

Internal Quarterly Report

Date of Report: 4th Quarterly Report - September 30, 2025

Contract Number: 693JK32410009POTA

Prepared for: U.S. DOT Pipeline and Hazardous Materials Safety Administration

Project Title: LNG Knowledge Development – Consequences of Catastrophic Failure of LNG Storage Tanks

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For quarterly period ending: September 30, 2025

1: Items Completed During this Quarterly Period:

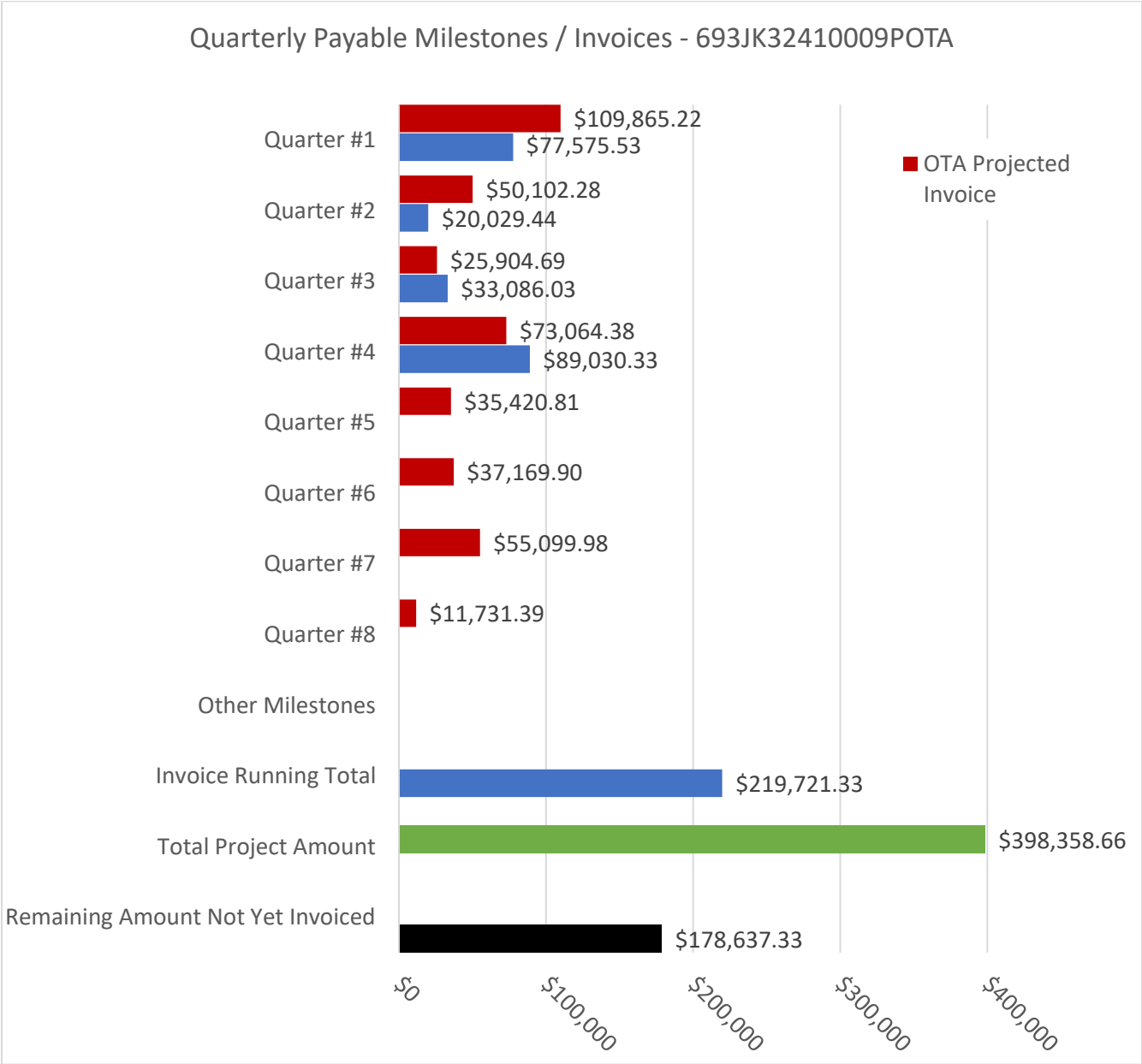
<i>Item #</i>	<i>Task #</i>	<i>Activity/Deliverable</i>	<i>Title</i>
9	2	FE Modeling of Typical LNG Tanks	FE models of LNG tanks shown in slides
12	2	FE Analysis and Post-processing	LNG tank analysis results shown in slides
15	2	Failure Cause Assessment	LNG tank failure causes summary shown in slides
16	3	BLEVE Analysis of LNG tank types	BLEVE analysis results for a range of LNG tanks shown in slides
19	5	4th Quarterly Status Report and Progress Presentation Slides	Submit 4th quarterly report

2: Items Not Completed During this Quarterly Period:

The project is on schedule.

<i>Item #</i>	<i>Task #</i>	<i>Activity/Deliverable</i>	<i>Title</i>	<i>Federal Cost</i>	<i>Cost Share</i>
14	2	Failure Rate Evaluation	LNG tank failure rates shown in slides	\$20,000	\$5,000
17	3	BLEVE Consequence Calculations	BLEVE consequences shown in slides	\$9,248	\$2,312
18	4	LNG Tank Failure Consequence Modeling	LNG tank failure consequences shown in slides	\$9,967	\$2,492

3: Project Financial Tracking During this Quarterly Period:



4: Project Technical Status –

We continued work in the fourth quarter by distributing our Hazard Identification and Characterization (HAZID-C) workshop report to the technical advisory panel (TAP) members. We provided a project update during a third TAP meeting on 19 August 2025. Based on the HAZID-C workshop and TAP member discussions, we formalized our modelling plan and completed several finite element (FE) modeling tasks.

[Item 9] [Task 2] [FE Modeling of Typical LNG Tanks] [FE Models of LNG Tanks Shown in Slides]

We completed our models of representative LNG tank configurations that were selected, including small volume and high-pressure LNG tanks (gross capacity ~500 m³), medium size (50,000 to 100,000 m³ gross capacity) single containment steel tank (and conceptual full containment steel-steel tank, updated from previous research project), and large (150,000 to 200,000 m³ gross capacity) full containment steel-concrete and conceptual steel-

steel tank (updated from previous research projects). We used these models to investigate structural response to a range of hazard scenarios. We updated the FE models and properties to capture the catastrophic failure modes.

[Item 12] [Task 2] [FE Analysis and Post-processing] [LNG Tank Analysis Results Shown in Slides]

We used our representative LNG tank models to apply extreme loading conditions that were selected based on the gaps and high priority catastrophic hazards identified during the HAZID-C workshop and TAP meeting discussions. Loss of roof containment was identified as a concern for single and full containment tanks during the HAZID-C.

- We analyzed a mid-size single containment tank subjected to a roof fire to assess potential failure modes. We identified damage localization at the roof-to-wall connection and buckling of roof framing at elevated temperatures.
- We used the same mid-size single containment system to evaluate the effect of instability from a partial loss of soil support or foundation failure. We considered differential settlement over 25% of the tank bottom and observed significant deformation and plastic strains in the bottom plates of the inner and outer tank. We also observed rotation of the ring wall beam that supports the inner and outer tank walls. The ring wall rotation led to deformation of the inner tank wall and buckling.
- We subjected the higher-pressure tank designed to ASME Boiler and Pressure Vessel Code to multiple fire scenarios to assess the system performance and to support BLEVE evaluations. Our analysis indicated that local heating over 50% of the tank bottom from a pool fire would lead to significant bowing deformation of the outer tank that causes local buckling of the outer tank in-between circumferential stiffeners. We also observed significant tensile strains in the tank shell and head that would make rupture likely. The inner tank is not significantly impacted by the heating of the outer shell, but rupture of the outer tank would create a scenario where insulation is dislodged, and a local portion of the inner tank is subjected to fire temperatures. In this scenario, failure of the inner tank subjected to a fire is likely.

[Item 15] [Task 2] [Failure Cause Assessment] [LNG Tank Failure Causes Summary Shown in Slides]

We used our FE analysis results, along with findings from prior research projects and our team experience, to develop a summary of potential failure modes that can lead to catastrophic events and hazards. We grouped failure modes by hazards identified during the HAZID-C workshop. We find that full containment and single containment atmospheric tanks have similar potential failure modes, with the scale of the hazard dependent on the size of the tank, extent of the structural failure, and aspects of the project site. One major difference is the behavior of the outer carbon steel tank for a single containment system, which is likely to experience some failure from any LNG release scenario. For higher pressure tank systems, these tanks are often grouped in batteries and potential escalation of failure to nearby tanks is a risk that can increase the impact of the hazard.

[Item 16] [Task 3] [BLEVE Analysis of LNG Tank Types] [BLEVE Analysis Results Shown in Slides]

We evaluated structural response of a range of LNG tanks under pool fire conditions. Our analyses indicate that a hot BLEVE is unlikely for modern LNG tanks, but there can be a risk of cold BLEVE depending on the operating pressure, pressure relief system design, fire protection, and extent of the fire impingement on the unwetted surface. Typical failure modes under major fire scenarios would be similar those observed in the literature and shown in our analysis. Rupture of the LNG tank leads to vapor release from the opening. The opening can be like a linear crack or a localized hole around a penetration point (localized BLEVE). Expected dimensions of the openings from our analyses will be considered in the BLEVE consequence modeling.

[Item 19] [Task 5] [4th Quarterly Status Report] [Submit 4th Quarterly Report]

This task includes project management, administration, and progress reporting. We discussed the project objectives, methodology, testing program, and analysis approach with the project team and members of the TAP. Monthly progress reports were shared on PRIMIS, and the fourth quarterly report was developed.

5: Project Schedule –

The project is on schedule. During the next quarter, we will complete process safety modeling of LNG tank failure consequences.

[Item 14] [Task 2] [Failure Rate Evaluation]

We will address this task towards the end of the project based on a review of project results and published studies, with an emphasis on comparing tank construction types.

[Item 17] [Task 3] [BLEVE Consequence Calculations]

In addition to our structural modeling of conditions potentially leading to BLEVE, we will assess the applicability of existing BLEVE models for LNG storage tanks and evaluate the scale and consequence of the event for our representative high pressure LNG tank.

[Item 18] [Task 4] [LNG Tank Failure Consequence Modeling]

We will continue LNG tank failure consequence modeling, including our Computational Fluid Dynamics (CFD) analysis of the extent of hazard development and performance of secondary and tertiary containment for varying LNG release scenarios.