LNG Working Group –Storage Integrity Issues
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CB&I Storage Tank Solutions
(a division of McDermott International)

LNG Storage Integrity Potential Issues for Study by DOT/PHMSA:

1. **Need for Inspection of Existing LNG Storage Tanks**
   - Existing tank inspection requirements and conditions.
   - Absence of applicable industry guidelines for LT&C tank inspections.

2. **Full Containment Steel Storage Tanks for LNG Service**
   - Benefits and use of full containment steel tanks for LT&C service.
   - Current 49 CFR 193 requirement only permits concrete outer tank.

3. **LNG Storage Tank External Hazard Identification and Design**

4. **Concrete wall liner design, configurations, and performance**

5. **Probabilities of Failure for Tank System Configurations**

ISSUE 1 – NEED FOR INSPECTION OF EXISTING LNG STORAGE TANKS

API 620 Double Wall Single Containment Tank Inspections:

- No current Industry Guideline for periodic External or Internal Inspections of LNG Storage Tanks
- Inspections are typically requested by Storage Tank owners, who specify the inspection requirements
- Inspections have been requested by Tank Owners to address proactive Risk Reduction or external issues that have become apparent
- Evaluation of Performance History
- General condition of in-service tanks based on CB&I experience:
  - Inner tank
  - Outer tank
  - Insulation system
  - Foundation
  - Appurtenances

There is no Industry guidance on the inspection requirements for LT&C tanks. API 653 entitled “Tank Inspection, Repair, Alteration, and Reconstruction” is limited in it’s scope to tanks built in accordance with API 650 and it’s predecessor API 12C. A document specifically for API 620 tanks with provisions for Appendix R and Q tanks is needed by the industry. The document should address the more complicated design requirements and details for LT&C Storage Tanks.

Inspections and Evaluations of Existing Tanks:

- **In-service Inspections** – External only. Typically can be done within a few days on-site, followed by a written report
- **Out-of-service Inspections** – Can be Internal and External. Long duration to include decommissioning and recommissioning of the tank if internal inspection is included. Several weeks to months depending on the extent of the inspection and NDE requested.
- **Tank Engineering Evaluations –** Comparisons of the as-built LNG Storage Tank configuration to the current code requirements or changed conditions for loads such as Seismic, Wind, other new External Loads. Results are for reference only as upgrades or operational changes not mandated by current code/regulation.

Potential Upgrades or Modifications of "Existing Tanks"to be Considered after Inspections:

- Addition of Internal Tank Valves (ITV's)
- Modify Storage Tank piping to reduce risk (e.g. over the top fill) or repair damage
- Add/modify size of process nozzles – due to changes to plant operations
- Adding or replacing Storage Tank level instrumentation – Displacer Gauges, High Level Switches, LTD Gauges
- Adding or changing Pressure Relief Valves(PRV's) - Add spare, meet current design conditions, etc.
- Upgrade PRV isolation valves to be full port – to meet API 2000
- Convert PRVs from weight loaded to pilot operated
- Add or replace cool down and/or leak detection RTD's
- Modify/add platforms on Storage Tank roof for better access to nozzles
- Add/modify handrail to existing platforms and stairways to be compliant with current OSHA requirements
- Repair/replacement of insulation systems
- Repair/replace corroded components
- Repair exposed portions of the concrete foundation as appropriate
- Foundation heating system repair or upgrade
- Modify tank to resist current seismic, wind, and external-loading conditions **if possible** or consider operation limitations.

FULL CONTAINMENT STEEL TANKS FOR LNG STORAGE

- Outer container is made from cryogenic grade steel
- Allowed by current NFPA 59A-2019
- Currently not permitted by 49-CFR-193 (section 193-2161)
- Regularly used for other Cryogenic and Low Temperature products (ethylene, ethane, propane, propylene, etc.)

Full Containment Steel Tanks
(Courtesy to Sunoco Logistics Partners L.P.)

ADVANTAGES COMPARED TO CONCRETE OUTER TANKS:

- No product vapor escape through the outer wall in the event of secondary container cryogenic liquid exposure (i.e. steel is impermeable)
- No damage to outer container in case of cryogenic liquid exposure
- Full Containment Steel outer tank can be more easily placed back in service after abnormal product exposure to secondary container

COMMON CONCERN IS THAT STEEL HAS A LOW RESISTANCE TO EXTERNAL HAZARDS

External Blast Loads, Projectile Impact, Thermal(Fire)

- **Analysis indicates that steel tanks provide significant resistance for both external blast loads and projectile impact hazards. Enhanced resistance is possible with increased steel thickness or shell stiffening**
- **Enhanced thermal(fire) resistance is possible with mitigation measures such as water deluge systems**

POTENTIAL DEVELOPMENT SUBJECT:

- **Better quantify secondary steel tank resistance to external hazards identified in Risk Assessment**
- **Address Full Containment Steel Tanks in Federal Regulations**

Typical External Hazards Specified by Owners

Blast:

Generally specified as a positive free field pressure at the face of the tank which varies as a function of time.

Projectile Impact:

Generally specified as a rigid mass with a minimum dimension and velocity. The stiffness of large projectiles may also be specified.

Thermal Radiation(Fire):

Generally specified as a thermal radiation intensity and duration. Radiation intensity may be constant over the tank surface or varied. Fire scenarios may also be specified which requires the determination of the thermal radiation on the tank surface.

Blast Design Methodologies:

Pseudo-static methodology based on an assumed pressure distribution on the tank surface which is varied in magnitude as a function of time.

3-D finite element time history analysis which applies the pressure on the tank surface based on a nearby TNT explosion using LS-DYNA and ANSYS.

Projectile Design Methodologies:

Tank thicknesses are evaluated for perforation by rigid masses based on empirical formulas developed for the nuclear industry.

3-D finite element analysis used for large flexible masses to determine tank deformations and strains.

Thermal Radiation Design Methodologies:

For steel tanks, duration of radiation determined to prevent excessive loss of strength. Mitigation with water curtains of water spray often required.

For concrete tanks, 3-D thermal analysis used to determine through thickness temperature of concrete, reinforcement, and pre-stress to evaluate tank integrity.

Blast:

Establish acceptance criteria for steel and concrete outer tanks. Generally, tank must maintain structural integrity sufficiently to contain the product liquid and vapor and allow a safe shutdown of the tank.

Projectile Impact:

Establish methodology to determine thickness required to prevent perforation for steel and concrete tanks with an established margin. Identify variations associated with concrete tanks which may be subjected to product hydrostatic loads. Limit local damage to prevent the loss of pre-stress if required for tank integrity.

Thermal Radiation(Fire):

Establish minimum allowable temperatures for steel tank surfaces. Establish acceptance criteria for thermal radiation and associated surface and through thickness temperatures for concrete tanks considering different concrete tank system configurations.

THIN WALL LINER FOR FULL CONTAINMENT TANK SYSTEMS WITH CONCRETE OUTER TANK

INDUSTRY CONCERN: Thin wall metallic liner (vapor barriers) may leak product vapor in service

CAUSES:

- **Significant liner deformation due to concrete wall post-tensioning, creep and subsequent straining by internal pressure.**
- **Current standards do not provide guidance on liner design**
- **Guidance on minimum liner thickness in current standard is inadequate**
- **No sufficient guidance on thin liner details, installation, welding and NDE in current standards**

DEVELOPMENT SUBJECT:

- **Develop comprehensive guidelines for thin wall liner design, details, installation and testing for concrete outer tanks**

ISSUE 5 - PROBABILITIES OF FAILURE FOR TANK SYSTEM CONFIGURATIONS

- API 625 §5.6 requires that a storage concept be selected based on a risk assessment. The assessment shall include risks both inside and outside the plant boundary.
- Tank System Failure Rates shown in NFPA 59A Table 19.6.1 do not consider effects due to external hazards. No sufficient guidance for comprehensive risk assessment is currently provided

Type of Failure	Failure Rate Per Year of Operation
Single-Containment Atmospheric Storage Tank System	
Catastrophic failure	1E-6 per tank system*
Catastrophic failure of tank system roof (steel roof only)	1E-4 per tank system
Double-Containment Atmospheric Storage Tank System	
Catastrophic failure	1.25 E-8 per tank system*
Catastrophic failure of tank system roof (steel roof only)	1E-4 per tank system
Full-Containment and Membrane Atmospheric Storage Tanks System (Concrete Outer Container)	
Catastrophic failure	1E-8 per tank system*
Catastrophic failure of tank system roof (steel roof only)	4E-5 per tank system
Membrane-Containment Atmospheric Storage Tanks System (Concrete Outer Container)	
Catastrophic failure	1E-8 per tank system*
Catastrophic failure of tank system roof (steel roof only)	4E-5 per tank system

*Consider effects due to external hazards when determining failure frequency.

PROBABILITIES OF FAILURE FOR TANK SYSTEM CONFIGURATIONS

A note to Table 19.6.1 states "Consider effects due to external hazards when determining failure frequency." This note does not sufficiently highlight the need to consider external hazards which are not considered in the failure rates provided.

Incorporate external hazards into NFPA 59A release scenarios and probabilities. Release scenarios and probabilities are discussed in NPFA 59A paragraphs 19.5 and 19.6. NFPA Table 19.6.1 entitled "Failure Rate Per Year of Operation for Various Tank Systems" provides failure rates for the following tank system configurations.

DEVELOPMENT SUBJECT:

- Perform a study on Tank Systems failure rates due to external hazards.
- Provide failure rates for each tank system considering both internal and external hazards. It will make Risk Assessment complete.

QUESTIONS ?