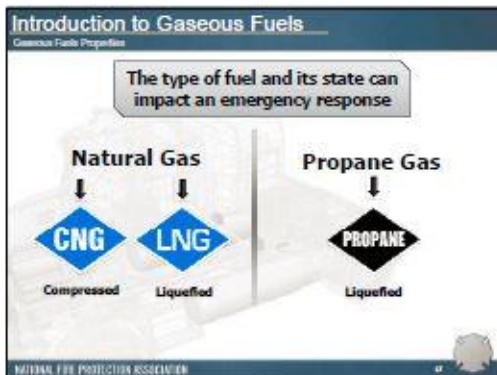
Section II – Gaseous Fuels Properties

OBJECTIVES

Following instruction, the student shall be able:

- ✓ Describe the physical properties and hazards of
 - ✓ Compressed Natural Gas (CNG)
 - ✓ Liquefied Natural Gas (LNG)
 - ✓ Liquefied Propane Gas (LPG)

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Natural Gas

Gaseous Fuels Properties

Same gas delivered to homes and businesses

Typically 1/4 to 2 psi

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Figure 10: Slides from Jason Emery, NFPA (page 3 of 25)

Natural Gas Characteristics

Gaseous Fuels Properties

Lighter than Air (Rises)

Auto Ignition Temp

Percentage in air

Flammable Range

Most Likely Ignition Source

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Natural Gas Characteristics

Gaseous Fuels Properties

Compressed Natural Gas (CNG)

Storage	Primary Hazards	Miscellaneous
<p>Pressures up to 3,600 psi</p>	<p>Flammability</p> <p>High Storage Pressure</p>	<p>Odorized to aid in leak detection</p>

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Natural Gas Characteristics

Gaseous Fuels Properties

Liquefied Natural Gas (LNG)

Storage	Primary Hazards	Miscellaneous
<p>Cooled to -260°F to liquefy</p> <p>Typical storage pressure of 120 psi</p>	<p>Cryogenic liquid</p> <p>Cannot be odorized due to temperature</p> <p>Flammable in gaseous state</p>	<p>Liquid to gas expansion ratio of 600:1</p> <p>Gas will sink if under -150 °F</p> <p>May have visible vapor cloud when released</p>

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Propane Characteristics

Gaseous Fuels Properties

1.5x Heavier than Air (Sinks)

Auto Ignition Temp

Percentage in air

Flammable Range

Most Likely Ignition Source

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Propane Characteristics

Gaseous Fuels Properties

Liquefied Propane Gas (Autogas)

Storage	Primary Hazards	Miscellaneous
<p>Liquefied by pressurization</p> <p>Typical storage pressure of 150 psi</p> <p>Max storage pressure of 250 - 315 psi</p>	<p>Frostbite possible from liquid contact</p> <p>Flammable</p> <p>Heavier than air, pools in low areas</p> <p>A simple asphyxiant</p>	<p>Odorant added for detection</p> <p>270:1 gas from liquid ratio</p> <p>Storage pressure temperature dependent</p>

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Gaseous Fuel Comparisons

Gaseous Fuels Properties

	CNG	LNG	LPG
Physical State	Gas	Liquid	Liquid
Storage Pressure	3,600 psi	Typically 120 psi	Typically 150 psi Temp dependent
Flammable range	5% - 15%	5% - 15%	2% - 10%
Auto Ignition Temp	1,100°F	1,100°F	1,000°F

Understanding the Difference in Fuel Properties is Critical

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Figure 11: Slides from Jason Emery, NFPA (page 4 of 25)

Gaseous Fuel Comparisons

Gaseous Fuels Properties

	CNG	LNG	LPG
Boiling Point	N/A	-260 °F	-44 °F
Liquefied	N/A	By cooling to -260° F	By Pressurization
Vapor Density	Lighter than air	Lighter than Air	Heavier than Air
Odorized	Yes	No	Yes
Hazard	Flammable gas High Pressure	Flammable Gas Cryogenic	Flammable gas

Understanding the Difference in Fuel Properties is Critical

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Review

Gaseous Fuels Properties

What type of fuel is stored at -260 °F?

How will LPG behave when released?

What are the primary hazards of CNG?

Which type of fuel cannot be odorized?

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SECTION III

VEHICLE SYSTEMS AND OPERATION

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Section III – Vehicle Systems

OBJECTIVES

Following instruction, the student shall be able:

- ✓ Describe the five different types of CNG cylinders responders may encounter
- ✓ Describe the construction of liquefied natural gas (LNG) tanks
- ✓ Describe the construction of liquefied propane gas (LPG) tanks

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Section III – Vehicle Systems

OBJECTIVES

Following instruction, the student shall be able:

- ✓ Describe the function of the low voltage solenoid
- ✓ Identify the purpose of temperature activated relief devices
- ✓ Describe the safety systems that may be found on CNG, LNG and LPG vehicles

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Gaseous vs. Conventional Vehicles

Vehicle Systems and Operation

Gaseous Fueled Vehicles

Have much more in common with traditional vehicles than electric or hydrogen fuel cell vehicles

Photo courtesy of General Motors

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Figure 12: Slides from Jason Emery, NFPA (page 5 of 25)

Fuel Distribution Control – Gaseous Fuel Vehicles

Vehicle Systems and Operation

Flow of Fuel

- Controlled by a low voltage solenoid
- Opens valve when low voltage is applied
- Closes when power is removed

Low voltage applied - Open

Low voltage removed - Closed

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Fuel Storage – CNG Vehicles

Vehicle Systems and Operation

CNG

Type I	Steel or aluminum	Similar to an industrial cylinder Wrap can be glass, carbon or basalt fiber
Type II	Steel or aluminum with a fiber-reinforced polymer overwrap	Metal vessel and wound composite materials share about an equal structural load
Type III	Metal liner, typically aluminum, with full carbon fiber composite overwrap	Composite materials carry the structural load
Type IV	A polymer liner is overwrapped with carbon fiber or carbon/glass fiber composite	No metal is used The structural load is carried by the composite overwrap
Type V	All composite construction	

Pressures up to 3,600 psi

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Fuel Storage – CNG Vehicles

Vehicle Systems and Operation

CNG

Cylinders
Designed to be very rigid and absorb impact energy

Composite Materials
Are shielded to protect from sunlight

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Fuel Storage – CNG Vehicles

Vehicle Systems and Operation

CNG

All cylinders exposed to fire must be inspected

Especially composite ones as they do not regain strength after cooling

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Fuel Storage – CNG Vehicles

Vehicle Systems and Operation

CNG

Cars and Light Duty Vehicles

Trunk or area where gas/diesel tank would usually be

Bed of pickup trucks

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Fuel Storage – CNG Vehicles

Vehicle Systems and Operation

CNG

Medium or Heavy Duty Vehicles

Mounted on frame rails or behind cab

Mounted on the roof in refuse trucks

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Figure 13: Slides from Jason Emery, NFPA (page 6 of 25)



Fuel Storage – CNG Vehicles
Vehicle Systems and Operation

CNG

Cylinder Use

	Light Duty Vehicles	Medium/Heavy Duty Vehicles and Buses
Type I	✓	
Type II	✓	
Type III	✓	✓
Type IV	✓	✓
Type V	✓	✓

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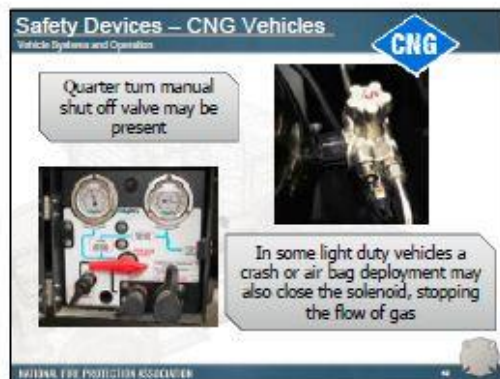


Figure 14: Slides from Jason Emery, NFPA (page 7 of 25)

Safety Devices – CNG Vehicles
Vehicle Systems and Operation

CNG



May be equipped with gas detection systems

Fire suppression systems will be found in transit buses




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Fuel Storage – LNG Vehicles
Vehicle Systems and Operation

LNG

Double-walled stainless steel tank with super insulated vacuum space



- Very stiff and strong
- Maintains temp 7-10 days
- Most commonly used on medium and heavy duty vehicles

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Fuel Storage – LNG Vehicles
Vehicle Systems and Operation

LNG



Multiple tanks will connect through a manifold



Mounted on frame rails or behind cab

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Fuel Distribution – LNG Vehicles
Vehicle Systems and Operation

LNG

Stainless steel fuel lines transport LNG to vaporizer



Fuel is warmed and converted to a gas


Fuel lines can contain a liquid or a gas

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Safety Systems – LNG Vehicles
Vehicle Systems and Operation

LNG

- Pressure relief devices (PRDs) are spring activated and re-seatable
- Piped away from tanks
- Can operate multiple times as necessary
- Two separate PRDs used
 - One operates at approx. 225 psi
 - Second operates at approx. 350 psi
 - Both reset at approx. 210 psi



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Safety Systems – LNG Vehicles
Vehicle Systems and Operation

LNG

LNG cannot be odorized due to low temperature



Alarm Thresholds

- Initial alarm 20-30% of LEL
- Additional alarms 50-60% of LEL

Gas detection systems must be installed


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Figure 15: Slides from Jason Emery, NFPA (page 8 of 25)

Fuel Storage – LPG Vehicles
Vehicle Systems and Operation

PROPANE

Single walled steel tanks



Typical storage pressure is approx. 150 psi, depending on ambient temperatures

Image courtesy of Robert Collier, Esq.

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Fuel Storage – LPG Vehicles
Vehicle Systems and Operation

PROPANE

Based on Application
(Light Duty Vehicle)

Trunk	Under Vehicle	Pickup Bed
		

Photo courtesy of Robert Collier, Esq.

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Fuel Storage – LPG Vehicle
Vehicle Systems and Operation

PROPANE

Medium & Heavy Duty Trucks & Buses

- Found on inside or outside of frame rails
- Because propane is heavier than air tanks, will not be on the roof






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Fuel Distribution – LPG Vehicles
Vehicle Systems and Operation

PROPANE

Liquid or gaseous propane is piped to engine

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Safety Systems – LPG Vehicles
Vehicle Systems and Operation

PROPANE

Spring operated relief device: 250 to 315 psi



Resets once safe pressure is reached

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ALTERNATIVE FUEL VEHICLES
SAFER BY DESIGN. PROUDLY.

VIDEO

ADVANCE SLIDE TO PLAY

Vehicle Systems Summary

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Figure 16: Slides from Jason Emery, NFPA (page 9 of 25)

NFPA ALTERNATIVE FUEL VEHICLES SAFETY TRAINING PROGRAM

VIDEO

ADVANCE SLIDE TO PLAY

Vehicle Systems Summary

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Vehicle Systems Activity

Vehicle Systems and Operation

Web Interface

Web 3D Scenario

Web 3D Plugin

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Review

Vehicle Systems and Operation

What type of vehicle is required to have a gas detection system and why?

Fusible Material

What type of fuel storage container are TPRDs utilized on?

Where would you anticipate seeing an LPG tank mounted on a light duty vehicle?

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NFPA ALTERNATIVE FUEL VEHICLES SAFETY TRAINING PROGRAM

SECTION IV

FUELING STATIONS

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Section IV – Fueling Stations

OBJECTIVES

Following instruction, the student shall be able:

- Describe the differences between fast and time fill CNG stations
- Identify the fuel storage pressures for CNG, LNG and LPG fueling facilities
- List four (4) safety systems you could encounter at a gaseous fueling facility

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CNG Stations – Time Fill

Fueling Stations

- Gas compressed into onboard cylinders
- Takes hours, typically overnight
- Found in fleet or residential applications
- Generally no large volume storage on site

Fleet Applications

Residential Applications

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Figure 17: Slides from Jason Emery, NFPA (page 10 of 25)

CNG Stations – Fast Fill

Fueling Stations

- Short fill times
- Can use existing infrastructure or it can be shipped in
- Gas compressed up to 5,000 psi and stored for later use
- Steel (most common) or composite cylinders

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LNG Stations

Fueling Stations

Fast Fill System Only

- Double walled heavily insulated tank
- Storage volume 15,000 – 30,000 gallons
- Storage pressure 20-40 psi

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LNG Stations - LCNG

Fueling Stations

Can be used to fill CNG Vehicles

LNG → Vaporizer converts to gas → CNG storage → CNG Fueling

May or may not be odorized

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LPG Stations

Fueling Stations

Fast fill process through a sealed system

Typically 2,000 gallons or more storage

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Fueling Stations Safety Systems

Fueling Stations

Fueling stations are designed with numerous safety systems installed

Type of system may vary based on fuel type

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VIDEO

ADVANCE SLIDE TO PLAY

Fueling Station Safety Systems

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Figure 18: Slides from Jason Emery, NFPA (page 11 of 25)

NFPA ALTERNATIVE FUEL VEHICLES SAFETY TRAINING PROGRAM


VIDEO

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Fueling Station Safety Systems

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Review
Fueling Stations




Where are time-fill CNG stations used?



What is a LCNG fueling station?



What are the storage pressures for CNG, LNG and LPG fuel stations?




List four safety systems at a gaseous fueling facility

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SECTION V

INITIAL RESPONSE PROCEDURES



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Section V – Initial Response Procedures
OBJECTIVES

Following instruction, the student shall be able:

- ✓ Describe the size-up procedures and scene hazards of an incident involving gaseous fuel vehicles
- ✓ Positively identify a gaseous fuel vehicle using visual clues and NFPA EFG
- ✓ Identify and describe proper immobilization techniques
- ✓ Identify vehicle disabling methods and techniques

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Scene Safety
Initial Response Procedures



Always ensure a safe work environment for responders

Use Proper PPE and Safety Equipment

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Scene Safety
Initial Response Procedures

Conduct a Scene Size-Up



Hazards



Types of Vehicles



Determine Course of Action

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Figure 19: Slides from Jason Emery, NFPA (page 12 of 25)


Common Hazards

Initial Response Procedures

Common Hazards to Consider

Initial actions are the same as conventional vehicles and other AFVs

- Downed Power Lines
- Unstable Vehicles
- Traffic
- Fuel or Hazmat Spills
- Environmental Ice, Flooding, etc.



Don't become so fixated on the AFV that you forget basic scene safety!

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Specific Hazards

Initial Response Procedures


Flammable Gas	High Pressure Storage	Cryogenic Liquid
		

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Procedures

Initial Response Procedures

Identify **Immobilize** **Disable**




NATIONAL FIRE PROTECTION ASSOCIATION

Procedures

Initial Response Procedures

Identify **Immobilize** **Disable**




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Identification

Initial Response Procedures

It may be difficult to distinguish a gaseous fuel vehicle from the standard model



CNG Civic



Standard Civic


Labels and badges may be the only external indicator

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Identification Methods

Initial Response Procedures

Assume
All vehicles are alternatively fueled (AFVs) until positive confirmation can be made




Approach at safe angle

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Figure 20: Slides from Jason Emery, NFPA (page 13 of 25)

Identification Methods
Initial Response Procedures

The driver may be one of the best resources to determine vehicle type



Commercial/transit drivers may have received additional training



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Identification Methods
Initial Response Procedures

Badging or Labeling
Is another method of identification



However, they can be damaged or hidden due to a crash



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Identification
Initial Response Procedures

"Advertising"
Type markings may be present





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Identification
Initial Response Procedures



May be labels or other indicators on the dash

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Identification
Initial Response Procedures

Identification Resources



NFPA EFG



2018 Compressed Natural Gas (CNG)
Chevrolet Express and GMC Savana
Emergency Response Guide

Manufacturer ERGs

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Identification – CNG Vehicles
Initial Response Procedures

Vehicle types can range from passenger cars...



...to over-the-road trucks



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Figure 21: Slides from Jason Emery, NFPA (page 14 of 25)

Identification – CNG Vehicles
Initial Response Procedures

CNG

Badging/Labels

Vehicles required to have blue diamond on the right rear of cab

May be at the fueling point as well

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Identification – CNG Vehicles
Initial Response Procedures

CNG

Light Duty Vehicles:
CNG design features may not be visible

Medium or Heavy Duty Vehicles:
Cylinders may be visible

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Identification – CNG Vehicles
Initial Response Procedures

CNG

Buses may have a raised roof line concealing cylinders

Refuse trucks can also have roof mounted cylinders

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Identification – LNG Vehicles
Initial Response Procedures

LNG

Generally used larger vehicles...

... such as over-the-road, refuse trucks and street sweepers

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Identification – LNG Vehicles
Initial Response Procedures

LNG

Badging/Labels

Blue diamond required at the right rear of the cab...

...and at the fueling port

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Identification – LNG Vehicles
Initial Response Procedures

LNG

Tank Locations

Most Common	Less Common
Along Frame Rail	Behind Cab

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Figure 22: Slides from Jason Emery, NFPA (page 15 of 25)

Identification – LNG Vehicles
Initial Response Procedures

LNG

There may be indicators on the dashboard

Gas detection system will be visible

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Identification – LPG Vehicles
Initial Response Procedures

PROPANE

Typically used in light to medium duty vehicles...

...Although it may be found in some heavy duty applications

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Identification – LPG Vehicles
Initial Response Procedures

PROPANE

Badging/Labels

Black diamonds with white letters required on right rear of vehicle

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Identification – LPG Vehicles
Initial Response Procedures

PROPANE

In passenger cars tanks are not visible

Trucks/ Pickup Trucks

School Buses

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Identification
Initial Response Procedures

CNG
LNG **PROPANE**

Consult Quick Reference Guide

- Compiled from manufacturer data
- Contains the most critical information

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Identification
Initial Response Procedures

CNG
LNG **PROPANE**

- Vehicle specific information
- Safety procedures

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Figure 23: Slides from Jason Emery, NFPA (page 16 of 25)

Identification
Initial Response Procedures

Always approach vehicles as if they are AFVs




Crash or fire damage may obscure identification



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Identification
Initial Response Procedures

Summary

- Use all available information to determine if vehicle operates on gaseous fuel.
- If indicators are not visible, take time to determine presence of CNG, LNG or LPG fuel.
- If badges are not visible due to vehicle damage, continue to look for additional clues.




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Procedures
Initial Response Procedures

Identify



Immobilize





Disable




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Approaching the Scene
Initial Response Procedures

Always approach at a 45° angle

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Approaching Vehicle Fires
Initial Response Procedures




Precautions


- It may be impossible to determine fuel type
- Extra precautions should be taken when approaching
- If identified as CNG
 - Immobilization & disabling may not be immediately possible
- Firefighting ops addressed later




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Preventing Movement
Initial Response Procedures

- 1 Deploy correctly sized wheel chocks
 
- 2 Set parking or emergency brake
 
- 3 Disengage Transmission
 



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Figure 24: Slides from Jason Emery, NFPA (page 17 of 25)

Procedures

Initial Response Procedures

Identify **Immobilize** **Disable**

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Disabling the Vehicle

Initial Response Procedures

Generally the same as conventional vehicles...

...but always confirm with EFGs and the NFPA ERG

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Disabling Procedures

Initial Response Procedures

Step 1 **Considerations**

Turn Ignition Off

- Stops engine
- Closes solenoid, stopping the flow of fuel
- Fuel flow stops

Proximity Key

- Some vehicles may be equipped with proximity keys
- Not typical on trucks and buses
- Disabled when low voltage power is disconnected

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Disabling Procedures

Initial Response Procedures

Step 2 **Considerations**

Disconnect Low Voltage Battery

- Disables SRS
- Prevents vehicle restart

12V Battery

- Typically under hood or in trunk
- Other locations

24V Battery

- Trucks/buses may have battery switch
- When cutting negative cable, cut the one going to chassis ground

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Controlling Fuel Flow

Initial Response Procedures

¼ turn valves may be present to shut off gas flow

Typically on CNG trucks and buses

Remember that the tanks/cylinders are still pressurized

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Review

Initial Response Procedures

Scene Safety

- Scene Size-up
 - Hazards
 - Types of Vehicles
 - Course of Action
- Use proper PPE and Safety Equipment

Don't become so fixated on the AFV that you forget basic scene safety!

NATIONAL FIRE PROTECTION ASSOCIATION 38


Figure 25: Slides from Jason Emery, NFPA (page 18 of 25)

Review

Initial Response Procedures


Identify	Immobilize	Disable
 <ul style="list-style-type: none"> • Driver/Operator • Badging/Labeling • Design Features • Emergency Field Guide 	 <ul style="list-style-type: none"> • Chock Wheels • Engage Parking or Emergency Brake • Place Vehicle into Park/Neutral 	 <ul style="list-style-type: none"> • Turn Ignition off • Disconnect Low voltage Battery

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SECTION VI

EMERGENCY OPERATIONS



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Section VI – Emergency Response Procedures

OBJECTIVES





Following instruction, the student shall be able:

- ✓ Identify and describe four emergency response concerns specific to gaseous fuel vehicles.
- ✓ Determine the appropriate actions for extinguishing fires in LNG and LPG vehicles.
- ✓ Identify the primary concern of CNG vehicle fires and the appropriate technique for mitigation of the fire.
- ✓ Identify and describe the procedures for handling incidents at fueling stations

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Emergency Response Considerations



Emergency Operations

 <p>Follow Dept. SOPs</p>	 <p>Approach at 45° Angle</p>
 <p>Wear PPE</p>	 <p>Always use CGIs</p>

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Emergency Response Considerations

Emergency Operations

 <p>Always treat cylinders or tanks as pressurized</p>	 <p>Always control ignition sources</p>	<p>If there is damage near the tank/cylinder, consider it damaged</p>
---	--	---

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Emergency Response Considerations

Emergency Operations

<p>Unlike gas leaks in a building...</p>  <p>Essentially Unlimited Supply</p>	<p>...Vehicles contain a limited amount of fuel</p>  <p>Limited Supply</p>
---	---


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Figure 26: Slides from Jason Emery, NFFPA (page 19 of 25)


Emergency Response Considerations

Emergency Operations

It may be necessary to contact fleet manager or vehicle manufacturer for additional information



Always inform tow operators of the vehicle type and special precautions required




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Emergency Response Considerations

Emergency Operations


Identify



Immobilize



Disable




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Crashes & Extractions – General Procedures

Emergency Operations

Use standard stabilization methods



Deploy handline with firefighter in full PPE

Extrication techniques remain the same

Always expose an area prior to cutting



Components not typically in areas consider cut points

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Crashes & Extractions – CNG Vehicles

Emergency Operations

- Cylinders are designed to withstand significant impacts
- Physical damage could result in a 3,600 psi release
- Damaged fuel lines may result in a release at a lower pressure





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Crashes & Extractions – CNG Vehicles

Emergency Operations

Roof mounted cylinders may alter center of gravity slightly




Natural gas rises...



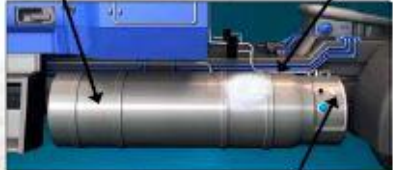
...so it is less likely to collect and reach flammable range

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Crashes & Extractions – LNG Vehicles

Emergency Operations

Doubled walled design resistant to damage



Frost may indicate leak or damage to outer tank

Even if gauge reads 0 psi-liquid may still be in tank

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Figure 27: Slides from Jason Emery, NFPA (page 20 of 25)

Crashes & Extractions – LNG Vehicles
Emergency Operations



Typically LNG will not leave the tank in a liquid state because it vaporizes so quickly

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Crashes & Extractions – LNG Vehicles
Emergency Operations

Gas detection is disabled after low voltage current removed



Firefighting PPE will provide limited splash protection only

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Crashes & Extractions – LPG Vehicles
Emergency Operations

Leaking LPG will pool in low areas and may reach its flammable range





It may be possible to disperse vapors with fog stream

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Vehicle Fires
Emergency Operations

Introduction

- Scene size-up, determine fuels involved
- Always assume fuel system is pressurized
- CNG vehicle fires may require special tactics



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VIDEO

ADVANCE SLIDE TO PLAY

Vehicle Fires

NATIONAL FIRE PROTECTION ASSOCIATION

VIDEO

ADVANCE SLIDE TO PLAY

Vehicle Fires

NATIONAL FIRE PROTECTION ASSOCIATION


Figure 28: Slides from Jason Emery, NFPA (page 21 of 25)

Fuel Station Responses

Emergency Operations


Conduct preplans to determine:

- Layout of facility
- Fuels present
- Safety measures present



Department of Energy website

- Searchable list of AFV fueling stations
- Includes contact information



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Fueling Station Responses: Incident Size-Up

Emergency Operations

Upon Arrival:


- Isolate and secure area
- Wear full PPE and SCBA monitor with combustible gas meters
- Make contact with facility personnel ASAP
- Look for DOT and NFPA 704 placards




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Fueling Station Responses: Control Hazards

Emergency Operations




- Activate emergency shutdowns
- Control any leaks from remote valves/controls
- Control ignition sources

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Fueling Station Responses: Fires

Emergency Operations

- Allow fires to burn if fed by active leak
- Protect exposures
- Cylinder type will determine if water can be applied




Photo courtesy of the San Francisco Examiner

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Fueling Station Responses

Emergency Operations

CNG

- Leaks will be audible due to high pressure release
- Most will be at small diameter pipe fittings, ESD will typically be effective to shutdown



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Fuel Station Response

Emergency Operations

CNG

Leaking gas will rise and dissipate...



Establish a safe perimeter

10 feet

5 feet

...However, if ignited will create a jet fire

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Figure 29: Slides from Jason Emery, NFPA (page 22 of 25)


Fueling Station Responses

Emergency Operations

CNG

DO use WATER on steel cylinders

- E extinguish impinging fires
- Cool cylinders



DO NOT use WATER on composite cylinders

- May prevent TPRD activation
- If TPRD activates, bleed down time longer than vehicle
- Composite cylinders not as common at fixed facilities


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Fueling Station Responses

Emergency Operations


LNG

Small Leaks



Likely to be in gaseous state

Large Leaks



May start off as a liquid contained by berm

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Fueling Station Responses

Emergency Operations

LNG

Direct contact with leak will cause freezing injuries

Full firefighting PPE with SCBA must be worn if operating near spill

**NO OPEN FLAMES
CRYOGENIC LIQUID**

Firefighting PPE will provide some level of splash protection



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Fueling Station Responses

Emergency Operations

LNG

Even though stations are outfitted with combustible gas detection systems...

...Combustible gas meters should be used at all responses

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Fueling Station Responses

Emergency Operations

LNG

Apply Water

to fires impinging on storage tanks as well as on the tanks to cool



Do Not Use Water

on leaked LNG as it will increase vapor production

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Fueling Station Responses

Emergency Operations

PROPANE

Leaking Fuel

Leaking gas will pool in low areas and containment berms



Control ignition sources and activate ESDs



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Figure 30: Slides from Jason Emery, NFPA (page 23 of 25)

Fuel Station Responses

Emergency Operations

PROpane

Extinguish impinging fires with at least 500 gpm

A higher GPM may be necessary, depending on size and number of tanks

If duration and frequency of relief valve activation increases it may be unable to maintain proper pressure.

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Activity 6.1 – Emergency Operations




Emergency Operations

Click on Image to Start Video

Video Activity

Identify and discuss:

1. What are the hazards present?
2. What are your initial response actions?
3. What steps would you take to fully mitigate the situation?

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Review

Emergency Operations

What are the procedures and concerns for each of these responses?





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NFPA ALTERNATIVE FUEL VEHICLES SAFETY PROGRAM

SECTION VII


GASEOUS FUEL VEHICLES MODULE REVIEW




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Introduction to Gaseous Fuel Vehicles


Module Review




Why is this course important to responders?



What are the two primary types of gaseous fuels used?



Who most commonly installs gaseous systems?



What is the difference between dual fuel and bi-fuel?

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Gaseous Fuels Properties

Module Review

DANGER
Cyanide formic acid
non-ox. eng. no. smok. 11
oxy. flam. wh. 25 feet

What type of fuel is stored at -260 °F?

PROpane
How will LPG behave when released?

CNG
What are the primary hazards of CNG?


CNG
LNG
PROpane
Which type of fuel cannot be odorized?

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Figure 31: Slides from Jason Emery, NFPA (page 24 of 25)

Vehicle Systems and Operation

Module Review



What type of vehicle is required to have a gas detection system and why?

What type of fuel storage container are TFRDs utilized on?




Where would you anticipate seeing an LPG tank mounted on a light duty vehicle?


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Fueling Stations


Module Review



Where are time-fill CNG stations used?



What is a LNG fueling station?



What are the storage pressures for CNG, LNG and LPG fuel stations?

List four safety systems at a gaseous fueling facility

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Initial Response Procedures

Module Review

Scene Safety

- Scene Size-up
 - Hazards
 - Types of Vehicles
 - Course of Action
- Use proper PPE and Safety Equipment

Don't become so fixated on the AFV that you forget basic scene safety!



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Initial Response Procedures

Module Review

Identify	Immobilize	Disable
 <ul style="list-style-type: none"> • Driver/Operator • Badging/Labeling • Design Features • Emergency Field Guide 	 <ul style="list-style-type: none"> • Chock Wheels • Engage Parking or Emergency Brake • Place Vehicle into Park/Neutral 	 <ul style="list-style-type: none"> • Turn Ignition off • Disconnect Low voltage Battery

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Emergency Operations

Module Review

What are the procedures and concerns for each of these responses?



Crashes/Extractions



Vehicle Fires



Fueling Facilities

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GASEOUS FUEL VEHICLES SAFETY TRAINING FOR FIRST RESPONDERS

FIRE SERVICE EDITION





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Figure 32: Slides from Jason Emery, NFPA (page 25 of 25)

NGVAMERICA
Natural Gas Vehicles for America

NFPA Alternative Fuel Vehicle Safety Summit
June 23, 2016
Detroit, MI

Who is NGV America?

Natural Gas – The Fuel

- Natural gas: ~90% methane
 - Primarily CH₄
 - Low carbon, energy dense fuel
 - **Lighter than air**
 - Specific Gravity= 0.55 - 0.55
 - Limited combustion ratio
 - 5-15%
 - High ignition temperature
 - + 1000 deg F

methane molecule - CH₄

NGVAMERICA

Fuel Properties

	CNG	LNG	Gasoline	Diesel
Physical State	Compressed Gas	Cryogenic Liquid @ -220°F	Liquid	Liquid
Vapor density vs. air	Rise	Rise (in gaseous state)	Sink	Sink
Storage Pressure	3,600 psi	Less than 220 psi	N/A	N/A
Flammable Range	5% - 15%	5% - 15%	1.2% - 7.1%	0.6% - 7.5%
Ignition Temperature	1,100°F	1,100°F	495°F	600°F

NGVAMERICA

Today's NGV Market

 NG Vehicles are seeing more use at major airports	 Over 24% of transit buses operate on NG	 Over 80% new refuse trucks order are NG
 Heavy-duty truck market continues to transition	 Rail industry piloting LNG locomotives	 Major marine companies deploying LNG-powered vessels

NGVAMERICA



Figure 33: Slides from Dan Bowerson, NGVA (page 1 of 4)

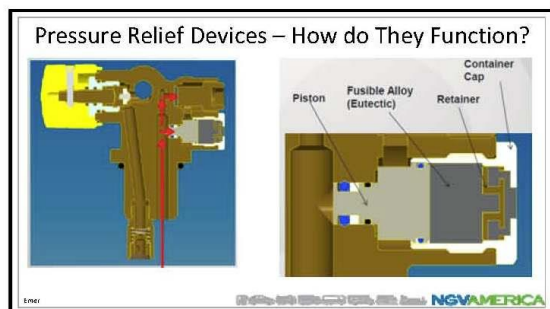
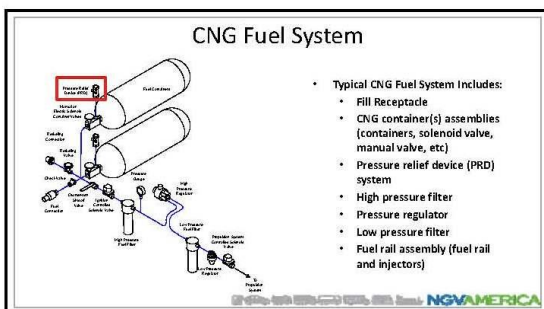
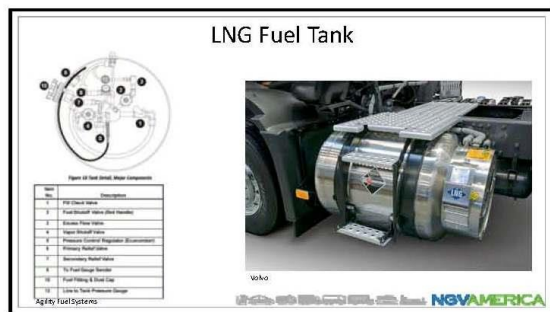


Figure 34: Slides from Dan Bowerson, NGVA (page 2 of 4)

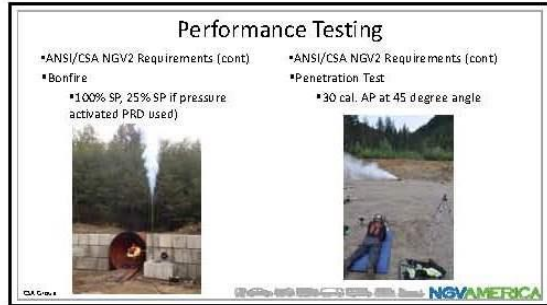
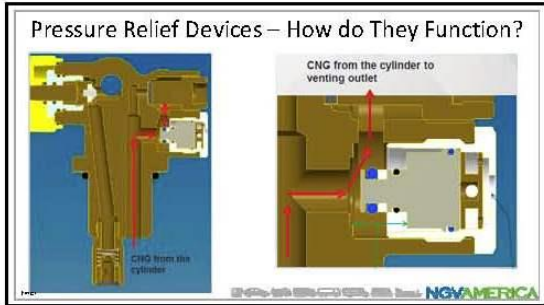


Figure 35: Slides from Dan Bowerson, NGVA (page 3 of 4)

Next Steps

- Continue to improve codes & standards
 - CSA NGV6.1 developing system bonfire test requirement
- Work with first responders, US DOT and industry to investigate incidents involving natural gas fuel systems
- Work closely with NFPA and other organizations to develop safety documentation and training
- Bring root cause analysis of incidents to industry, and interested parties, via NGVA Technology & Development Committee and codes/standard development organizations
- Publish best practices and safety recommendations



NGVAMERICA
Natural Gas Vehicles for America

Dan Bowerson
Director of Technology & Development, NGVAmerica
dbowerson@ngvamerica.org




Figure 36: Slides from Dan Bowerson, NGVA (page 4 of 4)

AutoGas Safety

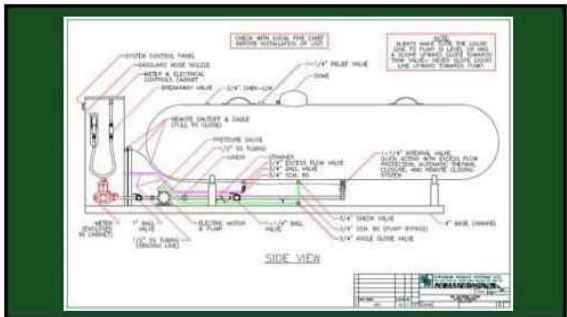



 © Superior Energy Systems, LTD
 Columbia Station, OH USA

Purpose

- The following slides serve to facilitate a conversation about how safety is engineered into an AutoGas dispenser.
- The idea is to make AutoGas fueling so safe and similar to gasoline that people aren't afraid of something different.
- NFPA 58, 6.25 – Vehicle Dispensing Stations

superiorNRG.com | (440) 236-6009 | info@superiorNRG.com



Propane Storage Container



- Tanks manufactured for its intended purpose
- All connections close to the cabinet
 - ✓ Cuts Down on Distances and Potential Leak Points
- Container Filling Connections Purposely Located On Opposite End of the Container Away From the Point Of Transfer

Internal Safety Control



- Threaded Directly Into The Container
- Provides Means for Mechanical, Thermal and Remote Emergency Closure
- Incorporates Excess Flow Technology
- Fusible Element Not To Exceed 250°F
- Pneumatic or Cable Operated


Positive Shutoff Valve



- Located in Several Places Within The Piping System to Isolate or Provide Backup Containment of the Product

Figure 37: Slides from Mike Walters, Superior Energy Solutions (page 1 of 4)

Piping and Strainer



- Piping
 - ✓ Solved to 80 (X106 Seamless)
 - ✓ Forged Carbon Steel Fittings (2000 WCO)
- Strainer -- Keeps Foreign Material Out of the Product, Going to the Pump

Flex Connector



- Protects the Piping System from the Effects of Vibration and Possible Settling
- May Be Stainless Steel Braid or Rubber

Pump Differential By-Pass Valve



- Protects the Pump From Effects of Overpressure
- Allows Adjustment to Create Differential Pressure
- The Heart of the Pumping System

Excess Flow Check Valve



- Protects Container From Unintentional Release Should Downstream Line Break
- Slugs by Differential Pressure or GPM Flowing
- Even If Valve Sheers Off, the Operator Would Remain in the Container
- Note -- Additional Positive Shutoff Valve

Stainless Steel Tubing



- SS Tubing Used to Provide Better Support for Liquid Bypass and Vapor Eliminator Lines
- Added Safety Value

Remote Shutoff Locations



- Remote Emergency Shutoff Required At Least Three-Feet From Point of Transfer
- Provides Mechanical Means of Closure
- Additional Electrical Disconnected Required at Building Not Less Than 20' nor More Than 100' From the Cabinet
- Both Propane and Electrical Shutoff Locations Required to be Readily Visible from Point of Transfer by Appropriate Signage

Figure 38: Slides from Mike Walters, Superior Energy Solutions (page 2 of 4)

Pull-Away Protection



- Provides Protection for Cabinet and Piping System Should Vehicle Pull Away.
- Separates at Approximately 130 Pounds Force

Hose



- Manufactured for Intended Service
- 350 psig W/P; 1750 psig Burst
- Perforated (Will Not Burst)
- Pressure Tested by Manufacturer at 120% of W/P
- Tagged by Manufacturer
- Must be Marked Appropriately
- NFP A 58 Requirement

Nozzles



- Gas Guard – Low Emission
 - ✓ Less Than 4cc
 - ✓ 1/4" ACME
- Staubli – No Emission
 - ✓ Less than 1cc
 - ✓ Euro Connection

Switches and Timers



- Boot (shown) Incorporates a Switch that Automatically Shuts Off Pump and Completes the Transaction When Nozzle is Hung Up
- Lockout Timer Will Shut Off Pump if No fuel Flow in 30 Seconds

Differential Valve



- Meter Incorporates a Differential Valve Sensing Downstream Pressure
- Will Shut Off Flow in Case of Line Break

Hydrostatic Relief Valve



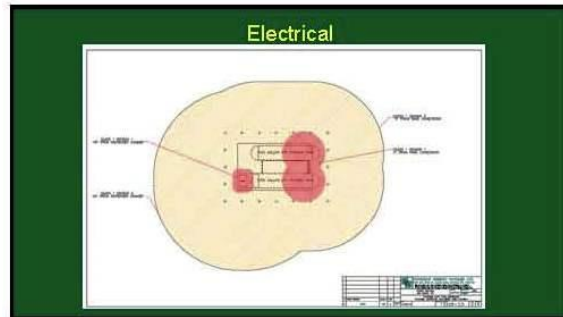
- Protects Liquid System and Piping From the Effects of Overpressure Due to Liquid Expansion
- Installed Anywhere in Piping Where Liquid May Be Trapped Between Two Positive Shutoff Valves

Figure 39: Slides from Mike Walters, Superior Energy Solutions (page 3 of 4)

Electrical



- Class 1, Group D, Division 2 Above
- Class 1, Group D, Division 1 Below
- Classified Areas in Accordance With NFPA 70, National Electric Code and NFPA 58



Superior Energy Systems



THANK YOU

superiorNRG.com | (440) 236-6009 | info@superiornrg.com

Figure 40: Slides from Mike Walters, Superior Energy Solutions (page 4 of 4)

HYDROGEN Safety Resources

Hydrogen Fuel Cells

Will James
 US DOE Fuel Cells Technology Office
 NPAA FV Safety Summit – Detroit, MI – June 23, 2016

JULY 2016 / 1

Fuel Cell Electric Vehicles (FCEV)

- Run on hydrogen
- Use a fuel cell and electric motor, no engine
- Quiet, mostly air compressor and valves
- Emit zero pollutants

JULY 2016 / 2

How a Fuel Cell Works

FUEL CELL ENERGY POWERS THE CAR!

1. **HYDROGEN** (H_2) Hydrogen fuel flows into the anode.

2. **ANODE** Negative Electrode

3. **NEA** Proton Exchange Membrane

4. **CATHODE** Positive Electrode

5. **OXYGEN** (O_2) Oxygen flows into the cathode, where it combines with hydrogen to produce water, which is vented from the vehicle.

6. **ELECTRONS** (e^-) The movement of electrons generates electricity to power the motor.

7. **VENT** = Heat & Water Vapor

<https://www.youtube.com/watch?v=ShZBv-cd8lD>

JULY 2016 / 3

Fuel Cell Applications

Fuel cells have a broad range of applications:

- Transportation
 - Light and medium duty
 - Heavy duty and transit
 - Auxiliary power for refrigeration trailers and trucks
 - Forklifts
 - Maritime
- Stationary power
 - Backup power for cell tower sites
 - Combined heat and power
 - Data centers, etc.
- Portable power

JULY 2016 / 4

Hydrogen Uses

The use of hydrogen is not new, private industry has used it safely for many decades. Nine million tons of hydrogen are safely produced and used in the United States every year. 56 billion kg/yr are produced globally. For example, H_2 is used for:

- Petroleum refining
- Glass purification
- Aerospace applications
- Fertilizers
- Annealing and heat treating metals
- Pharmaceutical products
- Petrochemical manufacturing
- Semiconductor industry
- Hydrogenation of unsaturated fatty acids in vegetable oil
- Welding
- Coolant in power generators

JULY 2016 / 5

Where Do We Get Hydrogen?

Renewable Sources
 Solar, wind, geothermal, hydro, biomass, algae

Traditional Sources
 Natural gas, gasoline, nuclear, coal

JULY 2016 / 6

Figure 41: Slides from Will James, DOE Fuel Cell Technologies (page 1 of 5)

Hydrogen Distribution

- DOT regulated transportation...
- Cryogenic liquid transport
 - -423°F (-253°C)
 - Low pressure (<100 psi)
- Pressurized gas trailers
 - ~2,000-6,500 psi
- Truck, rail, barge and pipeline




Photo: Pralair, Inc.










Photo: Genesco Photo: Air Products & Chemicals, Inc.

Hydrogen Safety Resources July 7, 2016 / 7

FCEVs here now, and more are coming soon...

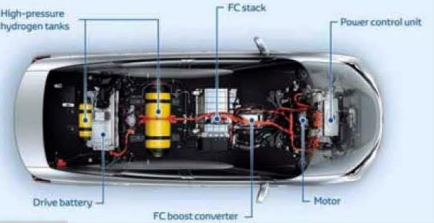





Hydrogen Safety Resources July 7, 2016 / 8

FCEVs are electric vehicles

The Toyota Fuel Cell System (TFC5) moves the Mirai




High-pressure hydrogen tanks FC stack Power control unit

Drive battery FC boost converter Motor


Hydrogen Safety Resources July 7, 2016 / 9

High Voltage System

- Same technology as other all fuel vehicles (gas/electric hybrids)
- Orange high-voltage wiring per SAE
- Isolated + and - sides (not grounded to the chassis)
- Automatic high voltage system disconnect
 - Inertia switch
 - Ground fault monitoring



Light Duty Vehicle





MAIN POWER Transit Bus

Hydrogen Safety Resources July 7, 2016 / 10

Onboard Hydrogen Storage

- Typically Type IV (polymer-lined), carbon fiber wrapped cylinders
- Hydrogen is stored as a gas at 70 MPa (approximately 10,000 psi)
- Tanks are tested to over 22,500 psi +
- Passenger vehicles currently store up to 6 kg of hydrogen gas
- Buses with multiple tanks can store as much as 40 kg to 50 kg of hydrogen gas at 35 MPa (approximately 5,000 psi)
- Other applications, like industrial trucks also use 35 MPa

Toyota Mirai fuel cell and an power train, motor, and hydrogen tank
Source: <http://www.toyota.com/usa/press/2016/07/07/000004>

Hydrogen Safety Resources July 7, 2016 / 11

Compressed Hydrogen Tank Testing

- In accordance with latest hydrogen vehicle tank standards (SAE J2579, CSA HGV2)
- Tests conducted as part of the design qualification testing for new tanks
- Vent only, no rupture



Hydrogen Safety Resources July 7, 2016 / 12

Figure 42: Slides from Will James, DOE Fuel Cell Technologies (page 2 of 5)

Compressed Hydrogen Tank Testing

- Flame impingement
- Bonfire
- Drop
- Gun fire
- Pressure cycling
- Overpressure
- Temperature
- Impact
- Permeation
- "Tank life" – at least 15 years
- Rated for 2.25x service pressure

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Safety Systems

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Vehicle safety testing

- Vehicles tested to NHTSA FMVSS, and ECE
- With operating fuel cell systems and hydrogen on board
- UN GTR to become Fuel Cell Vehicle FMVSS

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Second responders

- Recent publication of SAE J2990-1
 - For automakers to reference when creating vehicle requirements and ERGs
 - Includes recommendations for vehicle badging, emergency documentation (ERGs and QRSs)
 - Provides information for on-scene and post-incident inspection and actions

SAE INTERNATIONAL	SURFACE VEHICLE RECOMMENDED PRACTICE	J2990™-1	JUN2016
		Issued	2016-05

Gasoline Hydrogen and Fuel Cell Vehicle First and Second Responder Recommended Practice

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Hydrogen Fueling

- Closed-loop design, no leaks or vapors
- Experienced suppliers and providers: Linde, Shell Hydrogen, Air Products, Air Liquide, Hydrogen Frontiers, ProtonOnSite, First Element, HTEC, HyGen Industries and others

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Hydrogen Fueling Diagram

© ISO 2015

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Figure 43: Slides from Will James, DOE Fuel Cell Technologies (page 3 of 5)

Typical Station Configurations



- Hydrogen can be delivered or made on site
- Liquid delivered → gaseous H₂
- Gaseous delivered or piped → booster compressed gaseous H₂
- Natural gas → gaseous H₂
- Water + electricity → gaseous H₂

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General Station Safety Systems

- Pressure relief systems
 - Burst disks
 - Pressure relief valves/devices (PRV/PRD)
 - Safety vents
- Fire and leak detection systems
 - Telemetric monitoring
 - Hydrogen gas detectors
 - UV/IR cameras
 - Fueling line leak check on nozzle connect



ASME steel and composite stationary storage tanks

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General Station Safety Systems

Design elements

- Engineering safety margins and analysis (HAZOP, etc.)
- Hydrogen compatible materials
- Siting to established regulations



Other systems

- Emergency stops
- Dispenser hose break-away devices
- Impact sensors at dispenser
- Controlled access
- Excess flow control (fueling)
- Pre-coolers (-40oF)

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First Responder Hydrogen Safety Training


- **National Goal**
 - Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders
- **Integrated Activities**
 - Online, awareness-level training (<http://hydrogen.pnl.gov/FirstResponders/>)
 - Classroom and hands-on operations-level training
 - National training resource (enabling trainers) (<http://h2tools.org/fr/tnt/>)



A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications and their transformation in how we use energy.

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Training Resources - Timeline and Accomplishments



2002: CaFCP Developed an ER Education Program

2006: Online Awareness Level Training

2010: Operations Level Ccls and Props Available

2014: Release the National Hydrogen and Fuel Cells ER Training Resource


CaFCP training has reached over 7,000 first responders

Over 32,000 visits for the online resource

Operations level class has been attended by over 1,100 first responders

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National First Responder Training Resource



Hydrogen Vehicle Safety Systems

Can be downloaded at <http://h2tools.org/fr/tnt/>

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Figure 44: Slides from Will James, DOE Fuel Cell Technologies (page 4 of 5)



We need more...

- Outreach and 'training' for first responders, code officials, stakeholders
 - Enable jurisdictions to educate on their schedule
- Use of the same resources to promote current and consistent messaging

Contact Information

Please let us know if you have any questions or comments!

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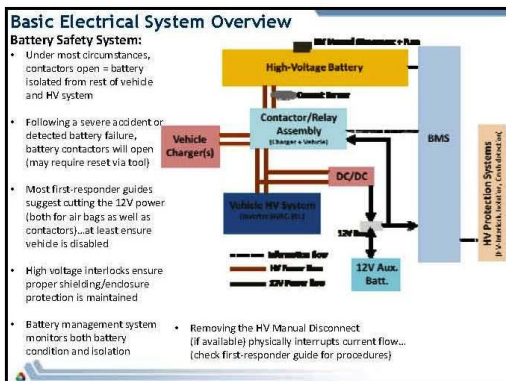
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Figure 45: Slides from Will James, DOE Fuel Cell Technologies (page 5 of 5)



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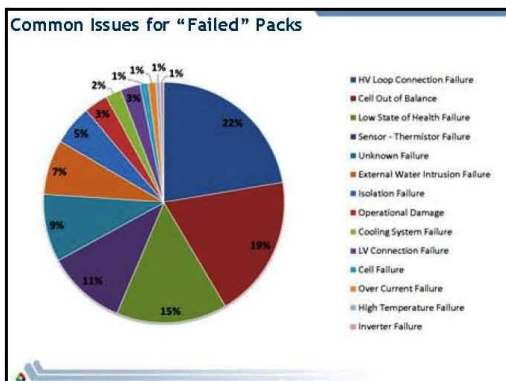
Highlighted Battery Safety Evaluation Techniques

<p>Pass/Fail Cell and Module Evaluations</p> <ul style="list-style-type: none"> Electrical Abuse <ul style="list-style-type: none"> Overcharge Short Circuit Thermal Abuse <ul style="list-style-type: none"> Thermal Stability up to X°C Mechanical Abuse <ul style="list-style-type: none"> Crush Nail Penetration 	<p>Pass/Fail Battery Pack Evaluations</p> <ul style="list-style-type: none"> Pack crush testing Open flame test (simulated fuel fire) External short-circuit <p>FMVSS 305 - ELECTRIC POWERED VEHICLES: ELECTROLYTE SPILLAGE AND ELECTRICAL SHOCK PROTECTION</p> <ul style="list-style-type: none"> Electrolyte spillage Component movement Electrical Isolation retention
--	--

Cell and Material Evaluation Tests

Stepping up temperatures until runaway...

- Accelerating-Rate Calorimetry
 - Cell heating only due to internal heating (adiabatic conditions)
- Thermal ramp testing
 - Closer to "open air" conditions



Highlighted Safety-Related Electrified Vehicle Trends

- Continued adoption of Li-ion across range of HEV/PHEV/BEV
- Improved integration of HV packs within vehicle structure
- Increased high and low voltage accessory electrification
- Significant increase in DC fast-charging capable vehicles (and wireless too)
- 48V systems (maybe)

Figure 46: Slides from Eric Rask, Argonne National Laboratory (page 1 of 2)

Manual Service Disconnect Locations

Clear and up-to-date first responder information is of critical importance
MSD placement and style varies depending on pack location and integration with vehicle...some vehicles removing MSD altogether

Under-hood Environment - HV Accessories and Cabling

The Expanded Charging Environment

DC-FC includes:

- Much higher power levels
- Direct HV bus connections
- Many more safety protocols

Wireless charging may not always be easy to identify...

Thermal Runaway and Firefighting Discussion

Rare but severe failure modes associated with Li-ion batteries are:

- 1) exothermic physical decomposition + gas generation and 2) release of electrolyte

Stages of Battery Degradation
Note: These vary significantly with battery materials, additives, composition, etc.

Phase 1: Creep
SEI breakdown > Increased reactivity between electrolyte and anode > Some gas generation due to electrolyte decomposition >

Phase 2: Acceleration
Continued heating and gas generation > Exothermic anode and cathode decomposition > Continue electrolyte decomposition (depends significantly on electrolyte composition) >

Phase 3: Runaway
Multiple high-race anode-electrolyte, cathode-electrolyte, and electrolyte decomposition reactions > Significant gas generation (some highly flammable) leads to possible electrolyte/gas expulsion and/or ignition

As discussed, extinguishing battery fires requires copious amounts of water...getting water directly to the pack will likely be difficult.

Delayed re-ignition can occur soon or well after initial extinguishment...
- Store suspect vehicle 50+ feet away from other items

Reh, E. Peter, Chris C. Crafts, Daniel H. Doughty, and James M. Ellen. "Advanced technology development program for Lithium Ion Batteries: thermal abuse performance of 13650 Li-ion cells." Sandia National Laboratories, Albuquerque, NM. SAND2004-0534

Damaged Pack Scenarios/Examples

Pack failures in the field are often a mix of several different failure modes
Fisker issues (from Sandy flooding) highlighted

Water Intrusion

BMS Damage and Shorting

Module Enclosure Damage

Arcing/Discharge

Cell Damage

Conclusions and Discussion

- Current on-board safety systems have been very successful in protecting against high voltage exposure.
- Electrified vehicles and related infrastructure are subject to continuous development and improvement, highlighting the need for continuing education and training.
- Significant amounts of water (or some other heat absorbing medium) are required to extinguish a battery fire and stop decomposition (if possible).
- Degradation issues are sometimes (often) delayed and intermittent. Can cause re-ignition following initial extinguishment.
- DO NOT attempt to breach/cut/open a pack to improve water access...this will expose HV and will likely amplify the on-going degradation!

Figure 47: Slides from Eric Rask, Argonne National Laboratory (page 2 of 2)

Determining Modifications Required for Adding CNG or LNG Vehicles to Existing Maintenance Facilities





Stephe Yborra - Managing Director
Yborra & Associates, LLC
 NFPA AFV Safety Summit - June 23, 2016 - Detroit Michigan






Defining the Problem/Opportunity

- NGV deployment is accelerating quickly, especially in fleet sector.
 - Economies of scale favor RTB and node-to-node fleets' adoption, most have centralized service facilities
 - Regional/long haul trucking and fueling operations will necessitate more ubiquitous CNG/LNG-capable service garages
- Problem: Lack of familiarity with NGV technology and applicable codes among fleets, design consultants and AHJs
 - Codes are "performance" docs, relying on hazard assessment, mitigation
 - Diversity of facility design/construction leads to variable interpretations
 - Conflicting codes, outdated government guidance and conflicting vendor information exacerbate confusion and over-cautiousness, leading to overly expensive retrofits
- Opportunity: Knowledge/ shedding light on subject can avoid costly errors and facilitate wider adoption of NGVs more quickly


Properties of CNG and LNG

- Natural gas: 98-99% methane (nett avg 93%)
 - Methane is CH4 (low carbon, energy-dense fuel)
 - Lighter than air (specific gravity: .55- .65)
 - Limited combustion ratio (5-15%)
 - High ignition temperature (1100°F)
 - Colorless, odorless, non-toxic substance
- Compressed Natural Gas (CNG)
 - Onboard fuel storage: 3600psi
 - Mercaptan added to CNG made from LNG
- Liquefied Natural Gas (LNG)
 - Cryogenic liquid @ -260°F
 - Methane content: ~95+%
 - 1 cu ft of LNG = 600 cu ft of natural gas @ atmospheric pressure; 3.5 lbs/gallon
 - Liquid LNG is not ignitable, vaporizes @ approx - -155°F (lighter than air).


Misperceptions About Dangers of CNG/LNG

- Work on CNG vehicles is not more or less dangerous than work on gasoline or diesel vehicles – it's just different due to physical characteristics of the fuel.
 - Auto-ignition points: Gasoline (-49°F), Diesel (-600°F), Natural Gas (-1100°F)
 - Lower Flammability Limit (LFL): Gasoline (1.4%), Diesel (1.0%), Natural Gas (5.0%)
 - Gasoline and diesel tanks are not nearly as robust/strong as CNG cylinders
 - Gasoline and diesel spills pool at the floor level until vaporizing at which point these heavier-than-air fuel vapors tend to disperse slowly and run and close to the ground. CNG is lighter than air and thus disperses very quickly as it rises.
- Thermal event vs "explosion"
 - All fuels burn given right mixture of fuel, oxygen and ignition source. The rate at which combustion occurs ("flame speed") drives the compression wave; the relative volume of fuel-air combusting vis-a-vis the total volume of the space determines whether there is a compressive event - an "explosion" - or just a thermal ignition event - whether the fuel is gasoline, diesel or CNG.
 - The relative impact of that compression wave is also measured along a continuum of consequence, e.g., minor pressure change that is just sufficient enough to blow shut a door but not enough to break a window, to one strong enough to bodily harm and/or structural damage.



Misperceptions About Dangers of CNG/LNG

- Recent Sandia National Laboratory CFD modeling of gas dispersion, ignition and relative impacts
 - Most regular maintenance procedures result in very little natural gas release, e.g. bleeding off residual pressure in an isolated line to do PM work such as injector cleaning, filter change. Amount released very quickly disperses and dilutes within matter of several seconds and <6 feet.
 - Due to properties, natural gas disperses as it rises – no chance of minor amounts "re-concentrating at ceiling."
 - CFD modeling shows that only a full release of entire cylinder contents results in quantities of ignitable mixtures within LFL-UFL range; duration of ignitable mixture conditions depends on volume of fuel ratio to space, height of ceiling, building structural characteristics and (to a lesser extent) ventilation strategy.
 - Based on "credible" release amounts associated with a large CNG cylinder (e.g., like those on transit bus), CFD modeling of compression wave strength results in breaking glass (at worst) in "typical" maintenance facility.



Codes Applicable to Vehicle Maintenance Facilities

- The following national codes are voluntarily adopted by states and local jurisdictions.
 - International Code Council's Intl Fire Code (IFC 2015)
 - International Mechanical Code (IMC 2015)
 - International Building Code (IBC 2015)
 - National Fire Protection Assoc. (NFPA) 30A (2015) Code for Motor Fuel Dispensing Facilities and Repair Garages
 - NFPA 52 (2013) Vehicular Gaseous Fuel Systems Code
 - NFPA 88 (2007) Standards for Parking Structures
 - ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality
- Local codes that are in force often are not the most recent versions of national model codes (adoption often lags behind by several years – if not more). Local AHJ is final decision-making authority and may enforce additional requirements.





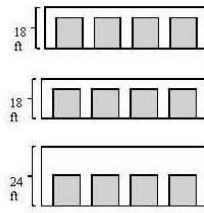
Figure 48: Slides from Stephen Yborra, Yborra & Associates (page 1 of 3)

Conflicting Direction Provided by Different Codes

- IFC's and NFPA30A's approach to ventilation are completely different; significant implications for facility design and ops.
 - IFC calls for 5 ACH of entire space. 5 ACH is likely far more ventilation than required for simple IAQ. (IFC's "5 ACH" language likely came from NFPA30A's indoor fueling garage requirements.)
 - NFPA30A focus appears to be on purging area most likely to be where gas might accumulate, i.e. 4 ACH of 18" ceiling zone.
 - Neither provides much direction re ventilation system design
 - HVAC systems vary widely (e.g., forced MAU vs passive; exhaust fans vs gravity venting; does ventilation design sweep and capture or disturb?)
- Result? AHJs are left to interpret and base requirements on assumptions about site-specific credible releases and potential hazard (amount of potential fuel release, volume of space and building characteristics => likelihood of ignitable mixture and duration)



70' x 80' (5600 ft²) repair garage




Scenario A (using IFC 5 ACH requirement):
Based on a mech. system operational design of 1.6cfm/ft², this facility would require 5600 cfm mechanical system. This 100,000 of facility would have an effective 3.3 ACH.

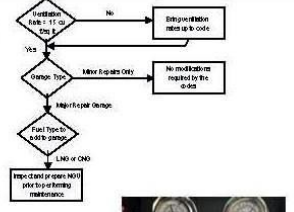
Scenario B (using IFC 5 ACH requirement):
Based on a mech. system operational design of 1.5cfm/ft², this facility would require 4400 cfm mechanical system. This 100,000 of facility would have an effective 5.0 ACH.

Scenario C (using IFC 5 ACH requirement):
Based on a mech. system operational design of 1.5cfm/ft², this facility would require 4400 cfm mechanical system. This 134,400 of facility would have an effective 3.75 ACH. To achieve a full 5.0 ACH would require 11,200 cfm mechanical system capability.



All scenarios above (using NFPA30A 4 ACH ceiling zone requirement):
Mech. system requirement for ceiling zone would be 560 cfm (5600 x 1.5 x 4 / 60). Focus would be on whether system design was effectively ventilating ceiling zone. Ex: How is air in vacated from space? Where is make-up air introduced?




Facility Modifications to Accommodate Work on CNG and/or LNG Vehicles






- Regardless of ventilation system operation, methane detection requirements, interlocking, etc....
 - Inspect/prepare your NGV
 - IFC 2211.5 – Isolate fuel container from rest of system
 - Inspect for leakage
 - (proposed temp/psl check)
 - NFPA 30A – No mention
 - (proposed temp/psl check)
 - RP: Operate NGV until it stalls after isolating fuel source

Facility Modifications to Accommodate Work on CNG and/or LNG Vehicles




- Maintenance/decommissioning of fuel containers
 - CNG cylinders have specific end-of-useful life date (see label), LNG tanks do not.
 - NFPA 52.6.13 (2013):
Written procedures should be in place for inspection and decommissioning of CNG cylinders. (Training of staff is recommended)
 - NFPA 52.6.14 (2013):
Major repair garage should install appropriate defueling apparatus (capture or direct atmospheric venting)

More R&D Needed to Develop Better Code Guidance; Additional Education of All Affected Stakeholders

- Gaseous fuel dispersion modeling and empirically based definition of potential hazard
- Definition of credible releases based on statistical data from field experience
- Integration and synchronization of different model codes using consistent set of data and assumptions
- Greater outreach and training; additional materials development and distribution



Thank you!

We look forward to your feedback and input.




Figure 50: Slides from Stephen Yborra, Yborra & Associates (page 3 of 3)