BRAEMAR

Tacoma LNG Fire and Safety Review

Braemar Technical Services

Report Number : BEP1251-05
Revision : 5

Final
Date: 02 July 2018

Prepared for:
The City of Tacoma Fire Department

AUTHOR	CHECKED	APPROVED
Alan Hatfield	Ken Nasit	Constantyn Gieskes

Revision History			
Revision	**Date**	**Detail**	**Author**
1	7/28/17	Draft Issued to Client	A. Hatfield
2	8/22/17	Update	A. Hatfield
3	9/26/17	Add P&ID Review	A. Hatfield
4	11/1/17	Client Review – TFD Received 6/14/18	A. Hatfield
5	7/2/18	Final Issued	A. Hatfield

Table of Contents

Table of Figures

1 Purpose

Braemar Technical Services' Engineering & Naval Architecture Group ("Braemar") is an engineering consulting group that specializes in liquefied natural gas (LNG) services worldwide with LNG Technical Advisors and Consultants having a wide range of LNG experience and expertise that covers the full spectrum of the LNG supply chain. Braemar was contracted by the Tacoma Fire Department to evaluate the proposed design and siting for compliance of the Tacoma LNG project during the Execution Phase (Figure 1) to validate that fire protection and safety systems conform to applicable LNG codes and standards, report findings and make recommendations to the designated City of Tacoma Fire Code Official whom reports directly to the Fire Chief. The Fire Chief directed Braemar to review the project with ultimate due diligence to ensure all relevant safety codes and standards are met.

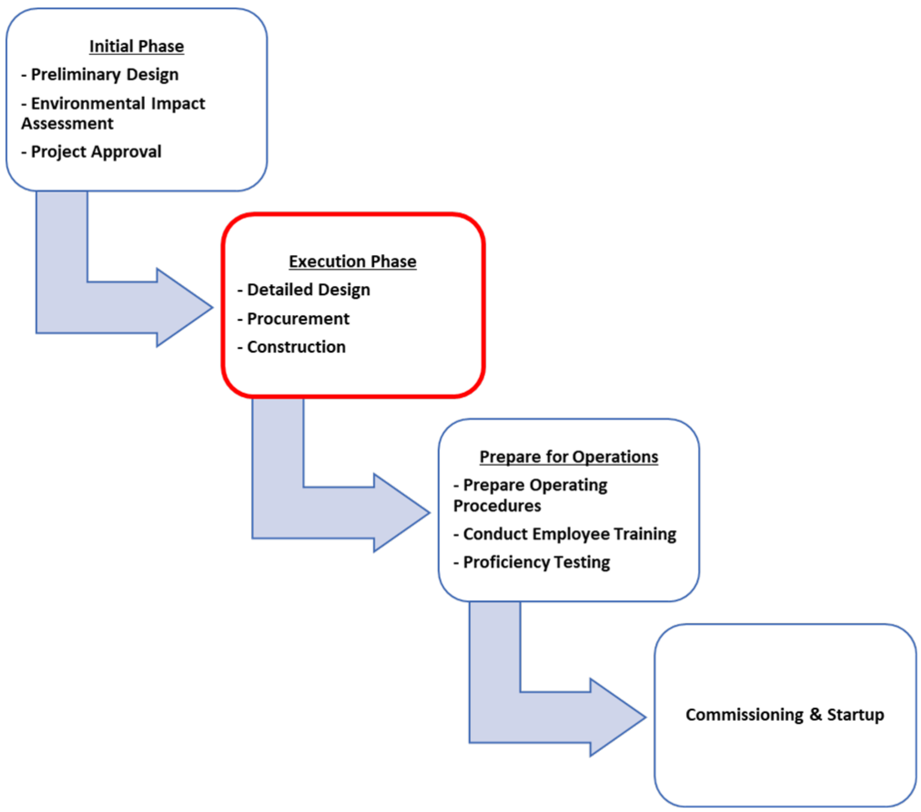


Figure 1 - Project Sequence

During the "Initial Phase", consulting firms Ecology and Environment, Inc. (ENE) and Braemar performed research, analysis and assessment to prepare the "Final Environmental Impact Statement (EIS), November 9, 2015, for the proposed Puget Sound Energy (PSE) Tacoma Liquefied Natural Gas Project". Braemar reviewed and provided analysis of the LNG facility's technical design, engineering and risk analysis included in the final EIS.

On behalf of the City of Tacoma Fire Department (TFD), the study area for this review includes the Tacoma LNG project infrastructure and operations for this LNG project. The Tacoma Fire Department is an Authority Having Jurisdiction (AHJ) to review and approve plant siting, fire protection, safety systems and emergency response requirements for the Tacoma LNG project.

The AHJ mandate includes review, interpret and approve the applicable adopted Fire codes and standards to the LNG facility design and site operations. This role is not limited to initial design, but is a long-term relationship between the City of Tacoma Fire Department and Tacoma LNG to carry out duties of fire prevention, control, and emergency services for Tacoma LNG facility, that includes:

- Design and construction permit review process:
  - Conducting applicable LNG code review for plant siting, process design, fire protection, and safety systems.
  - Plan reviews, inspections and approvals of building permits submittals.
  - Interface with WUTC and USCG to compare and agree on findings and recommendations.
- After operations begin, TFD will perform periodic inspections and the plant operator must ensure proper inspection, testing and maintenance (ITM) of fire protection systems.
- As first responders to a potential emergency incident at the Tacoma LNG facility or LNG transfer dock; protect the public, plant personnel, and LNG facility property from fire, escalation, and to provide rescue and emergency medical first responder services.

PHMSA (Pipeline and Hazardous Materials Safety Administration) and their state partner Washington Utilities and Transportation Commission (WUTC) also share responsibility for LNG code compliance review and approval of project siting, design conformance to applicable LNG codes, and future operations. The United States Coast Guard (USCG) has responsibility for the dock (marine transfer area), and LNG transfer operations to the TOTE Maritime ships.

2 Tacoma LNG Project Summary

The proposed Tacoma LNG project is a multipurpose liquefied natural gas (LNG) facility designed to produce LNG from pipeline natural gas, store LNG, and send-out LNG from the site as ship fuel, trucked LNG, or vaporized LNG for supplemental winter supply to the local gas distribution system (Figure 2).

Figure 2 - Artist Rendering of Proposed Tacoma LNG (Looking South)

The proposed LNG project is located at 1001 Alexander Ave. E, Tacoma, WA 98421 (47°16'31.6"N 122°23'58.3"W) on an approximately 30-acre brownfield industrial site (Figure 3). The property is leased from the Port of Tacoma in the Tacoma Tideflats area within the incorporated city limits of Tacoma, Pierce County, Washington. About 3 acres of additional submerged land is leased in the Hylebos waterway for existing marine structures.

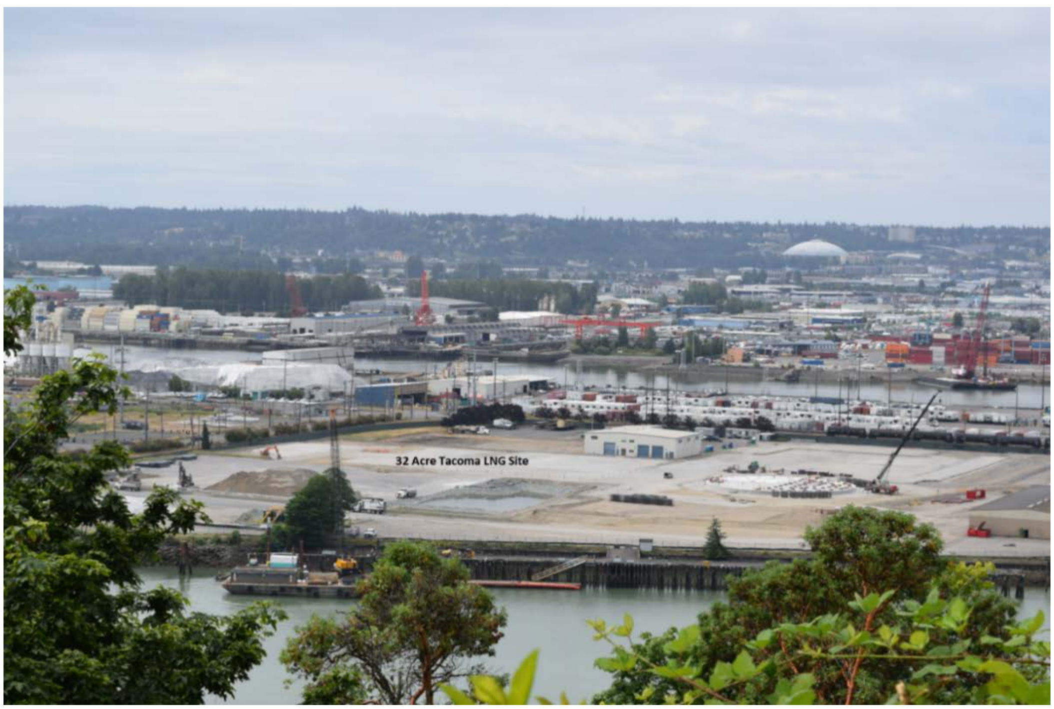


Figure 3 – Tacoma LNG Site, July 2017 (Looking South)

Puget Sound Energy (PSE) selected Chicago Bridge and Iron (CB&I) as the prime contractor responsible to design and construct the Tacoma LNG facility as a multi-use LNG facility. CB&I has served the LNG and natural gas industry for more than 50 years constructing the majority of the 80-plus existing LNG plants in the US, and constructing more than 200 LNG storage tanks worldwide. The LNG Tacoma facility is designed in accordance with the applicable LNG codes, 49 CFR Part 193, NFPA 59A, 2001 edition, and 33 CFR Part 127. At the time this report was prepared, the Tacoma LNG facility had begun initial construction with soil improvement, pile installation, surface preparation, and tank foundation work.

The Tacoma LNG property is in the Port Maritime and Industrial land use zone bordered by road frontage southwest on East Alexander Avenue and southeast on East 11th Street. The Hylebos Waterway is to the northeast boundary, and vacant land to the northwest. Property lines are shown to scale on the Pierce County tax map (Figure 4). The tax map is used as a base map to overlay and label the Tacoma LNG project property, adjoining streets, waterways, and general location of the underground LNG tunnel and Blair Waterway LNG bunker dock.

Figure 4 - Pierce County Property Tax Map

The Blair Waterway dock area is not contiguous with the main Tacoma LNG site since it is intersected by East Alexander Avenue, a public street right-of-way. As part of the Tacoma LNG project, an underground LNG and vapor transfer piping system to the Blair Waterway dock will connect the main LNG process area through a new interconnecting tunnel and short section of above ground piperack within the dock security fence (Figure 5). This crosses a congested industrial area (Figure 6) on the TOTE site where an above ground LNG pipe rack would interfere with TOTE terminal operations and reduce needed staging areas. Access to the Blair Waterway dock for Tacoma LNG personnel is through either of the TOTE terminal gates.

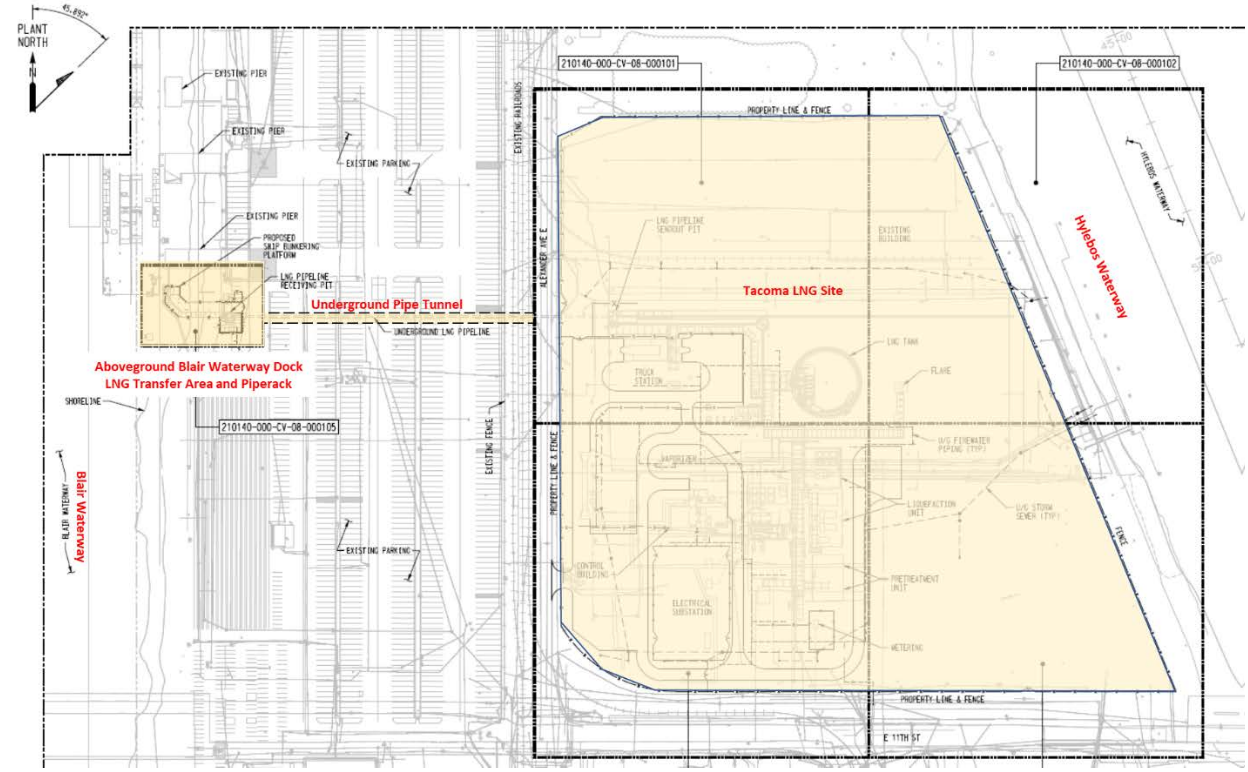


Figure 5 - LNG Facility and Transfer Lines to Blair Waterway

Figure 6 - Existing Site Aerial

The Blair Waterway and Hylebos Waterway have deep water access for general marine navigation. Both are active waterways and are maintained by dredging if necessary to retain navigational depth (Figure 7). For the current Tacoma LNG project, Hylebos Waterway LNG marine bunkering facilities are not included in the design, only at the Blair Waterway adjacent to TOTE. If Hylebos Waterway dock is ever pursued for LNG bunkering in the future, the additional LNG bunkering facilities would be handled as an expansion project, and require a full environmental and design review associated with the new Hylebos Waterway LNG dock components.

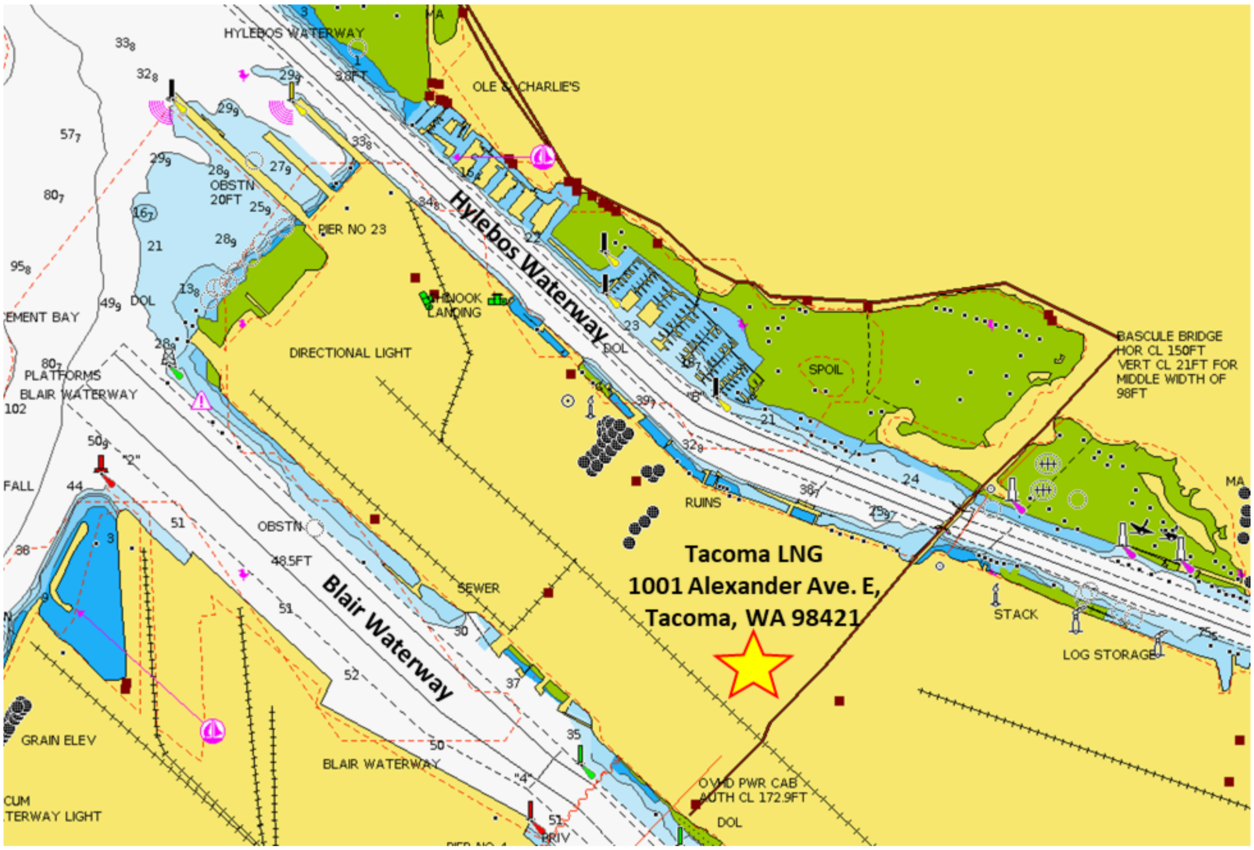


Figure 7 - Navigation Chart of Tacoma LNG Area

The Tacoma LNG facility will have nameplate liquefaction capacity to produce 250,000 gallons of LNG per day for marine and land-based transportation fuel (the actual production capacity could vary by approximately 10% depending on weather, gas composition, and the actual performance of the liquefier). During periods of high natural gas demand, peak LNG vaporization capacity will send-out up to 66 million standard cubic feet per day (66 MMSCFD) for supplemental winter gas supply to the PSE gas distribution system. One eight (8) million gallon full-containment LNG tank will be located on the site to provide LNG storage. The LNG facility will include infrastructure for loading LNG marine vessel transportation fuel to ships from a new fueling facility on the Blair Waterway. Two (2) truck bays are provided for LNG truck tanker loading with capability to also unload trucks if required. The liquefaction facility would receive natural gas from PSE's existing natural gas pipeline distribution system.

3 LNG Safety

The LNG industry is highly regulated, with strong oversight, by established industry standards developed over the past 50 years. Redundant layers of protection are compulsory to diminish the likelihood of an accidental release, to reduce the effects if it takes place, and to prevent an escalation from occurring. LNG safety standards require that LNG facilities be located a safe distance from LNG facility property lines, and equipment and buildings are suitably spaced apart within the plant.

LNG is a clear, colorless, odorless, passive, non-toxic liquid that is stable at –260 °F and atmospheric pressure. LNG will retain a constant temperature in the well-insulated LNG storage tank by maintaining constant low vapor pressure (about 1 psig) by routing excess boil off (evaporation) gas from the LNG tank send-out line to the gas distribution system or other beneficial closed loop processes in the plant without atmospheric venting. Boil-off gas is continuously created from the small amount of ambient heat that enters through tank insulation systems to the stored LNG. The tank boil-off rate is in equilibrium with atmospheric heat that enters through tank insulation systems and does not vary much from day to day. LNG Tank insulation systems have very high resistance to heat transfer to the inner tank where boil-off rates are generally unaffected by atmospheric cycles of ambient temperature, day-night, winter-summer, and humidity.

At the liquid-vapor interface inside an LNG tank, a physical phenomenon occurs when stored liquid boils to a vapor, referred to as boil-off. This results in miniscule bubbling at the liquid surface (evaporation from a liquid to a vapor) that causes “auto-refrigeration”, explained as “enthalpy of vaporization” that produces negative heat, (cooling is a net loss of latent heat), that occurs and reduces the temperature of the vapor produced. Auto-refrigeration provides a direct offset to balance the small amount of ambient heat entering through tank insulation systems. The result is temperature within the LNG tank remains constant at all times, which maintains a stable and passive environment inside the tank. LNG liquefaction process increases boiloff by adding flash gas to the tank, which is accounted for in boiloff recovery systems, however auto-refrigeration phenomenon remains in balance, and tank temperature remains constant, and stability is maintained.

A core design requirement is to effectively contain LNG within the process at all times, maintain design and operational integrity from the beginning of the development process to the end. This is accomplished by:

- Following proven engineering techniques throughout the design process,
- Requiring the highest quality materials suited for cryogenic service temperatures,
- Use all welded materials whenever practical to minimize potential leak points,
- Perform non-destructive and pressure testing of all pressure piping, vessels and equipment to prove integrity of containment systems.
- Maintaining systems for high integrity service.

It is required in LNG codes that in the unlikely event a primary LNG containment system has an accidental LNG release, LNG will be completely contained by secondary containment systems and flammable vapor releases will be retained within the LNG facility boundaries.

When operating an LNG facility, the main goal is to prevent any unsafe release of LNG and flammable gas to the atmosphere, and quickly diminish the impacts if it occurs. To achieve a high level of safety protection, LNG facilities utilize flammable gas, low temperature, and fire detection systems throughout the facility as the first line of defense to rapidly identify and alert plant operators of an unsafe condition. Operators use plant control systems to appropriately respond by using remote actuated and/or automatic fail-safe shut-off systems with high integrity.

3.1 U.S. LNG Code References

Federal LNG safety regulations were first adopted in 1972, incorporating NFPA 59A standards. On February 11, 1980, the Pipeline Safety Statute was codified in 49 U.S. Code § 60101, which directs US DOT to establish and enforce standard LNG pipeline facilities. U.S. Federal Safety Standards *49 CFR Part 193: Liquefied Natural Gas Facilities* is the primary LNG facility code for siting, design, operations, maintenance, security, and training. Relevant sections of the following four (4) jurisdictional codes and standards referenced for this evaluation are:

- 49 CFR Part 193, Federal Safety Standards: Liquefied Natural Gas Facilities is the primary LNG facility code for siting, design, operations, maintenance, security, and training.
- PHMSA Form 18 (Pipeline and Hazardous Materials Safety Administration) - LNG Facility Siting, Design, Construction, and Equipment (Rev. 3/18/09). To validate compliance to 49 CFR Part 193 and NFPA 59A 2001 edition, Form 18 is a consolidated checklist used by PHMSA and their state partner, Washington Utilities and Transportation Commission (WUTC), the authorities for inspecting new LNG facilities for compliance. Form 18 does not include all aspects of the marine area of the project which is also under USCG (United States Coast Guard) jurisdiction. Form 18 is divided into modules as follows:

    1. Preliminaries – Cover Sheet, Subpart A – Reporting & Subpart B – Siting Requirements
    2. Subpart C – Design; Subpart D- Construction; NFPA 59A Emergency Shutdown
    3. Protective Enclosures, Security, Power Sources
    4. Plant Siting & Layout, Soil Protection, Process Equipment & Vaporization Facilities, General & Basic Design
    5. Seismic Design, Container Insulation, Foundations, API 620 Tanks & Field-Fabricated Containers (193.2101
    6. High Pressure Tanks (>15 psi)
    7. Concrete Tanks, Relief Devices, Piping Systems & Components, Welded Pipe Tests & Inspection
    8. Corrosion Control (NFPA 59A & 193.2304)
    9. LNG Level Gauging, Refrigerant & Process Fluids, Pressure & Vacuum Gauges, Temperature Monitoring
    10. Electrical Equipment, Grounding & Bonding
    11. Transfer of LNG & Refrigerants
    12. Fire Protection Provisions
    13. ASME Small Containers (max 100,000 gal/tank and 280,000 gal aggregate)
    14. Construction Acceptance (193.2303); Design & Fabrication (193.2703); Construction, Installation, Inspection and Testing (193.2705); Records (193.2119); Warning Signs (193.2917)

- NFPA 59A 2001, 2006 (seismic only) & 2013 editions, National Fire Protection Association Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG) is incorporated by reference in 49 CFR Part 193, with some exceptions.
- 33 CFR Part 127, Waterfront Facilities Handling Liquefied Natural Gas and Liquefied Hazardous Gas is the primary USCG code for the marine LNG transfer area for new LNG waterfront facilities for design, operations, maintenance, security, and training.

Tacoma LNG has three (3) conditions that trigger PHMSA and state partner Washington Utilities and Transportation Commission (WUTC) jurisdiction:

1. Feed gas for the LNG facility is received from a 49 CFR Part 192 pipeline,
2. LNG vaporization is sent out to a 49 CFR Part 192 pipeline,
3. Exported LNG by truck may be used for offsite pipeline gas supply in a satellite LNG receiving and vaporization facility serving a 49 CFR 192 pipeline.

If feed gas for liquefaction was received from a non-49 CFR Part 192 pipeline source, LNG exported by truck was used for transportation fuel only, and no vaporization or tail gas is sent-out, then PHMSA/ and state partner Washington Utilities would not have jurisdiction.

The LNG industry has strict regulations and safety programs in place to prevent incidents from occurring and to reduce or mitigate the impacts of incidents if they occur. The siting and design of LNG facilities is a rigorous and detailed process that includes many layers of review and oversight.

4 Tacoma LNG Plant Areas for Review

The Tacoma LNG facility design layout is divided into plant areas for review in this report by process and function (Figure 8). Designated areas in the facility are grouped by function, and provide a logical progression of operational steps from one area to the next. Layout arrangement between areas, processes, and buildings are to be considered, and required to meet safety setbacks from property lines that can be built upon, and for security access.

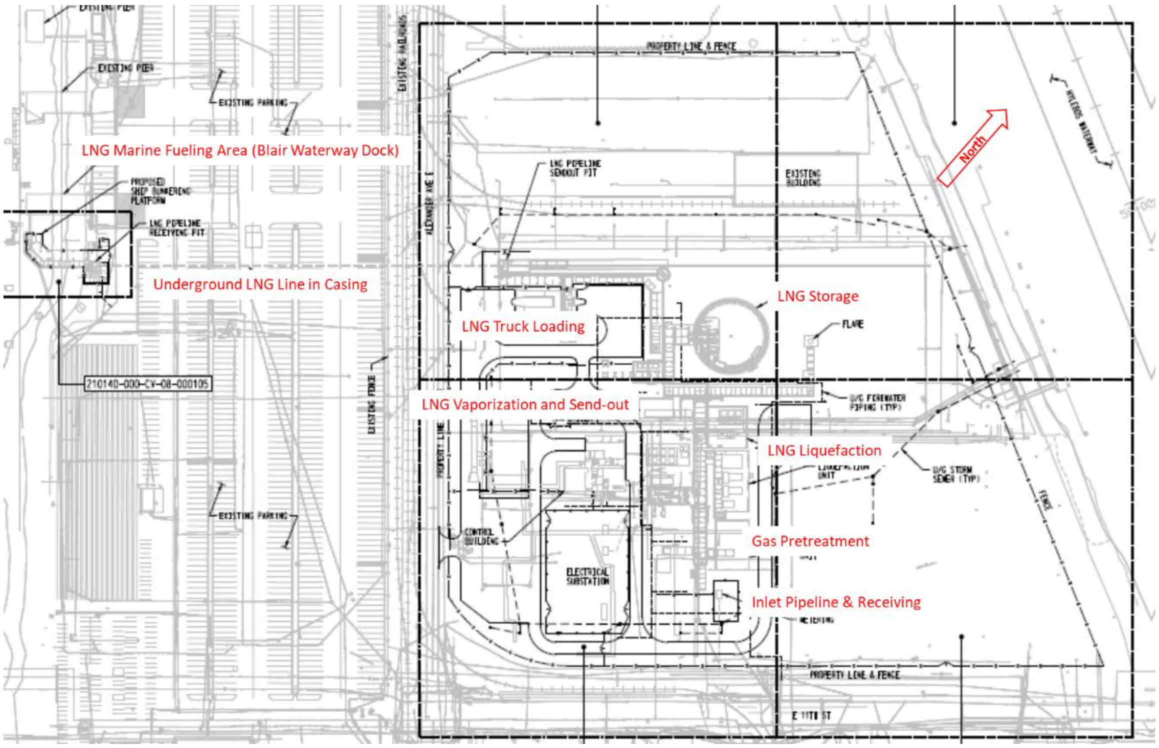


Figure 8 - Tacoma LNG - General Plant Layout

Tacoma LNG Plant areas are:

- Inlet Pipeline & Receiving
- Gas Pretreatment
- MRL (Mixed Refrigerant Loop) LNG Liquefaction
- External LNG Pump and Vaporization Send-out
- LNG Storage
- LNG Truck Loading
- Underground LNG Line in Casing
- LNG Marine Fueling Area (Blair Waterway Dock)
- Process Buildings/Shelters

A more detailed review of the fire and safety systems for compliance to specific codes and standards follows in subsequent sections. The following is an overview of each plant area, the safety features and fire suppression systems provided.

4.1 Inlet Pipeline & Receiving

Natural gas is supplied to Tacoma LNG from the existing natural gas distribution system for liquefaction to LNG. The functions within the inlet pipeline and receiving area includes gas filtering, custody transfer measurement and gas pressure control. First, natural gas flows through an inlet gas meter for custody transfer from the distribution system to the LNG facility, followed by an inlet filter separator to remove any solids or liquids, if present, then, and the supply gas is monitored for the required process operating pressure. When the liquefaction process is shutdown, no supply gas is required from the existing natural gas distribution system.

Inlet pipeline and receiving area systems were found to be designed in accordance with LNG codes & standards, and 49 CFR Part 192 pipeline code. Inlet pipeline and receiving adjoining areas are protected by several safety systems to prevent unsafe conditions. The inlet gas area is monitored from the plant control system to ensure process conditions are operating within normal parameters. An inlet ESD (Emergency Shut Down System) valve is located in this area to isolate incoming feed gas from the LNG facility if an ESD is activated. Firewater protection system provides two (2) monitors with coverage for this area. Additionally, a 300-lb. dry chemical extinguisher is located within 100 feet of this area.

4.2 Gas Pretreatment

Pretreatment of natural gas is an automated process for treating the inlet gas prior to liquefaction to remove unwanted components. Without pretreatment, the LNG process streams and exchangers would become blocked with frozen solids, requiring the process to be shut down for defrosting and removal of the frozen unwanted components. This does not create an unsafe condition, but process differential pressure will slowly increase, LNG production rates decrease proportionally, and eventually a point will be reached where the process must be shutdown to defrost clogged exchangers. Pretreatment must be started first and obtain process stability prior to starting liquefaction. When liquefaction is stopped for an extended period then pretreatment is also stopped.

Potential unwanted natural gas components that may or may not be present consist primarily of:

- Water
- Carbon dioxide (CO_2)
- Natural Gas Odorant
- Condensed heavy hydrocarbons and aerosols
- Dirt and scale
- Mercury (trace quantities, if any)
- Hydrogen sulfide (H_2S) (trace quantities, if any)

The pipeline quality gas for Tacoma LNG requires minimal treatment with the presence of water and CO_2 as the primary components to be removed. Other components listed may be present in lower concentrations, or not present at all, but will also be removed in the pretreatment process if present.

Pretreatment consists of a series of separators, filters, vessels, and other supporting processes that have continuous operations during LNG liquefaction. The range of potential natural gas compositions delivered from the supply gas pipeline to the LNG facility drives the design and pretreatment technology.

The pretreatment systems of Tacoma LNG's facility were found to be designed in accordance with the applicable LNG codes & standards. Pretreatment systems and adjoining areas are protected by several safety systems to prevent unsafe conditions. In the event of combustible gas detection in the air intake to the regen gas heater or amine reboiler heater, an automatic shutdown of the heater will occur. Fire, and gas, detectors are strategically located in the pretreatment area to alert operators of a potential unsafe condition caused by an accidental release or fire. One (1) ESD buttons is located within the pretreatment area that quickly and safely shutdown plant operations and close ESD valves. Pretreatment outlet piping is monitored by temperature sensors for hot gas send-out to liquefaction to alert operators of higher than normal outlet gas temperature.

Firewater protection system consists of buried and above ground pipe, fire hydrants, and five (5) monitors. Additionally, a 1,500-lb. dry chemical extinguisher with 150 foot hose reel is located in the pretreatment area as well as a 300-lb wheeled dry chemical extinguisher.

Pretreatment is performed in two (2) steps, CO_2 removal, then dehydration, as described below.

4.2.1 CO_2 Removal

There are multiple processes available for CO_2 removal from natural gas where the technology decision is based on removal for the worst (highest mole %) case. If actual CO_2 concentrations were to exceed the removal design capability, CO_2 carryover to the liquefaction process would occur causing frozen CO_2 builds-up in cryogenic exchangers as a solid (dry ice). Based on a historical review of pipeline gas quality, the CO_2 pretreatment removal capacity at Tacoma LNG is greater than the highest concentrations that may be present in the supply gas, and carryover to liquefaction is very unlikely to occur. A CO_2 analyzer samples natural gas in real time for CO_2 concentrations in the gas, and will alarm in the control system if the 50 ppmv threshold has been exceeded.

Tacoma LNG utilizes Methyl Diethanolamine (MDEA), amine technology to remove CO_2 from incoming natural gas. With a high affinity to absorb CO_2, MDEA is commonly used in the natural gas industry for gas treating. Amine processes involve a series of vessels, and filters in a closed system where a solution of water and MDEA amine remove CO_2 from incoming gas. Natural gas enters a contactor tower and rises through the amine solution entering from the top of the tower where treated gas flows from the top of the tower. The amine solution is now considered rich and is carrying absorbed CO_2 gas in solution. Rich amine is then heated in a regeneration tower that liberates the CO_2 which is sent to the plant flare system. Makeup water is required to replace water leaving the system as steam. MDEA has low flammability and toxicity, where handling recommendations are limited to goggles with face shield and gloves during transfer of the undiluted product or concentrated solutions. Any trace amount of H_2S will also be absorbed in the MDEA solution along with CO_2.

The Tacoma LNG CO2 removal system was found to be designed in accordance with applicable codes and standards.

Treated gas from an amine system is saturated with higher water content than the incoming gas stream. Therefore, dehydration is required to remove water from supply gas and water added by amine pretreatment before liquefaction.

4.2.2 Dehydration with Molecular Sieve System

Molecular sieve filtration is a process commonly found in LNG facilities to lower natural gas water (H_2O) content to less than 1 ppmv by adsorption. Mol sieve is contained in two (2) vertical adsorber pressure vessels with one in adsorption mode, and the other in regeneration or standby. Once saturated with water, the process is designed to switch vessels to allow alternating vessels to be in adsorption mode while the other is regenerated for a continuous uninterrupted operation. For regeneration, heated gas is routed from a gas heater through the saturated mol sieve at high temperature which regenerates by heating adsorbed water to steam and carried away in the regeneration gas outlet. If actual H_2O concentrations were to exceed the removal design capability, H_2O carryover to the liquefaction process would occur causing ice builds-up in cryogenic exchangers. This does not create an unsafe condition, but process differential pressure will slowly increase, production rates decrease proportionally, and eventually a point will be reached where the process must be shutdown to defrost clogged exchangers.

A molecular sieve filter is comprised of adsorption material consisting of inert clays, porous glass and other material that have open structures through which small molecules, such as nitrogen and water can diffuse. Methods for regeneration of molecular sieves include pressure change, heating and purging until adsorbed material is released. Natural gas used for regeneration will be is returned to the saturated process stream exiting the amine contactor. The H_2O pretreatment removal capacity at Tacoma LNG is greater than the highest concentrations that may be present in supply gas, and carryover to liquefaction is very unlikely to occur. An analyzer constantly monitors the natural gas stream after dehydration for H_2O concentrations in the gas, and will alarm in the control system if the 1 ppmv threshold has been exceeded.

The Tacoma LNG dehydration system was found to be designed in accordance with applicable codes and standards.

<u>Accident at Williams Pipeline LNG Plant, Plymouth, Washington</u>: On March 31, 2014, a serious accident occurred at the Williams Pipeline LNG Peak Shaving Plant in Plymouth, Washington. A molecular sieve adsorber pressure vessel and associated piping catastrophically failed between the adsorber vessel and the gas bath heater. Five (5) employees were injured and treated on site and one (1) employee was flown to the hospital for additional treatment with burns. An emergency shutdown was activated, plant personnel were evacuated, precautionary evacuations of the public near the facility, and significant property damage occurred. According to the PHMSA accident report dated April 28, 2016 the accident was caused by "*Operator Error - Vessel and piping failure from detonation caused by internal auto-ignition due to a purge that failed to remove a gas-air mixture from the system*". The root cause was the system had been opened for maintenance earlier, and was not properly purged of air prior to natural gas being reintroduced, and system placed back in service.

The accident at Plymouth LNG was a major wakeup call to the natural gas industry and had significant impact on training and hazard awareness in industry operating and maintenance practices. The accident reinforced the most fundamental rule for safe handling and storage of natural gas by pipeline or containment vessel, which is the avoidance of a gas-air mixture in a confined space under all conditions. Proper purging of pipelines and vessels with inert gas, typically nitrogen, is a critical step when taking these components out of service, or placing back in service to prevent a gas-air mixture in a confined space from ever occurring, under all operating conditions. This is a gaseous fuel issue, not an LNG issue, but includes all uses of flammable gases in a confined space. Operator training for safe handling of flammable gas is the key to prevention of this unsafe conditions.

4.3 LNG Liquefaction

For producing LNG liquid from natural gas there are multiple patented, licensed, and open source technologies commercially available that come in various capacities and efficiencies. LNG liquefaction theory starts with a simple cycle refrigeration process, but then modified for the much greater temperature differential (~300 °F) than ordinary refrigeration applications. Technology variations build on the simple cycle refrigeration process by using multiple stages and refrigerants suited to the application to increase process efficiency and reliability.

Tacoma LNG's decision to use a mixed refrigerant loop (MRL) process results in a simple and high efficiency liquefaction closed loop process. MRL is one of the most common liquefaction processes found in the LNG industry, and known for operating steady state for long periods with high reliability. MRL has fewer components; compressors and exchangers compared to other LNG processes. Tacoma LNG MRL liquefaction contains a blend of hydrocarbon refrigerants with fixed concentrations; propane, iso-pentane, ethylene, nitrogen and methane in a single loop. The liquefaction process is air cooled using ambient air circulated through fin-fan coolers. When shutdown, the liquefaction loop is stable without the need to de-inventory refrigerants or vent to the atmosphere. The main refrigerant compressor includes a seal gas recovery system that was added to the design to reduce seal gas losses from compressor seals, and subsequently decreased the amount of onsite refrigerant storage requirements by about 50%.

Propane, iso-pentane, and ethylene refrigerant for MRL process makeup is stored onsite in separate horizontal pressure vessels inside a mounded concrete vault for passive fire protection. The vault drains to the collection trench to the common process area spill impoundment sump to assure that a potential spill will flow away from the tanks. Underground soil encasement of refrigerant storage was chosen instead of aboveground installed storage vessels to reduce potential hazards from fire exposure or external damage. To prevent external vessel corrosion from soil and moisture contact, vessels and related piping are protected by cathodic protection. A heavy hydrocarbon storage vessel is buried adjacent to refrigerant storage vessels. This vessel is used to collect heavy end hydrocarbons that condense during liquefaction, and periodically transported offsite when the vessel is full.

Secondary containment is provided for the liquefaction area for the maximum accidental design spill scenario cases for LNG and mixed refrigerant. Vapor dispersion and thermal radiation modeling cases submitted to WUTC demonstrated compliance to NFPA 59A siting requirements.

Evaluation is also required for an overpressure caused by a vapor cloud explosion from a maximum accidental design spill of LNG or mixed refrigerant. Due to the open site plan and the low reactivity of natural gas (methane), scenarios involving natural gas were not deemed credible for a vapor cloud explosion. PHMSA prescribes a 1 psi overpressure threshold that was calculated at the property line that can be built upon and at any occupied buildings in the facility. Mixed refrigerant and its components are medium and high reactivity substances that have a higher susceptibility to generate explosive overpressure, were evaluated, and submitted to WUTC. Damaging overpressure levels of 1 psi were determined to remain within the property boundary and would not impact occupied buildings within the facility therefore meeting the requirements for overpressure cases.

The Tacoma LNG liquefaction systems were found to be designed in accordance with the applicable LNG codes & standards. Liquefaction systems, refrigerant storage, and adjoining areas are protected by several safety systems to prevent unsafe conditions. Fire, gas, and spill detectors are strategically located in the liquefaction area to alert operators of a potential unsafe condition caused by an accidental release or fire. One (1) ESD button is located within the liquefaction area that will quickly and safely shutdown the LNG liquefaction process and close ESD valves to block-in the process.

Passive systems protect piping and structures from radiant heat. Cryogenic pipe welds are subject to 100% X-Ray, non-cryogenic process piping 30%, and all is pressure integrity tested. Piping, vessels, and components are insulated, comprised of stainless steel or aluminum, and specified for suitability for pressure containment and cryogenic temperatures.

Firewater protection system consists of buried and above ground pipe, fire hydrants, and four (4) monitors. Additionally, a 1,500-lb. dry chemical extinguisher with a 150 foot hose is located at the liquefaction area, as well as a 300-lb wheeled dry chemical extinguisher.

4.4 LNG Vaporization and Send-out

Tacoma LNG provides supplemental winter gas supply (peak shaving) capacity to the utility gas distribution system with six (6) days of capacity reserved at the full send-out rate from one (1) horizontal indirect gas fired water-glycol bath vaporizer. Various designs of water bath LNG vaporizers are commonly found in US LNG facilities and known for operating at steady state for long periods with high reliability. The LNG vaporizer peak send-out capacity is 66 million standard cubic feet per day (66 MMSCFD) to the Tacoma gas distribution system. Vaporization capability provides increased utility gas supply reliability, reduces transmission pipeline demand charges to the rate base, and reduces offsite supplemental gas storage requirements. The majority of LNG storage volume in the LNG tank is reserved for utility peak shaving with the balance reserved for providing LNG as transportation fuel.

The Tacoma LNG vaporizer was found to be designed in accordance with the applicable LNG codes & standards. The vaporizer and adjoining area are protected by several safety systems to prevent unsafe conditions. In the event of combustible gas detection in the vaporizer combustion air intake, an automatic shutdown of the LNG vaporizer will occur. Vaporizer outlet piping is monitored by redundant temperature sensors to prevent cold gas send-out by automatically shutting down and isolating the vaporizer outlet. Fire, gas, and spill detectors are strategically located in the vaporizer area to alert operators of a potential unsafe condition from an accidental release or fire. Several ESD buttons are located at and near the vaporizers that quickly and safely shutdown LNG pumps, and close ESD valves to shut down and isolate the vaporizer. Secondary containment is provided for the vaporizer area for the maximum design spill of 1,630 gpm for 10-minutes. As required, odorant (mercaptan) is added in prescribed amounts to the natural gas flowing from the LNG vaporizer prior to it entering the distribution system which gives the gas a distinctive odor. Firewater protection system consists of buried and above ground pipe, fire hydrants, and three (3) monitors. Additionally, a 300 lb. dry chemical extinguisher with 100 foot hose reel is located at the vaporizer area.

4.5 LNG Storage

Tacoma LNG has one (1) full containment type LNG tank with eight (8) million gallon LNG storage capacity with approximate outer dimensions of 130’ diameter and 140’ tall. Full containment is defined as a double tank designed and constructed so that both the inner tank and the outer tank are capable of independently containing the LNG and controlling the vapors generated. The primary (inner) container is made of all welded 9% nickel steel plates which provides high strength and toughness and assures material integrity at cryogenic temperatures. The secondary (outer) container is made of pre-stressed concrete equipped with internal thermal insulators on an elevated concrete slab supported by piers and seismic isolators. The secondary containment is constructed of concrete and post-tensioning steel which are optimum for extreme low temperatures. All-welded carbon steel plate lines the inside wall and floor as a vapor pressure containing barrier. The post-tensioning steel tensile strength and the concrete compressive strength are not reduced, but rather increased, at cryogenic temperatures. The outer concrete tank wall is erected at a distance from the inner wall of about 6 feet providing an annular space for blown insulation, typically filled with expanded loose perlite insulation. There is a suspended deck over the open top of the primary containment upon which is comprised of 1' – 8" or more of fiberglass insulation (Figure 9).

Because of the low temperature of the LNG, it is necessary to thermally insulate the bottom, walls, and top of the primary containment to limit inflow of heat and the associated boiloff of the stored LNG. Below the primary containment, there is1' – 8" of structural insulation, which is composed of stacked structural insulating blocks with felt material between block courses to prevent convection currents from forming in the small spaces between the blocks. The inner and outer tanks are designed for an operating basis earthquake a safe shutdown earthquake internal and external fire conditions, and high impact forces as defined in the NFPA59A 2006 edition. The tank foundation consists of a base concrete slab, a set of seismic isolators, and an elevated upper concrete slab. To accommodate allowable movement of the seismic isolators, a small air gap exists between the base concrete slab and upper concrete slab. This air gap also allows air circulation under the tank that eliminates the need for a foundation heating system typically used to prevent cold temperature transfer to the soil under the tank that could cause ground frost/heave and ultimately compromise the tank foundation.

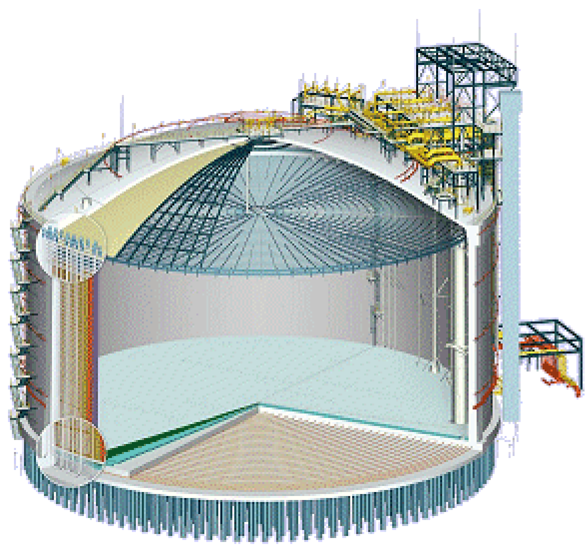


Figure 9 - Cross Section of Full Containment Tank Wall and Base

The tank and adjoining area are protected by a number of safety features and systems to prevent unsafe conditions.

- There are no penetrations of the inner and secondary liquid containment tank below the maximum liquid level; all nozzles and piping from pumps, fill lines, withdrawal lines, vapor lines, and instruments are routed through the roof.
- The roof is protected from fire exposure and potential LNG roof spills by a layer of concrete over the outer tank steel roof. Potential accidental roof spills are routed by curbs to a vertical downcomer pipe to grade and transferred to the spill impoundment.
- Fire, gas, and spill detectors are strategically located in the LNG tank area and tank roof to alert operators of a potential unsafe condition from an accidental release or fire.

- Electrical connections to in-tank pumps have dual seals to prevent vapor migration in electrical conduit, monitored for primary seal failure with a control system alarm.
- One (1) ESD button is located on the tank top platform that will quickly and safely shutdown LNG pumps, and close ESD valves to shut down and isolate the LNG tank.
- Secondary containment is provided for piping and equipment in the tank area for the maximum design spill of 4,890 gpm for 10-minutes.
- The LNG tank vapor system is protected by pressure relief valves, vacuum breakers, and discretionary vent to the flare.
- Firewater protection system consists of buried and above ground pipe, fire hydrants, and three (3) monitors. Additionally, a 300 lb. dry chemical extinguisher is located at the tank area.

The majority of the 130 or more LNG tanks in the US are of the single containment type. Compared to single containment, full containment LNG tank design is more substantial with the additional integral secondary containment concrete wall and roof that provides redundant passive protection from accidental releases, fire exposure, and forces from impact, flooding, or seismic. The Tacoma LNG tank design is considered very robust, and no credible unmitigated failure scenarios were identified that could cause an accidental release or failure of the tank and ancillary components. The Tacoma LNG tank was found to be designed in accordance with the applicable LNG codes & standards.

4.6 LNG Truck Loading

In addition to providing LNG fuel supply to ships, Tacoma LNG facility will also have the capability of transferring LNG to trucks (Figure 10). Two (2) LNG truck loading bays are proposed each of which is composed of control valves, LNG and vapor hoses, flow, pressure & temperature measurement devices, and pressure safety valves, and a station control system. An onsite weight bridge is used for custody transfer measurement, and confirm the truck is not overfilled and is within allowable highway weight limits.

The LNG truck loading system is designed to utilize the same LNG in-tank pumps as used for ship loading. Pressure control valves maintain the pressure required for the tanker trailers. The supply LNG line is equipped with remote shutdown valves to isolate the truck station in the event of an emergency. Tacoma LNG is also capable of receiving LNG from trucks. LNG from trucks may be the source of LNG for initial LNG tank cooldown.

Access for truck loading is through a dedicated gate, and area fenced to prevent access to other areas of the LNG terminal.

Fire, and gas detectors are strategically located in the LNG truck loading area to alert operators of a potential unsafe condition from an accidental release or fire. Two (2) ESD buttons are located at and near the LNG truck loading area that quickly and safely shutdown LNG pumps, and close ESD valves to shuts down and isolates the LNG tanker.

Secondary containment is provided for the truck loading area for the maximum design spill of 1,630 gpm for 10-minutes. Vapor dispersion and thermal radiation modeling cases submitted to WUTC demonstrated compliance to NFPA 59A siting requirements. Firewater protection system consists of buried and above ground pipe, fire hydrants, and three (3) monitors. A 1,500-lb. dry chemical extinguisher with 150' hose reel is located at the vaporizer area, in addition to a 300-lb wheeled dry chemical extinguisher.

Figure 10 – Example LNG Truck Tanker Loading Operation

4.7 Underground LNG Line in Tunnel

The dedicated tunnel connecting Tacoma LNG and the Blair Waterway dock will be installed within an easement from the Port of Tacoma on land leased by TOTE Maritime Alaska located at 500 E Alexander Ave, the operator of the TOTE cargo terminal. An LNG pipe tunnel, a more expensive option than above ground installations, will provide a casing for the installation of vacuum jacketed (pipe-in-pipe) LNG and vapor pipe supported inside the nitrogen purged tunnel. The tunnel also includes utilities and control system cables required at the Blair Waterway Dock. The pipe tunnel will be installed by horizontally drilling and excavating at depth, not open cut, to avoid disrupting trailer terminal operations during construction or future operations.

The underground pipe tunnel was found to be designed in accordance with LNG codes & standards. The design is considered robust, and no credible unmitigated failure scenarios were identified. Several additional layers of protection exist in the design to prevent the possibility of unsafe conditions. Vacuum jacketed (VJ) pipe in the casing is fully welded to avoid potential leaks at mechanical connections. In the unlikely event a leak occurs in the inner pipe; secondary containment of the fluid will be provided by the integral outer stainless steel pipe jacket with excess pressure routed through the vapor return line to the LNG circulation line. The tunnel casing has a continuous nitrogen purge to maintain a non-flammable environment and no ignition sources are present. Instruments monitor the casing for the presence of gas vapor and cold liquid and immediately alarm in the control room if detected. The underground tunnel is monitored from the plant control system to ensure process conditions are operating within normal parameters. Similar design concepts have been approved and successfully implemented at other US LNG projects where above ground LNG piping was not suited to the site-specific conditions.

Firewater protection system consists of buried and above ground pipe, fire hydrants, monitors, and 300-lb. dry chemical extinguisher is located at both ends of the tunnel.

4.8 LNG Marine Fueling Area (Blair Waterway Dock)

From the northwest end of the underground LNG pipe tunnel, LNG piping and utilities are routed toward the dock on an above ground pipe rack within a dedicated right-of-way which is fenced on both sides. LNG transfer to the ship is a closed loop process where no routine venting occurs. In the unlikely event of a leak in the loading area, secondary containment is designed for a 10-minute full rate design spill with a spill transfer trench leading to the west end underground tunnel impoundment. An above ground pipe-rack runs from the west end underground tunnel to the marine LNG ship fueling area, referred to as the “TOTE LNG Dock or Blair Water Dock”.

A dedicated LNG transfer dock will be used for LNG bunker transfer to the TOTE Ships. One (1) 6” LNG loading arm, and one (1) 2” vapor return hose are located on the dock for ship fueling. The peak LNG design loading rate is 2,640 gallons per minute (gpm), at 65 psig at the ship interface flange. At this rate the TOTE ship would be fueled in four (4) hours. LNG transfer is a closed loop process in which nitrogen is first used for purging to confirm an oxygen free environment. LNG and vapor are then recovered and sent to the LNG tank vapor space or if necessary, the flare. The ship vapor return line is normally not connected during ship loading, and would be infrequently used only if the ship board LNG tanks require commissioning cooldown or purge, such as after an extensive period of time out of service.

The LNG loading and vapor return arms are stainless steel, hydraulically operated, and specifically designed for local conditions that consider ship movement during transfer. This includes the full tidal range, weather events, and possible wake from passing ships. The arms utilize a Power Emergency Release Coupling (PERC) at the ship-to-shore interface located at the ship’s manifold. The LNG operator stands adjacent to the ship manifold and uses a wireless controller to precisely move the LNG and vapor arms into alignment for mating the quick connect couplings. In the unlikely event of excess ship movement during transfer, the PERC valves provide automatic breakaway protection. Limit switches monitor the arms to protect from moving beyond their operating envelope. First, an alarm will warn the local operator the arm is near the arm travel limit. The second limit switch trip point alarms and automatically stops LNG transfer pumps and flow to the ship. The third limit switch trip activates the PERC valves causing the valves to close, arms to release from the ship. The arms are would then be slewed hydraulically away from the ship after a PERC disconnection. This event could be caused by unusual tides in combination with wake caused by large passing ships. This is considered an extremely unlikely event at this location; however, the additional safety measures are still in place.

Attendance within the loading area by a designated LNG Operator is required for the full transfer period, from beginning to end. This includes arm movements, arm connections, preload testing measures, arm cooldown, LNG transfer, purging transfer arms & piping of LNG and flammable vapor, arm disconnect, and arm movement to their resting position. Operators are responsible to monitor and maintain safe transfer conditions. In the unlikely event of abnormal conditions, the Operator takes appropriate action to maintain safe conditions

The Tacoma LNG marine fueling area was found to be designed in accordance with the applicable LNG codes & standards, including USCG 33 CFR Part 127. The design is considered robust, and no credible unmitigated failure scenarios were identified. The transfer dock and adjoining area are protected by layers of safety systems to prevent unsafe conditions, and respond appropriately in the unlikely event they occur. Fire, gas, and spill detectors are strategically located in the dock and piping area to alert operators of a potential unsafe condition from an accidental release or fire. For compliance to USCG 33 CFR Part 127.205 b, gas detection above 40% of the lower flammability limit (LFL) in the ship transfer area will automatically initiate a shutdown of LNG transfer and quickly and safely shuts down LNG pumps, and close ESD valves. PERC valves protect from excess movement of the ship/loading arm outside of their operational envelop. A ship-to-shore cable provides an interface with the ship allowing the shore ESD to initiate a ship ESD, and vice-versa, and for emergency communications. Secondary containment is provided for the transfer area for the maximum design spill rate of 2,640 gpm for 10-minutes. Firewater protection system consists of buried and above ground pipe, two (2) existing fire hydrants, and two (2) new monitors. A 300-lb. dry chemical extinguisher is located at the LNG transfer area (Figure 11).

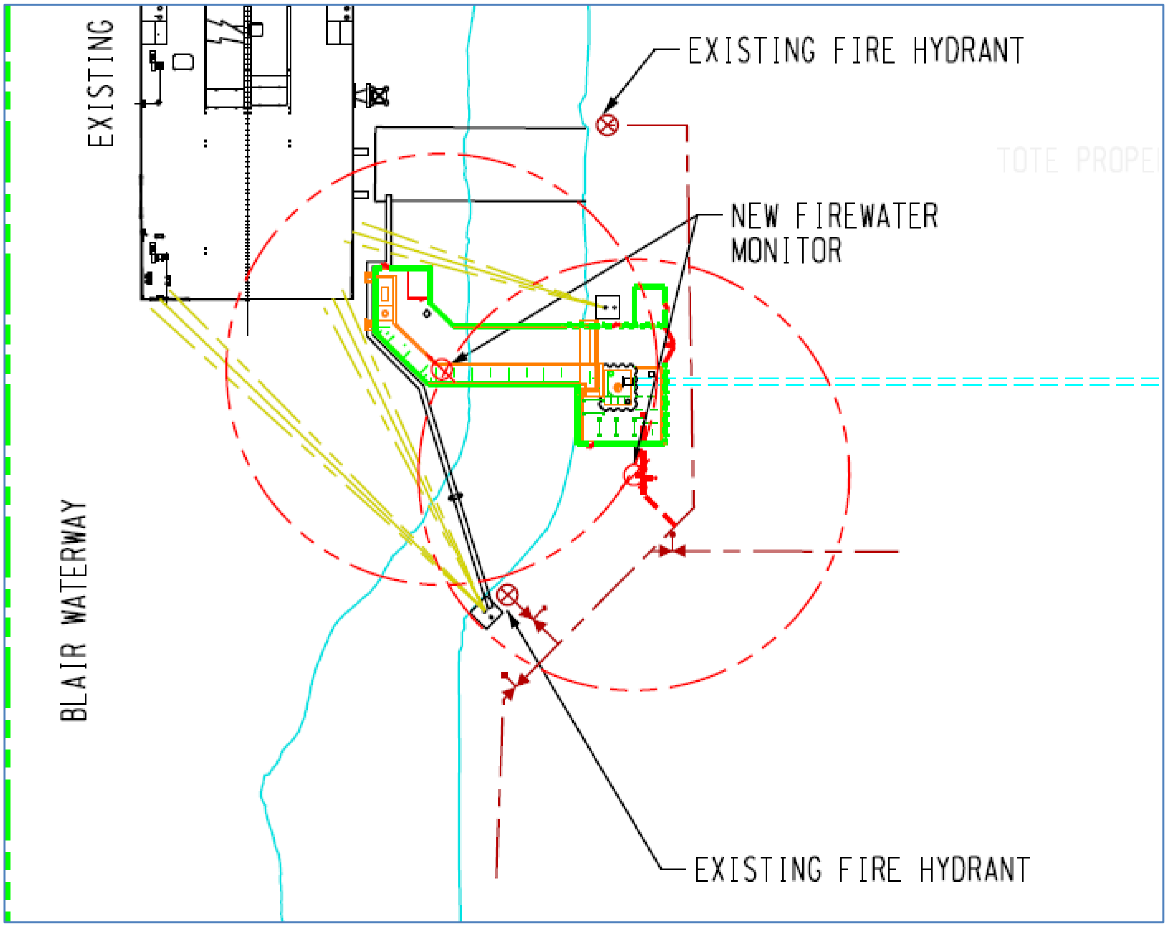


Figure 11 - Blair Waterway Dock Firewater Layout

4.9 Buildings, Process Buildings and Shelters

Tacoma LNG facility has an existing warehouse, and one (1) office building. The office building includes dedicated area for the main LNG facility control center, and for administration. These buildings were previously permitted, inspected, and approved under the City of Tacoma building codes to requirements as occupied structures. Occupied buildings with HVAC systems have sprinklers, fire and smoke detection, and alarm systems. Fresh air intakes are monitored by gas detectors that will automatically shut down HVAC systems to prevent entry of flammable gas into enclosed buildings, and alarm to alert personnel of the occurrence.

As part of the Tacoma LNG project, new additional unoccupied process and storage buildings and shelters will be constructed to contain process, electrical, and control equipment. Each building and shelter will be designed in accordance with the applicable code for the intended use, and include all required safety systems required in the City of Tacoma building code and applicable LNG standards.

4.10 Tacoma LNG P&ID Review

Piping and instrumentation diagrams (P&ID's) are detailed diagrams of all process piping and vessel configurations, together with the associated instrumentation and control devices. P&ID's shows all process and utility piping including arrangements of piping branches, reducers, valves, equipment, instrumentation and control interlocks. P&ID's are also used to operate the LNG facility process systems and utilities.

Tacoma LNG P&ID's were provided by PSE/CB&I to Braemar as a complete 69-page set. A review was performed by Braemar of the 69 P&ID drawings and clarification questions were submitted to PSE/CB&I for their response. Responses to all clarification questions of the current P&ID design drawings were provided by PSE/CB&I. Based on the review of the Tacoma LNG P&ID's, and responses to clarification questions, the process was found to be designed in accordance with the applicable LNG codes & standards, 49 CFR Part 193, NFPA 59A 2001 edition, and USCG 33 CFR Part 127.

P&ID's are considered one of the primary LNG process reference documents in operating procedures and emergency response plans of the operating LNG facility. Due to the preliminary nature of the project, operating procedures and emergency response plans currently have not been prepared, and expected later in project development. When complete, operating plans and emergency procedures will reference P&ID's by page number and assigned tag number for specific scenarios, process components, and instruments. P&ID's are to be available to operators, and kept up-to-date with revisions incorporated at least one time every year. P&ID's and references to operating plans and emergency procedures will be reviewed again later when available.

5 LNG Plant Siting and Layout Study

The following was evaluated in performing an "LNG Fire and Safety" compliance evaluation of the proposed Tacoma PSE LNG Facility and the TOTE ship to shore fueling facility.

In accordance with 49 CFR Part 193 Section 193.2051 an LNG facility must meet the minimum siting requirements of NFPA 59A 2001 edition, Chapter 2, "Plant Siting and Layout". This chapter addresses site specific design criteria that have a bearing on the safety of plant personnel and the surrounding public. Siting includes an evaluation of code prescribed hypothetical worst-case incidents and preventative safety measures incorporated in the design to mitigate their occurrence. Operating procedures of the facility were not evaluated at this time. Requirements considered in siting and layout include:

- Secondary Containment: Provisions for retention of worst case accidental spilled LNG scenarios, flammable refrigerants, and flammable liquids within the limits of plant property and for surface water drainage. This includes process areas, vaporization areas, transfer areas for LNG, flammable refrigerants, and flammable liquids, areas immediately surrounding flammable refrigerant, and flammable liquid storage tanks.

- Thermal Radiation: Provisions made to minimize the possibility of the damaging effects of thermal radiation flux from a fire emanating from a design spill from reaching beyond a property line that can be built upon and that would result in a distinct hazard.

- Vapor Dispersion: Provisions made to minimize the possibility of a flammable mixture of vapors from a design spill from reaching beyond a property line that can be built upon and that would result in a distinct hazard.

- Minimum Spacing: Minimum spacing for process equipment, storage containers, and transfer areas containing LNG, refrigerants, flammable liquids, or flammable gases from sources of ignition, from a property line that can be built upon, and from occupied buildings and structures.

- Vapor Cloud Explosion (VCE): Liquefaction refrigerants gases and blends proposed for Tacoma LNG will contain a mix of propane, ethylene, and iso-pentane which are referred to as heavy hydrocarbons. The proposed liquefaction process is a closed loop where flammable gases and liquids are not vented to the atmosphere during normal operations. There are conditions in an open environment where an accidental release of heavy hydrocarbons leading to a VCE can occur, if ignited. According to PHMSA, they are unaware of explosions occurring involving outdoor vapor clouds of natural gas and LNG vapor and do not believe that there is a risk of vapor cloud explosions (VCEs) due to a release of methane in an open area.

- Ventilation: Adequate ventilation of buildings or structural enclosures in which LNG, flammable refrigerants, and flammable gases are handled to minimize the possibility of hazardous accumulations of flammable gases or vapors.

- Fresh Air Intakes: Protection of fresh air intakes to buildings, structural enclosures and equipment to prevent intake of accidental LNG, flammable refrigerants, and flammable gas releases to minimize the possibility of hazardous accumulations of flammable gases or vapors.

In addition, 49 CFR Part 193 and NFPA 59A 2001 requirements consider other factors not included in the chapter on siting that have a bearing on the safety of plant personnel and the surrounding public. The requirements include an evaluation of potential incidents and safety measures incorporated in the design or operation of the facility that include:

- Hazardous Area Classification: The Hazardous Area Classification within the boundaries of Tacoma LNG facility considers the potential for flammable gas to be in the atmosphere to manage ignition sources within the LNG facility. Hazardous Areas are determined in accordance with the National Electrical Code NFPA 70 Article 500 and NFPA-59A. Hazardous Area Classification is considered when:
  - Specifies the type of electrical equipment allowed within the classified area,
  - Requires additional measures be taken during routine operations and maintenance to monitor the atmosphere for flammable gas.

- Electrical Grounding & Bonding: Tacoma LNG facilities will be electrically grounded and bonded in accordance with the National Electrical Code (NEC).

- Fire Protection and Safety" Evaluation: A formal "Fire Protection and Safety" evaluation is a code required task for new and existing LNG facilities. Per the US Federal Code for LNG Facilities, 49 CFR Part 193 Section 193.2801, Fire Protection states: "Each operator must provide and maintain fire protection at LNG plants per NFPA 59A 2001 edition sections 9.1 through 9.7 and section 9.9."

- Marine Transfer Area: NFPA 59A 2001 edition, Chapter 8 "Transfer of LNG and Refrigerants" and USCG 33 CFR Part 127 have specific additional requirements for LNG facilities with waterfront LNG transfer facilities.

- Security: Security for the site is under the jurisdiction of US Coast Guard regulation 33 CFR Part 105 (which supersedes the security requirements of PHMSA regulation 49 CFR Part 193) and the USCG will be responsible reviewing, approving, and auditing a facility security plan that meets MTSA (Marine Transportation Security Act) requirements.

5.1 Accidental Release Cases for Siting Studies

LNG codes and standards have mandatory and specific requirements for "Siting" studies that are given high importance during the design, construction, and operations of an LNG facility. The primary purpose is to protect the public, plant personnel, LNG facility property, and the environment from unsafe and harmful conditions for all code-prescribed hypothetical worst-case incidents using site specific conditions from accidental releases of flammable components at the facility.

LNG facility safety standards have a long history of expertise and risk management incorporated into LNG design codes and industry best practices that are regularly reviewed and updated.

The largest aspect of siting studies is to validate that adequate distance exists for LNG plant components from LNG facility property lines that can be built upon for code prescribed failure scenarios. Also, adequate space between components, separation of components from impoundments, separation from gas fueled equipment, management of ignition sources within the facilities are all part of siting and layout of an LNG facility. Permitting during design, and routine inspections during operations by the AHJ is a detailed process to validate the LNG facility siting requirements are met, and that an LNG facility is safe and code compliant at all times. The AHJ has full enforcement authority to take whatever measures are necessary if an unsafe condition is found.

The purpose accidental LNG spill containment systems that are prescribed in LNG codes and by PHMSA is to establish a basis that the worst-case accidental release scenarios are retained on site, and if ignited, thermal and overpressure impacts remain within the property boundaries that can be built upon. On site retention of accidental spill scenarios is prescribed in 49 CFR Part 193 and NFPA 59A 2001 edition. The cause or type of the accidental incident in the LNG facility for failure scenarios are not identified or speculated in LNG codes, or by PHMSA. Prescribed accidental spill rates do not imply that these events will actually occur since the cause, likelihood, spill rate, and duration for such a failure is incredibly low. LNG codes prescribe worst-case accidental spill cases to be evaluated and mitigated in the design. From the design review of Tacoma LNG, no unmitigated credible accidental spill scenarios were identified.

Secondary containment is required for all LNG and refrigerant components in the LNG facility where:

- 100% storage volume of the primary LNG tank and refrigerant storage tanks are used for sizing secondary containment.

- A 10-minute accidental release at the maximum design LNG flow rate is prescribed for sizing secondary containment systems for other LNG process components. 10-minutes is arbitrary and considered a very conservative time-period and not based on an actual accidental spill rate duration. 10-minutes is considered a worst-case maximum time it would take for an accidental spill to be detected and shutdown. Plant safety systems that detect and shutdown processes operate in real time, where processes can be shut down to a safe mode in seconds, or at the most a few minutes. A 10-minute accidental release at the maximum design LNG flow rate includes the following:

    - A 10-minute release at the maximum LNG liquefaction production rate
    - A 10-minute release at the maximum LNG vaporization rate
    - A 10-minute release at the maximum truck loading rate of 2-trucks
    - A 10-minute release at the maximum ship loading rate

To minimize potential LNG and refrigerant leak sources in the process, Tacoma LNG has selected a full containment LNG tank, the most robust LNG tank design available, mounded refrigerant storage tanks, and process equipment and components with high design factor margins that use all welded pipe and valves wherever possible. Accidental spill cases prescribed by LNG codes have a very low likelihood to occur, and extremely low likelihood to occur at full prescribed design volumes, flow rates and durations.

The following sections describe in detail the siting, layout, and design for Tacoma LNG.

5.2 Secondary Containment

NFPA 59A, 2.2 Major Site Provisions for Spill and Leak Control.

2.2.1.1 Provisions shall be made to minimize the possibility of the accidental discharge of LNG at containers from endangering adjoining property or important process equipment and structures or from reaching waterways.

LNG Tank: Per NFPA 59A 2001 edition Section 2.2.2, Impounding Area and Drainage System Design and Capacity, the LNG tank is required to maintain secondary containment for the total volume of liquid in the tank, assuming the tank is full. For Tacoma LNG, the requirements for secondary containment are met with the integral concrete secondary containment of the full containment tank design that would contain the full design spill if there was a failure of the primary container. The secondary containment tank is designed for cryogenic temperature and the liquid head.

Balance of Plant: Per NFPA 59A 2001 edition Section 2.2.1, the following areas in the balance of plant were found to be curbed and provided with an impoundment with sufficient capacity for the design spill rate to minimize the possibility of accidental spills and leaks that could endanger important structures, equipment, or adjoining property or that could reach waterways:

(1) Process areas
(2) Vaporization areas
(3) Transfer areas for LNG, flammable refrigerants, and flammable liquids
(4) Areas immediately surrounding flammable refrigerant and flammable liquid storage tanks

5.3 Pipeline and Control Measures Easement Agreement

TOTE and Tacoma LNG prepared, approved, and recorded a Pipeline and Control Measures Easement Agreement dated 8/2/2016. This agreement defines and agrees to various land uses within TOTE controlled property for transfer of LNG to the Blair Dock. This is a consolidated agreement that provides legal authorization and consent for a number of conditions related to code compliance, construction, and operations of the dedicated LNG facilities within TOTE controlled property. The following were assessed in the Pipeline and Control Measures Easement Agreement dated 8/2/2016 for LNG code compliance:

- Thermal Radiation Siting
- Vapor Dispersion Siting
- Minimum Spacing Layout
- Hazardous Area Classification Layout

The current Pipeline and Control Measures Easement Agreement defines in detail what is allowed and disallowed within the easement areas. Due to the preliminary nature of the project, operating procedures and emergency response plans currently have not been prepared, and expected later in project development, but prior to commissioning. To provide legal framework for operating procedures and emergency response plans within the Pipeline and Control Measures Easement Agreement, these plans are termed “Permitted Uses” and “Health and Safety Plan” that will include the specific operating procedures to be followed, for development and review later.

5.4 Thermal Radiation

For compliance to NFPA 59A 2001 edition Section 2.2.3.2, provisions were made to minimize the possibility of the damaging effects of a fire reaching beyond a property line that can be built upon and that would result in a distinct hazard. The CB&I Thermal Exclusion Zone Plan drawing (Figure 12), is a consolidated drawing of all the code required thermal radiation cases for the facility.

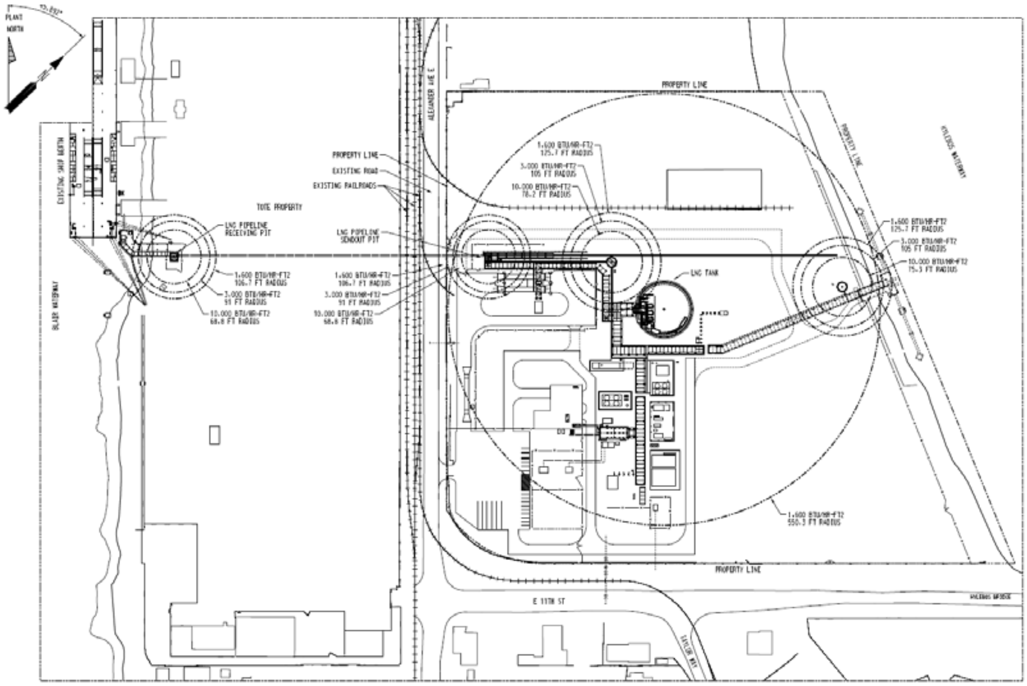
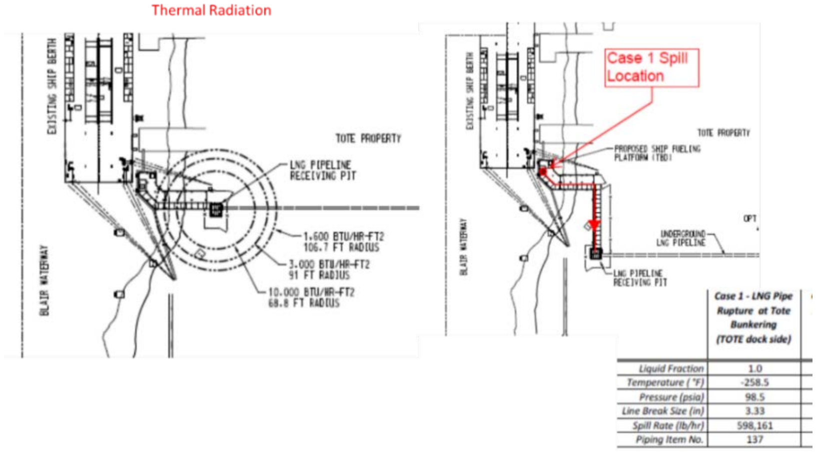


Figure 12 - Tacoma LNG Thermal Radiation Cases (Drawing 000-SE-01-000011, Revision D)

A code approved methodology for calculating thermal radiation siting was used to demonstrate the 1,600 BTU/ft^2-hr thermal isopleths remain within the LNG plant boundaries. Tacoma LNG was found to be code compliant with thermal radiation requirements, except one (1) case, identified at the Blair Waterway dock where thermal isopleths extend beyond the LNG facility fence boundary line (Figure 13). TOTE and Tacoma LNG prepared and approved a Pipeline and Control Measures Easement Agreement dated 8/2/2016 to mitigate the Blair Waterway dock area for thermal radiation.



	Case 1 - LNG Pipe Rupture at Tote Bunkering (TOTE dock side)
Liquid Fraction	1.0
Temperature (°F)	-258.5
Pressure (psia)	98.5
Line Break Size (in)	3.33
Spill Rate (lb/hr)	598,161
Piping Item No.	137

Figure 13 - Thermal Radiation (Drawing 186512-000-SE-RP-00001, Revision C)

In this easement agreement, TOTE legally accepts certain use limitations on their property within a defined 1.3812 acre "Control Measures Easement Area" (Figure 14), in green, that includes the effects of thermal radiation and achieves code compliance at this location for thermal radiation.

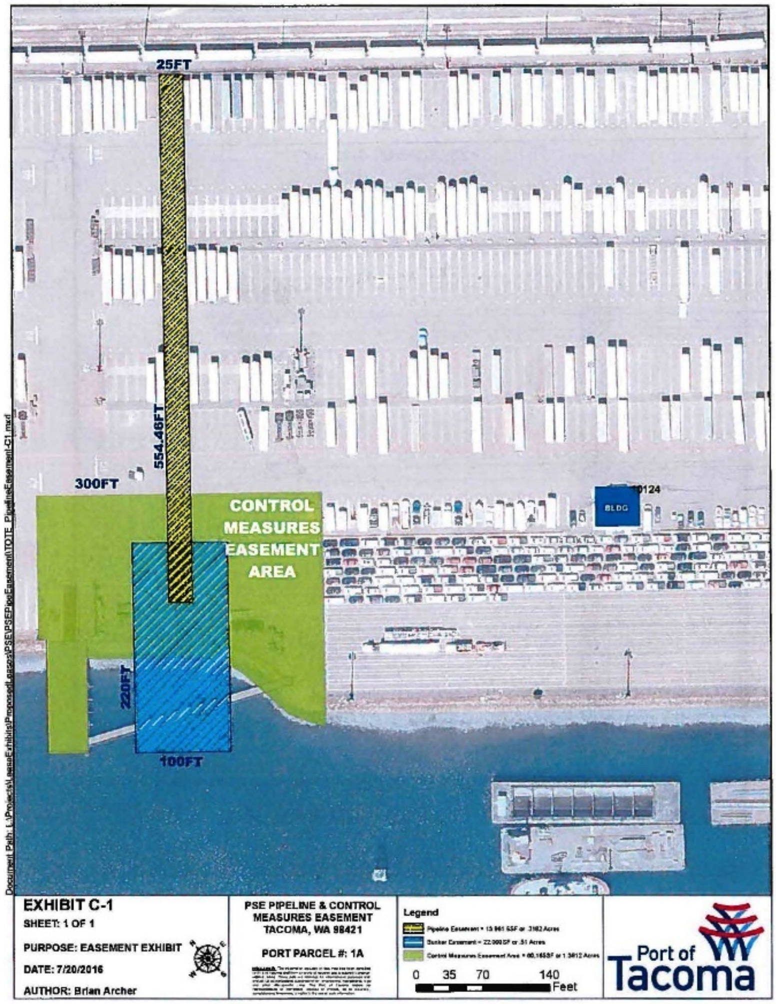


Figure 14 - Pipeline and Control Measures Easement Area

A fire incident at this location has greater consequences due to the dock area uses, and potential impacts to dock workers unaffiliated with the LNG facility operation. For an LNG incident scenario where LNG and vapor is released at or near the dock, and is ignited, depending on severity and location, thermal radiation may extend beyond the security fence to the adjacent TOTE property. Because this is an open area, and not a confined space, properties of LNG/natural gas will not cause a detonation (explosion) of the vapor. An ignited gas fire will burn as long as fuel is present.

If an unsafe condition exists, workers in this area will hear and see clear audible and visual warning systems to alert them. The proposed Health and Safety Plan and required training will provide TOTE workers with instructions on what they should do if an LNG related incident occurs. The extent of the high consequence area will be defined by signs or painted lines on the tarmac. Automatic systems for emergency process shutdown, hazard warning systems, were reviewed for code compliance. Adequate layers of detection, warning, and protection were found in the design for the conditions at this location.

5.5 Vapor Dispersion

For compliance to NFPA 59A 2001 edition Sections 2.2.3.3, and 2.2.3.5 siting, the spacing of an LNG tank impoundment, vaporizer, process equipment, transfer piping, and LNG & refrigerant loading areas cannot extend beyond to the property line that can be built upon with an average concentration of methane in air of 50 % of the LFL, in accordance with calculations in Table 2.2.3.5.

The CB&I report Appendix E – PHAST Analysis Results: Vapor Dispersion Plots, is a consolidated report containing fourteen (14) code-prescribed vapor dispersion design worst-case spill cases for the facility and evaluated for compliance. A code approved methodology for calculating vapor dispersion siting was used to demonstrate the 50% LFL isopleths remain within the LNG plant boundaries. Tacoma LNG was found to be code compliant and meets the vapor dispersion requirements, except one (1) case, identified at the Blair Waterway dock where vapor dispersion extend beyond the LNG facility fence boundary line. PHAST was used first by CB&I to evaluate vapor dispersion cases and summarized in Appendix K DOCUMENT NO.: 186512-000-SE-RP-00001, Revision C, 6/9/15 (Figure 15). The PHAST model is acceptable to PHMSA for demonstrating compliance to siting, and known to provide conservative results. The software illustrates the vapor dispersion limits as a circle, and is not sophisticated enough to account for 3-D graphical variations with the same detail as the Gexcon's CFD FLACS model. The PHAST model is also unable to include the 10-foot-high vapor barrier. The vapor limits are shown beyond the LNG security fence to the TOTE work areas.

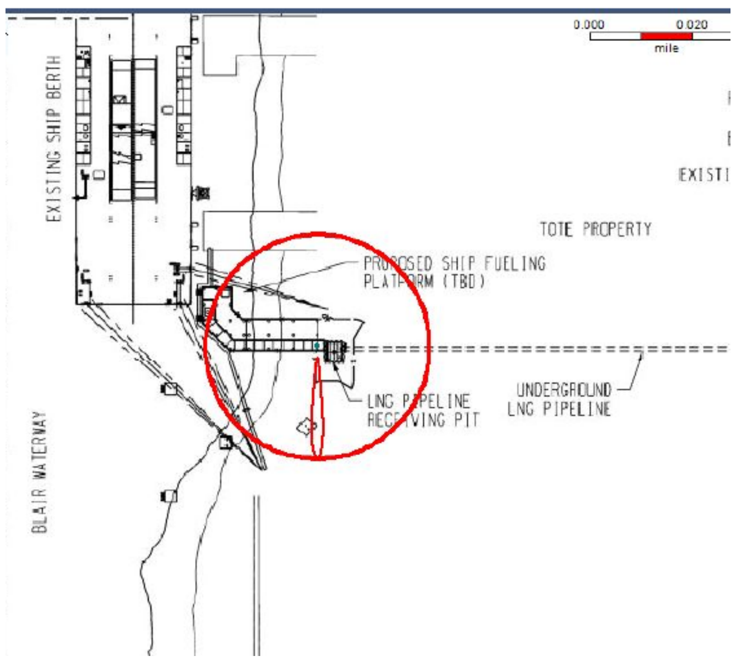


Figure 15 - Vapor Dispersion Blair Dock - PHAST Model

The Pipeline and Control Measures Easement Agreement dated 8/2/2016 mitigates the issue at the Blair Waterway dock area. It includes consideration of vapor dispersion beyond the LNG facility boundary fence for a worst-case design spill scenario. To reduce migration of flammable vapor toward the TOTE ship loading ramp, a 10-foot-high vapor barrier was added to the original design of the Blair Waterway dock. Vapor dispersion modeling was updated to include the effects of the added vapor barrier and more sophisticated software was used to analyze. A Supplemental Letter from Gexcon to CB&I dated 9/17/15 includes a number of updated vapor dispersion figures using their 3-dimensional computational fluid dynamics (CFD) vapor model "FLACS". The prevailing case from the Gexcon letter is shown with 1 m/s wind (Figure 16), where red indicates an impermeable barrier and green a 10% porous barrier. The vapor dispersion is less than before, but is still shown going beyond the LNG security fence to the adjacent TOTE dock work areas, including the loading ramp. The original Gexcon vapor dispersion modeling report dated 6/23/15 has several figures for the dock area, and for comparison, the 1 m/s wind case is shown in Figure 17.

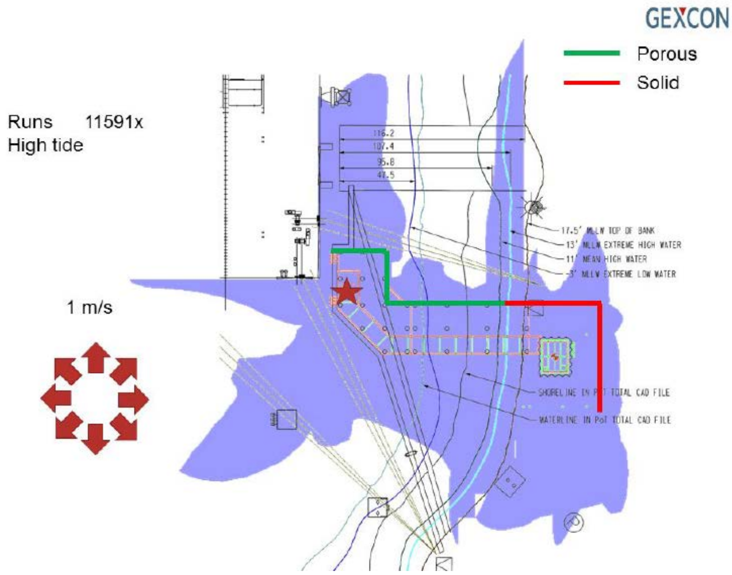


Figure 16 - Updated Gexcon Vapor Dispersion Model with Vapor Barrier and 1 m/s Wind

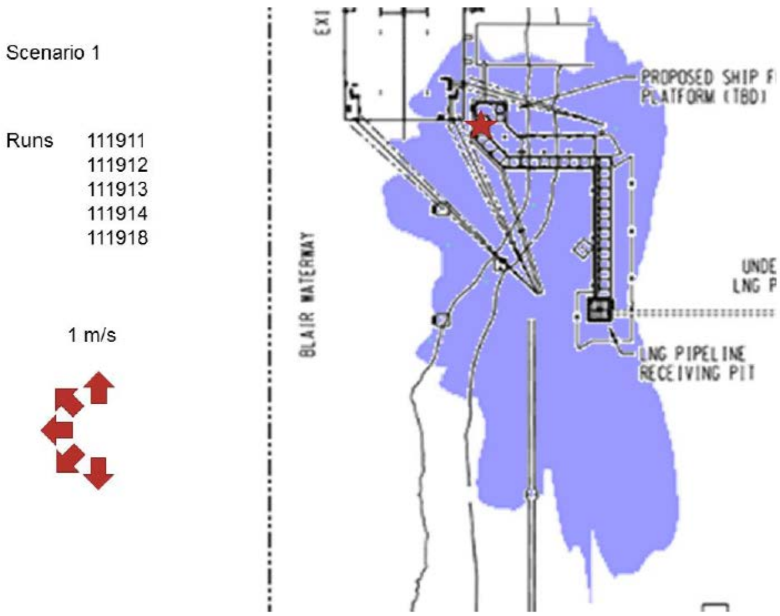


Figure 17 - Original 2015 Gexcon Vapor Dispersion Model - No Vapor Barrier 1 m/s Wind

A vapor release incident at this location has greater consequences due to the dock area uses, and potential impacts to dock workers unaffiliated with the LNG facility operation. For an LNG incident scenario where LNG and vapor is released at or near the dock, depending on severity and location, flammable methane vapor may extend beyond the security fence to the adjacent TOTE property. Uncontrolled ignition sources may exist in this area. Because this is an open area, and not a confined space, properties of LNG/natural gas will not cause a detonation (explosion) of the vapor.

If an unsafe condition exists, workers in this area will hear and see clear audible and visual warning systems to alert them. The proposed Health and Safety Plan and required training will provide TOTE workers instructions on what they should do if an LNG related incident occurs and the limits of the high consequence area. Automatic systems for emergency process shutdown, hazard warning systems, were reviewed for code compliance. Adequate layers of detection, warning, and protection were found in the design for the conditions at this location.

5.6 Minimum Spacing

NFPA 59A 2001 edition has a number of requirements for minimum spacing between components, buildings, and property lines. Tacoma LNG was evaluated to confirm minimum spacing requirements were met for the following NFPA 59A 2001 edition sections:

- **2.2.3.3** The spacing of an LNG tank impoundment to the property line that can be built upon
- **2.2.4.1** The minimum separation distance between LNG containers or tanks containing flammable refrigerants
- **2.2.5.2** Integral heated vaporizers shall be located at least 100 ft from a property line that can be built upon and at least 50 ft (15 m) from the following:
    - Any impounded LNG, flammable refrigerant, or flammable liquid, or the paths of travel of such fluids between any other source of accidental discharge and the impounding area.
    - LNG, flammable liquid, flammable refrigerant, or flammable gas storage containers or tanks, unfired process equipment containing such fluids, or loading and unloading connections used in the transfer of such fluids.
    - Control buildings, offices, shops, and other occupied or important plant structures.
- **2.2.6.1** Process equipment containing LNG, refrigerants, flammable liquids, or flammable gases shall be located at least 50 ft from sources of ignition, a property line that can be built upon, control rooms, offices, shops, and other occupied structures.
- **2.2.6.2** Fired equipment and other sources of ignition shall be located at least 50 ft from any impounding area or container drainage system.
- **2.2.7.1** A pier or dock used for pipeline transfer of LNG shall be located so that any marine vessel being loaded or unloaded is at least 100 ft (30 m) from any bridge crossing a navigable waterway. The loading or unloading manifold shall be at least 200 ft (61 m) from such a bridge.
- **2.2.7.2** LNG and flammable refrigerant loading and unloading connections shall be at least 50 ft (15 m) from uncontrolled sources of ignition, process areas, storage containers, control buildings, offices, shops, and other occupied or important plant structures.

Minimum spacing of Tacoma LNG components has been evaluated in accordance with NFPA 59A 2001 edition sections listed above. Adequate spacing has been provided to comply with these requirements and meets the LNG code.

5.7 Vapor Cloud Explosion (VCE)

Tacoma LNG facility requires a relatively small quantity of flammable refrigerants in the process to liquefy natural gas. The mixed refrigerant process selected is one of the most efficient, and uses a blend of propane, ethylene, and iso-pentane as refrigerant components, which are referred to as heavy hydrocarbons. Refrigerant and gas compressors incorporate seal gas recovery systems that recover seal gas, reducing waste and refrigerant storage requirements.

According to PHMSA, refrigerants are similar to gases that have resulted in a VCE at other petrochemical facilities. In the more recent years PHMSA sponsored the review of VCE incidents with the primary objective to improve the scientific understanding of vapor cloud development and explosion in order to more reliably assess hazards at larger LNG export facilities. For smaller LNG facilities using heavy hydrocarbon refrigerants, PHMSA requests that VCEs be considered in the design to confirm that an accidental release of heavy hydrocarbon refrigerants within the process area will not result in an overpressure event that causes an escalation or damage. PHMSA has indicated that a 1 psi overpressure threshold should be evaluated at the property line that can be built upon and at any occupied buildings in the facility. The request to perform a VCE study is recent, and not included as a requirement in NFPA 59A 2001 edition. The aim of reviewing of VCE's is to provide validation of the facility layout, determine if congestion of process equipment and components in areas containing heavy hydrocarbons are potentially contributing to the intensity and effects of a VCE, in the unlikely event it occurs.

A VCE associated with an accidental release of natural gas and LNG was not evaluated. For a methane vapor release in an unconfined environment and ignition, the speed at which a flame travels back to the source is too slow to support a detonation (explosion). Therefore, ignition of methane in an open space will create a fire until fuel is consumed, but will not cause a blast (explosion). Since an explosion is not possible in an unconfined space, gas codes do not address this case for accidental releases of gas or LNG.

Gexcon performed VCE modeling and generated a VCE analysis report for Tacoma LNG, Appendix L, Document No.186512-000-SE-RP-00001 REVISION: C, dated June 9, 2015. A single design spill scenario of Mixed Refrigerant Liquid (MRL) was used for modeling a VCE event. The plot plan was assessed for areas of congestion and confinement within the flammable vapor cloud of the credible MRL release scenarios, with a focus on scenarios in proximity to the control building (MRL Condenser Vessel V-204 failure). Two (2) areas were identified and modeled that may have the potential to hold up flammable vapor, show in Figure 18 and Figure 19:

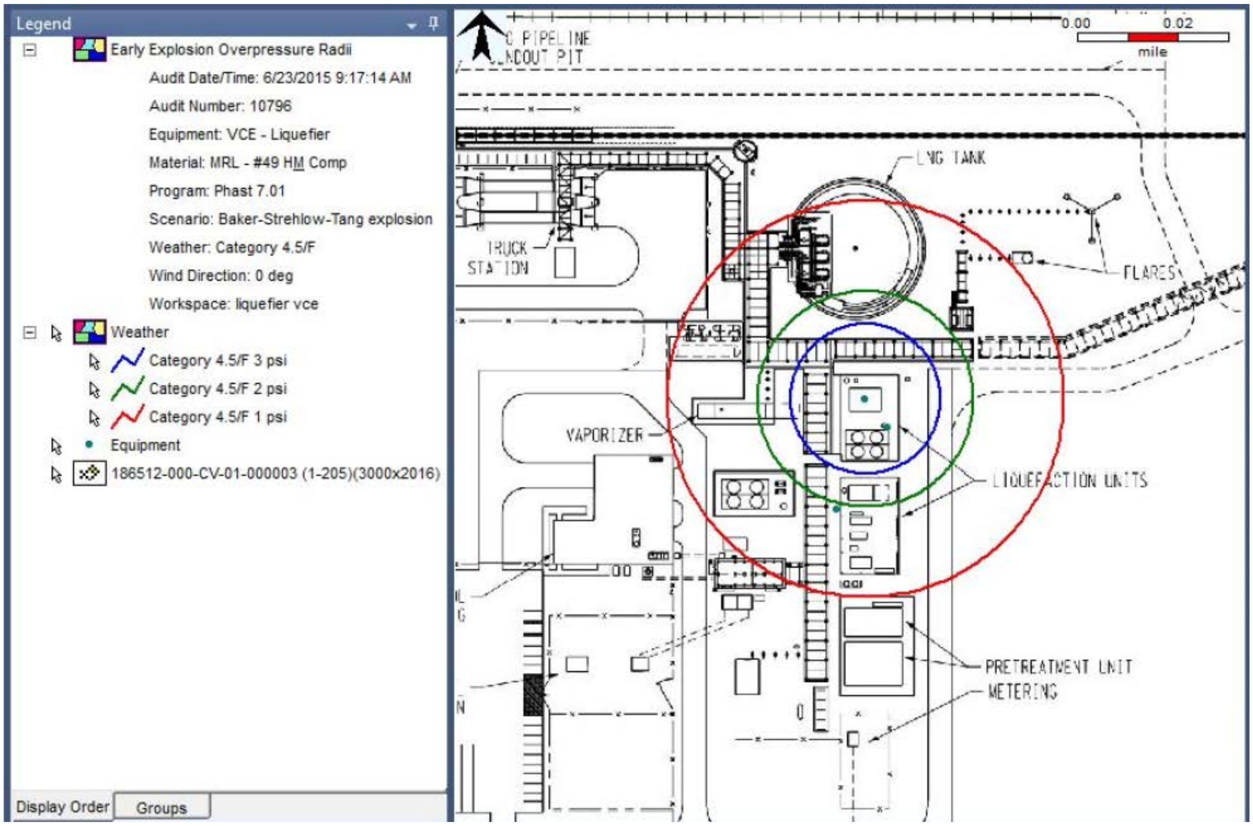


Figure 18 - VCE Area 1 Liquefaction Area

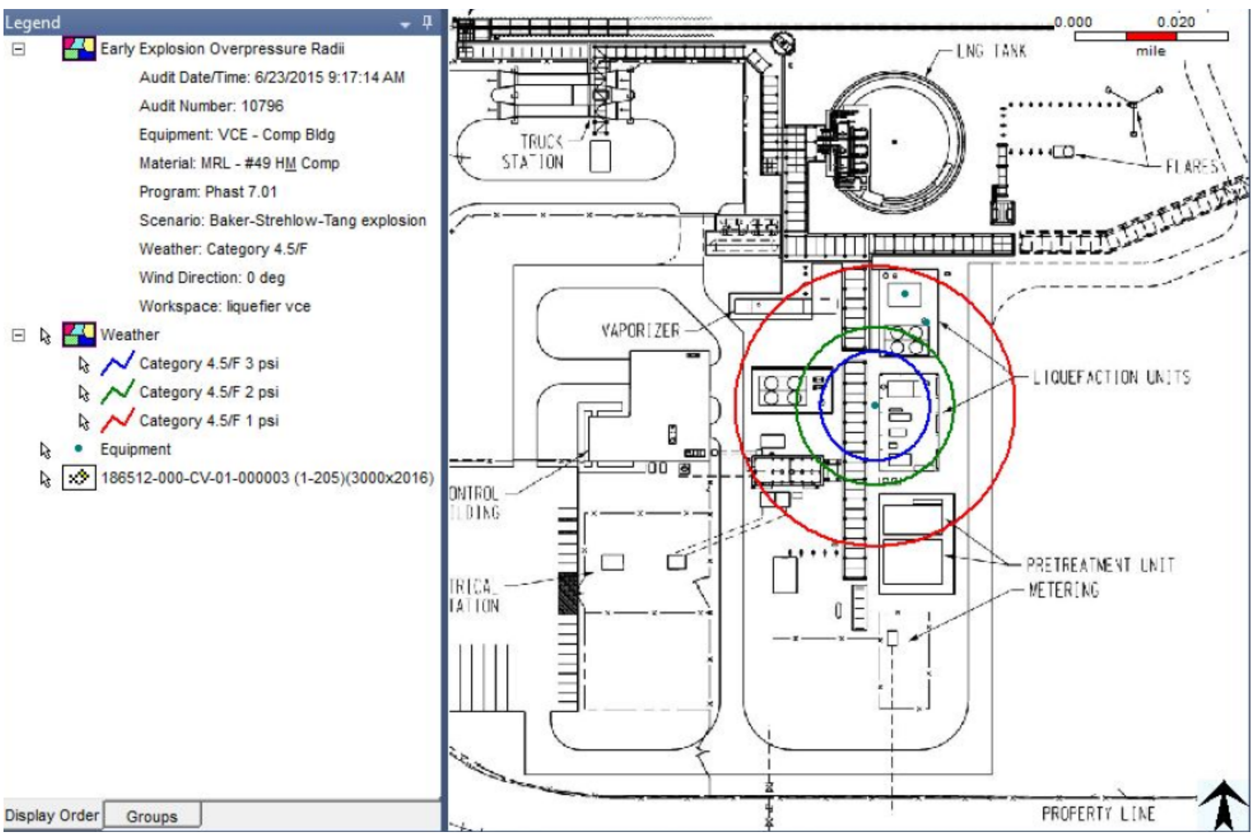


Figure 19 - Area 2 Adjacent to Compressor Building

Factors for congestion and confinement were identified based on qualitative assessment of the current facility layout and were assigned to each area. Results show that the 1.0 psi blast overpressure isopleth remains within the property line that can be built upon and does not encroach on occupied buildings in the facility (the control room). The LNG tank is protected from the VCE by its highly reinforced two-foot-thick concrete outer wall. The TOTE dock is outside the areas affected by VCE. Therefore, Tacoma LNG meets the criteria for VCE, and no additional measures are recommended.

5.8 Ventilation

The design of open buildings, shelters, and other areas in which LNG, flammable refrigerants, and flammable gases are handled may create a confined space and lead to the possibility of hazardous accumulations of flammable gases. For these conditions, the design should consider adequate ventilation of buildings or structural enclosures and gas detectors may be required to alert personnel of a gas release.

The Tacoma LNG compressor building was identified as a non-occupied building that requires ventilation and hazard detection. This building has multiple point infrared and open path gas detectors suited for methane, and heavy hydrocarbon vapors, and flame detectors connected to the Tacoma LNG hazard detection system to alert personnel of unsafe conditions. Adequate layers of detection, warning, and protection were found in the design for the conditions at this location.

5.9 Fresh Air Intakes

To minimize the possibility of hazardous accumulations of flammable gases in enclosed spaces, gas detectors are required to be located on the outside of fresh air intake vents and ducts to buildings, structural enclosures and equipment to prevent entry of accidental releases of LNG vapor, natural gas, and flammable refrigerants. Upon gas detection at the fresh air intake, the hazard detection system immediately initiates an automatic shutdown of affected equipment or building fresh air intakes, and alerts personnel of a gas release to prevent flammable gas from entering the confined space. The automatic shutdown of affected equipment or building fresh air intakes remains in effect until the source of flammable gas is fully resolved and an all-clear is given before the automatic shutdown is manually reset. Adequate layers of detection, warning, and protection were found in the design for the conditions at this location. Tacoma LNG gas detection located at fresh air intake are listed in Table 1.

Table 1 - Gas Detection Fresh Air Intakes

Tag No.	Location	Associated Shutdown
AAHH-7212A	U-981 - Standby Generator Air Intake	U-981 - Standby Generator
AAHH-7213A	E-402 - LNG Vaporizer Combustion Air Intake	E-402 - LNG Vaporizer
AAHH-7214A AAHH-7214B	PDC-101 - Facility PDC HVAC Air Intake	PDC-101 HVAC
AAHH-7215A	H-910 - Pretreatment WPG Heater Combustion Air Intake	H-910 - Water Propylene Glycol Heater
AAHH-7215B	H-951 - Pretreatment Regeneration Gas Heater Combustion Air Intake	H-951 - Regeneration Gas Heater
AAHH-7216A	Instrument Air Compressors Air Intake	C-601A/B - Instrument Air Compressors
AAHH-7217A	Control Room HVAC Air Intake	Control Room HVAC
AAHH-7222A	PDC-201 - TOTE Dock Power Distribution Center (Inside)	PDC-201 HVAC Pressurization Unit
AAHH-7224A	PDC-201 - TOTE Dock Power Distribution Center Fresh Air Intake	PDC-201 HVAC Pressurization Unit

5.10 Hazardous Area Classification

For Tacoma LNG, areas with equipment containing hydrocarbons are designated hazardous electrical classification areas (Class I Division 2) to reduce the possibility of ignition sources from electrical equipment within these areas. All secondary containment LNG sumps and trenches, where flammable materials can be present, are designated hazardous electrical classification areas (Class I Div 1). LNG codes and standards reference the following for compliance: Article 250 – 2005 Edition, IEEE Standard 1100-1999 Recommended Practice for Powering and Grounding Sensitive Electronic Equipment, IEEE Standard 142-1982 Grounding of Industrial and Commercial Power Systems.

For Tacoma LNG, designated hazardous classification area designs were found to be compliant to requirements described in applicable codes and standards. It is recommended that:

1. For future Tacoma LNG operations manuals, work within the hazardous classification areas will need to be defined for maintenance, hot work, etc.
2. Within the Pipeline and Control Measures Easement Agreement with TOTE, plans for “Permitted Uses” and “Health and Safety Plan” will need to address restricted activities within the hazardous classification areas.

Figure 20 is from CB&I drawing 210140-000-EL-10-000001 of the main plant area shows classified areas within the boundaries of the LNG security boundary fence. Figure 21 from CB&I drawing 210140-000-EL-10-000002 shows classified areas within the boundaries of the LNG security boundary fence.

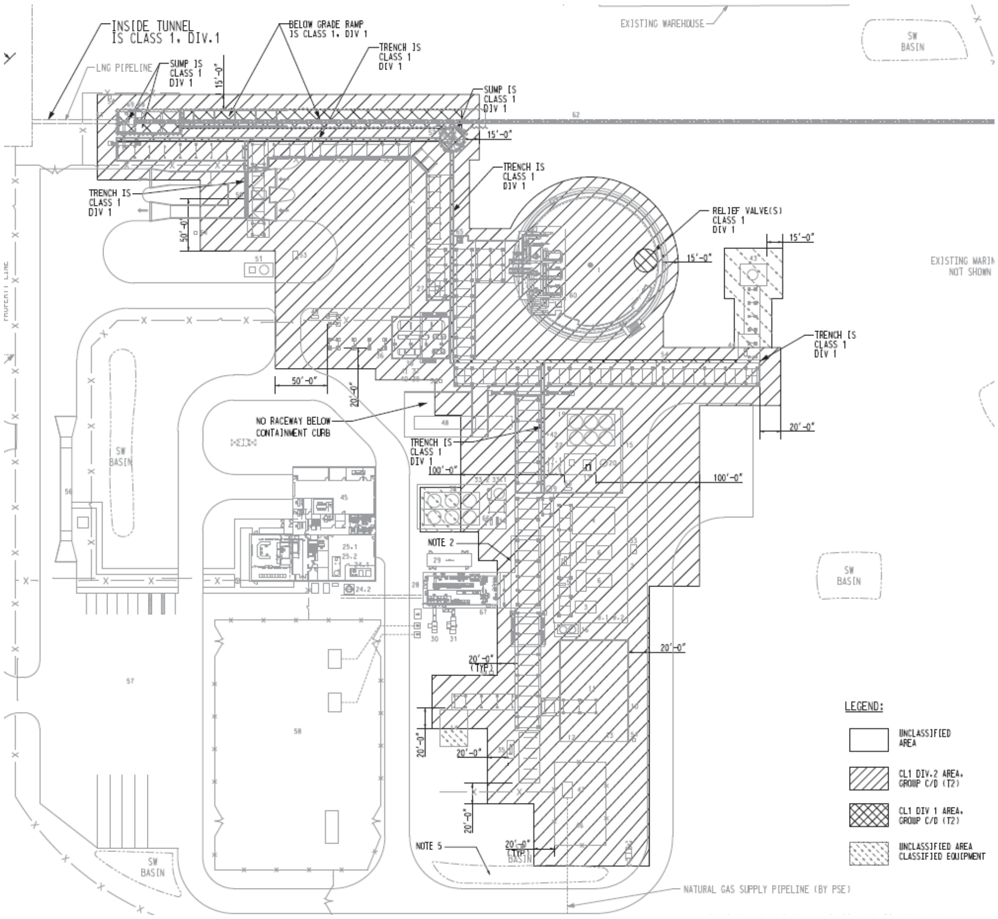


Figure 20 - Hazardous Area Classification Plan - Main Plant

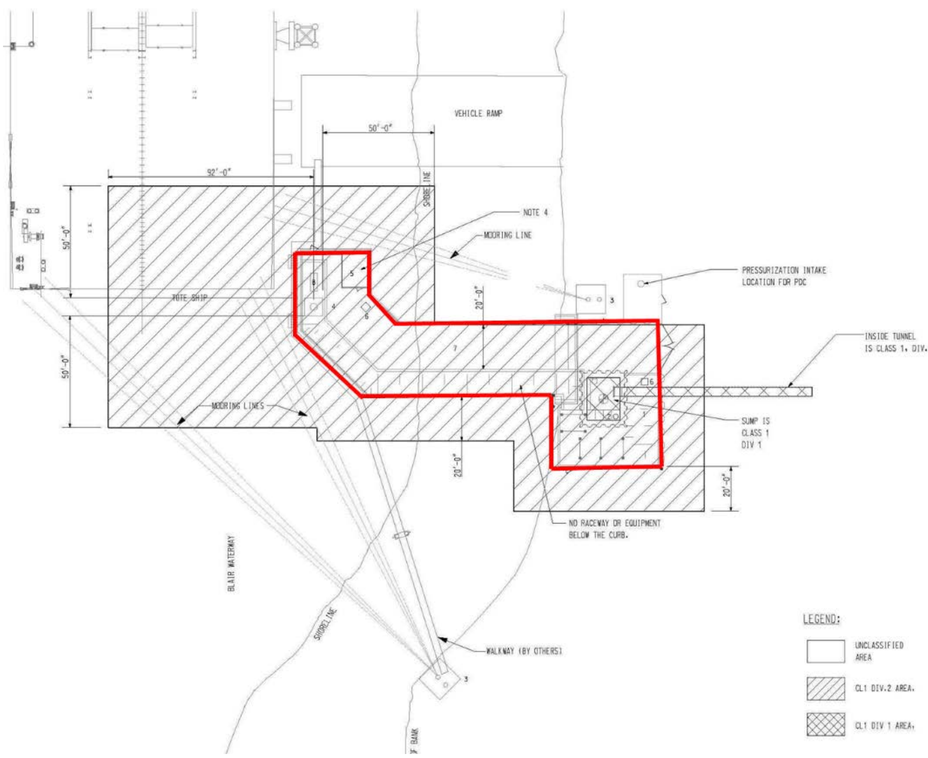


Figure 21 - Hazardous Area Classification Plan – Blair Waterway Dock

5.11 LNG Plant Fire and Safety Study

To confirm the design, installation and LNG operator training are compliant to the codes in place at the time the facility is constructed, an evaluation is performed during the design and construction phases by a 3rd party fire and safety specialist. This includes a review of the following to ensure adequate layers of protection are incorporated in the design:

- Design & Construction Codes
- Hazard Detection Systems
    - Fire
    - Gas
    - Low Temperature
    - Fresh Air Intakes
- Plant Controls and Emergency Shutdown Systems
- Fire Control Systems
    - Firewater System
    - Dry Chemical Extinguishers
- Underground LNG Line in Casing (Exclusive Case for Tacoma LNG)
- Operating Procedures, Training and Emergency Response Plan

Security Study:

Figure 22 provides the table of contents, and sections reviewed during design are highlighted. The USCG is the AHJ to review the design and confirm compliance to the design standards, operating procedures, and emergency plans. During operations, Tacoma Fire Department will have responsibility as first responders to an emergency at the Blair Waterway dock, and will access the location through the TOTE main gate. This review includes the following as shown in Figure 22, to ensure adequate layers of protection are incorporated in the marine interface design, and compatible with the balance of LNG plant systems. The marine transfer area is under the jurisdiction of the USCG who will review the design, and operating procedures associated with the Blair Waterway dock.

PART 127—WATERFRONT FACILITIES HANDLING LIQUEFIED NATURAL GAS AND LIQUEFIED HAZARDOUS GAS

Subpart A—General

Sec.
127.001 Applicability.
127.003 Incorporation by reference.
127.005 Definitions.
127.007 Letter of intent.
127.009 Letter of recommendation.
127.011 Inspections of waterfront facilities.
127.013 Suspension of transfer operations.
127.015 Appeals.
127.017 Alternatives.
127.019 Operations Manual and Emergency Manual: Procedures for examination.

Subpart B—Waterfront Facilities Handling Liquefied Natural Gas

127.101 Design and construction: General.
127.103 Piers and wharves.
127.105 Layout and spacing of marine transfer area for LNG.
127.107 Electrical power systems.
127.109 Lighting systems.
127.111 Communications systems.
127.113 Warning signs.

Equipment

127.201 Sensing and alarm systems.
127.203 Portable gas detectors.
127.205 Emergency shutdown.
127.207 Warning alarms.

Operations

127.301 Persons in charge of shoreside transfer operations: Qualifications and certification.
127.303 Compliance with suspension order.
127.305 Operations Manual.
127.307 Emergency Manual.
127.309 Operations Manual and Emergency Manual: Use.
127.311 Motor vehicles.
127.313 Bulk storage.
127.315 Preliminary transfer inspection.
127.317 Declaration of inspection.
127.319 LNG transfer.
127.321 Release of LNG.

Maintenance

127.401 Maintenance: General.
127.403 Inspections.
127.405 Repairs.
127.407 Testing.
127.409 Records.

Personnel Training

127.501 Applicability.
127.503 Training: General.

Firefighting

127.601 Fire equipment: General.
127.603 Portable fire extinguishers.
127.605 Emergency outfits.
127.607 Fire main systems.
127.609 Dry chemical systems.
127.611 International shore connection.
127.613 Smoking.
127.615 Fires.
127.617 Hotwork.

Figure 22 - USCG 33 CFR Part 127 Regulations

6 Properties of Natural Gas, LNG, and Flammable Refrigerants

Understanding the properties of natural gas, LNG, and refrigerants is important for routine safe handling, storage and transfer operations. Also, for abnormal and emergency situations, understanding their properties is critical for the most effective response, to avoid actions that may be ineffective or potentially escalate the situation.

6.1 Properties of Natural Gas

Natural gas is the vapor of LNG at ambient conditions. It is odorless, colorless, non-corrosive, and non-toxic. Natural gas can act as an asphyxiant if inhaled by displacing oxygen. Natural gas is composed primarily of methane (typically, at least 90%), with the balance being mostly other light hydrocarbons such as ethane, propane, butane, and possibly heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, and sulfur compounds, may also be found in natural gas.

Natural gas can be highly flammable, but it only burns in concentrations of 5% (LFL) to 15% (UFL – upper flammability limit) at atmospheric conditions when mixed with air and has an ignition temperature of about 1100°F. At ambient temperature, natural gas is lighter than air with a specific gravity of 0.55. The flame propagation speed of natural gas at ambient conditions is too slow to cause an explosion if ignited in an unconfined environment but can result in a flash fire that lasts as long as fuel remains present. Natural gas can explode if confined and the air-gas ratio are within flammability limits when ignited.

6.2 Properties of LNG

LNG (liquefied natural gas) is conventional natural gas with impurities removed that has been refrigerated to a temperature of approximately -260°F at atmospheric pressure, where it condenses to a liquid. When compared to other common gases, nitrogen condenses to a liquid at -321°F, liquid oxygen condenses at -296°F and liquid hydrogen at -423°F. One volume of LNG takes up about 1/615th the volume of natural gas at room temperature and weighs less than one-half the weight of water. LNG is odorless, colorless, non-corrosive, and non-toxic. Due to the extreme cold temperature of LNG, materials for LNG storage tanks, transfer piping and equipment are selected based on the ability to retain their mechanical properties and remain ductile at low temperature. 304/316 stainless steel, aluminum or low-alloy 9% nickel-steel are typically used for LNG storage, equipment and transfer piping. Skin exposure to LNG (or bare metal surfaces chilled by LNG) will cause external dermal frost burns also called cryogenic burns. If inhaled, LNG vapor can act as an asphyxiate by displacing oxygen.

Ambient temperature LNG vapor has the same properties as natural gas described above.

6.3 Flammable Refrigerants

Propane, iso-pentane, and ethylene refrigerants are added to the mixed refrigerant stream in different concentrations to provide the optimum blend of refrigerants in the closed loop liquefaction process. Refrigerants are needed to cool purified natural gas to a liquid state with the highest possible efficiency. The burning velocity of flammable gas is one measure of the volatility of the flammable vapor where higher velocity is associated with the greater likelihood of a detonation if within the flammability range and an ignition source is present (Figure 23). The properties of propane, iso-pentane, and ethylene refrigerants are described below.

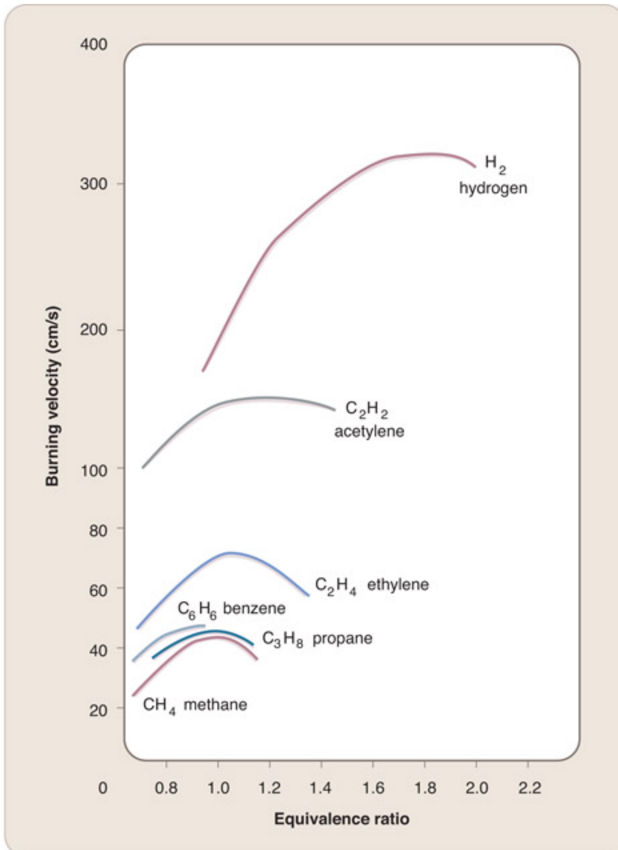


Figure 23 - Burning Velocity of Various Hydrocarbons and Flammable Gases

6.3.1 Properties of Propane

Propane (C_3H_8) is the third hydrocarbon after ethane, and before butane. Propane is odorless, colorless, non-corrosive, and non-toxic gas that can act as an asphyxiate if inhaled by displacing oxygen. Propane can be highly flammable, but it burns only in concentrations of 2.1 % (LFL limit) to 9.6 % (UFL) at atmospheric conditions when mixed with air and has an ignition temperature of about 850°F. Propane vapor is heavier than air and will stay near the ground or water with a specific gravity of about 1.52 at 60°F. Propane is stored as a liquid with a vapor space. The flame propagation speed of propane vapor at ambient conditions is faster than methane. Propane will not explode if ignited in an unconfined environment unless it is pre-mixed with air and within flammability limits. If propane vapors are within flammability limits with air and are ignited in a confined space, propane will explode.

6.3.2 Properties of Ethylene

Ethylene (C_2H_4) is a hydrocarbon with four hydrogen atoms bound to a pair of carbon atoms that are connected by a double bond. Ethylene has a slight sweet odor, is colorless, non-corrosive, and non-toxic gas that can act as an asphyxiate if inhaled by displacing oxygen, and high concentrations can cause anesthetic effects. Ethylene can be highly flammable, but it burns only in concentrations of 2.6 % (LFL) to 36 % (UFL) at atmospheric conditions when mixed with air and has an ignition temperature of about 914°F. Ethylene vapor is slightly lighter than air and may stay near the ground or water with a specific gravity of about 0.98 at 60°F. Ethylene is stored as a vapor at ambient temperature and elevated pressure. The flame propagation speed of ethylene vapor at ambient conditions is faster than methane. Ethylene will not explode if ignited in an unconfined environment unless it is pre-mixed with air and within flammability limits. Congestion in the unconfined space impacts the forces generated. If ethylene vapors are within flammability limits with air and are ignited in a confined space, ethylene will explode.

6.3.3 Properties of Iso-Pentane

Iso-pentane (C_5H_{12}) is a hydrocarbon liquid with a slight gasoline odor, is colorless, non-corrosive gas that can act as an asphyxiate if inhaled by displacing oxygen, can cause irritation of throat and lungs, and make breathing difficult. Iso-pentane can be highly flammable, but it burns only in concentrations of 1.4 % (LFL) to 8.3 % (UFL) at atmospheric conditions when mixed with air and with an ignition temperature of about 788 °F. Iso-pentane liquid is lighter than water and will float on the surface with a specific gravity of about 0.62 at 60 °F. Iso-pentane is stored as a liquid with a boiling temperature of 82 °F. The flame propagation speed of iso-pentane vapor at ambient conditions is faster than methane. Iso-pentane will not explode if ignited in an unconfined environment unless it is pre-mixed with air and within flammability limits. Congestion in the unconfined space impacts the forces generated. If iso-pentane vapors are within flammability limits with air and are ignited in a confined space, iso-pentane will explode.

BRAEMAR

7 49 CFR Part 193 - Liquefied Natural Gas: Federal Safety Standards

The following code evaluations apply to the Tacoma LNG facility. Code references evaluated are *italicized with a border* followed by a Braemar evaluation and compliance statement. Discussion may be included to expand on the intent of the code requirement and compliance.

49 CFR Part 193 Subpart A - General
193.2005 Applicability
(a) Regulations in this part governing siting, design, installation or construction of LNG facilities (including material incorporated by reference in these regulations) do not apply to LNG facilities in existence or under construction when the regulations go into effect.

Evaluation:

The Tacoma LNG facility was designed and is being constructed per 49 CFR Part 193, NFPA 59A, 2001 and 2013 editions, and 33 CFR Part 127 for the waterfront facilities. NFPA 59A, 2001 is the latest edition recognized by WUTC, a PHMSA state partner, and NFPA 59A, 2013 is the latest edition recognized by the City of Tacoma. Tacoma LNG will comply with the requirements that are most stringent.

193.2005 Applicability
(b) If an existing LNG facility (or facility under construction before March 31, 2000) is replaced, relocated or significantly altered after March 31, 2000, the facility must comply with the applicable requirements of this part governing, siting, design, installation, and construction, except that:
(1) The siting requirements apply only to LNG storage tanks that are significantly altered by increasing the original storage capacity or relocated, and

Evaluation:

The Tacoma LNG project is constructed after March 31, 2000, and therefore no part of the design or construction are exempted by applicability (grandfathered). Design and construction of the LNG facility is required to comply with the latest applicable codes listed in Section 3.1 of this report.

Subpart B—Siting Requirements
§ 193.2051 Scope. Each LNG facility designed, constructed, replaced, relocated or significantly altered after March 31, 2000 must be provided with siting requirements in accordance with the requirements of this part and of NFPA 59A (incorporated by reference, see § 193.2013). In the event of a conflict between this part and NFPA 59A, this part prevails.

Evaluation:

To meet siting requirements in NFPA 59A, the LNG facility is required to demonstrate that given accidental LNG release scenarios within the facility will not adversely impact adjacent property that can be built upon from thermal radiation or flammable vapor releases. Required credible scenarios are described in NFPA 59A and PHMSA guidelines for LNG, natural gas, and flammable refrigerants. Exclusion zones are required to be maintained within the facility boundaries to provide sufficient buffer area from secondary containment limits to the property line that can be built upon to avoid impacts beyond from:

1. Exposure to radiant heat exceeding 1600 Btu/h-ft^2.
2. LNG vapor to not exceed an average concentration of methane in air of 50% of the lower flammability limit (LFL).

In addition, accidental releases from LNG tanks, LNG piping, and equipment shall not endanger adjoining property or important process equipment, structures and personnel within the facility, or reach waterways.

Modeling programs are required to consider a range of inputs for site specific conditions. The LNG facility process design basis conditions for flow rate, pressure, and capacity cannot be increased after submittal. A range of ambient temperature, humidity, wind speed, wind direction, relevant dimensions, and geometry configurations of components are evaluated to identify the extent of the vapor dispersion and thermal radiation (VDTR) conditions. Using allowable modeling tools described in NFPA 59A and PHMSA guidelines, Tacoma LNG siting studies were performed and submitted to WUTC for review as part of the siting and permitting process. Meetings were held in 2015 between the PSE design team and WUTC to review the siting studies. WUTC is the AHJ for plant siting, and would advise Tacoma LNG if siting was not accepted.

Storage capacity of flammable refrigerant vessels have been significantly reduced in the design since the original modeling was performed in 2015. If performed again, refrigerant modeling cases would show reduced radiant heat from a fire, and reduced vapor dispersion from a spill.

§ 193.2067 Wind forces. (a) LNG facilities must be designed to withstand without loss of structural or functional integrity.

(b) (2) For all other LNG facilities: (i) An assumed sustained wind velocity of not less than 150 miles per hour, unless the Administrator finds a lower velocity is justified by adequate supportive data; or

<u>Evaluation:</u>

The CB&I design specifications for Tacoma LNG were prepared to comply with 49 CFR Part 193.2067 by performing location specific analysis to comply with ASCE 7 and local building design codes. According to Tacoma LNG site specific wind speed ASCE 7-05 Windspeed: the 3-sec peak gust is 85 mph, and ASCE 7-93 Windspeed: highest sustained is 71 mph.

Subpart I - Fire Protection 193.2801 Scope
Each operator must provide and maintain fire protection at LNG plants according to sections 9.1 through 9.7 and section 9.9 of NFPA 59A, 2001 edition (incorporated by reference, see 193.2013).

<u>Evaluation:</u>
Subpart I - Fire Protection and Safety 193.2801 Scope is incorporated by reference where the federal code references NFPA 59A, 2001 edition, Chapter 9 code compliance evaluation in the next section.

8 NFPA 59A - Chapter 9: Fire Protection, and Safety

8.1 Introduction to NFPA 59A, 2001, "Chapter 9 Fire Protection, Safety and Security"

Incorporated in federal regulations 49 CFR Part 193 Subpart I - Fire Protection and Safety 193.2801, the NFPA 59A, 2001 edition, "Chapter 9 Fire Protection, Safety and Security" compliance evaluation is a required standard checklist approach to evaluating and documenting required safety equipment and procedures in LNG facilities. The following sections, however, each have the requirements from Chapter 9 stated individually, in sequence, which is then followed by a Braemar statement evaluating the Tacoma LNG facility for compliance. Some requirements address operating procedures that at this stage of project development have not been prepared for the operational phase of the facility, and the requirement will be reviewed later when available.

Chapter 9 references are *italicized with a border* followed by a Braemar evaluation and compliance statement. Discussion may be included to expand on the intent of the code requirement and compliance.

8.2 General - Firewater and Fire Suppression

NFPA 59A, 2001 edition 9.1 General
9.1.1 This chapter covers equipment and procedures designated to minimize the consequences from released LNG, flammable refrigerants, flammable liquids, and flammable gases in facilities constructed and arranged in accordance with this standard. These provisions augment the leak and spill control provisions in other chapters. This chapter also includes basic plant security provisions.

9.1.2 Fire protection shall be provided for all LNG facilities. The extent of such protection shall be determined by an evaluation based on sound fire protection engineering principles, analysis of local conditions, hazards within the facility, and exposure to or from other property. The evaluation shall determine the following, as a minimum:
(1) The type, quantity, and location of equipment necessary for the detection and control of fires, leaks, and spills of LNG, flammable refrigerants or flammable gases

<u>Evaluation:</u>

The Tacoma LNG facility design has adequate equipment for the detection and control of fires. For the LNG process areas, LNG storage, LNG truck loading, and LNG ship loading area, adequate firewater is available to provide radiant heat protection and cooling for adjacent piping, equipment, structures, and buildings during a potential fire event.

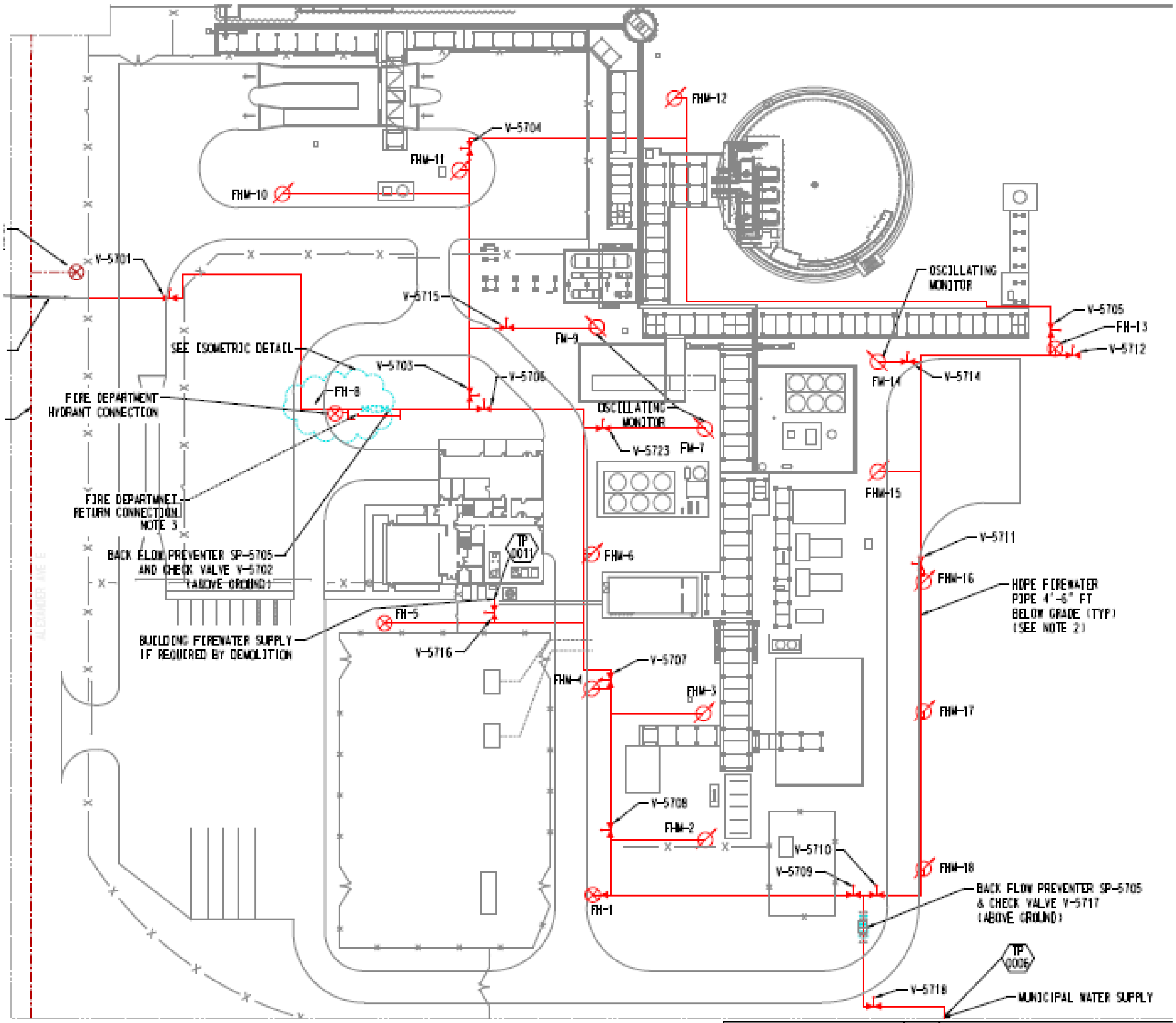


Figure 24 - Tacoma LNG Firewater System

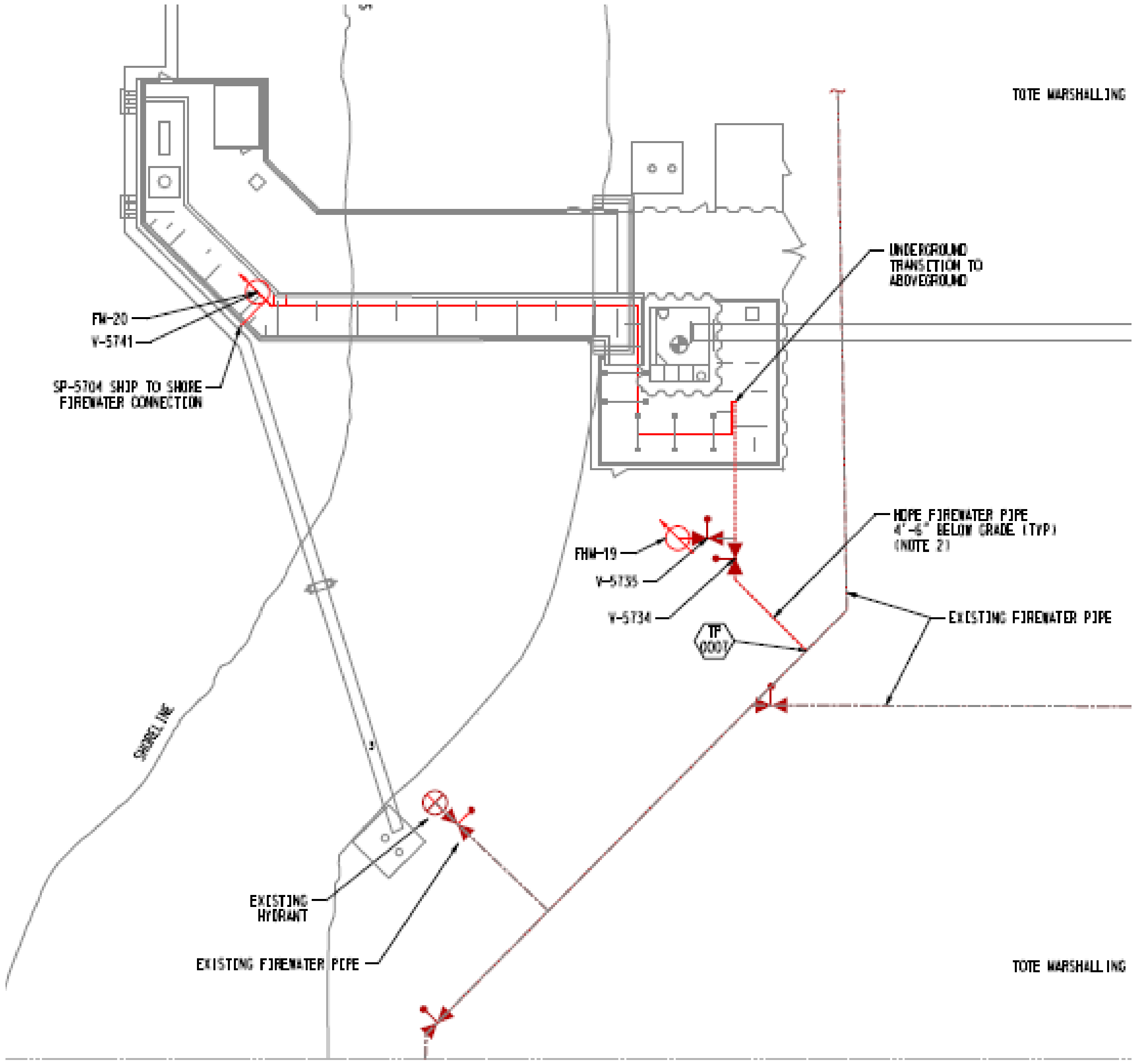


Figure 25 - TOTE Dock Firewater Distribution System

The Tacoma LNG firewater system consists of public utility water supply, looped distribution piping, hydrants and monitors, occupied building sprinkler systems, and fixed spray systems (Figure 24). The utility water system supplying the Tacoma LNG facility is owned and operated by Tacoma Water, a gravity fed system with more than enough pressure, capacity, and reliability to serve the peak demand fire case of 2,000 gpm for 2 hours without the need for onsite firewater storage backup. Firewater for the Blair dock marine transfer area is separate from Tacoma LNG, and is supplied by the existing underground firewater system within TOTE's facility (Figure 25). The TOTE firewater system is also fed from the same existing Tacoma Water firewater distribution system that is supplying Tacoma LNG and the Port of Tacoma.

8.2.1 Firewater

The Tacoma LNG firewater protection system consists of buried pipe, fire hydrants with monitors, and fire hydrants without monitors. The Tacoma LNG firewater protection system consists of mostly buried high density polyethylene pipe (HDPE), and aboveground firewater piping is Class 150 carbon steel piping painted red. Hose houses conform to NFPA 1961 and provide shelter for Tacoma Fire Department approved fire hoses, miscellaneous nozzles and adapters, and wrenches to be used in the Tacoma LNG terminal.

8.2.2 Stationary and Portable Dry Chemical Extinguishers

Dry chemical fire extinguishers are located at strategic locations within the Tacoma LNG facility. Activation of the extinguisher is operated by hand.

Dry chemical fire extinguishers use fire suppression agent Purple-K (PKP) for fighting Class B (flammable liquid and vapor) fires. Purple K is non-conductive and can be used for energized electrical equipment fires (Class C fires). Class B fires include:

- Gasoline and diesel
- Ethanol and methanol
- Isopropanol
- Acetone
- Acetylene
- Methane (Natural gas & LNG vapor)
- Butane
- Propane
- Iso-pentane

Dry chemical works by directly inhibiting the chemical chain reaction which forms one of the four sides of the fire tetrahedron (Figure 26: Heat + Oxygen + Fuel + Chemical Chain Reaction = Fire) required elements to start and sustain a fire. To a smaller degree, it also has a smothering effect — by excluding oxygen from the fire. Water should never be used on Class B fires as water is ineffective, can cause liquid fuel to scatter, and cause LNG and liquid hydrocarbons to vaporize faster which will spread the flames and increase radiant heat escalating the situation. For Class C fires, water can damage electrical equipment and be dangerous by conducting electricity creating an electric shock hazard.

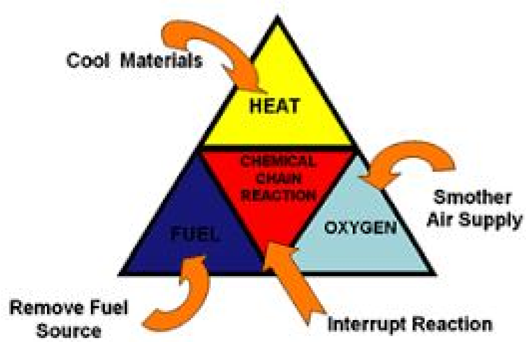


Figure 26 - Fire Tetrahedron

8.2.3 Stationary Dry Chemical Extinguishers

Two (2) large skidded (1500 lb) dry chemical extinguishing units with two (2) 150-foot-long hoses and long range nozzles mounted on concrete slabs are provided at the following locations in Tacoma LNG:

- Liquefaction/Pretreatment Areas
- Truck Loading/MRL Storage Areas

Eight (8) 300 lb wheeled dry chemical units with 100-foot reel hoses are provided at the following locations in Tacoma LNG:

- TOTE Bunkering Dock Platform Area
- Truck Loading area
- Pretreatment Heater Area
- Vaporizer Area
- Liquefaction Area
- Process Area Collection Sump
- Tunnel End Vault – Facility Side Sump
- Tunnel End Vault – Blair Dock Sump

Figure 27 shows the layout and coverage areas for stationary 300 lb and 1,500 lb dry chemical extinguishing units in the main facility and TOTE dock areas:

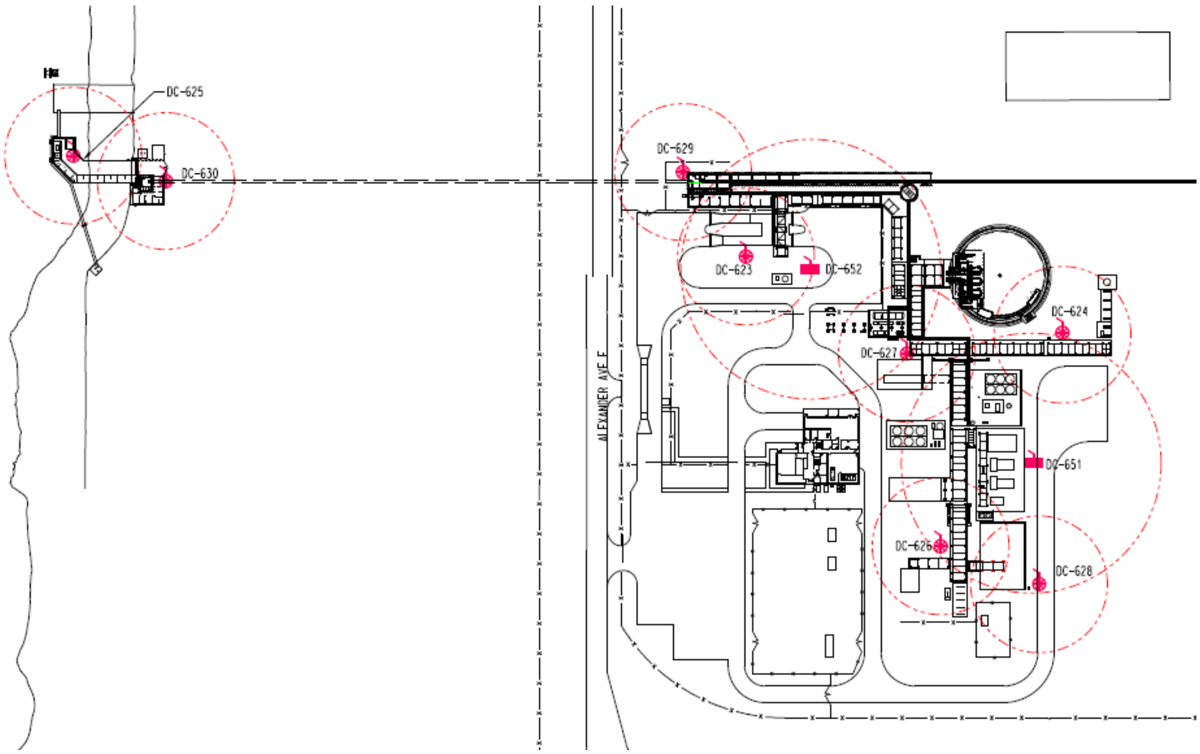


Figure 27 - Stationary Dry Chemical Extinguisher Layout and Coverage

8.2.4 Portable Dry Chemical Extinguishers

Handheld dry chemical fire extinguishers with 20 lb capacity are located per NFPA 10 throughout the Tacoma LNG facilities for fighting small fires.

8.2.5 LNG Tank PSV Fire Suppression

The Tacoma LNG storage tank design has nitrogen snuffing for each LNG tank top pressure relief valve (PSV) vent stack. This fire suppression system is to protect the concrete covered metal tank roof from excess radiant heat from a potential PSV fire, if ignited when discharging. This system is monitored by heat sensors that alarm through the control room fire panel and siren/beacon output. If a fire is confirmed, the system is manually activated by an operator. Activation discharges nitrogen to the outlet of the relief valve exhaust stack in sufficient quantity and duration for PSV fire to be snuffed by displacing flammable vapor, but does not restrict the relief valve capacity.

8.2.6 CO_2 Fire Suppression

Purple K and Carbon dioxide (BC Class) extinguishers, are located in occupied buildings, warehouse and compressor building. Purple K are the greatest majority, and suited for hydrocarbon fires.

8.3 Hazard Detection:

Evaluation:
The Tacoma LNG design includes a wide-ranging hazard detection system; with fire, gas, and spill detection as required by NFPA 59A. The type, quantity, and location of equipment necessary for the detection of fires, leaks, and spills of LNG, flammable refrigerants, or flammable gases are adequate and appropriate and shown in Figure 28 and Figure 29.

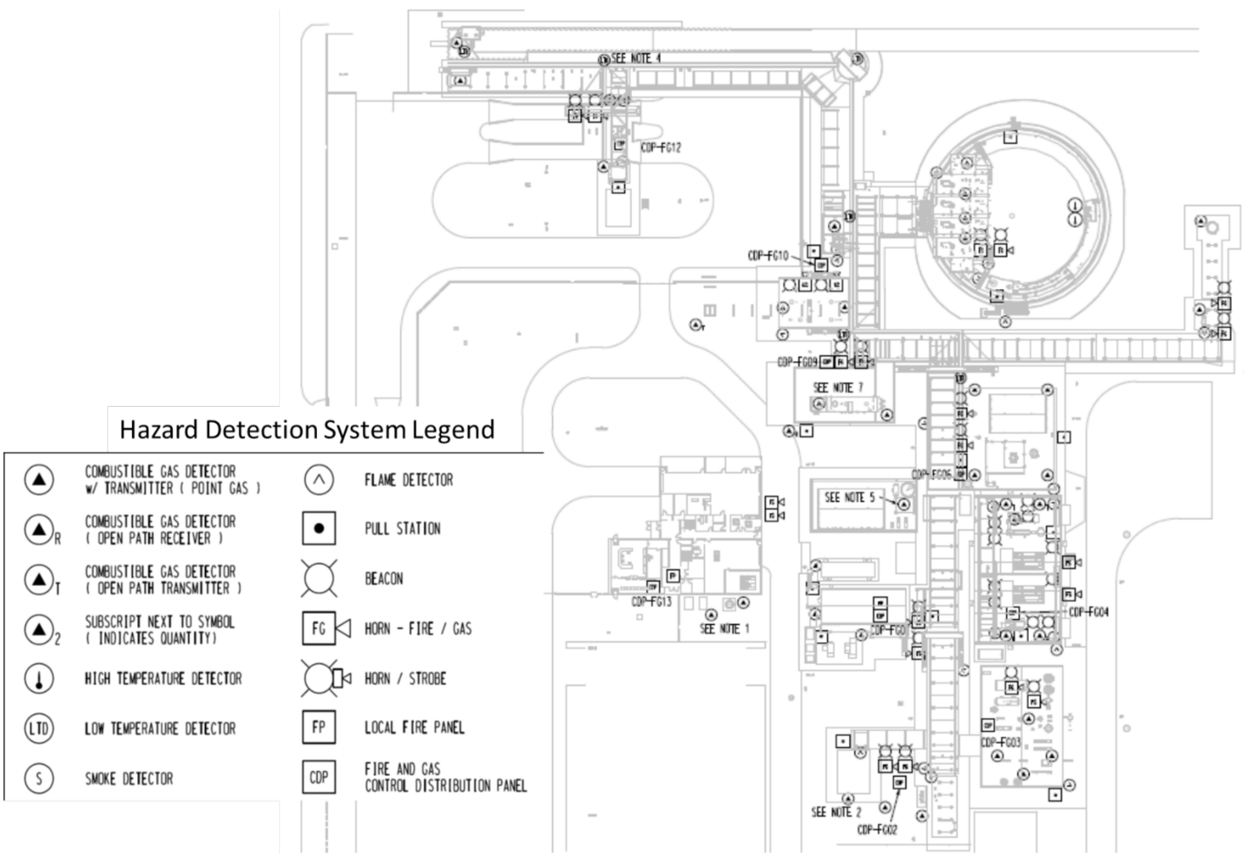


Figure 28 - Hazard Detection System Layout - Main Plant Area

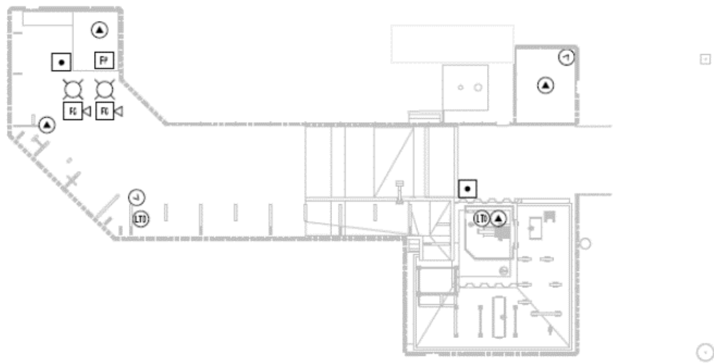


Figure 29 - Hazard Detection System Layout - Blair Waterway Dock Area

Horns, sirens, and beacons are located throughout the facility to alert personnel of hazard detection activation. Tacoma LNG also has a public-address and general alarm (PAGA) system where emergency alerts, detailed emergency announcements, instructions, and updates can be clearly heard throughout the facility. Stationary handsets are located strategically throughout the facility and transfer areas for field operators to communicate with the control center. Figure 30 and Figure 31 show the location of horns, speakers, and call stations of the PAGA system. This system is in addition to dedicated 2-way handheld radios used by operators, and provides for redundant communications with the control center.

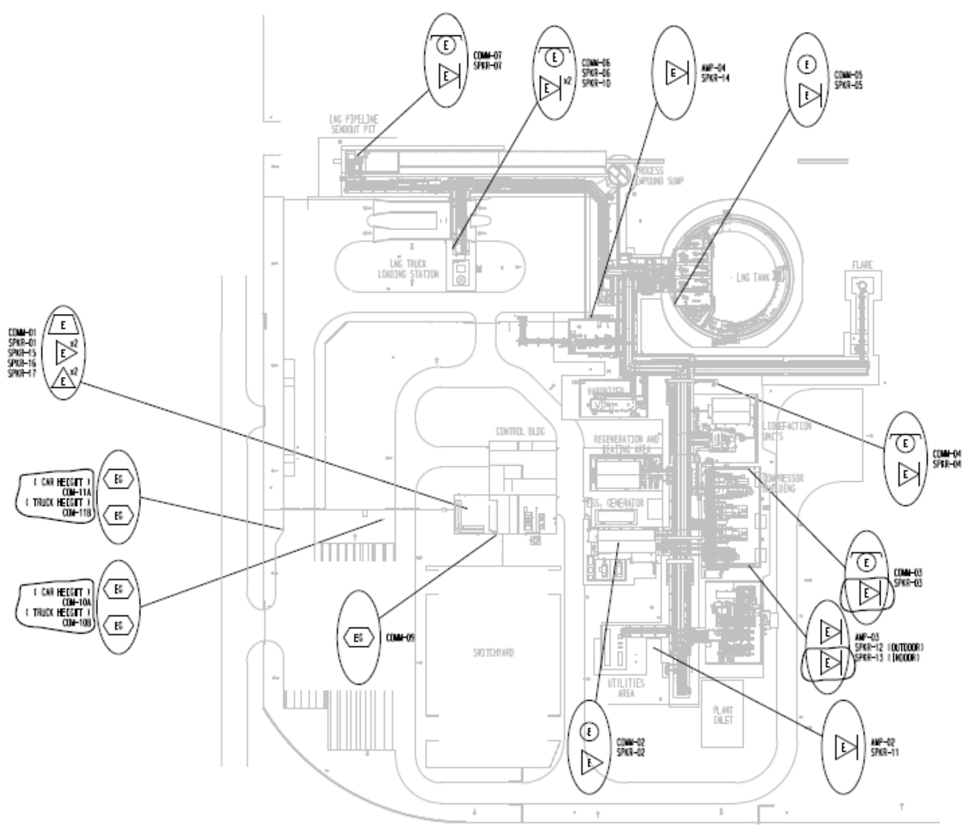


Figure 30 - Public Address System Main Plant Area

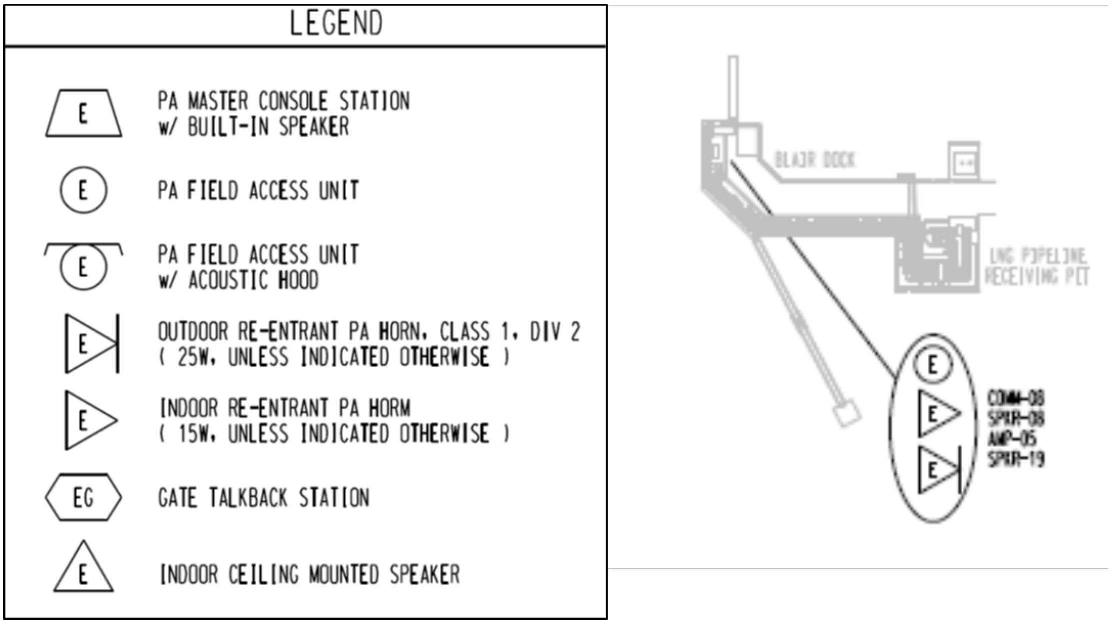


Figure 31 Public Address System - TOTE Dock

Hazard detection systems within the LNG terminal are the first line of defense to immediately alert plant personnel to a potential leak, fire or spill and in some cases automatically shut down equipment. LNG and refrigerant liquid and vapor are mostly odorless, colorless and the human senses of sight and smell cannot be relied upon to detect their presence in the environment. The system is designed as an early warning system to contain a potential fire or gas release to a single unit operation, and lessen the potential for injuries to personnel through audible and visual alarming, and protect capital investment of the facility by quickly containing the release or fire. The LNG terminal hydrocarbon liquid and vapor process systems are based on a “closed loop” design with no atmospheric venting of flammable liquid or gas during routine operations. However, due to the large quantities of combustible and flammable fluids that are being routinely stored and processed within the facilities, awareness and recognition of hazards is an every-day responsibility to plant personnel to maintain a safe work environment. LNG facilities require advanced safety monitoring systems that provide reliable hazard detection and mitigation with both high dependability and high availability of operations. As required by Tacoma building codes, occupied buildings are equipped with smoke detectors and sprinklers that generate alarms in the control room.

9.1.2 (2) The type, quantity and location of equipment necessary for the detection and control of potential non process and electrical fires

Evaluation:

The instrumentation, hazard detectors and surveillance are adequate and appropriate for detection of non-process fires and electrical fires. This is typically smoke, heat and flame detectors in buildings and shelters. Occupied buildings also have sprinklers.

9.1.2 (3) The methods necessary for protection of the equipment and structures from the effects of fire exposure

Evaluation:

Areas selected, and methods used for protection of the equipment and structures from the effects of fire exposure are adequate and appropriate. Process area equipment is protected from the effects of fire exposure either by mechanical protection or firewater. Some systems are automatic as required for compliance or to reduce response time. Structures supporting equipment and vessels containing liquid hydrocarbons in process areas use fire-rated materials. Any steel structures and equipment supports that require protection are protected for a minimum duration of 1.5 hours' hydrocarbon fire as defined in the UL 1709. Passive fire and cryogenic protection measures for the liquefaction area includes equipment and piping associated with:

- Vaporization Booster Pump
- Heavy Ends Heat Exchanger
- Liquefaction Heat Exchanger

9.1.2 (4) Fire protection water systems

Evaluation:

The type, quantity, and location of equipment necessary for the suppression of fires, leaks, and spills of LNG, flammable refrigerants, or flammable gases are adequate and appropriate.

The firewater system consists of public utility water supply, firewater piping, hydrants and monitors, and building sprinkler systems with adequate capacity and reliability. The LNG facility is served by buried HDPE firewater distribution looped main in the LNG facility from the Tacoma Water supply point. The main plant firewater layout is shown in Figure 24. The firewater distribution loop pressure is maintained to about 100 psig.

The firewater distribution system in the TOTE dock area is shown in Figure 25. This is an extension of the existing TOTE firewater system.

9.1.2 (5) Fire extinguishing and other fire control equipment

Evaluation:

The fire extinguishing equipment is designed to code, and judged to be adequate and appropriate.

9.1.2 (6) The equipment and processes to be incorporated within the emergency shutdown (ESD) system, including analysis of subsystems, if any, and the need for depressurizing specific vessels or equipment during a fire emergency.

Evaluation:

Upon an ESD activation, all major equipment is shut down or power is shut off to system equipment and processes for a controlled and safe shutdown. ESD valves are closed for supply gas pipeline isolation, LNG tank isolation, pretreatment, liquefaction, and vaporizer inlet for system ESD. If an operating mode, e.g., vaporization, is not active, valves are normally closed. Any equipment and pipe overpressure will be relieved via existing system relief valves and/or thermal relief valves.

9.1.2 (7) The type and location of sensors necessary to initiate automatic operation of the ESD system or its subsystems

Evaluation:

The LNG plant ESD system is an independent safety shutdown system utilized when the on-duty lead operator makes the decision to immediately shut down all equipment and isolate the plant. The ESD system is reserved for emergency situations only and should not be used when a controlled manual shutdown will suffice. The ESD system can be activated from manual push button locations throughout the facility.

9.1.2 (8) The availability and duties of individual plant personnel and the availability of external response personnel during an emergency

Evaluation:

Tacoma LNG's Standard Operating Procedures Manual and Emergency Response Manual were not reviewed. At this stage of project development, operating manuals have not yet been developed, and will be reviewed later when available. These manuals are required for the operating facility as part of the NFPA 59A - Chapter 9: Fire Protection, and Safety evaluation to describe procedures to be followed in an emergency, the availability and duties of individual plant personnel and outside responders.

9.1.2 (9) The protective equipment, special training, and qualifications needed by individual plant personnel as specified by NFPA 600, Standard on Industrial Fire Brigades, for his or her respective emergency duties

Evaluation:

At this stage of project development, protective equipment, special training, qualifications needed by individual plant personnel, and emergency duties have not yet been developed, and will be reviewed later when available.

All operating LNG plant personnel will be required to receive initial and continuous fire training conducted at intervals not to exceed more than 2-years. Training includes topics such as characteristics of various gas and LNG fires, electrical fires, fire prevention, and protective gear for incipient fires. Fire drills are performed at intervals not to exceed more than 2-years. LNG personnel compliance is to be confirmed through the written exam and attendance to recognized fire training. LNG Operators will not be required to attend fire school training for NFPA 600 certification, Standard on Industrial Fire Brigades. Tacoma Fire Department has agreed to provide industrial fire brigade emergency services.

9.1.3 The wide range in size, design and location of LNG facilities covered by this standard precludes the inclusion of detailed fire protection provisions that apply to all facilities comprehensively.

Evaluation:

At this stage of project development, manuals and duties have not yet been developed, and will be reviewed later when available.

9.2 Emergency Shutdown Systems
9.2.1 Each LNG facility shall incorporate an ESD system(s) that, when operated, isolates or shuts off a source of LNG, flammable liquids, flammable refrigerants or flammable gases, and shuts down equipment whose continued operation could add to or sustain an emergency. Any

equipment, such as valves or control systems, that is specified in another chapter of this standard shall be permitted to be used to satisfy the requirements of an ESD system except where indicated in this standard.

Evaluation:

The ESD actuation includes supply gas, pretreatment, liquefaction, LNG storage, ship loading, truck loading and vaporizer send-out equipment. Upon ESD, all electrical power to equipment is de-energized, and put in a safe shutdown condition. Facility equipment is de-energized to safe condition. The ESD system and functions are fully defined in the “Cause and Effect” document for the ESD system.

9.2.2 If equipment shutdown will introduce an additional hazard or result in substantial mechanical damage to equipment, the shutdown of such equipment or its auxiliaries shall be permitted to be omitted from the ESD system provided that the effects of the continued release of flammable or combustible fluids are controlled.

Evaluation:

Facility equipment is de-energized to safe condition upon ESD. No resultant hazardous conditions are anticipated.

9.2.3 The ESD system(s) shall be of a failsafe design or shall be otherwise installed, located or protected to minimize the possibility that it becomes inoperative in the event of an emergency or failure at the normal control system. ESD systems that are not of a failsafe design shall have all components that are located within 50 ft (15m) of the equipment to be controlled in either of the following ways:

(1) Installed or located where they cannot be exposed to a fire
(2) Protected against failure due to a fire exposure of at least 10 minutes duration

Evaluation:

Critical facility process equipment is fail safe, and de-energized to safe condition upon ESD. No resultant hazardous conditions are anticipated. Back-up ESD and communications are also in the system control center. 50-foot minimum distances are provided for pushbuttons as defined by NFPA 59A for liquefaction, and vaporization, ship loading, and truck transfer areas.

9.2.4 Operating instructions identifying the location and operation of emergency controls shall be posted conspicuously in the facility area.

Evaluation:

At this stage of project development, operating instructions identifying the location and operation of emergency controls cannot be posted conspicuously in the facility area. This requirement will be reviewed later when available.

9.2.5 Initiation of the ESD system(s) shall be either manual, automatic or both manual and automatic, depending on the results of the evaluation performed in accordance with 9.1.2. Manual actuators shall be located in an area accessible in an emergency, shall be at least 50 ft (15m) from the equipment they serve, and shall be marked distinctly and conspicuously with their designated function.

Evaluation:

ESD actuation is manual and buttons are appropriately located, and will be marked distinctly and conspicuously with their designated function. 50 foot minimum distances are provided for pushbuttons from the equipment they serve for pretreatment, liquefaction, storage, LNG vaporization, ship loading, and truck transfer areas.

9.3 Fire and Leak Control
9.3.1 Those areas, including enclosed buildings that have a potential for flammable gas concentrations, LNG or flammable refrigerant spills, and fire shall be monitored as required by the evaluation in 9.1.2.

Evaluation:

The Tacoma LNG process areas and main control center building and other auxiliary buildings and shelters are continuously monitored for the presence of a combustible gas, cryogenic spills, and fire by a dedicated system of hazard detectors. Tacoma LNG Fire Detectors are grouped by zone areas in the main control panel in the control center to identify the general plant area where the detection occurred. Hazard detection system status and events are recorded in a historian.

Gas Detection

Catalytic-bead gas detectors and open path line of sight optical gas detectors (Figure 32) will be used throughout the Tacoma LNG facility to provide full time monitoring for flammable vapors that indicate an accidental spill or release. Sirens and beacons in the vicinity of the detection will automatically be activated to alert field personnel to the activation, and to take appropriate action. Sirens and beacons will remain active until the detection is verified, issue resolved, and all clear given. The detection value of each detector will be monitored and history retained by plant systems.

Figure 32 - Example Catalytic Bead and Open Path Line of Sight Optical Gas Detectors

Fire (Flame) Detection

Multi-spectrum Infrared Flame Detectors are used throughout Tacoma LNG for fire detection (Figure 33), and monitored full time in the control center for indications of a fire. Sirens and beacons in the vicinity of the detection will automatically be activated to alert field personnel to the activation, and to take appropriate action. Sirens and beacons will remain active until the detection is verified, issue resolved, and all clear given. The detection value of each detector will be monitored and history retained by plant systems. This type flame detectors include advanced false alarm prevention. In accordance with 33 CFR Part 127, 2 of 2 voting of gas detectors at the Blair Waterway dock loading area automatically activate an ESD to immediately stop LNG pumps and ship transfer of LNG.

Figure 33 – Example Multi-Spectrum Infrared Flame Detectors

Low Temperature Spill Detection

Tacoma LNG will utilize cryogenic temperature switches for potential LNG spill detection in impoundments. Low temperature switches are monitored full time in the control center for indications of an LNG release. Sirens and beacons in the vicinity of the detection will automatically be activated to alert field personnel to the activation and automatically disables storm water pumps to prevent removal of LNG. The detection status of each detector will be monitored and history retained by plant systems.

9.3.2 Continuously monitored low temperature sensors or flammable gas detection systems shall sound an alarm at the plant site and at a constantly attended location if the plant site is not attended continuously. Flammable gas detection systems shall activate an audible and visual alarm at not more than 25 percent of the lower flammable limit of the gas and vapor being monitored.

Evaluation:

Continuously monitored flammable gas detectors and low temperature monitors have audible and visual alarms throughout LNG process areas, and in the control room. Flammable gas detection systems activate an audible and visual alarm at or above 20 % of the LFL of the gas and vapor being monitored.

9.3.3 Fire detectors shall sound an alarm at the plant site at a constantly attended location if the plant site is not attended continuously. In addition, if so determined by an evaluation in accordance with 9.1.2, fire detectors shall be permitted to activate portions of the ESD system.

Evaluation:

Tacoma LNG facility will have trained LNG operators attending the facility full time (24/7) in the control center from which LNG operations and warning devices are monitored, and emergency plans followed.

9.3.4 The detection systems determined from the evaluation in 9.1.2 shall be designed, installed, and monitored in accordance with NFPA 72, National Fire Alarm Code, or NFPA 1221, Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems, as applicable.

Evaluation:

NFPA 72 (2007) and NFPA 1221 (2007), Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems were Tacoma LNG used for the design of Tacoma LNG detection systems.

9.4 Fire Protection Water Systems
9.4.1 A water supply and a system for distributing and applying water shall be provided for protection of exposures; for cooling containers, equipment and piping; and for controlling unignited leaks and spills. Exception: Where an evaluation in accordance with 9.1.2 indicates the use of water is unnecessary or impractical.

Evaluation:

The current firewater supply and distribution design are adequate for protection of exposures; for cooling containers, equipment and piping; and for controlling unignited leaks and spills.

9.4.2 The design of fire water supply and distribution systems, if provided, shall provide for the simultaneous supply of those fixed fire protection systems, including monitor nozzles, at their design flow and pressure, involved in the maximum single incident expected in the plant plus an allowance of 1000 gpm (63 L/sec) for hand hose streams for not less than 2 hours.

Evaluation:

An allowance of 1000 gpm (63 L/sec) for hand hose streams for not less than 2-hours was used for the design capacity. The existing Tacoma Water supply is adequate and essentially has no time limit on supply. The supply and distribution system capability exceeds the requirements of this condition.

9.5 Fire Extinguishing and Other Fire Control Equipment
9.5.1 Portable or wheeled fire extinguishers recommended by their manufacturer for gas fires shall be available at strategic locations, as determined in accordance with 9.1.2, within an LNG facility and on tank vehicles. These extinguishers shall be provided and maintained in accordance with NFPA 10, Standard for Portable Fire Extinguishers.

Evaluation:

Portable or wheeled fire extinguishers recommended by their manufacturer for gas fires are designed to be placed at strategic locations, as determined in accordance with 9.1.2, within the Tacoma LNG facility. However, at this stage of project development, maintenance procedures have not been prepared for fire extinguishers in accordance with NFPA 10. This requirement will be reviewed later when available.

9.5.2 If provided, automotive and trailer-mounted fire apparatus shall not be used for any other purpose. Fire trucks shall conform to the applicable portions of NFPA 1901, Standard for Automotive Fire Apparatus.

Evaluation:

Tacoma LNG facility will not have a fire truck or trailer-mounted fire apparatus. Fire brigade emergency services will be provided by the City of Tacoma Fire Department who is responsible to conform to the applicable portions of NFPA 1901, Standard for Automotive Fire Apparatus.

9.5.3 Automotive vehicles assigned to the plant shall be provided with a minimum of one portable dry chemical extinguisher having a capacity of not less than 18 lb (8.2 kg).

Evaluation:

At this stage of project development, procedures have not yet been prepared for fire extinguishers for plant vehicles to ensure they are equipped with 20 lb dry chemical fire extinguishers.

9.6 Maintenance of Fire Protection Equipment -Facility operators shall prepare and implement a maintenance program for all plant fire protection equipment.

Evaluation:

At this stage of project development, procedures have not yet been prepared for maintenance manuals that provide maintenance and testing procedures of all plant fire protection equipment. This requirement will be reviewed later when available.

9.7 Personnel Safety
9.7.1 Protective clothing, which will provide protection against the effects of exposure to LNG, shall be available and readily accessible at the facility.

Evaluation:

At this stage of project development, procedures have not yet been prepared for Tacoma LNG personnel protective clothing requirements, and appropriate for their responsibilities. This requirement will be reviewed later when available.

9.7.2 Those employees who are involved in emergency activities, as determined in accordance with 9.1.2, shall be equipped with the necessary protective clothing and equipment and qualified in accordance with NFPA 600, Standard on Industrial Fire Brigades.

Evaluation:

At this stage of project development, procedures have not yet been prepared for Tacoma LNG personnel who are involved in emergency activities and their requirements for protective clothing appropriate for their responsibilities. This requirement will be reviewed later when available.

NFPA 600 Fire Brigade emergency services will be provided by the City of Tacoma Fire Department who is responsible to conform to the necessary protective clothing and equipment and qualified in accordance with NFPA 600 for Tacoma LNG emergency activities.

9.7.3 Written practices and procedures shall be developed to protect employees from the hazards of entry into confined or hazardous spaces.

Evaluation:

At this stage of project development, operating procedures have not yet been prepared for Tacoma LNG to provide guidance for this activity. This requirement will be reviewed later when available.

9.7.4 At least three portable flammable gas indicators shall be readily available.

Evaluation:

At this stage of project development at least three (3) portable flammable gas indicators for the operating facility have not been purchased. This requirement will be reviewed later when available.

9.8 Security
9.8.1 The facility operator shall provide a security system with controlled access that is designed to prevent entry by unauthorized persons.

Evaluation:

Security systems and security procedures for Tacoma LNG are not included with this evaluation.

9.8.2 At LNG facilities, there shall be a protective enclosure including a peripheral fence, building wall, or natural barrier enclosing major facility, such as the following:
(1) LNG storage containers
(2) Flammable refrigerant storage tanks
(3) Flammable liquid storage tanks
(4) Other hazardous materials storage areas
(5) Outdoor process equipment areas
(6) Buildings housing process or control equipment
(7) Onshore loading and unloading facilities

Evaluation:

Security systems and security procedures for Tacoma LNG are not included with this evaluation.

9.8.3 The provisions of 9.8.2 shall be permitted to be met by either a single continuous enclosure or several independent enclosures. Where the enclosed area exceeds 1250 ft2 (116m2), at least two exit gates or doors shall be provided for rapid escape of personnel in the event of an emergency.

Evaluation:

Security systems and security procedures for Tacoma LNG are not included with this evaluation.

9.8.4 LNG facilities shall be illuminated in the vicinity of protective enclosures and in other areas as necessary to promote security of the facility.

Evaluation:

Lighting for perimeter fencing are part of the security evaluation. Security systems and security procedures for Tacoma LNG are not included with this evaluation.

9.9 Other Operation
9.9.1 Manual emergency depressurizing means shall be provided where necessary for safety. Portions of the plant that can be isolated from storage tanks or other sources of supply can be depressurized by venting to the atmosphere. The discharge shall be directed so as to minimize exposure or equipment.

Evaluation:

Thermal relief valves will automatically depressurize blocked in sections of piping in overpressure condition. Tacoma LNG tank has a discretionary vent to the flare with remote actuation. The vaporizer outlet remains open to the send-out pipeline and has a pressure relief valve in the event of a sudden shutdown to protect against a blocked-in case.

9.9.2 Taking an LNG container out of service shall not be regarded as a normal operation and shall not be attempted on any routine basis. All such activities shall require the preparation of detailed procedures.

Evaluation:

The facility operating manuals have not yet been prepared at this stage of project development. When prepared, this requirement should specifically address taking the container out of service and that this is a special operation and a procedure that will be developed prior to such action. This requirement will be reviewed later when available.

9 Summary and Conclusions

The technical review of Tacoma LNG's fire and safety systems did not reveal any fatal flaws or visible design deficiencies. Tacoma LNG was designed to the applicable codes and standards with significant attention to detail, and a perceived objective of becoming a best in class LNG facility. Some Tacoma LNG design features go beyond code compliance to provide additional layers of protection from an unsafe event. Examples are full containment LNG tank type, mounded refrigerant and heavies' removal vessels, and discretionary vents to the flare.

The full containment type LNG tank has a robust design suited for the local conditions. The LNG tank features include integral secondary containment, foundations on piles with seismic isolators, lateral spreading barriers to control soil liquefaction, concrete coated roof, and no penetrations below liquid level in the primary container. The LNG tank design is per NFPA 59A 2006 edition that requires a safe shutdown earthquake (SSE) design without a loss of containment. No credible failure scenarios were identified for the full containment LNG storage tank.

Over the past 50 years CB&I has constructed a large portion of the US LNG utility and base load facilities bringing significant design and construction experience to this project. CB&I's portfolio of completed LNG projects includes some of the world's largest import and export LNG facilities.

9.1 Recommendations

Operating Procedures: Tacoma LNG Operating Procedures were not expected to be completed and available for review within the current stage of the Tacoma LNG project. Per Chapter 9, NFPA 59A 2001 edition, a "Fire and Safety Review" of an LNG facility includes an evaluation of operating procedures and plans that includes; operations, maintenance, emergency procedures, and qualifications of LNG operating personnel. Finalization of the operating sections will be performed later in the project cycle by Braemar when procedures are completed by PSE and CB&I and submitted for review for completeness and code compliance. Interfaces with the Tacoma Fire Department and other emergency responders are defined in the emergency plan. After acceptance, operating manuals are to be reviewed and updated (if needed) annually by Tacoma LNG: NFPA 59A 2001 edition requires operating manuals to include the following:

a. Facility Operations Manual
b. Facility Maintenance Manual
c. Facility Marine Manual (including ship loading)
d. Facility Emergency Response Manual
e. Operator Training Manual

TOTE "Control Measures Easement Area": "Permitted Uses" and "Health and Safety Plan" are referenced in the final "Pipeline and Control Measures Easement Agreement" between TOTE and PSE for allowable and restricted activities within the "Control Measures Easement Area" of TOTE controlled property that is outside the Tacoma LNG facility boundary fence at the Blair Waterway dock. However, due to the preliminary stage of project development these documents have not been developed, and were not reviewed. Finalization of the "Permitted Uses" and "Health and Safety Plan" will be performed later in the project cycle. When they are submitted, Braemar will review these documents for completeness and code compliance. For continuity with Tacoma LNG Operating Procedures, it is anticipated that Tacoma LNG Operating Procedures will be created first, and when completed, used to develop the "Permitted Uses" and "Health and Safety Plan" for the "Control Measures Easement Area" within TOTE controlled property.