AAR Locomotive Committee

H₂@Rail Workshop – Alternative Fuels Update

Michael Fore
Director – Technical Services-Locomotive Committee Manager
The Association of American Railroads

About Us and the Safety And Operations Department

- Founded in 1934, the Association of American Railroads (AAR) is the world’s leading railroad policy, research, standard setting, and technology organization that focuses on the safety and productivity of the U.S. freight rail industry.

- AAR Full members include the major freight railroads in the United States, Canada and Mexico, as well as Amtrak.

- Affiliates and Associates include non-Class I and commuter railroads, rail supply companies, engineering firms, signal and communications firms, and rail car owners¹.

- At the AAR, the tasks of research, technological development support and standard setting are part of the Safety and Operations Department (S&O) mission. Within the S & O Department are the Technical Services Committees under the Technical Services Group.
The AAR's Technical Services group of committees are responsible for the development, maintenance, and enforcement of North American railroad interchange rules, mechanical standards, and component specifications that promote an acceptable level of safety and efficiency.

Users of these publications include North American Class I, shortline, and regional railroads, Federal Railroad Administration, Transport Canada Railway Safety Directorate, private railcar owners, shippers, and freight car, locomotive, and component suppliers.
The Association of American Railroads

Safety And Operations Department and The Technical Services Group

- Technical Services Committee members include railroad and non-railroad experts in the areas shown in the accompanying organization chart. These technical experts provide direction on the development and maintenance of industry standards.
The Locomotive Committee's mission is to establish, improve, and maintain locomotive standards and rules.


These standards, specifications, and recommended practices are for the purpose of safety and interoperability.
The AAR Locomotive Committee (LC) has several docket's by and for the reporting and review of developments in alternative fuels.

The primary docket is the aptly named LM-126 Alternative Fuels Issues (Biodiesel, Renewable, etc.)

Two (2) other Committee docket items are linked to the Alternative Fuels Issues docket.

• LM-121 Natural Gas Fuel Tenders.
• LM-139 LC & LMOA Projects Coordination
  • (TAG Liaison & Updates)

• And at times, the LM-013 Locomotive Emissions docket has received updates about alternative fuels and the potential effect on locomotive emissions regulations
LC Alternative Fuels Docket Items:
LM-139 LC & LMOA Projects Coordination
(TAG Liaison & Updates)

- **LMOA** stands for *Locomotive Maintenance Officer’s Association*.

- *The LMOA is a Non-Profit organization consisting of Railroaders and Rail Vendors for the sole mission to offer improvements and recommendations for a safer and more reliable Rail Operation*².

- Through mutual members, the AAR Locomotive Committee & the LMOA have developed and continue to grow a working linkage with the LMOA and its various technical subject matter experts and other interested parties on a variety of topics.

- Under LM-139 the LC can receive and consider LMOA input and recommendations for standard setting via AAR LC initiated requests for papers that the LMOA may choose to research and publish within their annual schedule.
LC Alternative Fuels Docket Items:
LM-121 Natural Gas Fuel Tenders.

AAR Natural Gas Fuel Tender TAG Mission Statement

Develop Standard(s) for future Natural Gas Fuel Tenders for the railroad industry to support the use of natural gas (methane) as an alternative locomotive fuel.

- Safety
  - Minimize risk of outer and inner tank breaches & pressure spikes
- Tender design and construction
- Tender-to-locomotive connections
- Tender-to-refueling
- Tender interoperability and interchangeability between railroads
- Maintainability

A significant effort resulted in draft specifications, and a safety analysis. Today’s focus is on the standard.
**LC Alternative Fuels Docket Items:**
LM-121 Natural Gas Fuel Tenders.

AAR Manual of Standard and Recommended Practices (MSRP)
Section T - Interoperable Fuel Tenders for Locomotives,
*Specification M-1004 – Specifications for Fuel Tenders*

*Note - Section T has not yet been published*

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### 1.6 Organization of this Specification

This specification is organized into the following chapters and appendices:

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<tr>
<th>Chapters</th>
<th>Appendices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Introduction and General Requirements</td>
<td>A Tender Design Application Submission and Approval</td>
</tr>
<tr>
<td>2 Fuel Tank Requirements for Liquefied Natural Gas</td>
<td>B Tender Design Attributes</td>
</tr>
<tr>
<td>3 Fuel Tank Requirements for Compressed Gas</td>
<td>C Basic Process and Instrumentation Diagram</td>
</tr>
<tr>
<td>4 Fuel Tank Requirements for Other Alternate Fuels</td>
<td>D Tender End Plate Diagram</td>
</tr>
<tr>
<td>5 Piping, Service Equipment and Protective Structures</td>
<td>E Locomotive End Plate Diagram</td>
</tr>
<tr>
<td>6 Tender Control Unit</td>
<td>F Tender-Fill Interface Connections</td>
</tr>
<tr>
<td>7 Tender-to-Locomotive Interface</td>
<td>G Wiring and Electrical Hardware</td>
</tr>
<tr>
<td>8 Tender-Fill Interface</td>
<td>H Painting and Stenciling</td>
</tr>
<tr>
<td>9 Car Body Structure and Design</td>
<td>I Drain and Purge Procedures for Fuel Tender Hose Assemblies</td>
</tr>
<tr>
<td>10 Track Worthiness</td>
<td>J Inspections and Maintenance</td>
</tr>
<tr>
<td>11 Crashworthiness Requirements</td>
<td>K Qualification</td>
</tr>
<tr>
<td></td>
<td>L Documentation</td>
</tr>
<tr>
<td></td>
<td>M Tender Health and Status Protocol</td>
</tr>
<tr>
<td></td>
<td>N Prototype Tests for Compressed Gas Fuel Tanks</td>
</tr>
<tr>
<td></td>
<td>O Fire Resistance/Bonfire Test</td>
</tr>
</tbody>
</table>

Specification M-1004 – Specifications for Fuel Tenders

Chapter 1, *Introduction and General Requirements*, covers:

- General Design Parameters
- Organization of the Specification
- AAR Approval Authority
  - AAR Locomotive Committee
  - AAR Tank Car Committee
  - AAR Equipment Engineering Committee
- Manufacturing Facility Requirements
- Definitions
LC Alternative Fuels Docket Items:
LM-121 Natural Gas Fuel Tenders.

Specification M-1004 – Specifications for Fuel Tenders

Chapter 2, *Fuel Tank Requirements for Liquefied Natural Gas*, covers:

- Operating Requirements
- Fuel Tank Design and Construction Requirements
  - Materials
  - Pressure
  - Welding and Heat Treatment
  - NDE and Pressure Testing

<table>
<thead>
<tr>
<th>Operating Requirements</th>
<th>LNG Fuel Tank</th>
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</thead>
<tbody>
<tr>
<td>Design service temperature</td>
<td>−260 °F</td>
</tr>
<tr>
<td>Design test temperature</td>
<td>−320 °F</td>
</tr>
<tr>
<td>Maximum allowable operating pressure</td>
<td>Refer to Appendix B</td>
</tr>
<tr>
<td>Test pressure</td>
<td>Refer to Appendix B</td>
</tr>
<tr>
<td>Burst pressure (2.5 x test)</td>
<td>Refer to Appendix B</td>
</tr>
<tr>
<td>Water capacity (LNG inner tank)</td>
<td>34,500 US gallons (maximum)</td>
</tr>
<tr>
<td>Minimum outage (after fueling)</td>
<td>15% minimum. Alternatively, minimums less than 15% may be considered with the manufacturer’s design submittal (provided all other requirements of this specification are met).</td>
</tr>
<tr>
<td>Fueling rate and pressure</td>
<td>Refer to Chapter 8</td>
</tr>
</tbody>
</table>

Specification M-1004 – Specifications for Fuel Tenders

Chapter 3, Fuel Tank Requirements for Compressed Natural Gas:

• The NGFT has completed revisions to M-1004 to accommodate CNG tenders.

• The revisions have been issued on an AAR Circular Letter, for industry comment. The NGFT will begin addressing the comments, and expects to soon implement the revised M-1004 Specification.
LC Alternative Fuels Docket Items:
LM-121 Natural Gas Fuel Tenders.

Specification M-1004 – Specifications for Fuel Tenders

Chapter 4, Fuel Tank Requirements for Other Alternative Fuels

Currently vacant and reserved for future revisions to M-1004
LC Alternative Fuels Docket Items:
LM-126 Alternative Fuels Issues
(Biodiesel, Renewable, etc.)

- Under the Alternative fuels docket (LM-126), the LC now receives periodic updates from the LMOA’s Fuels Lubrication and Environmental Committee about their activities on items of mutual interest.

- The docket also has a Task Force comprised of AAR LC & LMOA members addressing concerns with the effects of HDRD on locomotive equipment.
Hydrogen refueling station compression and storage optimization with tube-trailer deliveries

Krishna Reddi a,⁎, Amgad Elgowainy a, Erika Sutherland b

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b U.S. Department of Energy, Fuel Cell Technologies Office, 1000 Independence Avenue SW, Washington, DC 20585, United States

ABSTRACT

Hydrogen refueling stations require high capital investment, with compression and storage comprising more than half of the installed cost of refueling equipment. Refueling station configurations and operation strategies can reduce capital investment while improving equipment utilization. Argonne National Laboratory developed a refueling model to evaluate the impact of various refueling compression and storage configurations and tube trailer operating strategies on the cost of hydrogen refueling. The modeling results revealed that a number of strategies can be employed to reduce fueling costs. Proper sizing of the high-pressure buffer storage reduces the compression requirement considerably, thus reducing refueling costs. Employing a tube trailer to initially fill the vehicle's tank also reduces the compression and storage requirements, further reducing refueling costs. Reducing the cut-off pressure of the tube trailer for initial vehicle fills can also significantly reduce the refueling costs. Finally, increasing the trailer's return pressure can cut refueling costs, especially for delivery distances less than 100 km. and in early markets, when
LC Alternative Fuels Docket Items: Reviewed Apr 2017 @ LC F2F under LM-.013

3-page press release

Web search: carb locomotive petition
**LC Alternative Fuels Docket Items:**
Reviewed Apr 2017 @ LC F2F under LM-.013-contd.

### Table 1:
**Existing Federal Locomotive Emission Standards and Percent Control**

<table>
<thead>
<tr>
<th>Emission Tier</th>
<th>Year of Manufacture</th>
<th>NOx Standard (g/bhp-hr)</th>
<th>NOx Percent Control</th>
<th>PM Standard (g/bhp-hr)</th>
<th>PM Percent Control</th>
<th>HIC Standard (g/bhp-hr)</th>
<th>HIC Percent Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Tier 0</td>
<td>1973-1999</td>
<td>13.5 ft</td>
<td>n/a</td>
<td>0.6 ft</td>
<td>n/a</td>
<td>1.0 ft</td>
<td>n/a</td>
</tr>
<tr>
<td>Tier 0 0+</td>
<td>2000-2001</td>
<td>9.5 ft</td>
<td>30</td>
<td>0.6 ft</td>
<td>0</td>
<td>1.0 ft</td>
<td>0</td>
</tr>
<tr>
<td>Tier 1 1+</td>
<td>2002-2004</td>
<td>7.4 ft</td>
<td>45</td>
<td>0.45 ft</td>
<td>25</td>
<td>0.55 ft</td>
<td>45</td>
</tr>
<tr>
<td>Tier 2 2+</td>
<td>2005-2011</td>
<td>5.5 ft</td>
<td>50</td>
<td>0.2 ft</td>
<td>87</td>
<td>0.3 ft</td>
<td>70</td>
</tr>
<tr>
<td>Tier 3</td>
<td>2012-2014</td>
<td>5.5 ft</td>
<td>50</td>
<td>0.1 ft</td>
<td>83</td>
<td>0.3 ft</td>
<td>70</td>
</tr>
<tr>
<td>Tier 4</td>
<td>2015</td>
<td>1.3 ft</td>
<td>90</td>
<td>0.03 ft</td>
<td>95</td>
<td>0.14 ft</td>
<td>86</td>
</tr>
</tbody>
</table>

**“Today”**
LC Alternative Fuels Docket Items:
Reviewed Apr 2017 @ LC F2F under LM-.013-contd.

### Table 1:
**Existing Federal Locomotive Emission Standards and Percent Control**

<table>
<thead>
<tr>
<th>Tier Level</th>
<th>Year of Manufacture</th>
<th>NOx (g/bhp-hr)</th>
<th>Percent Control</th>
<th>PM (g/bhp-hr)</th>
<th>Percent Control</th>
<th>HIC (g/bhp-hr)</th>
<th>Percent Control</th>
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</thead>
<tbody>
<tr>
<td>Pre Tier 0</td>
<td>1973-1999</td>
<td>13.5</td>
<td>n/a</td>
<td>0.6</td>
<td>n/a</td>
<td>1.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Tier 0 <strong>+</strong></td>
<td>2000-2001</td>
<td>9.5</td>
<td>30</td>
<td>0.6</td>
<td>n/a</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Tier 1 <strong>+</strong></td>
<td>2002-2004</td>
<td>7.0</td>
<td>45</td>
<td>0.45</td>
<td>25</td>
<td>0.55</td>
<td>45</td>
</tr>
<tr>
<td>Tier 2 <strong>2+</strong></td>
<td>2005-2011</td>
<td>5.5</td>
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<td>67</td>
<td>0.3</td>
<td>70</td>
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<tr>
<td>Tier 3</td>
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<td>50</td>
<td>0.1</td>
<td>83</td>
<td>0.3</td>
<td>70</td>
</tr>
<tr>
<td>Tier 4</td>
<td>2025</td>
<td>1.3</td>
<td>90</td>
<td>0.03</td>
<td>95</td>
<td>0.14</td>
<td>86</td>
</tr>
</tbody>
</table>

**“Today”**

### Table 2:
**Potential Amended Emission Standards for Locomotives and Locomotive Engines**

<table>
<thead>
<tr>
<th>Tier Level</th>
<th>Year of Manufacture</th>
<th>NOx (g/bhp-hr)</th>
<th>Percent Control</th>
<th>PM (g/bhp-hr)</th>
<th>Percent Control</th>
<th>GHG (g/bhp-hr)</th>
<th>Percent Control</th>
<th>HC (g/bhp-hr)</th>
<th>Percent Control</th>
<th>Proposed Effective Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2++</strong></td>
<td>2005-2011</td>
<td>1.3</td>
<td>90</td>
<td>0.03</td>
<td>95</td>
<td>NA</td>
<td>0</td>
<td>0.14</td>
<td>85</td>
<td>2023</td>
</tr>
<tr>
<td><strong>3+</strong></td>
<td>2012-2014</td>
<td>1.3</td>
<td>90</td>
<td>0.03</td>
<td>95</td>
<td>NA</td>
<td>0</td>
<td>0.14</td>
<td>85</td>
<td>2023</td>
</tr>
<tr>
<td><strong>4+</strong></td>
<td>2015-2024</td>
<td>0.3</td>
<td>90</td>
<td>&lt;0.01</td>
<td>99</td>
<td>NA</td>
<td>0</td>
<td>0.05</td>
<td>95</td>
<td>2023</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>2025</td>
<td>0.2</td>
<td>99</td>
<td>&lt;0.01</td>
<td>99</td>
<td>NA</td>
<td>10-25%</td>
<td>0.02</td>
<td>98</td>
<td>2025</td>
</tr>
</tbody>
</table>

**NEW**

*With capability for zero emission operation in designated areas.*

**“By 2023”**

**“By 2025”**
Challenges to Rail Implementation

- Safety
- Energy Density
- Infrastructure
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