

Quantitative Risk Assessment of LNG Transportation



PHMSA and FRA are examining the Methodologies, Input Data, and Risk Evaluation Approach needed to perform a QRA for Rail Transportation of LNG.

Key Takeaways

- ◆ All movements of hazardous materials present unique risks and challenges, but QRAs may be useful to establish baseline knowledge.
- ◆ A successful QRA for LNG transportation by rail must 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.
- ◆ QRAs generate comprehensive quantitative risk values. However, the risk values must 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.

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TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ How representative of all potential LNG movements is the unit train movement for the single O-D pair?
- ◆ Will a more general QRA be performed initially prior to getting the detailed route information?
- ◆ Will the authors address Block Planning for LNG transport?
- ◆ When will the QRA actually be conducted?
- ◆ Can we have a more detailed discussion of the assumptions and inputs, as well as the schedule?
- ◆ Will a more general QRA be performed initially prior to getting the detailed route information?

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 and PHMSA use a Finite Element Model (FE Model) to predict the puncture resistance of 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.
- ◆ The Department's November 2019 test confirmed both the inner and outer tank would puncture near the speed predicted by the FE model.
- ◆ The Department's June 2020 impact test on a "surrogate" tank designed to model the performance of a DOT-113C120W resulted in neither tank puncturing at a 17.3 mph impact speed. The FE model run at the same speed also shows no puncture of either tank.
- ◆ Full-scale impact testing of a "surrogate" DOT-113 filled with Liquid Nitrogen and Full-scale impact testing of a new DOT-113 filled with Liquid Nitrogen both planned for 2021.

Full-Scale Impact Testing on DOT-113



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TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ Is it possible for the inner liner to be fractured without an actual puncture?
- ◆ Due to a DOT113 having one or two closing seams, which are known to be weaker than a PWHT one, why is there no plans to test an impact on the closing seam?
- ◆ Are the findings of derailment studies and simulations considered in the design of the impact tests and simulations?
- ◆ Will any planned impact tests (or simulation thereof) be performed with partially filled tanks?
- ◆ Will a future report address similarity (or not) of relevant steel response properties at temperatures of liquid nitrogen vs. LNG? This may be necessary to support use of nitrogen proxy.

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

- ◆ The FRA has contracted the Southwest Research Institute (SwRI) to fire-test a portable tank filled with liquid nitrogen.
- ◆ The fire -test has two phases and demonstrates the performance of the tank's pressure relief valve (PRV) system.
- ◆ Phase one 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 Boiling Liquid Expanding Vapor Explosion (BLEVE).
- ◆ Phase two will engulf a UN T75 portable tank filled with LNG to a propane pool fire.
- ◆ Phase two setup is ready; but the test is delayed due to COVID-19.
- ◆ Results will enhance computer modeling of tanks in fire scenarios.

LNG UN T75 Portable Tank Fire-Testing



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TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ What are differences between the UN T75 portable tank fire and DOT-113 with regards to structural and thermal properties (including insulation)?
- ◆ Why was a propane versus LNG and a rectangular versus circular pool fire chosen with the tank placed such that the effect of wind cause non-persistent engulfment?
- ◆ Based upon the data and observations obtained from the tests, what scenario / conditions would increase the probability of the container experiencing a BLEVE?
- ◆ What are the experimental uncertainties, particularly that of the directional flame thermometers which didn't maintain contact?
- ◆ Why does the ISO tank have to be on a flat car which offers thermal protection? Wouldn't it be more like a tank car in a pool fire, if it weren't on a flat car, especially not upright and having some mechanical damage?
- ◆ Is there any international experience involving a tank container derailment / incident with fire impingement and failure?

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

- ◆ FRA and PHMSA modeled (i) unconfined spread of LNG without ignition, (ii) Dispersion of Vapors Emanating from Spreading LNG Pool, (iii) a pool fire on the spreading LNG, from immediate ignition during release, and (iv) a fireball type fire.
- ◆ Each model assumes five tank cars completely de-inventorying simultaneously into one pool and the most-hazardous conditions for that scenario.
- ◆ The radiant heat hazard distance for pool fires 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 high fire radiant heat emission values are used.
- ◆ 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.
- ◆ Vapor cloud footprint where the vapor concentration is higher than the 5% lower flammability limit (LFL) varies with time, distance, and weather conditions. The largest footprint occurs when weather conditions are low winds and stable atmosphere which does not promote rapid mixing with air.
- ◆ The hazard areas from vapor cloud ignition and fireball radiant heat effects are relatively small (both in area of hazard and the distance from spill point to which the hazard extends).

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.

TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ Are contrasts and/or comparisons made with known severe past U.S. events?
- ◆ What were the models and parameters used to calculate the radiant thermal hazard distances?
- ◆ What are the durations of the LNG pool fire and vapor cloud scenarios?
- ◆ What are the plans to address the potential for a BLEVE?
- ◆ Please discuss plans to include findings of Task 2.1 in the development of the worst-case scenario models.
- ◆ Each of these studies appear to be focused on the tank itself without any other fuels nearby which is unlikely in areas where either derailment or loading/unloading occur.
- ◆ Will the future report place the results of this task (Summary Table, pg. 18) within an evaluation context? For example, by comparing such a table to other flammable substances currently hauled by rail.
- ◆ What model was used to calculate dispersion distances and what is the mass flux of LNG vapors from the pool?
- ◆ Does PHMSA intend to perform any models or experiments where the urban canyon effects may take over for dispersion of vapor spread? How will the “trapped” pockets of vaporous phase gas affect evacuations

LNG Loading / Unloading Safety Evaluation



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

Key Takeaways

- ◆ LNG is safely transported in existing packaging schemes, such as a UN-approved International Organization for Standardization (ISO) portable tank or a DOT specification cargo tank motor vehicle (MC 338).
- ◆ PHMSA reviewed loading and unloading safety concerns 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 packaging.
- ◆ PHMSA engaged with subject matter experts, shippers, and liquefaction facilities to determine if additional considerations exist for authorized packaging that may be relevant to tank cars.
- ◆ Proper employee training and equipment maintenance are vital to safe loading and unloading of LNG.
- ◆ The LNG industry has a strong safety culture.

LNG Loading / Unloading Safety Evaluation



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TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ What were the circumstances and outcomes regarding past loading/unloading accidents?
- ◆ How would you rate the level of complexity and safety requirements of loading/offloading of LNG rail cars vs. that of LNG ships, LNG terminals, and LNG trucks?
- ◆ What are the control measures considered in loading/unloading terminals?
- ◆ What are the training and certification requirements and pertinent protective equipment for loading/offloading staff and first responders, including the local Emergency Medical Services personnel? For example, is PHMSA going to meet with the local Fire Department personnel in the Jacksonville and Hialeah, Florida locations to see what their observations and concerns are?
- ◆ Is PHMSA going to visit loading sites of class 2.1 and 2.2 cryogenic materials?

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

- ◆ FRA has contracted Sharma & Associates, Inc. (Sharma) to evaluate the likely number of punctures of a modified DOT-113C tank car using a derailment simulation model.
- ◆ Derailment simulation modeling can confirm the effects of safety improvements resulting from specific design changes and operational controls.
- ◆ The derailment model captures key parameters and combines them to provide a quantitative prediction about tank car puncture probability in the event of a derailment.
- ◆ In 40-mph derailments, DOT-113C cars with a 7/16" outer tank experienced 5 punctures on average, while cars with a 9/16" outer tank experienced 4.2 punctures on average.
- ◆ Other derailment speeds are currently being modeled.
- ◆ Results are incorporated into worst-case scenario predictions and combined with full-scale impact testing analysis to demonstrate safety levels of transporting LNG by rail.

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.

TRB LNG Committee Questions for PHMSA and FRA Regarding this task:

- ◆ What are inputs, assumptions, and outputs of the model?
- ◆ How was the data analyzed?
- ◆ How precisely did you model the data?
- ◆ When will the model be validated addressing the concerns of the TRB ECP committee which includes the concerns of this committee?
- ◆ Has any modeling been done to consider derailments that do not initiate at the lead car (the assumption made in the Letter Report)?
- ◆ How would a mid -train initiated derailment change the initiation/application of emergency braking?