FRA / PHMSA

LNG BY RAIL TASK FORCE

INTERIM REPORT – July XX, 2020

Contents

1. OVERVIEW

The Pipeline and Hazardous Materials Safety Administration (PHMSA), in collaboration with the Federal Railroad Administration (FRA), created a comprehensive, multi-action task force to evaluate the transportation of Methane, refrigerated liquid, commonly known as liquefied natural gas (LNG) by rail; to synthesize ongoing research and regulatory activities pertaining to LNG; and to identify and fill any potential gaps to ensure that any transportation risks are understood and mitigated properly.

1.1 PHMSA's Safety Mission

PHMSA's mission is to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. To do this, the agency establishes national policy, sets and enforces standards, conducts research to prevent incidents, and prepares the public and first responders to reduce consequences if an incident does occur. PHMSA and FRA share responsibility for the transportation of hazardous materials by rail and take a system-wide, comprehensive approach that focuses on prevention, mitigation, and response to manage and reduce the risk posed to people and the environment.

This task force contributes to a broader goal **to ensure the safety of LNG-by-rail transportation, by understanding the different aspects of LNG-by-rail risk in the present day and future, reducing that risk, and preparing emergency responders and industry for the materialization of that risk should an incident occur.** This broader goal extends beyond the duration of this task force, and future work will build on the foundation presented in this report.

1.2 Background

LNG has been transported by highways and marine vessels for over 40 years in the United States, and over 50 years internationally. However, federal hazardous materials transportation regulations did not authorize the bulk transport of LNG in rail tank cars, instead permitting rail transport of LNG only as authorized by the conditions of a PHMSA special permit or pursuant to an FRA approval.[1] Due to increased natural gas production in the United States, coupled with a growing domestic and international demand and existing constraints related to transportation infrastructure, the U.S. Department of Transportation (DOT) has determined that rail transportation of LNG is a safe alternative. PHMSA and FRA have found that notable improvements to the technology for rail tank cars has not only made moving LNG by rail achievable, but also provide increased opportunities for safe and efficient transportation.

[1] See 49 CFR 174.63(a).

On April 10, 2019, President Donald J. Trump issued *Executive Order on Promoting Energy Infrastructure and Economic Growth, 13868,*[2] which in addition to other provisions, directed the DOT to initiate a rulemaking to allow for the transport of LNG by rail in tank cars. In response to Executive Order 13868 and a petition for rulemaking[3] submitted by the Association of American Railroads (AAR) on January 17, 2017, PHMSA published a Notice of Proposed Rulemaking (NPRM) titled "Hazardous Materials: Liquefied Natural Gas by Rail" (HM-264; 84 FR 56964)[4] on October 24, 2019. The HM-264 NPRM proposed changes to the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) to allow for the bulk transport of LNG in DOT-113C120W specification rail tank cars.

On December 5, 2019, PHMSA granted DOT Special Permit (DOT-SP) 20534[5] to Energy Transport Solutions, LLC (ETS) authorizing transportation of LNG in DOT-113C120W tank cars between Wyalusing, PA and Gibbstown, NJ, with no intermediate stops, subject to certain operational controls. Recognizing the related subject matter, PHMSA published a notice[6] in the *Federal Register* on December 11, 2019, regarding the issuance of DOT-SP 20534 and extending the NPRM's comment period an additional 21 days, from December 23, 2019 to January 13, 2020. Although it has since published, the HM-264 final rule[7] was in development for the duration of the LNG task force.

PHMSA and FRA conducted a review of ongoing activities, and realized that there were numerous ongoing research and outreach activities related to LNG rail transportation safety. The agencies developed the LNG task force in January 2020 with the overarching goal to further ensure safety by synthesizing existing activities and conducting additional analysis separate from and beyond the regulatory scope of Executive Order 13868, the ongoing rulemaking and the special permit. As such, the task force also considered various other drivers within an

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[2] Section 4(b) of the President's April 10, 2019, *Executive Order on Promoting Energy Infrastructure and Economic Growth* directs the Secretary of Transportation to publish a Notice of Proposed Rulemaking (NPRM) that would propose to treat LNG the same as other cryogenic liquids and permit LNG to be transported in approved rail tank cars. The Executive Order also directs that the NPRM be published within 100 days of date of the order, and that a final rule must be published within 13 months of the date of the order. See https://www.whitehouse.gov/presidential-actions/executive-order-promoting-energy-infrastructure-economic-growth/

[3] AAR. Petition for Rulemaking to Allow Methane, Refrigerated Liquid to be Transported in Rail Tank Cars. January 17, 2017. [PHMSA-2017-0020 (P-1697)]

[4] PHMSA. U.S. DOT. Hazardous Materials: Liquefied Natural Gas by Rail NPRM. 84 FR 56964. October 24, 2019. PHMSA-2018-0025. See https://www.federalregister.gov/documents/2019/10/24/2019-22949/hazardous-materials-liquefied-natural-gas-by-rail

[5] PHMSA. U.S. DOT. Hazardous Materials: Notice of Issuance of Special Permit Regarding Liquefied Natural Gas. 84 FR 67768. December 11, 2019. PHMSA-2018-0025; Notice No. 2019-XX. See https://www.federalregister.gov/documents/2019/12/11/2019-26614/hazardous-materials-notice-of-issuance-of-special-permit-regarding-liquefied-natural-gas

[6] PHMSA. U.S. DOT. Hazardous Materials: Liquefied Natural Gas by Rail; Extension of Comment Period. 84 FR 70491. December 23, 2019. PHMSA-2018-0025. Notice No. 2019-14. See https://www.federalregister.gov/documents/2019/12/23/2019-27656/hazardous-materials-liquefied-natural-gas-by-rail-extension-of-comment-period

[7] Add cite to FR once published

evolving hazardous materials transportation sector. These drivers include technological development, the growing economic demand for LNG, various research and testing activities underway within the DOT, and PHMSA's underlying mission to uphold hazardous materials transportation safety.

1.3 Project Team

PHMSA assembled a cross-disciplined team of Subject Matter Experts (SMEs) in coordination with the FRA. The project team included a core group of 10 task leads and over 20 team members composed of varying degrees of technical expertise. Overall, the project team included engineers, chemists, economists, hazardous materials investigators, technical writers, and contracts and outreach specialists. Each task was structured to include a task lead, a task champion, and several team members. Together, the teams developed and engaged in initial steps to carry out a multi-action project plan to synthesize the existing data and information surrounding the transportation of LNG and to investigate any areas of concern to ensure proper mitigation of any potential transportation risks.

2. METHODOLOGY

The project team developed a unique risk-based framework to identify and execute a comprehensive collection of 16 tasks relevant to the properties of LNG and its safe transportation by rail.

2.1 Scope

As a result of its initial assessment, PHMSA and FRA identified 16 tasks that would synthesize ongoing activities, while also developing a comprehensive cross-section of the LNG environment for further analysis separate from and beyond the regulatory scope of Executive Order 13868 and the HM-264 rulemakings. Although diverse, the project tasks contained within the project plan are interrelated and involve research, outreach, statistical and scenario modeling, risk assessment, cost-benefit analysis, safety evaluation, and physical testing of hazardous materials packaging.

PHMSA believes that the project plan represents a comprehensive, transportation safety-focused analysis of the LNG environment, while still acknowledging it is not exhaustive of the present and future implications of the transport of LNG by rail. This report will inform further evaluation and future research and regulatory action.

2.2 Know, Predict, Reduce, Prepare

Looking closely at the broader goal to ensure the safety of LNG-by-rail transportation, it implies four approaches that, taken together, create a cohesive strategy for dealing with the transportation risk of LNG by rail. We simplify this strategy and refer to it here as (1) "know the risk," (2) "predict the risk," (3) "reduce the risk," and (4) "prepare for the risk."

Efforts to "know the risk" expand DOT's knowledge of the types and extent of risk posed by LNG-by-rail transportation, with a focus on research and testing. Efforts to "predict the risk" leverage modeling and simulation software and tools to analyze LNG-by-rail operations and potential risk outcomes. Efforts to "reduce the risk" relate the possible strategies and technologies that decrease the risk of transporting LNG by rail, especially through track inspection, tank car design, and operational factors. Efforts to "prepare for the risk" are focused on the emergency response community and ensure that—should an incident occur and the risks of LNG materialize—emergency responders have the awareness, training, and resources to keep themselves and the public safe.

Naturally, these efforts are interdependent and work together to explore safety concerns of transporting LNG by rail. However, for the purpose of this project plan, Table 1 presents the tasks within the established framework.

Table 1: Methodology for Addressing LNG-by-Rail Risk

Know the Risk	Predict the Risk	Reduce the Risk	Prepare for the Risk
• Empirical Review of international LNG Rail Transportation • LNG Loading / Unloading Safety Evaluation • Quantitative Risk Assessment of LNG Transportation • Full-Scale Impact Testing on DOT-113 • LNG UN T75 Portable Tank Fire-Testing	• Evaluate Likely Number of Punctures and Derailment Simulation Models • Develop Worst-Case Scenario Model • Safety / Security Route Risk Assessment • Train Energy and Dynamics Simulator (TEDS) • Modal Conversion between LNG by Truck and Rail	• Re-Evaluate Costs and Benefits of ECP Brakes • Evaluation of Train Operational Controls • Automated Track Inspection	• Validate Emergency Responder Opinions and Needs • Develop LNG Educational and Outreach Plan

In addition to the 15 tasks included in Table 1, PHMSA initiated a 16th task to coordinate with the Transportation Research Board (TRB) to review the task force's project plan and any completed, in-progress, and planned deliverables to foster continuous improvement in our concerted and continual effort to ensure the safe transportation of LNG by rail.

2.3 Timeline

For the purpose of the task force, the project scope was limited to the 16 tasks, as well as a structured timeframe to promote rapid progress. The project plan and initial phase of action began on January 21, 2020, culminating in a presentation to PHMSA and FRA leadership on April 8, 2020.[8] However, circumstances surrounding the ongoing Coronavirus Disease 2019 (COVID-19) public health emergency delayed certain project tasks and planned events, and the mandatory work-from-home order issued in Washington, DC on March 16, 2020, has introduced additional complexity. Nonetheless, the task force has made substantial progress toward all 16 tasks. PHMSA and FRA staff continue to engage in the completion of all ongoing project tasks, as well as further action within the scope of the DOT's regulatory authority. The DOT remains committed to ensuring the safety of LNG-by-rail transportation.

[8] Information contained herein may differ slightly from that which was presented on April 8, 2018, as result of further research and analysis that has since been undertaken by the task force team within the progression of the ongoing project tasks. DOT staff continue to engage in the completion of the project tasks and initiate further action, as appropriate.

3. TASK DISCUSSION

3.1 Know the Risk

Efforts to "know the risk" expand DOT's knowledge of the types and extent of risk posed by LNG-by-rail transportation, with a focus on research and testing.

3.1.1 Empirical Review of International LNG Rail Transportation

PHMSA is engaging with shippers in countries where LNG has been transported safely to gain lessons learned and best practices that can be adopted domestically.

Key Takeaways

- Japan, Germany, Spain, and Portugal transport LNG by rail currently in cryogenic tank cars and International Organization for Standardization (ISO) portable tanks.
- Other European countries including the United Kingdom, France, and Poland authorize LNG-by-rail transport and continue to monitor the market demand.
- Canada authorizes the TC-113 (which is a tank car equivalent to the DOT-113) for LNG-by-rail transport, but LNG has not been transported by rail in Canada, except as fuel for locomotive use.
- Several countries around the world including Russia, Estonia, Latvia, India, and Spain have begun pilot projects and feasibility assessments for the use of dual-fuel LNG locomotives as efficient alternatives to diesel locomotives. In North America, there is one railroad currently utilizing dual-fuel locomotives.
- PHMSA met with the Japan Freight Company (JR Freight) and Japan Oil Transportation (JOT) in February 2020 to discuss best practices that have enabled Japan to transport LNG for 2 decades without accident. These practices include a train-length limit that aligns with emergency braking distances; pre-determined routing; natural disaster protocol; limitations on storage time in rail yards; annual training that includes an LNG-specific qualification; and information sharing with employees, communities, and law enforcement and emergency response personnel.

Analysis

PHMSA reviewed international regulations and guidance to identify which countries authorize the transportation of LNG by rail currently. PHMSA also identified countries with the capabilities for loading and transporting LNG by rail that continue to monitor its demand within their respective international markets.

PHMSA engaged directly with Japanese shippers because LNG has been transported by rail in Japan for approximately two decades, first between the cities of Kanazawa, Niigata, and Aomori from 2000 to 2015, and more recently in Hokkaido, from 2013 to the present. In a meeting with PHMSA, the Japanese rail operator JR Freight relayed that there have been no accidents with an LNG container transported by rail in Japan. Demand for LNG cars is typically 8–10 cars per day and is most commonly transported in portable tanks measuring 12, 20, or 31 feet in size. In Japan, there is a universal train length limit for all types of freight (540 meters; or approximately 26 freight cars and 1 locomotive); however, there is no limit based on whether the rail car contains LNG or other dangerous goods. Prior to transporting LNG by rail, JR Freight coordinated with different governmental ministries, such as the Ministry of Economy, Trade, and Industry and the Ministry of Land, Infrastructure, Transport, and Tourism.

Planned Next Steps

PHMSA and FRA are drafting an internal report summarizing the information obtained on the international transportation of LNG by rail.

3.1.2 LNG Loading / Unloading Safety Evaluation

PHMSA and FRA are evaluating safety concerns in regards to the loading and unloading of LNG to further determine how the transportation of LNG by rail can be made even safer.

Key Takeaways

- PHMSA reviewed the HMR and 5800.1 Incident Report Forms to determine that LNG is safely transported in existing packaging schemes, such as a UN-approved ISO portable tank or a DOT specification cargo tank motor vehicle (MC 338).
- The PHMSA Incident Database contains 17 incident reports involving LNG that were reported from 1984 through March 2020. PHMSA determined that only 6 of the incidents involved loading or unloading operations, resulting in 0 deaths, 2 hospitalizations, and 1 significant fire in which the cargo tank did not lose pressure or release the contents.
- PHMSA reviewed loading and unloading safety concerns that focused on the unique properties of LNG; the existing authorized packaging schemes; and the existing use, performance, and maintenance of DOT-113 tank cars.
- PHMSA found that LNG has a proven transportation safety record in existing approved bulk packagings and that the LNG industry has a strong safety culture.
- Proper employee training and equipment maintenance are vital to safe loading and unloading of LNG.

Analysis

PHMSA conducted a multi-facetted analysis of current loading and unloading operations for LNG in packagings other than a DOT-113 tank car, as well as the training and equipment needed to safely enable loading and unloading activities. Notably, PHMSA reviewed the historical incident data for LNG and did not find a significant number of incidents related to loading and unloading activities. PHMSA also analyzed existing literature on safety concerns associated with loading, unloading, or transloading LNG to determine if any additional considerations exist and to identify any concerns with tank car fittings.

Furthermore, PHMSA conducted interviews with SMEs from FRA and the Environmental Protection Agency (EPA) and engaged current shippers and liquefaction facilities to determine if additional considerations exist for the transportation of LNG in other authorized packagings that may be relevant to the transport of LNG by tank car. PHMSA's safety evaluation focused on the specific risks involved with the intention of enabling the development of training and dissemination of best practices to ensure workplace safety and minimize risks incidental to transportation of LNG. Overall, PHMSA found that the industry learned from incidents and made safety-enhancing changes to their practices.

Notably, the following areas are important to ensure the safe loading and unloading of LNG:

- **Training:** Training for the transportation of LNG is covered under the general training requirements of the HMR as specified in 49 CFR 172.704. The HMR require training in four main areas: General Awareness, Function-Specific, Safety, and Security. Due to the unique hazards posed by flammable cryogenic liquids, personnel who perform loading and unloading functions must have appropriate training to address the hazards presented. Hazmat employers are required to provide the training required by the HMR, but they can tailor the training to the specific needs of the hazmat employee and the company.
- **Mechanical Equipment, Hardware, Fittings, and Hoses:** Means of containment and the equipment used for loading and unloading must be properly maintained and inspected regularly. Due to a large difference in temperature, the rapid transfer of heat from an object into the cryogenic liquid can cause burns if direct contact of liquid with skin occurs or if Personal Protective Equipment (PPE) is inadequate to prevent cold-temperature injury during an exposure. Additionally, large spills of the liquid onto metal structures that are not designed to withstand cryogenic temperatures can cause embrittlement and fracturing. LNG contains no odorant, making it difficult to detect a release.

Planned Next Steps

Circumstances surrounding the ongoing COVID-19 public health emergency have delayed planned travel and introduced additional complexity in regards to future in-person site visits. However, DOT personnel plan to visit LNG liquefaction and transportation sites in Hialeah, FL (New Fortress Energy) and Jacksonville, FL (JAX LNG) to assess current operating practices, review training materials, review operational procedures, and discuss operating practices with facility personnel. PHMSA anticipates that these site visits will help determine safety issues and concerns about employee training, equipment maintenance, and regulatory gaps in regards to the loading and unloading of LNG on rail cars for further consideration. The findings would inform future analysis and activities preparing for the loading and unloading of LNG on a DOT-113 tank car, with the goal to make the loading, unloading, and transloading of LNG safer by reducing the number of employee errors.

3.1.3 Quantitative Risk Assessment of LNG Transportation

PHMSA and FRA have developed a white paper that examines the methodologies, input data, and risk evaluation approach needed to perform a Quantitative Risk Analysis (QRA) for rail transportation of LNG and other hazardous materials.

Key Takeaways

- QRAs may be useful to establish baseline knowledge regarding the transport of hazardous materials, such as LNG, and their unique risks and challenges.
- A successful QRA for the transport of LNG by rail should include detailed information

about shipment volumes, route details and geography, equipment used, track conditions, accident history and probabilities, types of populations and population density near the transportation corridor, and potential consequences.

- While QRAs generate comprehensive quantitative risk values, the risk values should be viewed in the context of other safety data available and any recognized risk acceptance criteria.
- QRAs can provide the detail and rigor needed to show equivalent levels of safety, when the levels of safety are properly defined.

Analysis

QRA methodology can evaluate the potential risks to the general population arising from the transportation of hazardous materials. The basic philosophy of a QRA considers the frequency of accidents that lead to the release of hazardous materials and the consequence of such releases on the involuntarily exposed population. Different metrics are used in QRAs to determine the consequences of accidents, including fatalities, injuries, economic losses, opportunity loss, etc.

PHMSA's approach to performing a QRA for rail transportation of LNG begins with specifying the origin and destination points (O-D pair) and the rail route by which the shipment will be moving. Then, the route length is divided into segments of appropriate length and the risk in each segment is calculated.[9]

QRA procedure requires gathering the statistical data for historical train accidents occurring in mainline, in yards, and releases in filling and unloading stations and other data for the physical characteristics at different locations; performing calculations of the probability of accident occurrence, hazmat release, and its harmful effect areas; and considering the populations that may be exposed to the harmful effects of hazmat released. The subsequent behavior of the released liquid in the environment will determine the magnitude of the risk. In the case of LNG releases, a number of different hazardous behavior outcomes are possible, each with a conditional probability of occurrence upon release. These include pool spread, vapor dispersion with flash fire, pool fire, fire ball, and a boiling liquid expanding vapor explosion (BLEVE). Risk results include both the individual ("Involuntary Individual Risk" - IIR) and the society as a whole ("Societal Risk" - SR).[10]

Planned Next Steps

Furthermore, FRA and PHMSA have determined the following areas where ongoing or potential future research may be necessary to perform an accurate QRA for assessing the risks of transporting LNG by rail:

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[9] In the segmentation of the O-D route length, yards—if any—in the route must be included as separate segments. The loading facility and unloading facility are also included in the calculation of the total risk.

[10] In the case of societal risk, it is emphasized that all of the population next to the track from the origin to destination should be taken into consideration.

- Further analysis of the puncture resistance of a DOT-113C120W tank car to provide guidance on the severity of derailment in which the inner tank could be punctured (see section 3.2.1).
- Improved train dynamics modeling to estimate the values of the conditional probabilities of different puncture sizes of the inner LNG tank, given that the inner tank is punctured, and the dependence of this conditional probability on the accident parameters (see sections 3.1.4 and 3.2.1).
- Evaluation of the loading and unloading of LNG to gain additional data on the frequency and magnitude of spills (see section 3.1.2).
- Physical modeling to better understand how an LNG release will manifest in different types of hazards, the conditions under which each behavior is possible, and the congruence of such conditions in O-D pair transportation routes.
- PHMSA and FRA believe it is highly unlikely that an undamaged DOT-113 specification tank car that is involved in a derailment would fail due to a BLEVE because the tank car is specifically designed so that the loading pressure requirements for cryogenic materials, the mandated requirements for redundant pressure relief systems (valves and safety vents), and the insulation systems are built into each car. However, it is not possible to state with certainty whether a BLEVE could occur in the case of a LNG tank car derailment and what conditions would need to be present for such an event. Therefore, further research is recommended on this topic to determine the appropriateness of additional packagings, modes, and transportation practices.

3.1.4 Full-Scale Impact Testing on DOT-113

PHMSA and FRA are leveraging existing and future tank car impact research efforts to improve the safety of tank car transportation, including the transportation of LNG by rail.

Key Takeaways

- FRA contracted Volpe National Transportation Systems Center to perform Finite Elemental Model (FE Model) to calculate the puncture resistance of several tank car designs. The FE Model incorporates tank car design, lading, pressure, outage, and speed.
- These models are validated through physical tests, where existing tank cars are instrumented and impacted.
- Recent testing confirmed both the inner and outer tank would puncture near the speed predicted by the FE model.
- PHMSA has entered into an Inter-Agency Agreement (IAA) with the FRA to conduct an impact test on a tank car designed to model the performance of a DOT-113C120W tank car on a smaller scale.
- Further impact testing of a full-scale DOT-113 tank car is delayed pending procurement of an eligible tank car.

Analysis

In November 2019, FRA and PHMSA conducted a full-scale impact test on a current HMR specification DOT-113 tank car with a 7/16-inch-thick outer tank made of ASTM A 516 carbon steel. The results confirmed the Department's hypothesis that both the inner and outer tank would puncture near the speed predicted by the FE model. FRA will use these and future test results to inform the FE model, which will then be used to change the parameters to other conditions of interest, including cryogenic lading(s), internal pressure(s), other impact conditions (e.g., impactor size, wall support), and other tank materials and geometries.

On June 11, 2020, FRA and PHMSA conducted an impact test of a DOT-113 "surrogate" tank that was purpose-built with the essential features of a DOT-113 authorized to transport LNG by rail. The surrogate tank featured an outer tank of 9/16-inch TC 128 grade B normalized steel and an inner tank built to the current HMR specification. The results showed that the tank resisted the impact of 17.3 mph without compromising the inner or outer tank.

Planned Next Steps
The DOT is planning two additional impact tests. FRA and PHMSA have entered an IAA to build an intermediate and production tank and test them with a cryogenic liquid (liquid nitrogen) to simulate actual transportation conditions.

- In late 2020, the FRA will conduct a full-scale impact test on an intermediate tank car designed to model the performance of a DOT-113C120W tank car on a smaller scale.
- Another full-scale DOT-113 tank car will be tested in 2021, pending fabrication. The tank car will be manufactured during a commercial production run and will be representative of DOT-113C120W9 tank cars authorized for LNG rail transportation.[11]

3.1.5 LNG UN T75 Portable Tank Fire-Testing

FRA is conducting fire-testing to evaluate the survivability of LNG-laden UN T75 portable tanks in the event of a pool fire.

Key Takeaways

- FRA has contracted the Southwest Research Institute (SwRI) to fire-test a T75 ISO portable tank filled with liquid nitrogen.
- The T75 ISO portable tank employs the same basic design characteristics as the DOT-113 tank car. FRA will observe the T75 portable tank's behavior in a pool fire scenario and apply the findings to enhance computer modeling of DOT-113 tank cars in fire scenarios.
- The fire-test has two phases and demonstrates the performance of the tank's pressure relief valve (PRV) system and the survivability of the packaging when exposed to a pool

[11] The task force concluded on April 8, 2020. Since then, PHMSA has published the HM-264 final rule, which requires 9/16-inch TC 128B normalized steel for the outer tank of DOT-113C120W9 tank cars used for LNG transportation.

fire.

  - Phase 1 exposed a UN T75 portable tank filled with liquefied nitrogen to a propane pool fire. During phase one, PRVs opened successfully and relieved the pressure quickly to avoid a BLEVE.
  - Phase 2 will engulf a UN T75 portable tank filled with LNG to a pool fire of propane.
- Administrative and management changes at SwRI have delayed phase 2 from March 2020 to later this year.

Analysis

Phase 1 testing found that the PRVs opened successfully and relieved the pressure in the tank fast enough to avoid a BLEVE event. In addition, data was collected that will provide insight into how fire exposure affects the internal and external heating of the tank. Phase 2 (the engulfment test) will take place at SwRI's remote fire-test site in San Antonio, TX and will be conducted in accordance with the FRA-approved test plan.

Planned Next Steps

PHMSA staff will attend the full-scale UN T75 portable tank fire test after travel restrictions have been rescinded. The results will be analyzed to identify the major findings of interest and further incorporated into draft and final reports. Furthermore, PHMSA and FRA will use this analysis in future computer modeling efforts to predict performance with different tanks and fire scenarios.

3.2 Predict the Risk

Efforts to "predict the risk" leverage modeling and simulation software and tools to analyze LNG-by-rail operations and potential risk outcomes.

3.2.1 Evaluate Likely Number of Punctures and Derailment Simulation Models

PHMSA and FRA are evaluating the likelihood of an LNG release in derailment scenarios and using these results to develop strategies to improve puncture performance.

Key Takeaways

- Modeling is used to validate the effects of safety improvements resulting from specific design changes (i.e., shell thickness) and operational controls (e.g., speed restrictions).
- FRA has contracted Sharma & Associates, Inc. (Sharma) to evaluate the likely number of punctures of a modified DOT-113C tank car using a validated derailment simulation model.
- Derailment simulation modeling can confirm the effects of safety improvements resulting from specific design changes and operational controls.
- The puncture resistance of DOT-113C120W cars with a 7/16-inch outer tank were compared to the puncture resistance of cars with a 9/16-inch outer tank, at multiple derailment speeds. Results were incorporated into worst-case scenario predictions and combined with full-scale impact testing analysis to demonstrate safety levels of transporting LNG by rail. Simulation results suggest that the 9/16-inch tank cars perform about 16 percent better than 7/16-inch tank cars at a speed of 40 mph.

Analysis

Tank cars are subject to various forces during a derailment scenario, including different impactor sizes, shapes, and speeds. FRA engaged Sharma to evaluate the likely puncture performance of a current design and a modified DOT-113C tank car design using a validated derailment simulation model. The Sharma model captures several key parameters (e.g., multiple derailment scenarios, dynamics, impact load distributions, tank car design) and combines them into a probabilistic framework that can evaluate the relative merit of proposed mitigation strategies.

Scenarios involving the current design (7/16-inch outer shell) and the modified DOT-113C120W9 tank car design (9/16-inch outer shell) were modeled in a 100-car unit train configuration. The modeling provided a quantitative prediction about tank car puncture probability in the event of a derailment. Simulation results suggested that the modified tank cars perform about 16 percent better than the current tank car design at a speed of 40 mph. This methodology provided a theoretical framework for quantifying the risk-reduction benefits that may result from various mitigation strategies. Additionally, it helped to address the overall reduction in risk (i.e., reduced probability of puncture and release) that is afforded by increasing minimal shell thickness.

Planned Next Steps
The results of the Sharma modeling will be incorporated into various worst-case scenario predictions (see section 3.2.2) and combined with full-scale impact testing analysis (see section 3.1.4) to improve PHMSA's overall QRA efforts.

3.2.2 Develop Worst-Case Scenario Model

PHMSA and FRA have identified and developed four worst-case scenarios for a potential accident involving a unit train carrying LNG.

Key Takeaways

- The vapor cloud footprint where the vapor concentration is higher than 5 percent lower flammability limit (LFL) on the ground varies with time, distance from the source, weather conditions, and terrain. The most hazardous weather conditions are low winds and a stable atmosphere, which does not promote rapid mixing with air.
- Conversely, the most hazardous conditions for pool fires are high wind conditions [9 m/s (30 mph)], which bend the flame significantly in the direction of the wind.
- The hazard areas presented by vapor cloud ignition and the fireball radiant heat effects are relatively small, both in area of hazard and the distance from spill point to which the hazard extends. The radiant heat hazard distance from a pool fire is the largest of the four different types of LNG behavior considered. This assumes that the fire size is always the pool diameter and that the high fire radiant heat emission values are used.

Analysis
PHMSA and FRA modeled the following scenarios:

- The radial spread of an unconfined and unignited pool of LNG.
- The dispersion of unignited vapors from the spreading and evaporating LNG pool.
- The radiant heat hazard distance from an expanding ignited pool of LNG.
- The radiant heat hazard distance from a fireball type fire.

Each model assumed one, two, and five tank cars completely de-inventoried simultaneously into one pool and the most-hazardous conditions for that scenario.[12] However, the conditions used in these calculations are extremely unlikely and do not occur without alignment in train conditions, local topography, soil properties, weather, and other conditions.

Unignited LNG Pool Spread on the Ground: For spills from one and five tank cars, the radii of spread for the maximum spill rate is 51 meters (m) and 95 m, respectively. The total length along the diameter for 5-car pile would be about 20 m. Therefore, the unignited liquid pool can spread to a maximum radius of about 10 times the tank car pileup radius.

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[12] The main assumptions are: 1, 2, and 5 tank car breaches and LNG releases; the puncture hole (in the inner tank) in each tank car was at the bottom most part of the tank car and each puncture was a 12" x 12" hole; all leaking cars release simultaneously and into the same spot.

Dispersion of Vapors Emanating from Spreading LNG Pool: For spills from one and five tank cars, the LFL downwind distance[13] is 1,310 m and 2,380 m, respectively. The dispersion calculation is based on a continuous vapor injection at the rate used for the spill time of 41 seconds (s).[14] At 2.5 m/s wind speed, it will take the cloud about 8 minutes and 45 seconds for the one-car tank spill and 15 minutes and 50 seconds for the five-tank car spill to reach the LFL distance.

Radiant Heat Hazard from a Spreading Pool Fire: For spills from one and five tank cars, the calculated distances to hazard from pool fires are 300 m and 670 m, respectively. The distance to the skin burn hazard[15] is calculated on the basis of the following: the fire size is always at the maximum diameter; a 9 m/s (30 mph) wind, which bends the flame significantly in the direction of the wind; and the relative humidity is 50 percent because radiant heat is absorbed by the intervening atmosphere if the distance is large and the relative humidity is high. These distances are smaller than the distances to which a dispersing flammable cloud can extend (until the vapor concentration is below the LFL).

Radiant Heat Hazard from a Lifting Fireball: For spills from one and five tank cars, the calculated distances from center of fireball on the ground to hazard[16] are 112 m and 230 m, respectively. The results indicate that the skin burn hazard distance at the ground for a fireball is smaller than that from a pool fire. For a five-tank car release, the fireball hazard distance is 230 m, whereas the same release is 670 m for a pool fire. A fireball puts out more radiant heat flux than a pool fire, but it is short-lived, whereas a pool fire is anchored to the ground and lasts longer (fireball = 15 s; pool fire = 60 s).

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[13] The distance to which the LNG vapors disperse, mixing with the ambient air, before being diluted to below 5 percent LFL vapor concentration in air. In evaluating the LNG pool spread while evaporating on the ground, PHMSA and FRA analyzed LNG vapor dispersion using heavy gas dispersion models. The heavy gas dispersion models provide at any specified time, the vapor concentration contours for specified average gas concentration in air. In general, the contour and area of interest is that enclosed within the 5 percent methane concentration contour at ground level. This concentration forms the lower flammability of natural gas in air.

[14] 41 seconds represents the mean duration of spill from tank cars based on the maximum release rate for 1, 2, and 5 tank cars.

[15] The hazard of concern in this case is the distance from the fire center on the ground to a person receiving radiant thermal heat flux of 5 kW/m^2 (1600 Btu/hr ^{ft2}).

[16] The hazard distance is calculated using the modified thermal dosage criterion [300 $\{kW/^{m2}\}^{(4/3)}$ s] for second degree burn to a person from short-term exposure to high level of radiant heat flux.

Hazard Distances due to Worst-Case Release Scenarios from LNG Tank Cars in Train Derailment					
LNG Behavior	**Property or other Parameter**	**Value**	**Value**	**Value**	**Units**
Number of Tank Cars (assumed to be) releasing LNG		1	2	5	
LNG Pool Spread on Land	Maximum Spread Radius of Circular, unignited LNG Pool	51	68	95	m
Vapor Dispersion	Down wind maximum distance to Lower Flammability Limit (LFL) Concentration	1,310	1,760	2,380	m
	Maximum area of 5% (LFL) contour on the ground	56,300	103,500	221,300	m^2
	Circular radius (or semi-width) of maximum area of the 5% contour	134	182	265	m
Expanding Pool Fire	Radial distance from fire center on the ground to 2nd degree skin burn hazard to a ground level observer, with consideration of atmospheric absorption of radiant heat.	300	424	670	m
Fireball	Radial distance for 2nd degree burn hazard (using modified thermal dose criterion) from center of fireball projected on the ground to a ground level observer, with consideration of atmospheric absorption of radiant heat.	112	150	230	m

Planned Next Steps

PHMSA and FRA believe it is highly unlikely that an undamaged DOT-113 specification tank car involved in a derailment would fail due to a BLEVE because the tank car is specifically designed so that the loading pressure requirements for cryogenic materials, the mandated requirements for redundant pressure relief systems (valves and safety vents), and the insulation systems are built into each car. However, it is not possible to state with certainty whether a BLEVE could occur in the case of a LNG tank car derailment and what conditions would need to be present for such an event. Additional theoretical and experimental research is recommended to further understand the precise conditions under which a double-tank LNG rail car could possibly undergo a BLEVE.

3.2.3 Safety / Security Route Risk Assessment

PHMSA and FRA are applying the additional route analysis requirements included in 49 CFR 172.820 to the routes designated for transportation of LNG by rail in DOT-SP 20534.

Key Takeaways

- Rail carriers routinely analyze the safety and security risks of rail routes and ensure that decisions on the routing of specific hazardous materials minimize these risks.
- Under the HMR, the rail carrier must select the most practicable route posing the least overall safety and security risk, review route selection and alternative routes annually, and make routing analysis and selection available for FRA review. If FRA finds that a selected route is not the safest and most secure practicable route, FRA, in consultation with the Transportation Security Administration (TSA) and the Surface Transportation Board (STB) may require the use of an alternative route.
- Class I railroads utilize the Rail Corridor Risk Management System (RCRMS) to conduct route analysis. RCRMS generates a risk score for each route, and on a per-mile basis, by specifying the O-D pair, track profile, the hazardous material

transported, annual commodity flow, and type of rail car or other hazmat packaging.
- RCRMS accounts for more than 27 risk factors, including maximum operating speeds, population exposure, proximity to environmentally sensitive areas and iconic targets, and commingled passenger rail traffic.
- Preliminary RCRMS results demonstrate three viable routes between Wyalusing, PA and Gibbstown, NJ, with two deemed "most attractive" and one as "less attractive" based on risk scoring.

Analysis

Pursuant to DOT-SP 20534, ETS is required to provide a shipping plan for the movement of LNG by rail. Upon receipt of the shipping plan, FRA and PHMSA will coordinate with the rail carriers on the finalization of their routing analysis results, which will inform the carriers' route selection process for the proposed shipment of LNG by rail. Preliminary RCRMS results demonstrated three viable routes between Wyalusing, PA and Gibbstown, NJ, with two of these routes scoring equally as "most attractive" and one route scoring as "less attractive." Four rail carriers may be involved in transporting LNG between this origin and destination.

Planned Next Steps

PHMSA and FRA are waiting for ETS to submit the shipping plan. Then, FRA will use RCRMS to generate final risk scores based on specific conditions within the shipping plan, such as train scheduling and configuration, incident response planning, and remote monitoring. Rail carriers will use the final RCRMS results to comply with the HMR requirements for rail routing. PHMSA and FRA will review the final analysis to determine if additional operational controls or engagement is needed to ensure the safety of LNG by rail along these routes.

3.2.4 Train Energy and Dynamics Simulator (TEDS)

PHMSA and FRA are simulating train operations using the Train Energy and Dynamics Simulator (TEDS) on the routes designated for the transportation of LNG by rail in DOT-SP 20534.

Key Takeaways

- FRA developed TEDS in 2014 to conduct safety and risk evaluations, incident investigations, studies of train operations, and ride quality and equipment evaluations.
- TEDS software simulates train operations and performance over a specified route. Results enhance safety evaluations and accident investigations by producing data about operating speeds, coupler and drawbar forces, and L/V ratios.
- FRA is simulating a DOT-113 unit train on two routes between Wyalusing, PA and Gibbstown, NJ through Philadelphia, PA.
- The simulations assume a 100-car train configuration with one buffer car; three 4,400-horsepower locomotives; and a total train length of approximately 8,500 feet (1.6 miles) with a trailing tonnage of 13,300 tons.

- The simulation of route one has been completed and route two is in-progress.
- Unit train operations on route one will produce coupler forces and L/V values that are reasonable and within engineering and industry safety limits.

Analysis
TEDS software simulates train operations, including acceleration, braking, steady state running, hilly terrain operations, and emergency conditions, over a specified route and generates data for gross train dynamics (e.g., position, velocity, stopping distance), as well as inter-car or in-train forces (e.g., coupler forces). TEDS is a high-fidelity model; its predictions were validated against real-world train operations data and found to be accurate.

PHMSA and FRA will simulate the designated routes from Wyalusing, PA to Gibbstown, NJ. The simulation will include a 100-car train configuration, with 1 buffer car and 3 locomotives in a head-end power configuration.

Planned Next Steps
The simulation has been completed as of July 2020. The resulting Technical Report and analysis will inform future activities to prepare for the future transportation of LNG by rail.

3.2.5 Modal Conversion between LNG by Truck and Rail
PHMSA is performing geospatial analysis to compare the risk profile of LNG transportation by truck with the risk profile of LNG transportation by rail tank car.

Key Takeaways
- PHMSA compared various aspect of LNG transportation by truck with LNG transportation by rail.
- Assumptions included comparable endpoints and three truckloads for every tank car load.
- PHMSA used North American Rail Network and Highway Network shapefiles to flow shipments of LNG from start point to endpoint.
- Each mode has a unique exposure profile.
    - Rail lines between LNG facilities tend to travel through rural areas and directly through cities.
    - Truck routes between LNG facilities tend to travel through more populated areas but avoid densely populated urban areas.
- Highway transportation produces more fatalities and injuries per ton-mile than rail transportation.

Analysis
PHMSA compared the rail route identified by the rail carrier through RCRMS with likely highway routes between Wyalusing, PA and Gibbstown, NJ, the O-D pair authorized for the transport of LNG in DOT-SP 20534. These highway routes were determined using industry route planning software and combined with hazmat route restrictions. A spatial

representation of the worst-case scenario footprint was overlaid on each path for highway and for rail. Each point along each route was given a weight based on the census block population touching the worst-case scenario footprint at that point. The cumulative sum of this risk was then compared between modes by normalizing for volume, probability of incident, and non-hazmat fatalities caused by freight transportation of that mode.

Planned Next Steps

PHMSA and FRA are waiting for ETS to submit the shipping plan. Then, PHMSA will repeat this analysis using the actual shipping route identified by ETS and the rail carrier(s).

3.3 Reduce the Risk

Efforts to "reduce the risk" relate the possible strategies and technologies that decrease the risk of transporting LNG by rail, especially through track inspection, tank car design, and operational factors.

3.3.1 Re-Evaluate Costs and Benefits of ECP Brakes

PHMSA is evaluating the cost and benefits of requiring electronically controlled pneumatic (ECP) brakes for LNG-by-rail transportation.

Key Takeaways

- PHMSA re-examined the costs and benefits of requiring ECP brakes on tank cars transporting LNG.
- Equipment costs were assumed to be zero to reflect minimal cost of including ECP brakes on new tank car builds.
- Training costs were still included.
- Benefits were primarily business benefits.
- Effectiveness rates from the TRB study were used.
- Costs far exceeded business and safety benefits.
- There could be long-term benefits to include ECP brake mounts on new tank car builds so that the fleet can switch when economic viability to do so exists.

Analysis

Signed in 2015, the Fixing America's Surface Transportation Act (FAST Act) produced a requirement for high-hazard flammable trains (HHFTs)[17] to be equipped with ECP brakes to increase the performance of braking systems on unit trains. This requirement was dependent on an accurate analysis about the performance of ECP brakes and the safety gains associated. In 2018, after the National Academy of Sciences TRB re-examined its original performance analysis, PHMSA withdrew this requirement considering existing and predicted exposure measures relative to the increased braking performance. The analysis at that time only considered widespread transportation of crude oil and ethanol and did not consider widespread transportation of LNG.

Therefore, PHMSA re-assessed the balance between costs and benefits of mandating ECP brakes assuming LNG transportation has continuous demand. This breakeven analysis assumed equipment costs were zero to reflect the minimal cost of including ECP brakes on new tank car builds. The evaluation also used effectiveness rates from the most recent TRB report on ECP brake performance. To determine potential LNG growth, this analysis did not look at market demand, but assumed that the DOT-113 tank cars would be produced at maximum capacity and all cars both existing and produced would be used full-time for LNG transportation. The analysis did not consider increased production

[17]As defined in 49 CFR 171.8, an HHFT means a single train transporting 20 or more loaded tank cars of a Class 3 flammable liquid in a continuous block or a single train carrying 35 or more loaded tank cars of a Class 3 flammable liquid throughout the train consist.

capacity beyond existing maximums. The breakeven analysis determined it would take nearly 50 years of continued production to have volume such that the benefits exceeded the costs.

Planned Next Steps
PHMSA is coordinating with the Bureau of Transportation Statistics to collect data about DOT-113 builds and DOT-113 build capacity to maintain awareness about the possibility of increased volume or builds that may alter this analysis.

3.3.2 Evaluation of Train Operational Controls
PHMSA and FRA are evaluating use of existing operational controls and verifying compliance with railroad operating practices to ensure safe and effective transportation of LNG by rail.

Key Takeaways
- AAR Circular OT-55, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials* [18] is a joint effort between shippers, car owners, and the railroads to take a proactive approach to the safe transportation of hazardous materials.
- PHMSA and FRA engaged directly with multiple railroads to discuss compliance with Circular OT-55 and key train requirements.
- The project team developed a comprehensive checklist to guide DOT personnel during the review of rail carrier compliance of their operational controls, worst case scenario preparedness, and employee training.
- FRA is not aware of any instances of non-compliance with Circular OT-55, and AAR has noted they recommend compliance.
- Some hazardous materials shippers use remote sensors on tank cars to detect and monitor potential tank car failures, thereby being proactive to prevent hazardous situations.
- Simulation data shows that unit trains operating under DOT-SP 20534 will travel at speeds above 40 mph for 13 percent of the distance between Wyalusing, PA, and Gibbstown, NJ.
- PHMSA and FRA will plan additional site visits nationwide to further inform best practices throughout the country.

Analysis
Originally published in 1990, Circular OT-55 is a detailed protocol establishing recommended railroad operating practices for the transportation of hazardous materials. All Class I rail carriers operating in the United States have implemented the recommended practices, with short-line railroads following on as signatories. Circular OT-55 is comprehensive in its reach, outlining requirements for all train movements that fit within its terms. Notably, Circular OT-55 limits "key trains" to operate with a maximum

[18] Circular OT-55, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials*, https://www.railinc.com/rportal/documents/18/260773/OT-55.pdf.

speed of 50 mph at all times. "Key trains" are defined as:

- One tank car load of Poison or Toxic Inhalation Hazard (PIH or TIH) (Hazard Zone A, B, C, or D), anhydrous ammonia (UN1005) or ammonia solutions (UN3318), or;
- 20 car loads of intermodal portable tank loads of any combination of hazardous material, or;
- One or more car loads of Spent Nuclear Fuel (SNF), High Level Radioactive Waste (HLRW).

PHMSA reviewed the following information as it pertains to the operational controls of certain rail carriers and requirements regarding Circular OT-55:

- **AAR Circular OT-55-Q:** All Class I rail carriers are recommended to follow the most current revision.
- **Norfolk Southern HM-1:** PHMSA staff verified that the requirements of Circular OT-55-Q are outlined in Norfolk Southern's (NS) current operating practices.
- **DOT-SP 20534 and the comments received:** In December 2019, PHMSA issued this special permit authorizing the transportation of LNG by rail between Wyalusing, PA and Gibbstown, NJ.
- **HM-264 NPRM and the comments received:** In October 2019, PHMSA published an NPRM proposing to authorize the transportation of LNG by rail nationwide. The final rule was under development for the duration of the task force.

Additionally, PHMSA and FRA conducted site visits at two rail carriers along the special permit route: NS and Conrail Shared Asset Operations (Conrail). In support of these visits, PHMSA and FRA developed a Safety Verification Checklist to ensure consistent evaluation and findings. The visits included a tour of the dispatch center; a presentation on OT-55 training for new employees, engineers, and conductors; and opportunity to observe the technology used to identify and monitor key trains, such as mobile applications and remote sensors. The team found that NS and Conrail are not only complying with OT-55, but also that it is built in to their training, self-audits, and daily operations.

PHMSA and FRA analyzed the TEDS simulation (see section 3.2.4) to determine the percentage of maximum authorized speed along the route in the special permit because it is believed that a possible derailment would be less severe if the train were operating at a slower speed. The project team found that 40.2 percent of a specific route was authorized at 50 mph, and additionally 29.7 percent of the same route was authorized at 40 mph. However, the TEDS simulation confirmed that the train will be operating at these lower speeds due to terrain and curvature of the track. In fact, as it applied to a 100-car train of LNG, the TEDS simulation indicated that 13 percent of the route will allow for 50 mph and 17.5 percent will allow for 40 mph. In total, this means that a train transporting LNG along one of the routes authorized under DOT-SP 20534 will be traveling at a speed of 35 mph or less 69.5 percent of the time.

Planned Next Steps
PHMSA plans to schedule additional site visits nationwide to further inform best practices throughout the country. However, circumstances surrounding the ongoing COVID-19 public health emergency have delayed planned travel, and its continued progression has introduced additional complexity in regards to future in-person site visits. In the interim, PHMSA and the FRA are awaiting additional information from Conrail and Norfolk Southern.

3.3.3 Automated Track Inspection
FRA is using track geometry vehicles to survey rail routes nationwide, including the two routes designated for transportation of LNG by rail in DOT-SP 20534.

Key Takeaways
- Building on over 40 years of experience, FRA's Automated Track Inspection Program (ATIP) geometry measuring vehicles inspect large quantities of track without risk of human error or bias.
- In 2019, FRA's fleet of 8 geometry measuring vehicles conducted operational surveys over more than 125,000 miles of the U.S. rail transportation network.
- FRA and railroad inspectors use ATIP data to ensure track safety is being maintained and to assess trends within the industry. Having realized the benefits of this technology, industry has begun voluntarily implementing geometry car systems to help locate and correct exceptions as a quality assurance measure to enhance their track inspection and maintenance programs.
- With the increase in ATIP surveys and geometry measuring vehicles, FRA anticipates the number of cited track defects will decrease nationwide.
- FRA deployed ATIP vehicles to survey the designated routes from Wyalusing, PA to Gibbstown, NJ to ensure track quality, maintenance, and safety.
- FRA compared the March 2020 data with testing that has occurred over these two routes during the past 10 years to note any trends in track safety, determining that the Binghamton via Enola route has fewer track exceptions.

Analysis
Throughout March 2020, FRA deployed ATIP vehicles to survey the routes designated in DOT-SP 20534: Binghamton via Enola and Binghamton via Allentown. Geometry car inspections are snapshots in time, and prior results are not necessarily indicative of present conditions. Therefore, the FRA compared the March 2020 data with testing that has occurred over these two routes during the past 10 years to note any trends in track safety.

The March 2020 analysis showed that the Binghamton via Enola route had zero two-class drops, whereas previous surveys indicated a total of 6, and the Binghamton via Allentown route had 57 two-class drops, whereas previous surveys indicated a total of 12. A two-class drop typically occurs where the track geometry is permitted to degrade to the point that it fails to comply with the regulation for the class of track that the railroad operates at and instead of repairing or slow ordering, the railroad continues operation as the track continues to degrade to the point it is out of compliance with the next lowest class as well. FRA did not survey the Buffalo via Conway route because operations studies determined it was no longer a reasonable alternative (see section 3.2.3).

FRA issued the survey reports to the maintaining railroads for each route segment. When exceptions are noted during ATIP surveys, FRA performs verifications either that same day or shortly thereafter. While compliance with the Track Safety Standards are mandatory, railroads have the opportunity to upgrade their infrastructure and/or maintain the track in a state of good repair to the point where subsequent track geometry surveys could have a very different outcome. However, in the snapshot of time in which the geometry surveys were conducted, the surveys indicate that the Binghamton via Enola route has fewer track exceptions.

Planned Next Steps
FRA will continue to conduct surveys nationwide in accordance with the ATIP Program. Additionally, FRA will survey the designated routes from Wyalusing, PA to Gibbstown, NJ again prior to the first shipment of LNG and will compare the results to those from March 2020 to ensure track quality, maintenance, and safety.

3.4 Prepare for the Risk

Efforts to "prepare for the risk" are focused on the emergency response community and ensure that—should an incident occur and the risks of LNG materialize—emergency responders have the awareness, training, and resources to keep themselves and the public safe.

3.4.1 Validate Emergency Responder Opinions and Needs

PHMSA is engaging the emergency response community to ensure they have the information and tools to safely respond to an LNG-by-rail incident.

Key Takeaways

- PHMSA directs a comprehensive hazardous materials grants program to increase safety and efficiency when responding to transportation incidents involving hazardous materials, like LNG.
- PHMSA collaborated with the U.S. Coast Guard, the Federal Emergency Management Agency (FEMA), and FRA to host a town-hall meeting with emergency responders to learn about responder concerns of LNG transportation by rail.
- Participants noted that there is no heightened concern in the response community regarding LNG or LNG transportation by rail.
- Specifically, emergency responders with Hazardous Materials Technician training are oriented to the challenges of LNG incident response, and experienced response personnel regularly handle materials that have greater potential hazardous results and/or impacts than LNG.
- However, additional training may be necessary to prepare emergency responders below the Hazardous Materials Technician level for potential LNG release incidents.

Analysis

PHMSA's hazardous materials grants program has helped States, Territories, and Tribal entities since 1990 by providing approximately $20 million in grant funding annually. By focusing on the unique challenges of hazardous materials transportation, PHMSA's grants program encourages a comprehensive approach to emergency training and planning that increases overall safety and efficiency when responding to transportation incidents involving hazardous materials, like LNG.

On October 14, 2019, PHMSA and the FEMA U.S. Fire Administration sponsored a Town Hall Meeting in Lancaster County, PA to seek input from the emergency preparedness community and its stakeholders to better inform the DOT about their needs should LNG by rail be authorized. The meeting consisted of a series of technical presentations on LNG transportation risks and incident response protocols, including known safety hazards, current handling and response procedures, and emergency response community readiness. Attendees provided general inputs on issues related to improving the overall effective response capability in the event of a rail incident of LNG and had an opportunity to raise issues or concerns in open discussions.

Planned Next Steps

Circumstances surrounding the ongoing COVID-19 public health emergency have delayed previously planned events and introduced additional complexity in regards to hosting in-person stakeholder gatherings. Nonetheless, PHMSA is committed to continued engagement with stakeholders on this topic and will reassess the following planned activities as health and safety permits:

- Meeting with Philadelphia Fire Commissioner – Previously scheduled for March 18, 2020; Cancelled
- NY/NJ Town Hall Meeting – Previously scheduled for April 2020; Postponed until further notice
- International Association of Fire Chiefs Roundtable – Previously scheduled for June 2020; Rescheduled for June 2021
- Town Hall Meeting (Location TBD) – Previously scheduled for September 2020; Postponed until further notice

3.4.2 Develop LNG Educational and Outreach Plan

PHMSA is compiling and producing materials to ensure emergency responders have the requisite training and knowledge to protect the public if an LNG incident were to occur.

Key Takeaways

- PHMSA enhances public safety and emergency preparedness through the development and dissemination of training materials, technical assistance, seminars and workshops, and outreach initiatives.
- PHMSA is developing a Reference Sheet for LNG Commodity Preparedness and Incident Management, as well as illustrations and prototype models of the DOT-113 tank car to better educate stakeholders on the packaging design, structure, and safety features.
- The LNG industry, trade associations, government agencies, and emergency responders have existing structures in place to develop education and outreach materials in collaboration with one another.
- PHMSA is facilitating increased coordination between stakeholders to improve education outcomes and ensure that emergency responders receive the necessary LNG response training.
- PHMSA will publish any relevant outreach and education materials, including links to external materials, to its LNG-dedicated webpage.

Analysis

PHMSA reviewed the following outreach and education mechanisms that industry, government agencies, and stakeholder organizations have created and made available.

- The **Center for Liquefied Natural Gas (CLNG)** has outreach materials on their website that provide general awareness on LNG, the LNG value chain, and LNG economics.

- FRA has provided grant funding to **Transportation Community Awareness Emergency Response (TRANSCAER®)** to develop an LNG workshop for emergency responders. CLNG and the **American Petroleum Institute (API)** are providing expertise and will deliver content by Fall 2020, with the first workshop scheduled for Winter 2021.
- **USCG Liquefied Gas Carrier National Center of Expertise (LGC NCOE)** has developed various resources and trainings for UCSG Marine Inspectors, many of which are publicly available on its website.
- The seven major **Class I Railroads** work with the **Security and Emergency Response Training Center (SERTC** - operated by the Transportation Technology Center, Inc. [TTCI], a subsidiary of the **AAR**) to conduct training and outreach with local emergency response organizations. Class I railroads also conduct trainings along routes to ensure that local emergency responders receive general and commodity-specific hazmat training. The railroads also actively promote the AskRail® mobile application, which is available to emergency responders to quickly and accurately identify a commodity being transported in a specific rail car. As with crude oil, there is precedent, for the railroads to sponsor trainings for emergency responders along their routes based on commodity flow.
- The **Short Line Safety Institute (SLSI)**, a DOT grantee, is developing LNG trainings and other resources to ensure that emergency responders located near short line railroads receive adequate training and preparedness resources ahead of any LNG transport.
- **Texas A&M Engineering Extension Service (TEEX)**, a DOT grantee, has developed an LNG spill control and fire suppression course for emergency responders and works with USCG to deliver trainings to emergency responders.
- **Northeast Gas Association (NGA)**, in partnership with the **Massachusetts Firefighting Academy**, offers a comprehensive LNG safety and emergency response training program that combines classroom instruction and hands-on training.

Planned Next Steps

PHMSA will work to facilitate coordination between organizations to influence education outcomes and ensure that emergency responders receive the necessary LNG response training and will publish any relevant outreach and education materials, including links to external materials, to its LNG-dedicated webpage. Additionally, to supplement existing industry resources, PHMSA is developing the following materials:

- An **LNG Commodity Preparedness and Incident Management Reference Sheet** that will provide emergency response organizations with a standard incident management framework based on pre-incident planning and preparedness principles and best practices. It will cover transportation safety and precautions, hazard assessment and risk, rail safety procedures, logistics, and the tools, equipment, and resources necessary to prepare for and respond to LNG rail transportation incidents. PHMSA and DOE-Hammer have entered into an IAA and have begun to assemble a team of SMEs, to include government, industry, and emergency response representatives. DOE-Hammer is developing a project plan with an estimated timeline of 6–9 months for development. The COVID-19 public health pandemic is not expected to impact delivery because all working sessions can be completed remotely. Expected delivery is January–April 2021.

- In March 2020, PHMSA and FRA developed a draft **illustration of the DOT-113 tank car** similar to those that appear in the Emergency Response Guide Book (ERG). The illustration will depict the DOT-113's external construction and features (including fittings compartment). It will be used primarily for outreach and training purposes; however, PHMSA will assess the inclusion of the DOT-113 tank car illustration during development of the 2024 ERG.
- A **prototype model of the DOT-113 tank car** to demonstrate the scale and construction of the DOT-113 tank car. This model can be used to educate stakeholder groups, including Congress and emergency responders, on the integrity of the tank car construction and safety features. Also, PHMSA is developing **prototype models of the T75 UN portable tank and the MC-338 cargo tank** for scale comparison to the DOT-113 tank car.
    - Chart Industries (packaging manufacturer) has provided PHMSA CAD drawings of the three packaging types that the Empire Group (3D printer/prototype modeler) uses to develop the physical models.
    - Empire Group is currently printing and building the DOT-113 tank car model with delivery expected in July 2020. Upon satisfactory delivery of the tank car model, PHMSA will engage with Empire Group to develop the T75 UN portable tank model and the MC-338 cargo tank model.
    - Empire Group's turnaround time has ostensibly been affected by the COVID-19 public health pandemic and by the difficulty in scaling the CAD drawings down to an appropriate size. Estimated delivery time on the remaining two packaging prototype models would be up to 3 months from tasking date (tentatively October 2020).

3.5 Validate the Risk

3.5.1 Stand-up TRB Collaboration for LNG Research

PHMSA is working with the National Academy of Sciences to validate the scope and direction of the task force through a TRB study on the transportation of LNG by rail tank car.

Key Takeaways

- On December 20, 2019, President Donald J. Trump signed the "Further Consolidated Appropriations Act, 2020," which requires PHMSA to enter a contract with the National Academy of Sciences to complete a study through the TRB on the transportation of LNG in rail tank cars.
- PHMSA has executed a not-to-exceed $1 million cost reimbursable research contract (contract #: 693JK320C000001) with the National Academy of Sciences.
- Task I of the study will validate or identify gaps in the evaluation, criteria selection, and approach used by the LNG Task Force.
- Task II of the study will inform regulatory and policy communities about the hazards and mitigation of incidents involving LNG-by-rail transport, as well as knowledge gaps that would need further exploration in the long term.
- The Task I report will be delivered to PHMSA 7 months after contract execution (estimated November 2020) and the final report for Task II is expected Spring 2022.

Analysis

TRB will appoint a committee consisting of between 10 and 14 experts. It will hold a total of 6 in-person meetings, as well as additional short meetings by conference call. The Task I report is expected in Fall 2020, which will be peer reviewed and delivered to PHMSA and Congress upon completion. It will also be made available to the public. After the release of the first report, the committee will begin work on the more in-depth study, building upon the previous findings. At the fourth meeting in Winter 2020, the committee will convene a workshop to hear from a wide range of experts and practitioners who can inform on the key study topics outlined above. Additional experts will be invited to brief the committee during the fifth meeting in March 2021.

PHMSA and FRA officials will be invited to attend all open sessions during these committee meetings. During closed sessions, the committee will focus on shaping its second report. The committee's final meeting will take place in Summer 2021. This meeting will be held largely in closed session to finalize the Task II report, which will be submitted for institutional peer review in Summer 2021. Once the Task II report has cleared peer review, it will be released in final (but prepublication form) during Fall 2021. Printed, typeset reports will be delivered by Spring 2022.

Planned Next Steps

The first public meeting of the committee, FRA, and PHMSA has been set for July 20, 2020 and the second meeting has been tentatively set for the first week in September 2020.

4. TASK DELIVERABLES UNDER DEVELOPMENT

DOT staff continue to engage in the completion of the project tasks and initiate further action, as necessary. Therefore, various task deliverables are under development within PHMSA and FRA. These deliverables seek to foster continuous improvement in the DOT's concerted and continual effort to ensure the safe transportation of LNG by rail. Although referenced throughout this report, Table 2 consolidates the deliverables that are currently underway or planned in support of the task force, as well as their expected date of delivery.

Table 2: Expected Delivery Dates of Ongoing Task Deliverables

Deliverable	Expected Delivery Date
DOT-113 Tank Car Prototype Model	July 2020
LNG Commodity Preparedness and Incident Management Reference Sheet	January - April 2021
T75 UN Portable Tank and the MC-338 Cargo Tank Prototype Models	October 2020
Derailment Model Simulations- Evaluation Of Risk Reduction From LNG Tank Car Design Improvements	August 2020
TEDS Technical Report	August 2020
UN T75 Fire-Testing Draft Report	Fall 2021
Un T75 Fire-Testing Final Report	Fall 2021
Internal Report on International LNG by Rail Transportation	Fall 2020
TRB Task I Report	Spring 2022
TRP Task II Report	Fall 2020

5. CONCLUSION

The properties of LNG are well understood. History shows that LNG has been transported safely by highways and marine vessels for decades both within the United States and internationally. More recently, technological and scientific advancements in tank car development have made rail a viable transportation alternative, providing increased opportunities for safe and efficient transportation of LNG to meet the growing domestic and international demand.

The HM-264 final rule is the first step to enabling the transportation of LNG by rail, and PHMSA and FRA are confident that it will ensure transportation safety. However, the hazardous materials transportation sector is constantly evolving and, as such, research and analysis must continue to progress. The goal of the task force was to conduct additional analysis separate from and beyond the regulatory scope of Executive Order 13868 and the HM-264 rulemakings. This goal extends beyond the duration of this task force, and future work will build on the foundation presented in this report.

The task force did not identify any new safety gaps related to the transportation of LNG in tank cars. The findings of the task force related to the use of Circular OT-55-Q in the rail industry and the increased thickness for the outer tank of the DOT-113 tank car design are consistent with the decisions made in the development of the HM-264 final rule. However, as the agencies responsible for the safe transportation of hazardous materials, PHMSA and FRA will continue to pursue research and testing efforts designed to reduce the risks inherent in LNG transportation and hazmat transportation more broadly.