U.S. Department of Transportation

**Federal Railroad Administration**

# REVIEW OF CODES, STANDARDS, AND REGULATIONS FOR NATURAL GAS LOCOMOTIVES

Office of Research
and Development
Washington, DC 20590


DOT/FRA/ORD-14/15

Final Report
June 2014

NOTICE

This document is an overview of selected codes, standards, and regulations presumed applicable to gaseous fueled vehicles not a complete review of all natural gas standards. The observations within this report are not recommendations for the design or safety of natural gas systems.

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13. ABSTRACT (Maximum 200 words)

This report identified, collected, and summarized relevant international codes, standards, and regulations with potential applicability to the use of natural gas as a locomotive fuel. Few international or country-specific codes, standards, and regulations specifically written for natural gas fueled locomotives and tender cars were found, so the search was expanded to include natural gas as a transportation fuel. The inquiry yielded 181 documents primarily from countries that were reviewed as part of this project.

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# METRIC/ENGLISH CONVERSION FACTORS

## ENGLISH TO METRIC / METRIC TO ENGLISH

### LENGTH (APPROXIMATE)

| English to Metric | | | Metric to English | | |
|---|---|---|---|---|---|
| 1 inch (in) | = | 2.5 centimeters (cm) | 1 millimeter (mm) | = | 0.04 inch (in) |
| 1 foot (ft) | = | 30 centimeters (cm) | 1 centimeter (cm) | = | 0.4 inch (in) |
| 1 yard (yd) | = | 0.9 meter (m) | 1 meter (m) | = | 3.3 feet (ft) |
| 1 mile (mi) | = | 1.6 kilometers (km) | 1 meter (m) | = | 1.1 yards (yd) |
| | | | 1 kilometer (km) | = | 0.6 mile (mi) |

### AREA (APPROXIMATE)

| English to Metric | | | Metric to English | | |
|---|---|---|---|---|---|
| 1 square inch (sq in, in$^2$) | = | 6.5 square centimeters (cm$^2$) | 1 square centimeter (cm$^2$) | = | 0.16 square inch (sq in, in$^2$) |
| 1 square foot (sq ft, ft$^2$) | = | 0.09 square meter (m$^2$) | 1 square meter (m$^2$) | = | 1.2 square yards (sq yd, yd$^2$) |
| 1 square yard (sq yd, yd$^2$) | = | 0.8 square meter (m$^2$) | 1 square kilometer (km$^2$) | = | 0.4 square mile (sq mi, mi$^2$) |
| 1 square mile (sq mi, mi$^2$) | = | 2.6 square kilometers (km$^2$) | 10,000 square meters (m$^2$) | = | 1 hectare (ha) = 2.5 acres |
| 1 acre = 0.4 hectare (he) | = | 4,000 square meters (m$^2$) | | | |

### MASS - WEIGHT (APPROXIMATE)

| English to Metric | | | Metric to English | | |
|---|---|---|---|---|---|
| 1 ounce (oz) | = | 28 grams (gm) | 1 gram (gm) | = | 0.036 ounce (oz) |
| 1 pound (lb) | = | 0.45 kilogram (kg) | 1 kilogram (kg) | = | 2.2 pounds (lb) |
| 1 short ton = 2,000 pounds (lb) | = | 0.9 tonne (t) | 1 tonne (t) | = | 1,000 kilograms (kg) |
| | | | | = | 1.1 short tons |

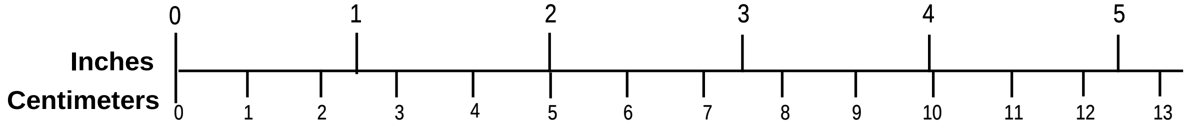
### VOLUME (APPROXIMATE)

| English to Metric | | | Metric to English | | |
|---|---|---|---|---|---|
| 1 teaspoon (tsp) | = | 5 milliliters (ml) | 1 milliliter (ml) | = | 0.03 fluid ounce (fl oz) |
| 1 tablespoon (tbsp) | = | 15 milliliters (ml) | 1 liter (l) | = | 2.1 pints (pt) |
| 1 fluid ounce (fl oz) | = | 30 milliliters (ml) | 1 liter (l) | = | 1.06 quarts (qt) |
| 1 cup (c) | = | 0.24 liter (l) | 1 liter (l) | = | 0.26 gallon (gal) |
| 1 pint (pt) | = | 0.47 liter (l) | | | |
| 1 quart (qt) | = | 0.96 liter (l) | | | |
| 1 gallon (gal) | = | 3.8 liters (l) | | | |
| 1 cubic foot (cu ft, ft$^3$) | = | 0.03 cubic meter (m$^3$) | 1 cubic meter (m$^3$) | = | 36 cubic feet (cu ft, ft$^3$) |
| 1 cubic yard (cu yd, yd$^3$) | = | 0.76 cubic meter (m$^3$) | 1 cubic meter (m$^3$) | = | 1.3 cubic yards (cu yd, yd$^3$) |

### TEMPERATURE (EXACT)

| English to Metric | | | Metric to English | | |
|---|---|---|---|---|---|
| [(x-32)(5/9)] °F | = | y °C | [(9/5) y + 32] °C | = | x °F |

## QUICK INCH - CENTIMETER LENGTH CONVERSION




## QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

| °F | -40° | -22° | -4° | 14° | 32° | 50° | 68° | 86° | 104° | 122° | 140° | 158° | 176° | 194° | 212° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °C | -40° | -30° | -20° | -10° | 0° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | 100° |

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

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- The Association of American Railroads – For providing access to their Manual of Standards and Recommended Practices for our review and allowing attendance to Natural Gas Fuel Tender Car technical group meetings

- Clean Energy Fuels – For providing industry insights on LNG use and their suitability for rail transport and allowing inspections of their LNG fueling station located in Long Beach, CA

- Southern California Gas Company – For guidance regarding applicable natural gas regulations and for providing introductions to industry professionals

- Los Angeles California Fire Department – For discussing fire-related regulations, codes, and standards around natural gas usage

- Metrolink (Southern California Regional Rail Authority) – For discussing the Federal TIGER grant, its applicability, and the benefits of converting locomotives to LNG fuel

- South Coast Air Quality Management District – For discussing emission control processes and key pollutants

- Southern California Gas – For discussing LNG handling processes at their facilities and best practices around the world

# Contents

## Illustrations

# Executive Summary

On behalf of the Federal Railroad Administration (FRA), Ricardo Strategic Consulting identified, collected, and summarized relevant codes, standards, and regulations from across the globe with potential applicability to the use of natural gas as a locomotive fuel. The study focused on key countries in the Americas, Europe, and Asia that have adopted natural gas as an energy source for transportation. The study was supplemented by a very high level review of natural gas vehicle (NGV) related activities in select emerging countries. The primary geographic areas searched were the United States, Germany, Australia, and Japan. The researchers conducted a high-level survey of regulatory bodies, standard-setting organizations, and activities concerning use of natural gas or liquefied propane gas (LPG) as a transportation fuel for Brazil, Russia, India, and China. Few codes, standards, and regulations specifically written for natural gas fueled locomotives and tender cars were found, so the search was expanded to include natural gas as a transportation fuel. The investigation yielded 181 documents from the 4 primary countries which were reviewed as part of this project.

References to other documents were noted as part of the review process. While many of the documents reviewed referenced one another, they also pointed to a larger population of codes, standards, and regulations linked to applications of natural gas and LPG-fueled vehicles. The body of knowledge used to design, build, and operate gaseous fueled vehicles is not self-contained; it is a web of interrelated disciplines covering a broad range of technical and tactical objectives from engineering considerations like material properties and thermodynamics to practical concerns like fire and worker safety.

The review of codes and regulations was focused mostly on the Federal level. Some U.S. States, most notably Texas, have developed their own regulations regarding natural gas as a transportation fuel. Interviews with knowledgeable industry professionals revealed stark differences in the way ordinances were interpreted and enforced in local municipalities. Local and regional regulatory variance is a pragmatic issue for gas fueled locomotives traveling on an intercontinental rail network and could be an area of further study since it is not fully explored in this report.

Each of the primary regions' approaches codes, standards, and regulations for natural gas fueled transportation differed. The United States has the most specific fire codes regarding natural gas fueled vehicles. Germany has both national and international regulations and requirements with which to comply. The strength of the International Organization for Standardization (ISO) standards seems to have displaced the need for natural gas vehicle (NGV) standards published by Germany's standards organization, DIN. The Japanese government created a high pressure gas safety institute to develop and maintain standards, some of which get the force of law from the Japanese Ministry of Economy, Trade, and Industry (METI). Australian provinces take the lead on regulations, but lean heavily on the very comprehensive standards written by Standards Australia International (SAI), a non-governmental organization and the Australian member of ISO and IEC.

While variation in the specificity and the balance between local, national, and international regulations was found, major gaps were not identified as part of this study. It was also apparent

that codes, standards, and regulations were informed by their counterparts in other regions. The United Nations guidelines for the transport of dangerous goods seemed particularly influential as common language and references to this document are found in all regions studied. ISO, American National Standards Institute (ANSI), and American Society of Mechanical Engineers (ASME) standards were also frequently cited in documents outside of their home regions.

This report provides an overview of codes, standards, and regulations presumed applicable to gas fueled vehicles, not a comprehensive or exhaustive review of all natural gas standards. The observations within this report are not recommendations for the design or safety of natural gas systems.

# 1. Introduction

## 1.1 Overall Approach

The goal of this study was to create a single reference document of codes, standards, and regulations relevant to natural gas as a fuel for rail applications and identify where gaps might exist. The effort began with discussions with rail industry contacts and visits to natural gas demonstration projects. Information gathered during this exercise was used to develop the high level subsystem map. The sub-system map provided the component elements, operational relationships, and design alternatives within the gaseous locomotive fuel system used to identify and screen codes, standards, and regulations for pertinence to rail.

After the high level subsystem map was completed, the effort shifted to identifying and acquiring codes, standards, and regulations in each of the four primary countries: United States, Germany, Australia, and Japan. Documents were screened for direct applicability to rail, or natural gas as a transportation fuel. Natural gas codes, standards, and regulations without applicability to transportation were not considered for review. Also, generic component or material codes, standards, and regulations without explicit or easily identifiable reference to natural gas usage in a mobile application were not reviewed. While collecting codes, standards, and regulations from the United States, researchers formalized and perfected a standard review process and one-page summary format. This process was applied to all codes, standards, and regulations reviewed during the course of the project.

Ricardo also conducted an overview of NGV activities and regulatory actions in the four secondary countries: Brazil, Russia, India, and China (referred to as BRIC from here onward). All these countries have demonstration programs and discussions on natural gas for the different transportation applications, including rail. Government groups in these countries have begun organizing regulatory regimes for safety and, in some cases, emissions from NGVs. Some national standards organizations have also begun work on local standards. The detailed findings of the research into gaseous vehicle developments in BRIC countries are in section 4.3 of this report.

The review summaries of the codes, standards, and regulations from each of the primary target countries were used to create the standards matrix with the documents listed down the rows and the subsystem components listed across the columns of the matrix. A four point scale was used to indicate applicability of the document to particular components within the gaseous locomotive fuel system. A blank entry indicates no mention of the component within the document. An open circle indicates a generic mention of the component. A half circle indicates detailed requirements with some engineering parameters, and a full circle denotes in-depth design and engineering requirements. The matrix enables the reader to quickly scan for codes, standards, or regulations which apply to specific components or subsystems and get an indication of the specificity of the requirements contained within the document.

## 2. High Level Subsystem Map

This report section provides a definition of the major categories of fueling system components for both compressed natural gas (CNG) and liquefied natural gas (LNG) systems. Ricardo developed high level subsystem maps as a guide to categorize and catalog codes, standards, and regulations related to the use of natural gas as a fuel for locomotives. These maps identify the components related to each subsystem and define the categories into which the identified codes (e.g., pressure vessels), standards (e.g., interoperability), and regulations (e.g., applicable sections of the Code of Federal Regulations, CFR) will be placed.

Natural gas has been available as a fuel for more than a century, but its utility for rail transportation has been hindered by concerns regarding onboard storage technology and price differences when compared with alternatives like diesel. The two major storage methods for onboard storage are high pressure CNG and low temperature LNG. Each has unique advantages and disadvantages related to the application. Both are candidates for rail applications. Each has distinct hardware components. Ricardo has developed separate subsystem maps for both system types.

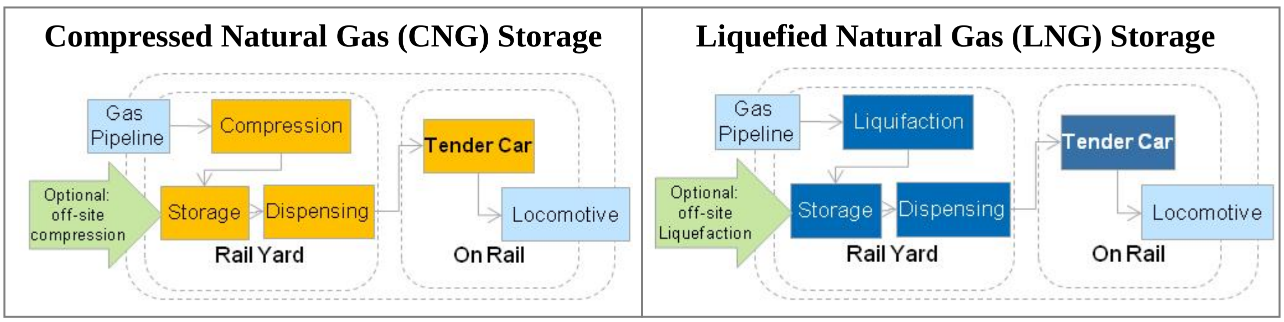


**Figure 2(a). Natural Gas Storage**

CNG increases the volumetric energy density of natural gas by storing it at high pressures (above 200 bar). These pressures require specially designed components (e.g., pressure vessels) and maintenance procedures such as periodic inspections to check for corrosion or cracks.

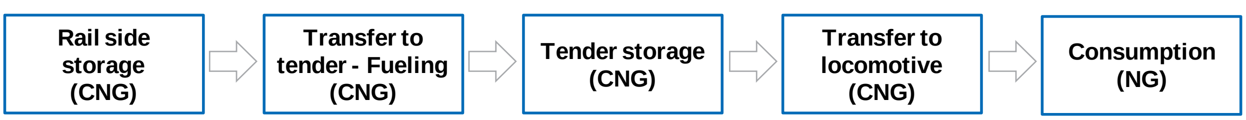


**Figure 2(b). CNG Usage Cycle**

LNG is cryogenically compressed natural gas. The gas is cooled below -260 °F during the compression process, which causes it to liquefy. The storage vessel, typically a double wall tank with an insulating mild vacuum in between the inner and outer walls, is designed to maintain LNG temperatures. Long-term storage requires active refrigeration, but for onboard use, vaporization as the fuel is consumed can be used to remove latent heat from the tank and keep the liquid cool. This, coupled with the effectiveness of the double-wall design, eliminates the need for active, onboard refrigeration in applications that do not sit for long periods of time.

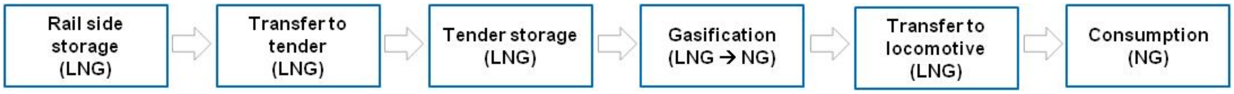


**Figure 2(c). LNG Usage Cycle**

## 2.1 Compressed Natural Gas (CNG)

CNG is intended to remain under pressure without any active management until it is consumed. CNG is well suited for short-haul vehicle applications, but the lower energy density compared with LNG is a deterrent to long distance operations.

### *2.1.1 Compression and Rail Side Storage*

For the purpose of this study, trackside compression, distribution, and storage are out of scope, as are the connections to the land-based gas distribution network from the utility company. Depending on the feed pressure and the desired storage pressure, multiple stages of compression may be required. The standards, codes, and regulations, including site selection requirements, were examined for natural gas compression to pressures above 3,000 psi.

**Figure 2(d). CNG Compressor**

**Figure 2(e). CNG Storage Tank**

It is anticipated that some on-site stationary buffer storage of CNG will be required to facilitate seamless, continuous fueling operations. Pipes, fittings, valves, tanks, and related parts at the compression and refueling site are considered within the scope of this study. Ricardo has developed a system overview of the compression and storage site which includes identified ancillary safety systems and monitoring equipment.

### *2.1.2 Fueling*

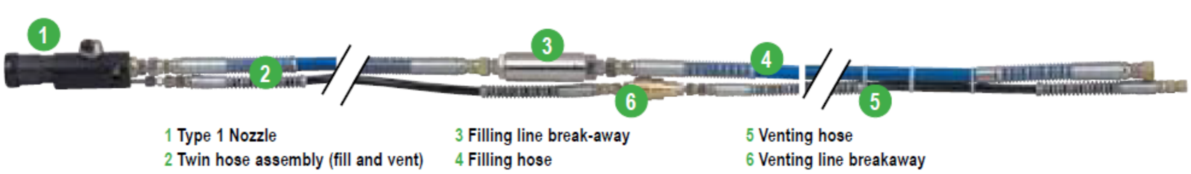


**Figure 2(f). CNG Fueling Hose Assembly**

The identification of codes, standards, and regulations associated with the filling operation, from stationary buffer storage or directly from the compressors, is included in the scope of this project. Components have been identified in the system diagram and include the filling management, controls, and safety systems. In the interest of interoperability, particular attention was paid to standards surrounding the interconnections between stationary and mobile systems.

**Figure 2(g). CNG Filling Nozzle**

### 2.1.3 Onboard Storage

The rail industry has significant experience in and institutional knowledge of the safe handling and transportation of pressurized gases, as well as hazardous and flammable cargo and fuels. Ricardo examined the applicability and relevance of existing rail codes, standards, and regulations for compressed, flammable gases.

**Figure 2(h). Carbon-Fiber CNG tanks**

Mobile storage of CNG has been an active and developing area of technology in recent decades. Motor vehicles are particularly burdened by the weight of high-pressure tanks designed to withstand impacts caused by accidents and collisions. As a result, exotic materials and construction techniques have been used to create strong but lightweight CNG storage devices for automotive and commercial vehicle use. Ricardo surveyed the developments in all types of onboard storage for standards potentially applicable to rail applications.

### 2.1.4 Transfer to Locomotive

For class 1 railroads, it is likely that CNG will be stored in a tender car and transferred to the locomotive as fuel is used. The hoses, interconnections, regulators, valves, and safety and monitoring devices needed to transfer CNG from a tender car to a locomotive are included in the system map.

### 2.1.5 Consumption

A wide variety of systems have been developed to allow the use of natural gas in an internal combustion engine. These range from direct injection (single-fuel configuration) to port injection (dual-fuel configuration). The natural gas fuel delivery lines, hoses, and valves are included in the project scope. Also included are the major commercially available types of natural gas ports and injectors for use in both

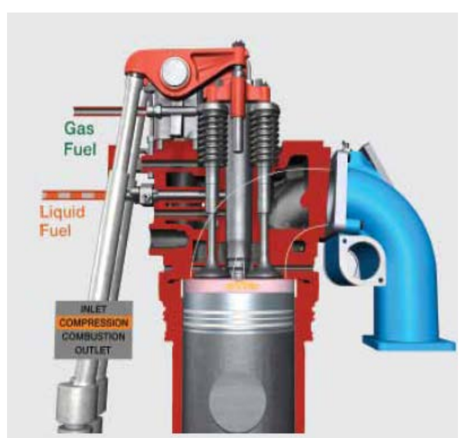


**Figure 2(i). Diesel/Gas Dual Fuel Engine Cylinder Cutaway**

spark ignited and compression ignition engines.

System provisions for fuel metering and control, as well as engine safety monitoring systems related to the natural gas fuel system, are included in the subsystem map.

## 2.2 Liquefied Natural Gas (LNG)

Cooling of natural gas below -260 °F causes it to condense into a liquid at near atmospheric pressure. This condensate provides energy density with low-pressure storage system requirements. However, LNG must be maintained at very low temperatures, and those temperatures introduce new potential hazards since the cryogenic liquid can cause injury and material failures. LNG has been used safely to store natural gas in stationary and certain mobile applications for decades, so there is a mature collection of codes, standards, and regulations for LNG which can contribute to this study for possible application to locomotive use. In addition, LNG has been transported in marine vessels for several decades, so this report offers a review of current practices and identifies agencies that have jurisdiction over this application.

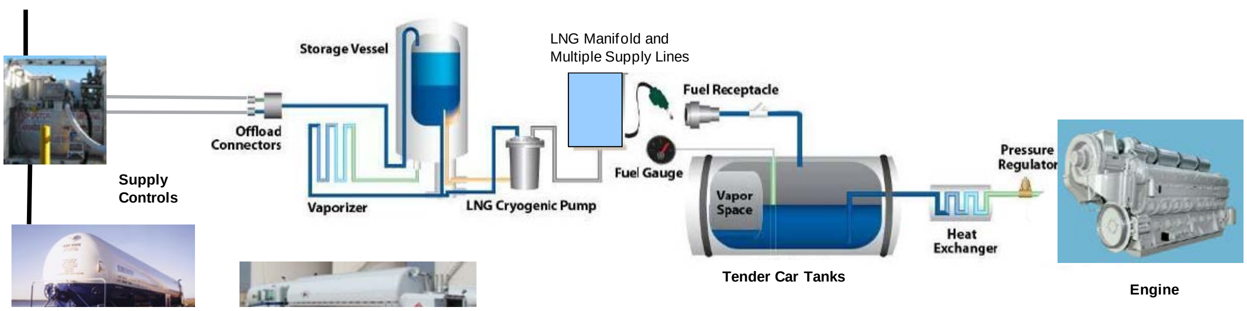


**Figure 2(j). LNG Consumption Cycle**

### *2.2.1 Liquefaction and Rail Side Storage*

**Figure 2(k). LNG Storage Tanks**

The liquefaction process equipment may be located at the wayside fueling yard or off site. The standards, codes, and regulations pertaining to the natural gas cryogenic compression equipment, including those related to site selection, are excluded from the scope of this project.

After cryogenic compression, the condensed LNG will be stored trackside in preparation for transfer to locomotives and fuel tender cars. Distribution pipes, fittings, valves, tanks, and related parts at the LNG storage site are also considered out of scope for this study.

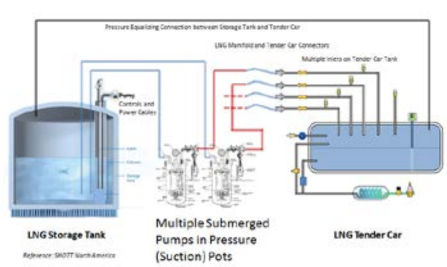


**Figure 2(l). LNG Fuelling Diagram**

### 2.2.2 Fueling

Submersible and in-line cryogenic pumps used to transfer LNG from the stationary storage tanks to the mobile storage, as well as all the pipes, hoses, valves, monitoring and control devices, and ancillary safety equipment, are included in the scope of this report.

**Figure 2(m). LNG Transfer Equipment**

### 2.2.3 Onboard Storage

The LNG tender storage tank, insulation, pipes, hoses, valves, pressure relief devices, and refrigeration equipment (if used) are included in the subsystem map.

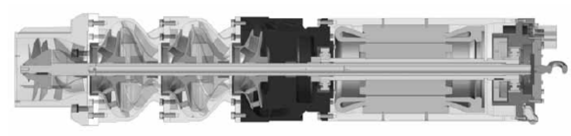

**Figure 2(n). Submersible Pump Cutaway**

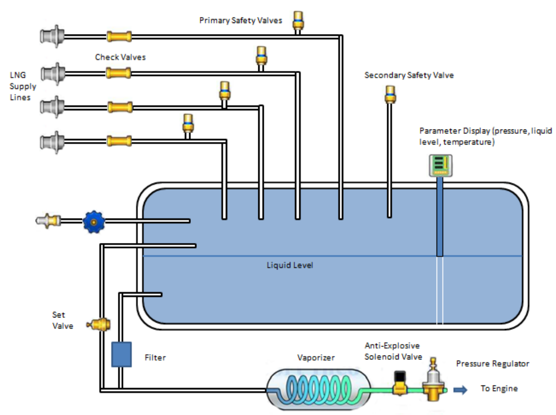


**Figure 2(o). Tender Car System Diagram**

Ricardo leveraged the rail industry's experience and institutional knowledge in safely handling and transporting flammable liquids and cryo-compressed liquefied gases like nitrogen to explore applicability and relevance of existing rail codes, standards, and regulations to LNG.

Onboard tank insulation and the potential need for refrigeration equipment is included in the system map.

LNG is also safely transported over the road by truck; therefore, the codes, standards and regulations relating to truck transport are applicable to rail use.

### 2.2.4 Transfer to Locomotive

Transfer of LNG to a locomotive may be done in either the liquid or gaseous form. For class 1 railroads, the emerging concept is the tender car stores the LNG and transfers the fuel as a gas to the locomotive. The hoses, interconnections, regulators, valves, safety and monitoring devices needed to transfer either LNG or CNG to the locomotive are included in the subsystem map.

### 2.2.5 Gasification

LNG must be heated and vaporized before it can be used as a fuel. This heating and vaporization may occur on the tender car, or on the locomotive. For tender car gasification, hot engine coolant may be used to provide

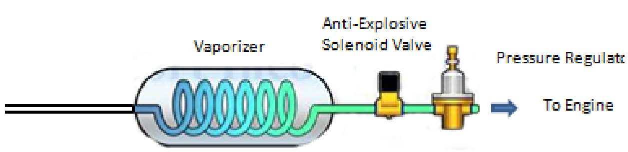


**Figure 2(p). LNG Gasification Diagram**

vaporization heat. Regardless of the location of the process, the components associated with gasification of LNG are included.

### 2.2.6 Consumption

After gasification, the consumption of LNG in an internal combustion engine is identical to the consumption of CNG. The natural gas fuel delivery lines, hoses, and valves are included in the project scope. Also included are the major commercially available types of natural gas ports and injectors for use in both spark ignited and compression ignition engines.

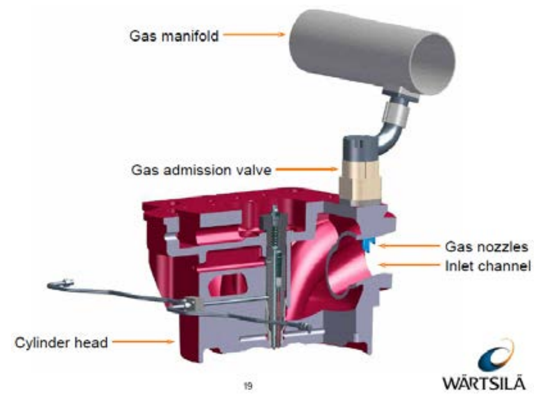


**Figure 2(q). Natural Gas Port**

System provisions for fuel metering and control, as well as engine safety monitoring systems related to the natural gas fuel system including gas leak detectors, if needed, are included in the subsystem map.

Summaries of the major CNG and LNG subsystems are shown in Figures 2(r) (CNG) and 2(s) (LNG).

High-Level Sub-System Map

# CNG processes from rail side to consumption are diagramed to identify classes of relevant component parts

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## CNG rail related systems and sub-systems


System process

**Rail side storage (CNG)**
- Incoming valving
- Incoming piping / hose
- Compressors
- Storage tank
- Storage monitoring
- Outgoing valving
- Outgoing piping / hose
- System monitoring
- Safety systems

**Transfer to tender - Fueling (CNG)**
- Valving
- Transfer piping / hose
- System monitoring
- Safety systems

**Tender storage (CNG)**
- Incoming valving
- Incoming piping / hose
- Storage tank
- Storage monitoring
- Outgoing valving
- Outgoing piping / hose
- System monitoring
- Safety systems

**Transfer to locomotive (CNG)**
- Valving
- Pressure regulation
- Transfer piping / hose
- System monitoring
- Safety systems

**Consumption (NG)**
- Incoming valving
- Fuel metering
- Incoming piping / hose
- Safety systems

Physical components

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**Figure 2(r). Summary of Major CNG Subsystems**

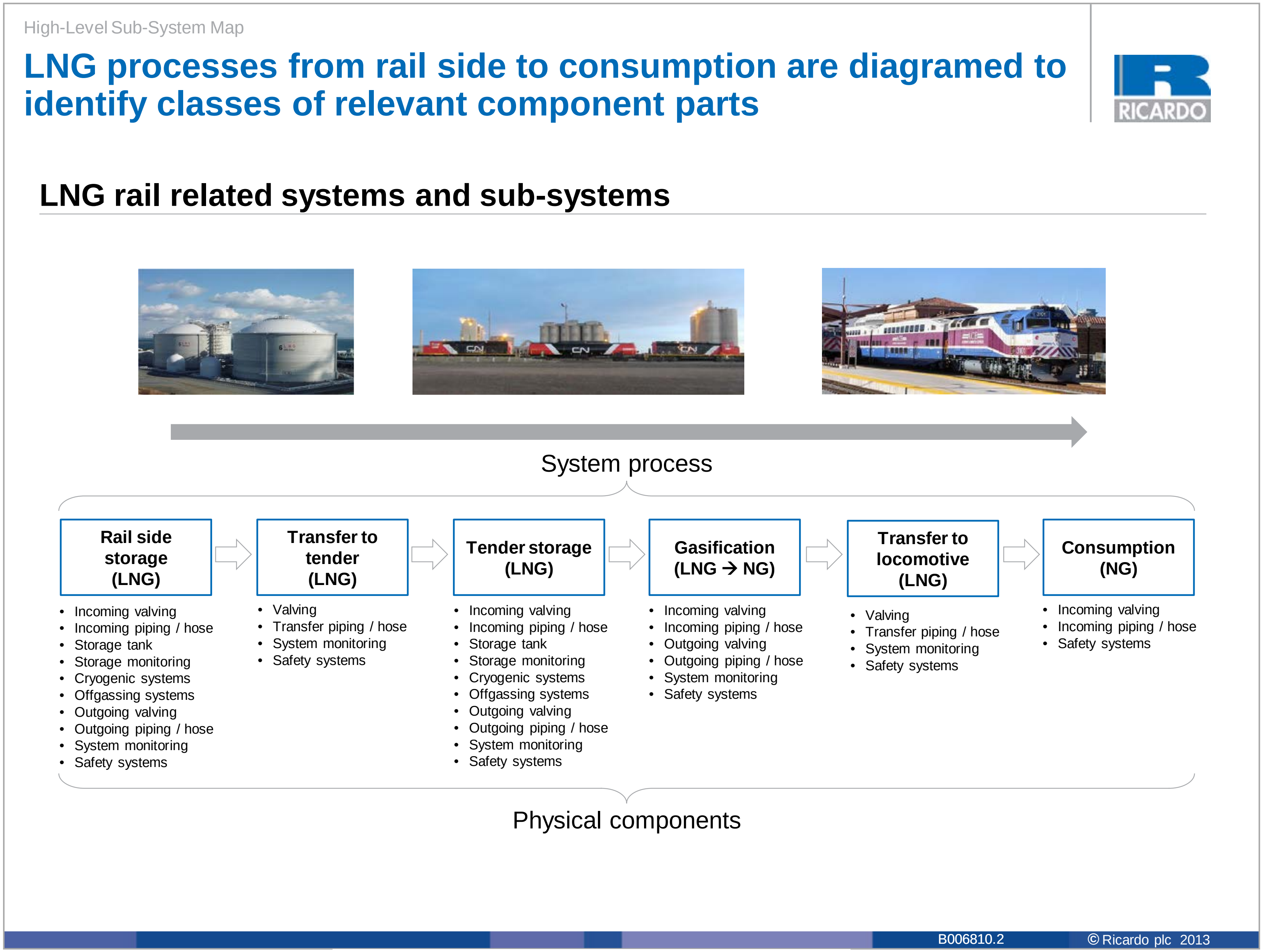


**Figure 2(s). Summary of Major LNG Subsystems**

Note: The category of safety systems includes those related to both worker safety (e.g., OSHA requirements), public safety (Federal, State, and local ordinances), and industry recommendations (e.g., use of static discharge grounding systems).

# 3. Codes, Standards, and Regulations Research

## 3.1 Identification and Acquisition Process

Researchers carried out an international review of codes, standards, and regulations. The approach was to make a focused review of the U.S. market and then compare with Germany, Japan, and Australia. These countries were selected because of their use of natural gas as a transportation fuel. For completeness, a high level review was made of practices in the emerging markets represented by BRIC countries (Brazil, Russia, India, and China).

Since natural gas is not widely used commercially as a rail fuel, the study surveyed documents and practices in all transportation industries. The goal was to provide a complete review of industry practice and requirements and indicate to which parts of the rail system map these might apply.

Each of the four key regions targeted, United States, Germany, Australia, and Japan, required different approaches to identify and acquire documents related to this project. Local Ricardo offices provided perspective and support in understanding the landscape of codes, standards, and regulations related to transporting natural gas in CNG or LNG form. Within each country, industry and domestic advocacy groups were identified which provided summary lists of pertinent codes, standards, and regulations for that region. A common thread found in the countries examined was a local version of the model UN regulation on the labeling and transportation of dangerous goods. The focus of the work was on national regulations, although it is recognized that local laws and ordinances can supplement the regulatory environment within each region.

### *3.1.1 ISO (International Organization for Standardization) Standards*

The ISO has a long series of standards issued for both LNG and CNG powered vehicles that are referenced by various governing bodies to supplement local literature. ISO has also developed many standards related to CNG storage vessels and cryogenic equipment that are widely referenced by all countries and organizations. In addition, countries like the United States and Japan choose to develop and adopt their local standards based on ISO standards, but many countries like Germany and Australia have chosen to adopt ISO standards directly.

### *3.1.2 United States and North America*

Advocacy organizations within the United States like the Clean Vehicle Education Foundation have created lists of codes and standards applicable to NGVs. Also, the Federal Transit Administration published several white papers in the late 1990s regarding the use of natural gas in LNG or CNG form as a fuel for city buses. These sources formed the starting point for research into codes, standards, and regulations applicable to natural gas as a locomotive fuel. The Association of American Railroads (AAR) cooperated in the creation of this report and provided guidance in identifying codes and standards.

State and local level regulations like the CNG and LNG regulations issued by the Railroad Commission of Texas were not reviewed as part of this effort.

#### 3.1.2.1 U.S. Regulations

The U.S. regulations examined, which include regulations under the Department of Transportation (DOT), Title 49, the Environmental Protection Agency (EPA), Title 40, and the Department of Labor (DOL), Title 29, related mostly to natural gas on a moving vehicle. Naturally, most of the examined regulations are in CFR Title 49 – Transportation. Under Title 49, Parts 229, 230, 232, and 238 relate directly to rail. Also reviewed were commercial truck and passenger car regulations in Part 571 for vehicle fuel safety, Part 393 for CNG tanks, Part 178 for LNG tanks, and Part 193 for LNG handling. Dispensing and emissions standards are covered under Title 40 – Environment. Lastly, occupational health and safety regulations under Title 29 – Labor were reviewed for applicability to LNG or CNG use and fueling in a rail application, and relevant parts were added to the list of covered regulations.

#### 3.1.2.2 North American Codes and Standards

Fire codes issued by the National Fire Protection Association (NFPA) cover a wide variety of pertinent topics including fueling and fuel stations, vehicle fuel systems for gaseous fuel, usage of gas as a combustion fuel, LNG vehicle systems, LNG liquefaction facilities, and LNG storage. All of these are supported by the national electrical code.

AAR is actively developing railroad standards for the handling, storage, and consumption of natural gas as a locomotive fuel. AAR has formed a Natural Gas Fuel Tender Technical Advisory Group (NGFT-TAG) to identify and develop new rail standards to enable the use of natural gas as a railroad fuel.

American standards organizations American National Standards Institute (ANSI), the Society of Automotive Engineers (SAE), and the Compressed Gas Association (CGA) have developed standards applicable to natural gas fuel and storage systems for passenger cars and commercial vehicles. Many of the ANSI standards were co-developed with the Canadian Standards Association (CSA) and cover a broad range of components. These standards are frequently cited by other codes, regulations, and standards globally.

### 3.1.3 Germany and Europe

Germany has a particularly sophisticated set of codes, regulations, and standards pertinent to the use of natural gas as fuel for locomotives. This sophistication arises from overlapping national bodies in Germany at the country level, and the European Union level, and the complementary United Nations Economic Commission for Europe (UNECE). Furthermore, Germany has a well-established set of industries and engineering traditions that encourages the development of standards.

#### 3.1.3.1 German Regulations

As a member of the European Union, Germany has some regulations that are extensions of the European Parliament’s rail standards, which are in effect throughout Europe. Germany is also a member of the Organization for International Carriage by Rail (OITF) with 42 member states in Europe, North Africa, and the Near East. The OITF issues uniform standards for member states on the rail transport of dangerous goods covering both LNG and CNG transport by rail.

Other regulations in Germany are national and apply only within the country. Such is the case with ordinances dictated by mandatory safety and casualty insurance for the protection of industrial workers and the laws governing filling equipment for compressed gas cylinders.

The United Nations Economic Commission for Europe has a Working Party on Global Technical Regulations (WP.29/GRPE) for Pollution and Energy regulations for transportation and under that umbrella there is an Informal Working Group for Gaseous Fueled Vehicles (GFV). The GFV working group develops and informs European regulations, and while they are discussing modifications and additions to existing regulation, there are currently four key UNECE regulations (49, 67, 110, 115) affecting natural gas powered vehicles. UNECE 49 covers emissions and is not restricted to vehicles fueled by natural gas. UNECE 67 covers fuel storage and handling equipment on commercial trucks and buses burning LNG. UNECE 110 covers all unique components necessary to fuel a vehicle with CNG. UNECE 115 covers retrofits of vehicles to CNG or LNG. Current discussions are underway regarding the applicability of UNECE 115 on Heavy Duty Dual Fuel (HDDF) applications and retrofits. A draft regulation is under development to specifically cover HDDF retrofits; the new regulation will be added to the current set of UNECE regulations.

#### *3.1.3.2 German and European Codes and Standards*

The German Federal Institute for Occupational Health and Safety (BAuA) and the Committee on Industrial Safety (ABS) have issued codes useful in the deployment of natural gas as a transportation fuel. These codes classify and label hazardous substances, filling and storage of pressurized and flammable gas, and mitigate the dangers of potentially explosive atmospheres.

Standards regarding natural gas fuel published by the German Institute for Standardization (DIN) concentrate mainly on stationary applications and natural gas storage and transportation. These DIN standards are closely related and similar to standards issued by the ISO.

### *3.1.4 Australia*

Australian regulations often reference particular Australian Standards; hence, the two appear to be tightly related. Gas Energy Australia is an advocacy group promoting the value and benefit of using LPG, CNG, and LNG in transportation as well as other areas. They have identified Australian standards and technical specifications that enable safe and legally compliant natural gas consumption and have an organized standards management committee.

#### *3.1.4.1 Australian Regulations*

National regulations appear less numerous in Australia than in North American and European countries. The Ministry of Local Government, Territories, and Roads issues Australian Design Rules (ADRs), which are regulations mandating particular features on road vehicles. The only ADR pertinent to NGVs is a section of ADR 44 covering LPG retrofits which has recently been amended to cover natural gas. The national government’s Rail Safety National Law and the Dangerous Goods Act are typically mirrored and enforced by the provinces.

#### 3.1.4.2 Australian Codes and Standards

SAI develops and manages a wide variety of Australian Standards. There are many Australian Standards with clear applicability to natural gas fueled vehicles. Several bespoke standards are written expressly for CNG and LNG fueled vehicles. These cover onboard hardware, storage, operation, and maintenance. Some of these were originally written for LPG fuel systems, but have been expanded to cover likely areas of synergy between LPG vehicles and CNG or LNG vehicles. There are also standards covering gas fueled small industrial vehicles commonly used in factories and warehouses. Australia's standards for tankers for cryogenic liquids, flammable liquids, and dangerous goods are all used in the transport of LNG. Pressure vessel and pressure piping standards were also reviewed because of their deep integration with the other standards covered.

### 3.1.5 Japan

As a country with limited domestic production of natural gas, Japan does not seem to have strong advocacy groups encouraging the consumption of natural gas, as has been seen in other countries. Within the scope of this study, it was not possible to identify an established Japanese organization committed to providing information and guidance on standards and regulations related to using natural gas as a transportation fuel. It is possible the advocacy done in Japan is carried out by individual companies.

#### 3.1.5.1 Japanese Regulations

Japanese laws and regulations of natural gas as a transport fuel appear to hinge on three key acts: the High Pressure Gas Safety Law (HPGSL), the Industrial Safety and Health Law (ISHL), and the Fire Service Law (FSL). The technical details of regulation are codified in quasi-government organizations established by the law. The HPGSL established a High Pressure Gas Safety Institute which publishes standards specifying equipment and procedures for handling high pressure gases. These standards are tied to ordinances issued by Japan's METI. It is our understanding that these ordinances are consistent with the standards issued by the High Pressure Gas Safety Institute, although a more detailed review of the METI regulations was beyond the scope of the current study.

#### 3.1.5.2 Japanese Codes and Standards

Japan has a thriving automotive industry and the Japanese Automotive Standards Organization (JASO) is as organized and sophisticated as the rest of the domestic Japanese industry. JASO is the Japanese member of SAE International. JASO has developed five standards detailing equipment use for CNG fueled vehicles.

The High Pressure Gas Institute (KHKS) has also developed several standards to describe the equipment and inspection procedures around LPG fuel systems, high pressure containers, and tank trucks. Seven of these KHKS standards were selected for review as part of this exercise.

## 3.2 Codes, Standards, and Regulation Review Process

The review process started with the set of information required from each document. The standard summary document was developed by Ricardo in consultation with FRA and AAR and based on informal discussions with railroad industry contacts. The basic information in the summary page was set by the project proposal. The name, description, service sector, geographical coverage, and authorizing/issuing agency were all required for the project. To this basic framework other insights were added where relevant to the discussion about natural gas as a fuel for locomotives.

Examination of the references to other documents helped demonstrate their interconnectedness to other documents. The references also helped build the list of documents to be reviewed. Those standards with a large number of references typically referenced related standards issued by the same organization (for example, Australian Standards reference many other Australian Standards). It is clear from the research that the authors of standards from around the world were aware of related standards from other organizations and countries. ISO is the most commonly cited organization, but standards from ASME, ASTM International, and ANSI are also frequently cited in the standards written by other organizations.

To provide a detailed reference for the documents, a cross-match was made between the regulations, codes, and standards and the specific components in the system map developed for CNG and LNG use in rail. The level of detail found within the document for each type of component is denoted on a four point scale from an open circle for a generic mention or reference to another document, to a half circle for requirements with incomplete engineering specifications, to a full circle for documents including in-depth design and engineering requirements for the component.

Often, documents provide guidance on entire systems without offering details about particular parts within the system. Nevertheless, they are useful for the operation or maintenance of NGVs. The written summaries of these types of documents cannot identify applicability to specific gaseous fuel hardware, so the matrix shows no part applicability; however, these documents were included in the review because they were determined to be relevant to NGVs or locomotive fueling.

For this project, the researchers reserved a space in the lower right hand box of the summary page for their qualitative impressions of the standards, codes, and regulations documents under review. These comments can be the key take-aways and industry practices not covered in the other parts of the summary page. The overall mission of the review process was to provide the reader of the report with the key information covered by the various standards, codes, and regulations.

## 3.3 BRIC Countries

Codes, standards, and regulations documents from BRIC countries were not reviewed in detail as part of this study. Research did, however, reveal NGV activity in each of the BRIC countries and identify regulatory agencies, standards organizations, and companies involved in NGV development.

### 3.3.1 Brazil

Natural gas safety and distribution is regulated by the National Agency of Petroleum, Natural Gas, and Biofuels (ANP). Railroads, commercial vehicles, and overland transportation infrastructure are regulated by the National Transportation Agency (ANTT). The National Institute of Metrology, Standardization, and Industrial Quality (INMETRO) has issued quality and safety requirements for aftermarket retrofits of gaseous fuel for vehicles. However, since INMETRO is a government agency, these requirements have the force of law and are thus regulations. The Brazilian Institute of Environmental and Renewable Natural Resources (IBAMA) has issued emissions requirements for natural gas fueled vehicles.

The CNG committee of the Brazilian Institute of Oil, Gas, and Biofuels (IBP) recently held several workshops aimed at encouraging the use of natural gas medium and heavy duty vehicles. Commercial vehicle manufacturer MAN presented a prototype CNG municipal bus with a Bosch dual fuel diesel – natural gas engine as part of this ongoing effort (as of 2013). Indeed, there is growing interest in increasing the sustainability of transportation in the Rio de Janeiro area as part of the preparations for the upcoming FIFA world cup in 2014 and summer Olympic games in 2016.

### 3.3.2 Russia

Gazprom, the state-owned energy company, expects NGV to be an attractive market for future growth, both in Russia and in the European countries to which it exports gas. Russia is the world's second-largest gas producer after the United States and has realized large economic and environmental benefits in vehicle demonstrations. Earlier this year, Gazprom and Russian Railways signed a Memorandum of Cooperation with the aim of using gas as a fuel for railroad applications. The parties agreed to jointly develop and implement programs to design, test, and use gas-powered locomotives. To this end, Gazprom and Russian Railways will prepare a draft of Federal Target Program on Natural Gas as a Motor Fuel for the Railway Rolling Stock between 2014 and 2020. Russian Railways plans to gradually increase the number of gas-powered locomotives and their maintenance facilities along with the development of NGV fuel production capacities and refueling infrastructure.

Regulations in Russia have already provided guidance pertaining to use of natural gas as a fuel for cars. Even before the auto industry officially joined in, aftermarket retrofit kits were readily available. The Russian National Gas Vehicle Association (NGVRUS) provides control and guidance to utility and railway enterprises to promote the use of natural gas as a propulsion fuel, but, overall, regulations in Russia are quite limited.

### 3.3.3 India

In the fall of 2013, the Ministry of Railways within the Indian government showed interest in exploring both CNG and LNG as potential replacement fuels for diesel powered locomotives. CNG is being looked at as more of a short distance fuel, and LNG is being considered for longer distance trains. Research Design & Standard Organization, a research wing of state-owned Indian Railways, is currently working with engineering service providers to develop an LNG-based prototype locomotive. Once proven in the field, 20 more are planned based on the same concept.  After the initial deployment, it is expected to take 2–3 years for the LNG locomotives to become commercially available.

A short distance Diesel Electrical Multiple Unit (DMU) has been converted into a CNG-driven locomotive in Delhi and is expected to be replicated in 40 other trains in the future.

The Bureau of Indian Standards (BIS) has developed sixteen standards for road vehicles covering equipment related to CNG, LNG, and LPG; half of these have been released in the last 2 years.

### *3.3.4 China*

China is responding to upward pressure on oil prices by investing in new transportation fuel technologies, including natural gas. According to an article by CVWorld, the NGV population in China is made up of more than 1.1 million vehicles, almost all CNG.

Domestic production of natural gas in China is also growing and the Chinese are working with foreign companies to help develop the resource.  GE has begun manufacturing reciprocating compressors in China for their small-scale "CNG in a Box" fueling solution.  GE signed a Memorandum of Understanding (MOU) in September 2013 to produce 260 of these systems in China over the next 3 years.

The Sichuan Provincial Institute of Automotive Engineering Professionals has established an NGV committee.

# 4. Gap Analysis and Compilation

Often, codes, standards, and regulations found pertinent to natural gas as a transportation fuel or related to locomotive safety do not contain specific requirements for components or systems. The general requirements create a framework of performance attributes and requirements that allow the industry some latitude to develop alternative engineering approaches in compliance with the requirements. The following sections cite codes, standards, and regulations which have explicit guidance or specifications relating to particular components or systems. While some of the regions studied have fewer codes, standards, or regulations with *explicit requirements*, complementary documents with general requirements help complete coverage.

## 4.1 Natural Gas Fueling

In the United States, fueling is covered by the national fire code. As the fueling operation is associated with a fixed structure and also a place of business, this is a natural fit for the NFPA. These codes are often given the force of law within the building and fire codes of municipalities who have the authority to inspect and enforce local fuel dispensing establishments.

North American standards organizations have also covered natural gas powered vehicle fueling as part of their NGV standards. SAE, ANSI, and CSA have issued standards covering components of both CNG and LNG fueling.

In Germany, the fueling operation is also strictly regulated within the OTIF agreements for rail transport and the requirements for mandatory insurance for handling gases and liquefied gases. There is also one Federal regulation, TRB 851, stipulating some requirements for fueling hoses and valves.

Several codes in Germany cover the fueling operation. TRGS 751 / TRBS 3151 provides technical guidance on preventing dangers at filling stations, TRBS 2141 covers hazards related to pressurized gas/vapor, and TRBS 2153 discusses the prevention of ignition hazards due to the buildup of electrostatic charge. Refueling connectors (quick connectors) for CNG are covered under ISO 14469 parts 1–3.

Australian standards cover the fueling with several standards, including one AS 5092 devoted exclusively to CNG refueling stations. LNG fueling operations are covered by Australian Standard AS 3961.

While it is possible that regional gaps exist in codes, standards, and regulations regarding fueling systems for vehicles fueled with LNG or CNG, taken as a whole, we found documents covering the entire gamut of vehicle fueling components and operations. The OTIF regulations in Europe are particularly pertinent to fueling rail tender cars with natural gas. Other codes and standards were written for similar, but not exactly the same, rail applications.

## 4.2 Onboard Natural Gas Storage

Locomotives have contained high pressure gases and boiling liquids since their invention in the 19th century. The ASME Boiler and Pressure Vessel Code (BPVC) is widely cited throughout the world. The United Nations' model regulation on the labeling and safe handling of dangerous goods is similarly influential. Indeed, the transport of material similar to LNG and CNG is established practice among the world's rail carriers.

Where natural gas onboard storage for use as a transportation fuel is concerned, the United States has several pertinent regulations. Three separate OHS standards cover compressed gases, flammable liquids, and LPG (which could be of interest for this application). Three FRA regulations cover cut-off safety requirements, venting, and grounding of fuel tanks. Several other regulations within Title 49 spell out requirements for the transport of natural gas.

There are two U.S. fire codes covering onboard vehicle equipment for natural gas: NFPA 52 the Vehicular Gaseous Fuel System Code and NFPA 57 the LNG Vehicular Fuel System Code. SAE, ANSI, CSA, and the Compressed Gas Association (CGA) cover onboard vehicle storage systems for LNG and CNG in several North American standards.

German safety regulations include the handling of dangerous goods as part of the mandatory casualty insurance and the international agreements on the handling of railway freight. Additionally, the UNECE has two regulations (110 and 115) covering the onboard equipment for CNG and LNG fueled vehicles, including the storage tanks and associated components.

Tanks, valves, hoses, fittings, regulators, and methane sensors associated with the onboard storage systems are covered by many ISO standards, as detailed in Appendix A. ISO also issued a number of standards around tanks and pressure vessels designed for cryogenic liquids which are not specific to vehicles but could be pertinent to rail storage of LNG fuel.

Australian Federal regulation of components is limited to Design Rule 44, which provides few specifics on components, and the Rail Safety Law, which is similar to other rail regulations in North America and Europe. The project researchers also reviewed 10 Australian Standards covering onboard storage, pressure vessels and piping for LNG, CNG and LPG, although the regulations do not provide specific guidance on fuel storage.

## 4.3 Transfer to Locomotive

Gaseous fuel movement from a tender car to the locomotive presents engineering challenges unique to the application which are not completely covered by any of the codes, standards, or regulations studied. However, there are documents providing guidance on the individual component elements of the fuel transfer system (i.e., fittings, hoses, regulators, etc.). Hoses and fittings are covered most often, and the breakaway function of the fuel transfer is the least defined system element, but it is not completely absent from the reviewed documents.

In the United States, fuel transfer components are explicitly covered by SAE J2343 and several of the ANSI NGV standards. The NFPA code 52 contains requirements for the hoses, breakaway and regulators. A few Title 49 CFRs address hoses and breakaway, and Title 29 CFR 1910 has specific requirements for hoses and fittings.

ISO covers all the elements of fuel transfer for LPG, LNG, and CNG systems. LPG hoses and fittings are covered under ISO 8789. LNG vehicle components are covered by ISO 12614 and cryogenic hoses and regulators are detailed in ISO 21012 and 21013, respectively. CNG vehicle component requirements for hoses and fittings are documented in ISO 15500 and 15501.

German regulations include the Federal BGR 500, operating systems for handling gases, RID, the international agreement for rail transport of dangerous goods, and UNECE regulations 67, 110, and 115. Transfer hoses and fittings are mentioned in the code for accident prevention while handling liquefied gases: BGV D34.

Australian standard AS 1869 specifies hoses and fittings for LPG vehicle applications and may have some applicability for tender to locomotive transfer. AS 2739 covers methane fuel systems for vehicle systems more explicitly and includes component specifications for hoses, fittings, regulators, and breakaway devices which could be adapted for locomotive use. Three specialized Australian standards also may contain guidance for transfer systems: these are AS 3961 for the storage and handling of LNG, AS 4041 pressure piping, and AS 4983 gas fuel systems for industrial vehicles.

Japanese standard KHKS 0150 includes specifications for high pressure gas regulators which may have applicability for gaseous fuel transfer from a tender car to a locomotive.

## 4.4 Gasification of LNG

LNG must be gasified before it can be used to fuel an internal combustion engine, so this critical function is covered by codes and standards written for LNG fueled vehicles. Typical components in this system are a heat exchanger or vaporizer, valves, and pressure regulators.

SAE J2343 includes requirements for the vaporizer while several of the ANSI NGV standards specify valves and regulators for the gasification system. The NFPA code 52 for gaseous vehicle fuel systems and withdrawn code 57 specifically for LNG fueled vehicles both cover the gasification process.

U.S. regulation title 49 CFR 229.93 has requirements for valves, and title 29 CFR 1910 section 110 also has requirements for valves related to worker safety.

ISO draft 12614 part 16 is dedicated exclusively to the gasification vaporizer for vehicles and ISO 24490 covers the vaporizer from a more generic cryogenic vessel and pump perspective. Valves and regulators associated with gasification are covered in other parts of ISO 12614 and the CNG ISO standards 15500 and 15501.

German regulations specifically applicable to the LNG gasification systems are the UNECE regulations 67, 110, 115, and BGV D34, the code for accident prevention while handling liquefied gas.

Australian standards have requirements for the gasification system in both the LPG fuel system standard AS 1425, the natural gas fuel system standard AS 2739, and the storage and handling of LNG AS 3961. The pressure piping standard, AS 4041, covers valves used in the gasification system, and gas fuel system standard for industrial vehicles AS 4983 includes some guidance on valves and regulators in the gasification system. Likewise, Japanese LPG supply standard KHKS 0501 provides guidance on regulators which could be used in the gasification system.

The Japanese automotive standard JASO E205 contains more explicit requirements for valves used in vehicle gasification systems.

## 4.5 Consumption

The consumption cycle of a locomotive closely resembles burning methane in engines for other types of vehicles. Given the similarities in the gaseous fueling system between locomotives and other vehicles, codes and standards written for other classes of vehicles are more likely to be applicable to locomotives.

In the United States, ANSI NGV standards 3.1, 4.2, 4.6, and B109-01 provide specific requirements for the valves, regulators, fittings, pipes, and sensors used in the gas consumption cycle. SAE J2343 also provides some specifics on the consumption system, including fuel metering. The NFPA fire codes 52 and withdrawn code 57 provide requirements for the valves, regulators, pipes, hoses and sensors used in gas consumption on a vehicle. U.S. title 49 CFR 229 contains several sections with specific guidance for vehicle gaseous fuel system components. Also, U.S. title 29 CFR part 1910 section 110 contains requirements for valves, regulators, pipes, and hoses for LPG consumption.

The ISO standards studied cover every category of component in the gas consumption system of a vehicle for LPG, LNG, and CNG. ISO 8789 has specifics on LPG pipes, hoses, and fittings. ISO 10876 provides details on LNG metering and sensors. Further details of LNG vehicle hardware for the gas consumption cycle are included in the ISO draft 12614 standard. CNG consumption specific vehicle hardware is covered by ISO 15500 and ISO 15501.

German vehicle regulations for gaseous fuel consumption include BGR 500 with guidance on valves, regulators, pipes, and hoses. Also, the UNECE regulations 67, 110, and 115 mandate requirements for the components related to gas consumption and the gaseous engine fueling system. The German accident prevention code BGV D34 also contains guidelines for fittings, hoses, and pipes related to gaseous fuel consumption.

Engine LPG fuel systems and components are specified by Australian standards AS 1425 and AS 1869. AS 2739 provides details for road vehicle methane fuel systems and components while AS 4983 does the same for industrial vehicles and forklifts. Some gas carrying components of the consumption system are also covered by the pressure piping Australian standard AS 4041. Vehicle retrofits to gaseous fuel are regulated in Australia by NCOP9: light vehicle fuel system construction modifications.

Two Japanese automotive standards have explicit requirements for valves, regulators, fittings, pipes, and hoses used in gaseous fuel consumption. These are JASO E205, CNG vehicle valve requirements, and JASO E207, CNG vehicle tubes and fittings.

## 5. Conclusion

Ricardo developed a subsystem map for locomotive natural gas fuel systems from wayside storage/fueling to gas consumption concentrating on the two most common methods for mobile storage of natural gas: CNG and LNG. The study found that at the national level, codes/regulations and standards were established for NGV fuel applications in the United States, Europe, Australia, and Japan. However, codes, standards, and regulations written specifically for rail applications were scarce.

One hundred eighty one documents from the four primary countries were studied. Summary sheets for each of these are contained in the appendix, along with a detailed cross reference relating the documents to the system maps. Additionally, Ricardo reviewed progress on standards and codes/regulations in the emerging BRIC countries. In all of the BRIC countries, natural gas had been deployed as a vehicle fuel, and demonstrations and discussions were evident on natural gas rail applications. Although not reviewed in detail, Ricardo did observe code/regulation and standard activities at least starting, if not established, in the BRIC countries for natural gas. The activities are similar to those that have been undertaken in the United States, Germany, Japan, and Australia.

This document offers an overview of selected codes, standards, and regulations presumed applicable to gaseous fueled vehicles, not a complete review of all natural gas standards. The observations within this report are not recommendations for the design or safety of natural gas systems.

# 6. References

References included in appendices.

## 6.1 Codes, Standards, and Regulations in Appendix by Application

| Application Area | Standards | Codes & Documents | Regulations | Total |
|---|---|---|---|---|
| **Rail** | | 1 | 27 | 28 |
| **Other Transportation** | 73 | 10 | 11 | 94 |
| **Marine** | 4 | 1 | 2 | 7 |
| **Stationary** | 23 | 15 | 14 | 52 |
| **Total** | 100 | 27 | 54 | 181 |

## Abbreviations and Acronyms

| | |
|---|---|
| AAR | Association of American Railroads |
| ABS | German Committee on Industrial Safety |
| ADR | Australian Design Rules |
| ANP | Brazil National Agency of Petroleum, Natural Gas, and Biofuels |
| ANSI | American National Standards Institute |
| ANTT | Brazilian National Transportation Agency |
| AS | Australian Standard |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| BAuA | German Federal Institute for Occupational Health and Safety |
| BIS | Bureau of Indian Standards |
| BPVC | ASME Boiler and Pressure Vessel Code |
| BRIC | Brazil, Russia, India, and China |
| CFR | Code of Federal Regulations |
| CGA | Compressed Gas Association |
| CNG | Compressed Natural Gas |
| CSA | Canadian Standards Association |
| DIN | German Institute for Standardization |
| DoT | US Department of Transportation |
| EPA | US Environmental Protection Agency |
| FMVSS | Federal Motor Vehicle Safety Standards |
| FSL | Japanese Fire Safety Law |
| GFV | Gaseous Fueled Vehicle |

| | |
|---|---|
| HPGSL | Japanese High Pressure Gas Safety Law |
| IBAMA | Brazilian Institute of Environment and Renewable Natural Resources |
| IBP | Brazilian Institute of Oil, Gas, and Biofuels |
| INMETRO | National Institute of Metrology, Standardization, & Industrial Quality |
| ISHL | Japanese Industrial Safety and Health Law |
| ISO | International Standards Organization |
| JASO | Japanese Automotive Standards Organization |
| KHKS | Japanese High Pressure Gas Institute |
| LNG | Liquefied Natural Gas |
| LPG | Liquefied Petroleum Gas (propane) |
| METI | Japan Ministry of Economy, Trade, and Industry |
| MOU | Memorandum of Understanding |
| NFPA | National Fire Protection Association |
| NGFT-TAG | AAR Natural Gas Fuel Tender – Technical Advisory Committee |
| NGRUS | Russian Natural Gas Fuel Association |
| OITF | Organization for International Carriage by Rail |
| OSHA | Occupational Safety and Health Administration |
| RDSO | Indian Research, Design, and Standards Organization |
| SAE | Society of Automotive Engineers |
| SAI | Standards Australia International |
| UN | United Nations |
| UNECE | United Nations Economic Commission for Europe |