REGULATIONS, CODES, AND STANDARDS (RCS) FOR MULTI-FUEL MOTOR VEHICLE DISPENSING STATIONS

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ABSTRACT

In the United States, requirements for liquid motor vehicle fuelling stations have been in place for many years. Requirements for motor vehicle fuelling stations for gaseous fuels, including hydrogen, are relatively new. These requirements have, in the United States, been developed along different code and standards paths. The liquid fuels have been addressed in a single document and the gaseous fuels have been addressed in documents specific to an individual gas. The result of these parallel processes is that multi-fuel stations are subject to requirements in several fuelling regulations, codes, and standards (RCS). This paper describes a configuration of a multi-fuel motor vehicle fuelling station and provides a detailed breakdown of the codes and standards requirements. The multi-fuel station would dispense what the U.S. Department of Energy defines as the six key alternative fuels: biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. The paper will also identify any apparent gaps in RCS and potential research projects that could help fill these gaps.

NOMENCLATURE

ANSI: American National Standards Institute
API: American Petroleum Institute
ASME: American Society of Mechanical Engineers
ASTM: American Society of Testing Materials
CGA: Compressed Gas Association
CNG: compressed natural gas
CSA: Canadian Standards Association
NGV: Natural gas vehicle
NFPA: National Fire Protection Association
RCS: Regulations, codes, and standards
SAE: SAE International
UL: Underwriters Laboratories

1.0 RCS FOR SIX KEY FUELS

The U.S. Department of Energy has defined six key alternative vehicle fuels [1]. These fuels are listed in the 1992 Energy Policy Act [2]. The Energy Policy Act also lists fuels classified as emerging fuels. These emerging fuels were not considered in this paper. This paper consists of an analysis of existing U.S. alternative fuel RCS to identify the important alternative fuel documents followed by a discussion of apparent gaps in these alternative fuel RCS documents. These RCS gaps point to areas of safety research where work would need to be performed to produce the data required to develop safety requirements. The gap analysis is partially based on a representative multi-fuel station as well as literature review and interviews with multi-fuel station designers. The safety research areas are discussed in the conclusion section.

The six key alternative fuels are:

- Biodiesel
- Electricity
- Ethanol

- Hydrogen
- Natural gas
- Propane.

Fig. 1 shows the number of fuelling stations deployed for the six key fuels [3]. More than 80% of the stations support electric vehicles. On the other end of the spectrum, hydrogen fuelling stations are too few in number to visually register on the bar chart. However, this bar chart does not indicate how many of these stations dispense multiple fuels. The bar chart implies that for emerging alternative fuels, such as hydrogen, a dedicated fuel station may not be financially sustainable due to the low number of vehicle fuellings. Hydrogen and other fuels may have to be grouped at a common fuelling site to produce a fuelling configuration that is financially viable. Hence there is a need to analyze RCS for multi-fuel stations.

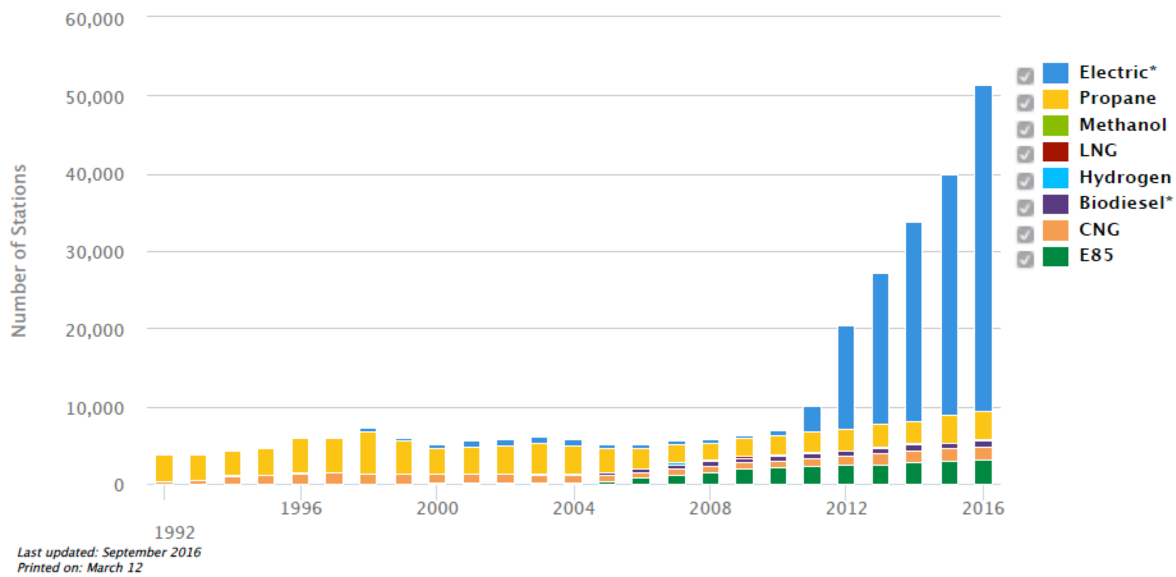

Figure 1. Alternative fuel fuelling stations by fuel type in the United States

Tables 1–6 list RCS for the six key fuels. The International Building Code and the International Fire Code, used primarily in the United States despite their names, apply to all six fuels and are not listed in the tables. These codes set basic construction and fire safety requirements for the built environment. In addition, the National Electrical Code (NFPA 70) would apply to installations for all six fuels and is not listed in the tables except for electric vehicle requirements. The tables are intended to identify fuel-specific RCS.

Fig. 2 and Fig. 3 show the basic RCS structure for both vehicles and infrastructure. The basic structure is a flow from high-level general requirements to very detailed requirements. Typically the document at the top of the pyramid is adopted by a jurisdiction as law and the documents at the lower levels of the pyramid become law by being referenced in the documents at the top of the pyramid. It is important to note that without a jurisdiction adopting a document as law the document is not typically enforceable. The pyramids are intended to complement the information in the tables by providing a picture of the hierarchy for applying the respective RCS. Combining the information in the fuel-specific RCS tables with the hierarchy that is typically applied to these documents provides a picture of how the documents are applied. Typically documents that are identified as standards reside at the third level in the pyramid hierarchy. An example of this hierarchy for biodiesel would be a jurisdiction adopting a Fire code, which references the NFPA 30A Code for Motor Fuel Dispensing Facilities and

Repair Garages (second level of the pyramid), which in turn references the UL 2080 Standard for Fire Resistant Tanks for Flammable and Combustible Liquids (third level of the pyramid).

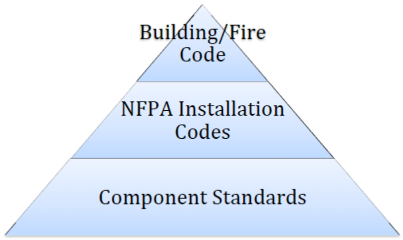

Figure 2. Hierarchy of infrastructure RCS

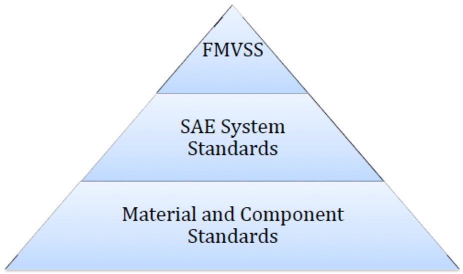

Figure 2. Hierarchy of vehicle RCS

Table 1. Biodiesel requirements

Document	Subject matter
NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages	Installation of all station components and systems, siting requirements, operations, and maintenance
NFPA 30, Flammable and Combustible Liquids Code	Flammable and combustible liquid storage requirements for above and below grade storage
UL 330B	Standard for hose and hose assemblies for use with dispensing devices dispensing diesel fuel, biodiesel fuel, diesel/biodiesel blends with nominal biodiesel concentrations up to 20 percent (B20), kerosene, and fuel oil
UL 2586B	Standard for hose nozzle valves for diesel fuel, biodiesel fuel, diesel/biodiesel blends with nominal biodiesel concentrations up to 20 percent (B20), kerosene, and fuel oil
Middle Distillate Fuels, ASTM D6751	Fuel specification standard
ANSI/UL 2245, Standard for Below-Grade Vaults for Flammable Liquid Storage Tanks	Design standard for vaults
SAE J313, Diesel Fuels	Fuel specification standard
UL 2080, Standard for Fire Resistant Tanks for Flammable and Combustible Liquids	Fire design/testing standard for tanks

Table 2. Electricity requirements

Document	**Subject Matter**
National Fire Protection Agency (NFPA) NFPA 70 National Electrical Code Article 625: Electric Vehicle Charging System Equipment	Vehicle charging system performance requirements
National Fire Protection Agency (NFPA) NFPA 70 National Electrical Code Article 626: Electrified Truck Parking Spaces	Sets conductivity and other requirements for parking spaces used for vehicle charging
SAE J-2293 Part 1: Energy Transfer System for EV Part 1: Functional Requirements and System Architecture	SAE J2293 establishes requirements for electric vehicles and the off-board electric vehicle supply equipment used to transfer electrical energy to an electric vehicle from an electric utility power system (utility) in North America
SAE J-1772: SAE Electric Vehicle Conductive Charge Coupler	This SAE standard covers the general physical, electrical, functional, and performance requirements to facilitate conductive charging of electric vehicles and plug-in hybrid electric vehicles in North America.
SAE J-1773: SAE Electric Vehicle Inductively-Coupled Charging	Safety and performance requirements
SAE J-1850: Class B Data Communications Network Interface	This SAE standard establishes the requirements for a Class B Data Communication Network Interface applicable to all on- and off-road land-based vehicles. It defines a minimum set of data communication requirements such that the resulting network is cost effective for simple applications and flexible enough to use in complex applications.
SAE J-2293 Part 2: Energy Transfer System for EV Part 2: Communications Requirements and Network Architecture	This stabilized recommended practice documents for reference the historical state of energy transfer systems and communications for electric vehicles as they existed in 2008, as defined in SAE J1772 (per published version 11-1-2001) for conductive charging and SAE J1773 (per published version 11-1-1999) for inductive charging. SAE J1772 continues to be updated to reflect the latest in conductive charging technology.
SAE J-2836 Part 1: Use Cases for Communications between Plug-In Vehicles and the Utility Grid	The use cases described here identify the equipment (system elements) and interactions to support grid-optimized AC or DC energy transfer for plug-in vehicles, as described in SAE J2847.
SAE J-2836 Part 2: Use Cases for Communications between Plug-In Vehicles and the Supply Equipment	This document will use the on-board charger as a basis, then add and delete info that address the new criteria for vehicle architectures that have been introduced as plug-in electric vehicles. Rechargeable energy storage systems.
SAE J-2836 part 3: Use Cases for Communications between Plug-In Vehicles and the Utility Grid for Reverse Flow	This is a baseline document; first published in January 2013, that serves as a general reference on reverse flow from the vehicle to the grid.

Table 3. Ethanol requirements

Document	Subject matter
NFPA 30, Flammable and Combustible Liquids Code	General flammable and combustible liquid safety requirements including storage and container design
NFPA 30A	Installation of all station components and systems, siting requirements, operations, and maintenance
UL 2245, Standard for Below-Grade Vaults for Flammable Liquid Storage Tanks	Design requirements for vaults
US DOT 10 CFR49	U.S. Department of Transportation design and testing requirements for flammable and combustible liquid tanks
NFPA 91, Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids	Safety requirements for any ethanol exhaust
UL 2080, Standard for Fire Resistant Tanks for Flammable and Combustible Liquids	Fire test standard
UL 2085, Standards for Protected Aboveground Tanks for Flammable and Combustible Liquids	Fire test standard
API 653, Tank Inspection, Repair, Alteration, and Reconstruction	Tank inspection standard to complement construction standards

Table 4. Hydrogen requirements

Document	Subject matter
NFPA 2 Hydrogen Technologies Code	Comprehensive hydrogen technologies safety code
NFPA 30, Flammable and Combustible Liquids Code	Flammable and combustible liquid storage requirements for above and below grade storage
CGA G-5.5 Vent Systems	Vent stack and discharge geometry design standard
S-1.1 Pressure Relief Device Standards - Part 1- Cylinders for Compressed Gases S-1.3 Pressure Relief Device Standards - Part 3 - Stationary Storage Containers for Compressed Gases	Pressure relief device design
ASME B31.3/12	Pressure piping design codes
CGA H-5 Standard for Bulk Hydrogen Supply Systems	General hydrogen safety standard
ASME Boiler and Pressure Vessel Code	Design document for pressure vessels
CSA FC/1	Standard for performance of stationary fuel cells

Table 5. Natural gas requirements

Document	Subject matter
NFPA 52 Vehicular Fuel Systems Code, Chapter 8 CNG Compression, Gas Processing, Storage, and Dispensing Systems	General requirements for compressed natural gas (CNG) compression, gas processing, storage, and dispensing systems
NFPA 52 Vehicular Fuel Systems Code, 8.4 System Siting	Requirements for system setback distances
NFPA 52 Vehicular Fuel Systems Code, Table 8.4.2.9 Electrical Installations	Requirements for classified areas
Natural Gas Vehicle (NGV) 2 Natural Gas Vehicle Containers	Set of standards that address component testing for certification purposes for natural gas vehicle fuelling infrastructure and vehicle tanks
NGV 1 Compressed NGV Fueling Connection Devices	Set of standards that address component testing for certification purposes for natural gas vehicle fuelling infrastructure and vehicle tanks
NGV 3.1 Fuel System Components for Natural Gas Powered Vehicles	Certification document for fuel system components
NGV 4.1 Dispensing Systems	Certification document for fuel systems
NGV 4.2 Hoses for Natural Gas Vehicles and Dispensing Systems	Certification document for fuelling hoses
NGV 4.3 Temperature Compensation Devices for Natural Gas Dispensing Systems	Standard to address fuelling parameters require to achieve defined state-of-charge
NGV 4.4 Breakaway Devices for Natural Gas Dispensing Hoses and Systems	Certification document for dispenser hoses
NGV 4.5 (draft) Priority and Sequencing Equipment for Natural Gas Dispensing Systems	Document in development that sets procedures for fuelling operations
NGV 4.6 Manually Operated Valves for Natural Gas Dispensing Systems	Certification document for dispensing system valves
NGV 4.7 (draft) Automatic Valves for Use in Natural Gas Vehicle Fueling Stations	Certification document for fuel system compressors
NGV 4.8 Natural Gas Fueling Station Reciprocating Compressor Guidelines Pressure Relief Devices -1 for NGV Fuel Container	Certification document for fuelling compressors
ASME B31.3 Process Piping	Process design piping standard
C-6 Standards for Visual Inspection of Steel Compressed Gas Cylinders	Inspection standard to complement design standard
S-1.1 Pressure Relief Device Standards - Part 1- Cylinders for Compressed Gases S-1.3 Pressure Relief Device Standards - Part 3 - Stationary Storage Containers for Compressed Gases	Pressure relief for different container configurations

Table 6. Propane requirements

Document	Subject matter
NFPA 58 LP-Gas Code, 5.22 Vehicle Fuel Dispensers	5.22 Vehicle Fuel Dispensers
NFPA 58 LP-Gas Code, Table 6.5.2.1 Distance Between Point of Transfer and Exposures	Table 6.5.2.1 Distance Between Point of Transfer and Exposures
NFPA 58 LP-Gas Code, Table 6.23.2.2 Electrical Area Classification	Table 6.23.2.2 Electrical Area Classification
NFPA 58 LP-Gas Code, 6.25 Vehicle Fuel Dispenser and Dispensing Stations	6.25 Vehicle Fuel Dispenser and Dispensing Stations
NFPA 58 LP-Gas Code, Chapter 11 Engine Fuel Systems	Chapter 11 Engine Fuel Systems
S-1.1 Pressure Relief Device Standards - Part 1- Cylinders for Compressed Gases S-1.3 Pressure Relief Device Standards - Part 3 - Stationary Storage Containers for Compressed Gases	Propane tank venting

2.0 REPRESENTATIVE MULTI-FUEL STATION CONFIGURATION

Several parameters must be defined to characterize a representative retail multi-fuel station. These parameters are to a large extent defined by code requirements. These requirements include setback distances for storage and dispensing that derive primarily from the NFPA code for the various fuels. Fig. 4 is a schematic representation of a multi-fuel retail fuelling station. The multi-fuel station depicted in Fig. 4 has the following characteristics:

- Charging stations located at parking spaces
- Fuelling for five of the six key fuels; propane is not included because it is not typically dispensed at retail facilities
- Integrated control systems
- Separation between fuel storage for different fuel types including below grade storage for liquid fuels and liquefied hydrogen
- Defined electrically classified areas at dispensing and storage areas
- Visual and audible alarms
- Charging stations for electric vehicles at convenience store parking spaces
- Storage venting and pressure relief systems
- Vehicle loading egress

The multi-fuel station illustrated in Fig. 4 may be more complex than stations that simply add an alternative fuel to an existing conventional liquid fuel station. For example, for many of the hydrogen fuelling projects currently deployed or under development in the United States, a hydrogen dispenser is added to an existing gasoline fuelling station [4].

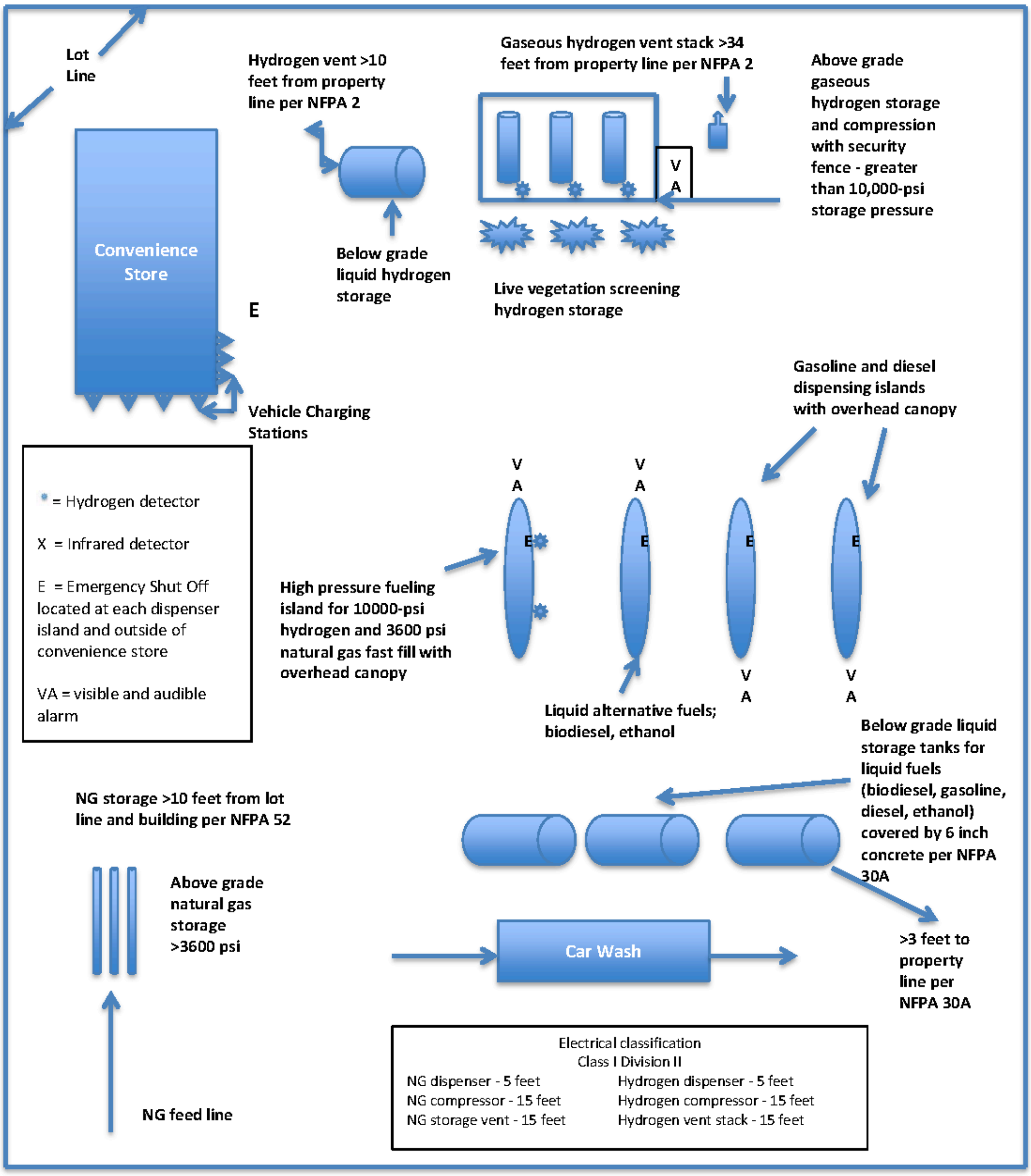

Figure 3. Schematic of multi-fuel station

3.0 SAFETY ISSUES AND RCS GAPS

All six of the key alternative fuels have comprehensive safety requirements that reside in multiple codes and standards [5]. Propane and CNG have been deployed longer than the other fuels and in most areas have more established RCS. Analysis of the RCS and expert interviews show key findings and issues of concern with multi-fuel stations [6–9]. The interviews include companies that have designed multi-fuel stations and staff of code development organizations. The findings and issues include the following points:

- Within the United States codes and standards there is a complete set of requirements that would allow the installation and operation of a multi-fuel retail station.
- The number of documents, the multiple cross references within documents to other documents, as well as the cost of obtaining these documents represents a barrier to both project developer compliance and code enforcement.

- The codes and standards requirements for the different fuels reside in several documents and the requirements of these documents are not fully integrated.

- E-stops (emergency station shut-down stops) and other control requirements are not integrated within the RCS (for example initiating an E-stop for hydrogen fuelling would not necessarily shut down all fuelling operations conducted at a multi-fuel station).

- Fuel storage and dispensing setback distances for one fuel can impinge on those for another fuel, such as setback distances for hydrogen storage impinging on setbacks for CNG storage.

- Fire panels are not designed for the multiple signals that would be produced by the multiple sensing devices required at facilities storing and dispensing multiple fuels.

- Blending fuels can create flammable atmospheres in tank head space where they did not previously exist by changing the flammability range of the vapour accruing in the tank head space.

- Retrofitting of existing facilities to add new fuelling capability creates many issues with bringing an out of compliance facility into review with current requirements.

- When managing changes, the impacts of modifications to one system need to be evaluated regarding their site wide impacts.

4.0 CONCLUSION

The gaps in RCS point to several potential research areas. These research areas include the following:

- Sensors that can perform in a multi-fuel environment

- Station layout analysis factoring in all of the various setback distances to produce an optimal use of space at a specific location

- Hazard analyses by component level nodes for multi-fuel operation and impacts of intentional and unintentional releases scenarios, including the safety impacts of routine venting operations

- Impacts of operations of different fuels on safety aspects of other fuels, such as routine maintenance activities for one fuel impacting safety for another fuel

- The safety impact of heavier-than-air fuels potentially migrating into below grade storage areas

- Multi-fuel impacts on materials—for example, the combination of fuels degrading materials that are designed for use with a specified fuel or impacting materials at the station not designed to withstand the impact of that fuel.

The next step in this process would be performing a comprehensive risk analysis involving experts from different areas of the fuelling industry. NREL has begun work in assembling these expert groups and will proceed with the comprehensive risk analysis.

There would also be a benefit to developing an integrated RCS compliance tool for multi-fuel stations as the level of deployment of these fuels increase.

ACKNOWLEDGEMENTS

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-08GO28308 with Alliance for Sustainable Energy, LLC, the Manager and Operator of the National Renewable Energy Laboratory. NREL would like to acknowledge the support from the U.S. Department of Energy's Fuel Cell Technologies Office in performing this work.

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