Working Group #3: Liquefied Natural Gas (LNG) Facility Fire Protection System Design

Summary Report-Out

Roadmapped Research Gaps

Prioritized Gap #1: Conduct pool fire tests at scales typical to liquefied natural gas (LNG) impoundment installations to provide data sets to support model validation and quantify the performance of pool fire mitigation measures.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?
    - LNG Impoundment Pool Fire Testing Validation.
2. What is the suggested objective statement for this gap?
    - Conduct pool fire tests at scales typical to LNG impoundment installations to provide data sets to support model validation and quantify the performance of pool fire mitigation measures.
3. Can any regulatory, congressional, or National Transportation Safety Board (NTSB) drivers (more than one category can be included) be identified as associated with this gap?
    - Pipeline and Hazardous Materials Safety Administration (PHMSA) – The code requires LNG Fire 3 for pool fires. Provide data for future modal adoption and validation.
4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?
    - Assess different software and how those models can conduct experiments for evaluation.
    - Measure the burn rate of the pool.
    - Record heat flux at various distances up to several pool diameters from the source with a focus on the down winded direction.
    - Include surface emissive power, flame length, and flame tilt as other test data.
    - Provide all relevant meteorological data with the test.

- Perform test performed with and without pool fire mitigation measures, including high expansion foam and insulating floating foam blocks.
- Include LNG in the test at a minimum; it is desired to include additional fuel, propane or higher hydrocarbon, with and without insulating floating foam blocks.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - Technology Development: Model validation.
   - General knowledge: Filling a gap in available test data.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - Reference Question #4 response for testing output.
   - Use computational fluid dynamics (CFD) models to handle this modeling.

7. Does the gap address a related consensus standard (i.e., National Fire Protection Association (NFPA) 59A) or best practice?

   - NFPA 59A.
   - NFPA 11.

8. What are anticipated targets or timeframes to complete this research (months)?

   - 24 months.

Prioritized Gap #2: Water spray and/or curtain design validation to ensure effectiveness and suggested locations for fire and vapor dispersion mitigation based on two scenarios: 1) to ensure vapor dispersion mitigation; and 2) blocking pool fire thermal radiation.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?

   - Water Spray and/or Curtain Design Validation for Vapor Dispersion and Thermal Radiation.

2. What is the suggested objective statement for this gap?

- Water spray design validation for effective vapor dispersion mitigation, and/or water curtain design validation to ensure effectiveness for reducing or blocking pool fire thermal radiation and vapor dispersion mitigation. In addition, identify suggested installation locations.

3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?

   - PHMSA – siting and design review.

4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?

   - Use a water spray system to provide a thermal break and vapor break between two different areas.
   - Provide testing conditions that allow for variable vapor cloud sizes and thermal radiation along with variable water droplet size in order to test the effectiveness of the water curtain for multiple scenarios.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - Proper design methodology to achieve goals, which includes ensuring design of facility model is accurate to the curtain.
   - Primary output: efficacy of water curtains/spray systems for the two hazards being evaluated, which flows into the validation of CFD models.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - Reference response from Question #5.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - NFPA 15.

8. What are anticipated targets or timeframes to complete this research (months)?

   - 18 – 24 months (depends on readily available testing facilities or if one needs to be developed).

Prioritized Gap #3: Hydrogen blending impacts on hazard detection and other hazard mitigation designs/installations and failure modes and likelihood.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?
    - Hydrogen Blending Impacts on Hazard Detection and Other Hazard Mitigation Designs and Associated Failure Modes and Suggested Process Changes for Existing and Proposed LNG Facilities.
2. What is the suggested objective statement for this gap?
    - How hydrogen blended feed gas could affect a dispersion of a feed gas leak.
    - How hazard detection system design might need to change to account for a hydrogen blended feed gas.
    - What are the failure modes and likelihood?
    - How hydrogen and feed gas could affect piping and instrumentation equipment and whether it could affect design of instrumentation systems and safety integrity levels (SILs).
    - What process design changes would need to be implemented?
    - What maintenance practices would be appropriate?
3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?
    - Regulatory: Federal Energy Regulatory Commission (FERC) and PHMSA.
4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?
    - Reference response from Question #2.
5. Which research output is being suggested from the gap (technology development or general knowledge)?
    - General knowledge development.
6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?
    - Produce summary report.
    - Begin with engineering modeling study.
    - Follow with process conditions and equipment study.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?
    - Does not address any current standards or codes.
8. What are anticipated targets or timeframes to complete this research (months)?
    - 12 months.

Prioritized Gap #4: Experiments to validate the integrity and effectiveness of passive pool and jet fire mitigation systems; guidance on fire scenarios to be included in passive mitigation design and guidance on failure criteria for pressure vessels and steel.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?
    - Validation of Passive Mitigation Systems for Pool and Jet Fires.
2. What is the suggested objective statement for this gap?
    - Experiments to validate the appropriateness and effectiveness of passive pool and jet fire mitigation systems; guidance on fire scenarios to be included in passive mitigation design and guidance.
    - Failure criteria for structural steel and a boiling liquid expanding vapor explosion (BLEVE) threshold for pressure vessels.
    - Effectiveness of mitigation measures against cryogenic spills.
3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?
    - PHMSA + FERC.
4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?
    - Reference response from Question #2.
5. Which research output is being suggested from the gap (technology development or general knowledge)?
    - Knowledge development in the form of an engineering study.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?
    - Not relevant.
7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?
    - American Petroleum Institute (API) 2218 – closest standard.
8. What are anticipated targets or timeframes to complete this research (months)?
    - 12 – 24 months, depending on if it's a mathematical model vs. experimental testing.

Prioritized Gap #5: Continuous monitoring of LNG infrastructure using long open-path standoff gas detection to provide a low-cost and flexible solution. Looking at gas leaks in facilities. Looking at temperature cracks, gas detection for safeguarding facilities; and open path detectors.

The following questions are provided for the roadmapping of each research gap:

1. What is the suggested gap name for this research project?
    - Open Path Gas Detection and Emission Rate Quantification to Continuously Monitor LNG Infrastructure.
2. What is the suggested objective statement for this gap?
    - Evaluate any benefits of utilizing open path gas detectors in replacement of point detectors or in support of point detectors.
    - Develop a low-cost system.
    - Discriminate between equipment venting and leak scenarios to reduce false alarms.
3. Can any regulatory, congressional, or NTSB drivers (more than one category can be included) be identified as associated with this gap?
    - Does not address any current standards or codes. Is more so industry guidance.
4. What key technical details or scope items are necessary and recommended to be incorporated into the research project?
    - Point sensors and open-path sensors.

- Scalability of facilities.
- Testing in different meteorological conditions.
- Leak detection response time, quantification accuracy, detection and quantification thresholds, localization accuracy.
- Incorporate emission due to operation, such as equipment venting, to do better testing that is comparable to a real environment.

5. Which research output is being suggested from the gap (technology development or general knowledge)?

   - Technology validation/general knowledge.

6. [Answer if relevant] What type of data output or tool/model functionality is required to successfully address the gap?

   - Develop the modeling tool that would figure out the number of sensors needed to cover a test area.

7. Does the gap address a related consensus standard (i.e., NFPA 59A) or best practice?

   - More for industry/best practice.

8. What are anticipated targets or timeframes to complete this research (months)?

   - Develop a model tool would take approximately 24 months to complete.

List of Prioritized Consolidated Gaps

#	**Consolidated Gap**
1.	Conduct pool fire tests at scales typical to LNG impoundment installations to provide data sets to support model validation and quantify the performance of pool fire mitigation measures.
2.	Water spray and/or curtain design validation to ensure effectiveness and suggested locations for fire and vapor dispersion mitigation based on two scenarios: 1) to ensure vapor dispersion mitigation; 2) blocking pool fire thermal radiation.
3.	Hydrogen blending impacts on hazard detection and other hazard mitigation designs/installations and failure modes and likelihood.
4.	Experiments to validate the integrity and effectiveness of passive pool and jet fire mitigation systems; guidance on fire scenarios to be included in passive mitigation design and guidance on failure criteria for pressure vessels and steel.
5.	Continuous monitoring of LNG infrastructure using long open-path standoff gas detection to provide a low-cost and flexible solution. Looking at gas leaks in facilities.

	Looking at temperature cracks, gas detection for safeguarding facilities; open path detectors.
6.	Develop guidance / scenario framework for fire protection evaluation so operator can have a better idea on how to approach fire protection system design; Subtopic: Evaluation of necessary use of water protection systems (small scale LNG facility).
7.	Low-cost gas leak imager for surveying LNG tanks and LNG process piping.
8.	Radiant heat time based thresholds where typical steel fails.
9.	Experimental data or validation for basis of design and distances used in electrical area classification consistent with basis in other standards such as NFPA 497 and American Petroleum Institute 500.
10.	Conduct pool fire tests at scales typical to LNG impoundment installations to provide data sets to support model validation and quantify the performance of pool fire mitigation measures.