U.S. Department
of Transportation
Pipeline and Hazardous Materials
Safety Administration

1200 New Jersey Avenue SE
Washington DC 20590

February 11, 2019

VIA ELECTRONIC AND CERTIFIED MAIL

Mr. Douglas D. Shanda
President
Cheniere Energy, Inc.
700 Milam Street, Suite 1900
Houston, Texas 77002

Re: CPF No. 4-2018-3001H

Dear Mr. Shanda:

Enclosed is the Decision and Order in response to your Request for Final Determination pursuant to the provisions of the April 20, 2018 Consent Agreement.

Sincerely,

Alan K. Mayberry
Associate Administrator
for Pipeline Safety

Enclosure

cc: Ms. Mary McDaniel, Director, Southwest Region, OPS
Mr. Michael Weller, Senior Counsel, Cheniere Energy, Inc.
Mr. Kevin Ewing, Bracewell, LLP, 2001 M Street, NW, Suite 900, Washington, DC, 20036
Ms. Bryn Karaus, Van Ness Feldman, LLP, 1050 Thomas Jefferson St NW, Washington, DC, 20007

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

UNITED STATES DEPARTMENT OF TRANSPORTATION
PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION
OFFICE OF PIPELINE SAFETY
WASHINGTON, D.C. 20590

In the Matter of	)	
	)	
Sabine Pass Liquefaction, LLC,	)	
a subsidiary of Cheniere Energy, Inc.,	)	**CPF No. 4-2018-3001H**
	)	
Respondent.	)	

On October 10, 2018, Cheniere Energy, Inc. (Cheniere) submitted a Request for Final Determination (RFD) on certain terms of a Consent Agreement that was executed on April 20, 2018, between the Pipeline and Hazardous Materials Safety Administration (PHMSA) and Cheniere.[1] Specifically, Cheniere requested a final determination from the Associate Administrator with respect to the scope of the Work Plan for Tank S-101 pursuant to Paragraph 22 of the Consent Agreement governing the return to service of tank operations at Cheniere's Sabine Pass Liquefaction, LLC,[2] facility located in Cameron Parish, Louisiana (Sabine Pass or Respondent).

Procedural Background

Sabine Pass houses five liquefied natural gas (LNG) storage tanks, with an aggregate capacity of 16.9 billion of cubic feet equivalent (Bcfe), two marine berths with a nominal capacity of up to 266,000 cubic meters, and vaporizers with a regasification capacity of approximately 4.0 billion cubic feet per day (Bcf/d). On the liquefaction side, Respondent is currently operating four liquefaction trains, with two other trains (Train 5 and Train 6) under construction or in the process of being commercialized.[3] Sabine Pass is authorized to ship domestically produced LNG by vessel from the Sabine Pass LNG terminal through two jetties, each with four marine loading arms.

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[1] *In the Matter of Sabine Pass Liquefaction, LLC*, Consent Agreement, CPF No. 4-2018-3001H (Apr. 20, 2018) (Consent Agreement).

[2] Sabine Pass Liquefaction, LLC, is a subsidiary of Cheniere Energy Inc. Cheniere's website, *available at* https://www.cheniere.com.

[3] Cheniere Energy, Inc., Form 10-K for the fiscal year ended December 31, 2017 (filed Feb. 23, 2018), *available at* https://www.sec.gov/Archives/edgar/data/3570/000000357018000031/0000003570-18-000031-index.htm (last accessed Feb. 1, 2019).

On February 8, 2018, the Associate Administrator for PHMSA's Office of Pipeline Safety (OPS) issued a Corrective Action Order (CAO) under authority of 49 U.S.C. § 60112 and 49 C.F.R. § 190.233, finding that continued operation by Sabine Pass's LNG terminal would be hazardous to life, property, or the environment.[4] The CAO made preliminary findings that the hazards were associated with a release of LNG discovered on January 22, 2018, and that the hazards would continue unless certain corrective measures were taken. Pursuant to 49 C.F.R. § 190.233(b), the CAO was issued expeditiously without prior notice because failure to do so would have resulted in a likelihood of serious harm to life, property, or the environment. On February 16, 2018, Cheniere requested review of the CAO to determine whether the order should remain in effect. In accordance with 49 C.F.R. §§ 190.211 and 190.233(c), a hearing was held on March 21, 2018 in Houston, Texas, before a Presiding Official from PHMSA's Office of Chief Counsel. Prior to issuance of a decision, the parties reached a settlement agreement, the terms of which are contained in an April 20, 2018 Consent Agreement and Order that was ratified by the Associate Administrator.

Terms of the Consent Agreement at Issue

The Consent Agreement ordered Cheniere to take certain corrective actions on Tank S-101 and Tank S-103. With regard to remediation actions for Tank S-101, which is the subject of the instant dispute, the Consent Agreement permitted Cheniere to return the tank to temporary operations pending the submission of a Temporary Operations Plan to the Southwest Region Director (Director) for review and approval. The Consent Agreement also required Cheniere to undertake a Root Cause Failure Analysis (RCFA) of Tank S-101, as a condition of developing and completing a Work Plan for Tank S-101.[5]

The process envisioned that Cheniere would evaluate whether the findings and conclusions in the RCFA were applicable to development and execution of the Work Plan for Tank S-101 to ensure that temporary mitigation measures and longer term operations could be conducted in a safe manner consistent with federal standards. Section 13 of the Consent Agreement specifically acknowledged the need for Cheniere to evaluate the cause of "unexpected vapor seepage from the bottom of Tank S-101, and [develop] a repair plan, if required, that is consistent with 49 C.F.R. Part 193 and relevant industry standards."[6] Under the terms of the Consent Agreement, the Director had the authority to approve, reject or modify the proposed Work Plan for Tank S-101.

On September 21, 2018, the Director rejected Cheniere's Work Plan for Tank S-101, finding that it was insufficient in multiple respects. The Director concluded that the similar pattern of temperature excursions associated with the "geyser" effect of LNG entering the annulus "was an

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[4] *In the Matter of Sabine Pass Liquefaction, LLC*, Corrective Action Order, CPF No. 4-2018-3001H (Feb. 8, 2018) (CAO).

[5] *In the Matter of Sabine Pass Liquefaction, LLC*, Root Cause Failure Analysis Report, CPF No. 4-2018-3001H (Oct. 5, 2018) (RCFA). The RCFA included an assessment of all five storage tanks to evaluate whether similar events occurred at the other tanks, including whether underlying causal factors were consistent with data and observations from the Tank S-101 incident.

[6] Consent Agreement, at P 13(ii).

indication that there was potentially more damage to Tank S-101" than what Cheniere had suggested before the RCFA was completed.[7] The Director also noted concerns with Cheniere's proposal to rely on the tank's concrete foundation as a permanent solution for containing natural gas vapors that migrated through the documented "openings" in the tank floor, especially given the fact that a partial inspection around the perimeter of the tank's pile cap revealed the existence of uniform "hairline cracks." The Director concluded that it was not possible to adequately determine the extent of damage to the tank without a thorough inspection of the pile cap and the entire floor of the tank, including the need for Cheniere to conduct a porosity study. As a result of the RCFA and inspections by Southwest Region's inspectors, the Director also noted the discovery of significant cracking of the carbon steel floor plates in four separate zones within Tank S-103's annulus, with some cracks measuring 50 inches and extending inward under the inner tank. All of these considerations led the Director to conclude that it was necessary for Cheniere to "enter Tank S-101 to examine the bottom of the tank and initiate repairs" consistent with Work Plan for Tank S-103.

Cheniere disagreed with the Director's determination, and pursuant to Paragraph 22 of the Consent Agreement, the Parties engaged in informal discussions in attempt to resolve the dispute. The Parties were unable to achieve resolution, and on October 10, 2018, Cheniere submitted an RFD to the Associate Administrator, along with supporting documentation. On November 28, 2018, the Associate Administrator convened the parties in Houston, Texas, to conduct an on-site inspection of the Sabine Pass facilities, and subsequently held a meeting at PHMSA's Southwest Region Office to review technical information prior to rendering a decision on the claims contained in the RFD. The RFD presents seven Assignments of Error in the Director's September 21, 2018 decision rejecting the Work Plan for Tank S-101. Each specification or alleged error is discussed below.

Question 1: ***Is the RCFA sufficient to inform the Work Plan for Tank S-101?***

In January 2018, Tanks S-101 and S-103 experienced operational problems that resulted in damage to the tanks. Tank S-103 was affected more significantly as demonstrated by LNG and a significant amount of perlite insulation found on the ground outside the tank after LNG cracked the floor plate and the outer carbon steel wall. Four zones of cracking were observed along the outer steel tank wall. Additionally, a sheet of ice was found on the exterior of the outer tank wall along with natural gas vapor leaking from the cracks in the tank. Tank S-101 experienced a significant vapor leak in the vicinity of the bottom fill line and icy buildup at the following locations: (1) on the bottom base of the external tank shell; and (2) on the underside of the concrete foundation.[8] As described in the RCFA, the presence of LNG in the annular space between the inner and outer tank walls likely resulted in high thermal stresses and temperatures well below the ductile-to-brittle transition temperature for the outer tank steel, and ultimately led to brittle cracking of the outer tank.[9]

[7] Correspondence from Mary McDaniel, Southwest Region Director, to Douglas Shanda, President, Sabine Pass Liquefaction, LLC (Sept. 21, 2018).

[8] RCFA, at p. 32.

[9] RCFA, at p. 6.

The Direct Cause mechanism, discussed in the response to Question 2, of the damage to Tank S-101 and Tank S-103 is the same for each tank. The damage to Tank S-103 occurred during January 2018 in the vicinity of the tank bottom fill line, coincident with low temperature excursions within the tank annulus in the vicinity of the bottom fill line. Similarly, damage to Tank S-101 occurred during January 2018 in the vicinity of the tank bottom fill line, coincident with low temperature excursions within the tank annulus also in the vicinity of the bottom fill line. For reasons discussed more fully below, the RCFA investigation and analysis of the events leading to the damage to the carbon steel shell of Tank S-101 and Tank S-103 show that these events shared common causal factors that are materially relevant to the consideration and development of the Tank S-101 Work Plan.

Question 2: ***Does the temperature excursion data found in the RCFA indicate that there is potentially more damage to Tank S-101 than what Cheniere previously suggested?***

The RCFA reported that 28 separate low-temperature excursions were identified from June 14, 2009, through January 22, 2018, on Tanks S-101 (5 events), S-102 (7 events), S-103 (13 events), and S-105 (3 events), with 24 of the 28 events occurring since 2016 with the conversion to liquefaction operations.[10] Within that period, from January 7, 2016 to August 24, 2016, eight separate temperature excursions occurred on Tank S-103, of which six events approached LNG temperatures.[11] Four of these events occurred in August 2016 with an approximate weekly frequency; each of these four events also correlates with bringing the tank back online to receive LNG from liquefaction after previously receiving LNG from the jetty return. After the last temperature excursion in August 2016, Cheniere disabled the Bottom Fill Valve on Tank S-103 by placing a supervisory lock (closed) in the Distributed Control System (DCS). The Tank S-103 Bottom Fill Valve remained disabled from August 26, 2016, until January 17, 2018, during which time no additional temperature excursions were recorded on Tank S-103. Further, after the temperature excursions in August 2016, Cheniere consulted with Matrix PDM Engineering to investigate why the excursions were occurring on Tank S-103. Matrix PDM issued an initial Root Cause Analysis (RCA) report to Cheniere on March 7, 2017.[12]

Although there were no additional temperature excursions recorded on Tank S-103 from August 26, 2016, until January 17, 2018 (when the Bottom Fill Valve was locked), there were other temperature excursions recorded on Tanks S-101, S-102, and S-105 during this period:

- From January 22, 2017 through December 7, 2017, six temperature excursions occurred on Tank S-102, when five of the six excursions approached LNG temperature.
- From March 17, 2017 to January 1, 2018, three temperature excursions occurred on Tank S-101, when one of the three excursions approached LNG temperature.
- From June 30, 2017 to October 30, 2017, two temperature excursions occurred on Tank S-105; both excursions showed clear deviations from ambient temperatures, but neither approached LNG temperature.

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[10] Tank S-104 had no low temperature events.

[11] Approximately -260°F [-160°C].

[12] RCFA, at p. 12.

The Direct Cause mechanism of all 28 separate temperature excursions and the Tank S-103 leak on January 22, 2018, was a transient operational condition caused by a sudden increase in the flow of LNG through the Bottom Fill piping inside the LNG tank. Due to the funnel design characteristics and proximity to the tank's inner wall ([redacted]), some of this overflow or "splashing" of LNG/two-phase material was directed towards a gap between the top of the tank inner wall and below the suspended deck, thus allowing LNG to escape through the gap and into the perlite-filled annular space between the inner and outer tank walls.[13]

Tank S-101 was also damaged, but to a lesser extent than Tank S-103 based on visual observations. In January 2018, Tank S-101 was found to be leaking vapor at the outer tank wall interface with the concrete pile cap foundation in close vicinity to the bottom fill line location on the tank. Cold spots and icy build-up on the outer shell bottom and underside of Tank S-101 were also observed. There was no sign of LNG or perlite insulation on the ground, nor were there any visible cracks in the wall of Tank S-101. However, a multitude of vapor leaks were detected at 14 different locations along the perimeter of the tank. This high number of leak locations indicates that the outer carbon steel tank floor plate likely suffered from additional cracking as a result of quantities of LNG entering the annulus and ultimately reaching the carbon steel floor plates.[14]

The Tank S-101 Work Plan dated July 20, 2018, suggested that one or both of the following two scenarios are the most likely causes of the outer tank bottom opening and are summarized below:

1. Annular space opening
    - Location: Adjacent to Bottom Fill Nozzle [redacted] degree tank orientation
    - Cause: Cracking in tank bottom base metal caused by exposure to LNG temperatures
    - Evidence: TI [redacted] degree tank orientation reaching -244°F on January 1, 2018.

2. Annular space opening
    - Location: Approximately [redacted] tank orientation
    - Cause: 2008 non-metallic repair failure of pinhole defect during original tank construction. Likely failure modes include seal degradation due to the inability to inspect and maintain the seal condition and/or control original application surface conditions.
    - Evidence: 2008 Matrix Report. Location confirmed by Acoustic emissions testing.

It is not clear why Cheniere would link the Tank S-101 construction defect from 2008 with the vapor leak of January 2018. The leak points are far apart and apparently resulted from very different causes as documented by the relative locations of the leaks – 102 degrees (roughly 3:30 on a clock face), and 208.5 degrees (7 o'clock on a clock face) respectively. Furthermore, the 2008 leak clearly entailed a very small leak as is evident from the following observations and conclusions that were drawn from previously collected data obtained after the 2008 vapor leak incident:

1. The location of the emission is identified.
2. The size of hole from where the gas is coming out is very small.

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[13] RCFA, at p. iii.

[14] CAO, at p. 2.

3. The quantity of emission is very small.
4. The emission is vapor and not liquid based on temperature data.[15]

This description of the 2008 vapor leak stands in stark contrast to the data and information obtained from the 2018 incident, when vapors were detected at measurable levels at 14 different locations. It is noteworthy that since 2016, 24 different temperature excursions occurred approximately within two years from the time when Cheniere converted the facility from an import operation to a liquefaction plant.[16] Of those 24 identified temperature excursions, 10 triggered low temperature alarms.

In 2016, Cheniere started the process of investigating the temperature excursions. Cheniere retained Matrix PDM to perform a RCA of the Tank S-103 temperature excursions related to the bottom fill line operation. However, despite successfully identifying the cause of the temperature excursion problem for Tank S-103, Cheniere apparently did not recognize that the same problem was occurring at Tanks S-101, S-102, and S-105. The available information and data related to historical tank operations indicates a high degree of probability that there is similar damage to Tank S-101's outer containment shell (i.e., cracks in the carbon steel floor plate) and that the damage is likely the underlying cause of the significant number of natural gas vapor leaks that were documented around the outer base of the tank.

Question 3: ***Was Cheniere's inspection of the pile cap sufficient given the failure to survey the entire bottom surface?***

Cheniere is proposing to rely on an epoxy material to seal the area between the bottom of the carbon steel plate and the top of the pile cap. While this method is likely capable of stopping vapor flow through the chime (i.e., the area where the bottom metal plate of the tank meets the top of the concrete pile cap at the base of the tank), it does not address the potential for vapors to escape from the pile cap into the atmosphere. Cheniere's proposed solution necessarily relies on using the concrete pile cap as a pressure containing element. The constituents of the pile cap are not, however, designed or envisioned to be rated pressure containing elements, nor were the composite materials designed to be vapor tight. As indicated from visual examinations around the perimeter, the pile cap already shows signs of hairline cracking, and there is a risk of further cracking and/or porosity over time. Furthermore, it cannot be easily inspected as indicated in the Director's decision. As the pile cap ages, its condition will continue to degrade and thus require more intensive examination, particularly if the materials have continuous contact with cold natural gas vapors. Vapor tightness is a fundamental feature of the LNG tank design to prevent cold vapor migration to portions of the tank structure that are not designed for cold temperature exposure.

Cheniere has not inspected the complete underside of the pile cap, citing safety concerns related to confined space entry. In the absence of the ability to conduct frequent and comprehensive inspections of the present and future condition of the pile cap structure, it is not possible to verify that vapor is not flowing from cracks in the pile cap. A hydrocarbon detector placed at the

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[15] Memo from Lisa Tonery of Fulbright & Jaworski L.L.P. to the Federal Energy Regulatory Commission, Docket No. CP04-47-000, at p. 3 (Aug. 22, 2008).

[16] RCFA, at p. 11.

perimeter of the tank may not detect a leak due to the fact that the reliability of the gas detector is dependent on wind direction, and the pile structures under the tank forms an excellent mixing chamber that would create flow eddies as the air and methane move towards the perimeter of the pile cap, thereby diluting any leak before it arrived at the tank perimeter, and ultimately evading detection. Accordingly, visual inspection of the underside of the pile cap from the perimeter does not constitute an adequate and complete inspection of the pile cap for purposes of ensuring near-term and long-term containment of natural gas vapors.

Question 4: ***Is it necessary to enter Tank S-101 in order to properly evaluate the findings of the RCFA?***

The Direct Cause mechanism described in RCFA matches the known observations and explains the cracks in the carbon steel shell in the vicinity of the bottom fill line location on both Tank S-101 and Tank S-103. Entry into Tank S-103 confirmed multiple anomalies that were consistent with the Direct Cause mechanism.[17] It is unlikely, therefore, that entering Tank S-101 will provide additional support for or refute the Direct Cause mechanism given the experience with Tank S-103 in this regard. Notwithstanding, and for the other reasons stated in this decision, entry into Tank S-101 is still necessary to evaluate and repair all cracks, leak paths and anomalies in the carbon steel floor in order to reestablish vapor containment consistent with the construction and repair standards contained in 49 CFR Part 193, as enumerated in the response to Question 5 (below).

Question 5: ***Is the Tank Repair Plan consistent with 49 C.F.R. Part 193 and NFPA 59A Repair Requirements? Does installation of an epoxy sealant constitute a permanent repair?***

This case raises the question as to whether Cheniere's repair method for Tank S-101 is consistent with 49 C.F.R. Part 193 and National Fire Protection Association (NFPA) 59A Repair Requirements. The regulatory path describing how the cracks in the Tank S-101 bottom plate should be repaired is contained in the text of 49 CFR § 193.2617, which requires that repair work on components must be tested, in a manner, as far as applicable, that complies with Part 193, Subpart D, "Construction."[18]

Subpart D relates to construction, and requires that each LNG facility constructed after March 31, 2000 must comply with requirements included in Subpart D, as well as NFPA 59A[19] (incorporated

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[17] Investigation of Sabine Pass Tank Release January 2018 – Additional Supporting Details, p. 2.

[18] 49 CFR § 193.2617, Repairs, states as follows:

> (a) Repair work on components must be performed and tested in a manner which:
> (1) As far as practicable, complies with the applicable requirements of Subpart D of this part; and
> (2) Assures the integrity and operational safety of the component being repaired.
> (b) For repairs made while a component is operating, each operator shall include in the maintenance procedures under §193.2605 appropriate precautions to maintain the safety of personnel and property during repair activities.

[19] NFPA 59A (2001), which is incorporated into 49 CFR §§ 193.2301 and 193.2303, states as follows:

> 4.2 Metal Containers.

by reference see § 193.2013). It also requires that no component be placed into service until it passes all applicable inspections and tests prescribed by Subpart D and NFPA 59A. Regarding nondestructive testing, storage tanks with internal design pressures at 15 psig or less, ultrasonic examinations of welds on metal containers must comply with the Section 7.3.1.2 of NFPA 59A (2006) and Appendices Q and C of the American Petroleum Institute (API) 620 Standard, "Design and Construction of Large, Welded, Low-pressure Storage Tanks."[20]

The references to NFPA 59A (2001) in §§ 193.2301 and 193.2303 make it clear that each LNG facility, pipeline facility and components (all as defined in 49 CFR § 193), must be constructed as specified in NFPA 59A (2001). NFPA 59A (2001), paragraph 4.2.1, specifies that all welded metal containers designed for operation at 15 psig and less must comply with API 620, Appendix Q.

Because Cheniere's LNG storage tanks are metal containers that operate at less than 15 psig, the construction (and repair) of these tanks must comply with API 620, Appendix Q. Therefore, to satisfy the requirements of 49 CFR § 193.2617, all repairs to the Sabine LNG storage tanks must be made to the same specification as the construction specification.

The following analysis of API 620, Appendix Q demonstrates the construction and/or repair of the outer carbon steel tank must be vapor tight, metal, welded components. Appendix Q forms a guide for the "the materials, design, and fabrication of tanks to be used for the storage of liquefied ethane, ethylene, and methane."[21] Section Q.1.5 defines the outer carbon steel tank as a secondary component that includes "those components that will not be stressed to a significant level by the refrigerated liquid, those whose failure will not result in leakage of the liquid being stored, those exposed to product vapors, and those that have a design metal temperature of -60°F or higher." Section Q.2.3 describes the material components of the outer carbon steel tank, including the design conditions applicable to Sabine Tank S-101.[22] Section Q.2.3.1 states that material for the outer tank that contains the vaporized liquefied gas but is primarily subjected to atmospheric temperatures may conform to Section 4, Table 4-1, which provides the "Minimum Requirements for Plate Specifications to be Used for Design Metal Temperatures," and contains only metal listings and does not contain or discuss any epoxy listings.[23] Section Q.5.1 specifies

> 4.2.1 Containers Designed for Operation at 15 psi (100 kPa) and Less. Welded containers designed for not more than 15 psi (100 kPa) shall comply with API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks.* API 620, Appendix Q, shall be applicable for LNG with the following changes…

[20] NFPA 59A (2001) is incorporated into §§ 193.2301 and 193.2303, while NFPA 59A (2006) is incorporated into § 193.2321.

[21] API 620, Appx. Q, Section Q.1.1, General.

[22] API 620, Appx. Q, Section Q.2.3.1.

[23] Q.2.3.1 Material for the outer tank that contains the vaporized liquefied gas but is primarily subjected to atmospheric temperatures may conform to one of the following:

> a. Table 4-1 for design metal temperatures down to - 35°F (lowest one-day mean ambient temperature of - 35°F) without impact tests unless they are required by Table 4-1 or by the purchaser.

that the enclosure of the annular space be vapor tight,[24] with Section Q.5.3.1 reinforcing that all materials that are part of the outer tank must be metal as specified in Q.2.3.[25] Section Q.6 states that the secondary components such as the outer carbon steel tank, must be welded. This section goes on to specify that outer tank shall conform to the welded construction requirements contained in Q.7.1.2.2.[26] Section Q.7.1.2.2 reinforces the welding requirement that for the outer tank bottom components exposed to vaporized liquefied gas and joined together by fillet welds shall have a minimum of two passes.

To summarize, 49 CFR § 193.2617(a)(1) states that any repair must comply with Subpart D, Construction, as far as practicable. Subpart D's scope pertains to construction, and the incorporation by reference of NFPA 59A (2001) into 49 CFR §§ 193.2301 and 193.2303 make it clear that each LNG facility, along with pipeline facilities and related components (all as defined in 49 CFR Part 193), must be constructed and/or repaired as welded metal containers designed for operation at 15 psig or less, consistent with API 620, Appendix Q.

The Sabine LNG storage tanks are metal containers that operate at less than 15 psig, so the construction of these LNG storage tanks must comply with API 620, Appendix Q. Therefore, to satisfy the requirements of 49 CFR § 193.2617, all repairs to the Sabine LNG storage tanks must be made to the same specification as the initial construction specification. That is, the outer carbon steel container must be vapor tight and of welded construction. Accordingly, the epoxy repair method that was utilized by Cheniere for Tank S-101 does not qualify as a permanent repair under Part 193.

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b. Table R-4 for design metal temperatures down to -60°F without impact tests unless they are required by Table R-4 or by the purchaser.

c. Paragraph Q.2.1 without impact tests unless they arc specified by the purchaser.

d. If approved by the purchaser, the material may be selected according to the requirements of 4.2.2.

[24] Q.5.1 Design Specifications. The outer bottom, shell, and roof of a double-wall tank shall enclose an insulating space around the bottom, shell, and roof or insulation deck of the inner tank that contains the stored liquid. The annular space shall be maintained at a low positive pressure, which necessitates **that the enclosure be vapor-tight**. The purchaser shall specify the design metal temperature and pressure of the inner tank and may specify the design temperature and pressure of the outer tank. The purchaser shall state the specific gravity of the content to be stored, roof live loads, wind load, earthquake load where applicable, and corrosion allowance, if any. (Emphasis added).

[25] Q.5.3 Minimum Wall Requirements:

Q.5.3.1 Outer Tank

The outer tank bottom, shell, and roof shall have a minimum nominal thickness of 3/16 in. (7.65 lbf/ft2) and shall conform to the material requirements of Q.2.3.

[26] Q.6 Welding Procedures

The rules in this section shall apply to all primary components of the tank. Covered electrodes and bare-wire electrodes used to weld 9% and 5% nickel steel shall be limited to those listed in AWS 5.11 and AWS 5.14. The secondary components shall be welded in accordance with the basic rules of this standard unless the requirements of this appendix or Appendix R are applicable. The outer tank, which is not in contact with the vaporized liquefied gas, may be of single-welded lap or single-welded butt construction when the thickness does not exceed 3/8 in.; at any thickness, the outer tank may be of double-welded butt construction without necessarily having lull fusion and penetration. Single-welded joints shall be welded from the outside to prevent corrosion and the entrance of moisture. When the outer tank is in contact with the vaporized liquefied gas, it shall conform to the lap- or butt-welded construction described in this standard except as required in Q.7.1.2.2.

Question 6: ***Has Cheniere sufficiently addressed its plan to prevent stratification within Tank S-101 by disabling bottom-fill flow operations?***

The "Cheniere LNG Storage Tanks Stratification Prevention and Correction, SP-OPS-PRDOPS-SOP-003020, 10/15/2018, revision 5.0" O&M stratification mitigation procedure (Revised O&M Stratification Procedure) was revised to disable the LNG bottom-fill option in all five (5) LNG tanks while retaining the capability to mitigate stratification.[27]

This Revised O&M Stratification Procedure appears acceptable and three additional clarifications and/or revisions are listed below as conditions of acceptance.

Condition 1: Cheniere shall provide written notification to the Director when the temperature and density deviation alarm software has been installed and tested for all five (5) tanks. This software will allow monitoring and alarming capability based on temperature and density as the probe traverses through the tank level. Output reports for all 5 tanks shall be provided to demonstrate that the software is functioning properly.

Condition 2: Cheniere shall provide to the Director a copy of the preventative maintenance procedure(s) for the LNG tank stratification monitoring system.

Condition 3: The Revised O&M Stratification Procedure does not presently consider all LNG facility operating modes that may impact stratification mitigation actions. Mitigating stratification in a given tank may require different actions depending on the facility operating mode (e.g., LNG liquefaction, LNG ship unloading, LNG ship loading, vaporization/LNG send-out, or combinations thereof). Each of these operations may require flow to be diverted, curtailed or stopped, depending on the circumstances, to avoid further aggravation of problematic conditions. Accordingly, Cheniere is directed to devise O&M Stratification mitigation procedures, as follows:

a. Perform a technical analysis to assess the potential for stratification during LNG liquefaction, LNG ship unloading, LNG ship loading or LNG vaporization/send-out and what additional mitigation actions or adjustments may be necessary.

b. Options discussed in Operating Procedure 1.1[28] states that Intra-Tank Transfer, Tank to Tank(s) Transfer, LNG Send Out, Ship Loading, or any combination thereof are acceptable means of eliminating a stratification layer from an LNG Storage Tank. Section 4.0 contains prescriptive instructions for actions to be followed by operators at the time stratification corrective measures are implemented, however, the procedure does not recognize that possible operating mode(s) may affect the corrective measures listed, requiring additional or alternate measures to be followed. The procedure should include the process by which the corrective measures for a stratification event shall be defined and which staff must participate in the formal decision process to arrive at the optimal path forward at the time stratification occurs.

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[27] RCFA, at p. 61.

[28] *See supra*, at p. 4.

Cheniere shall provide written notification to the Director of any findings for each case, and if warranted, update the Revised O&M Stratification Procedure as deemed necessary or as otherwise ordered by the Director.

Question 7: ***Should Cheniere submit an additional fitness-for-service evaluation meeting the requirements of API RP 579-1/ASME FFS-1?***

The epoxy solution described in the response to Question 3 seeks to address the vapor tightness requirement for Tank S-101. This proposed solution is not consistent with 49 CFR § 193, NFPA 59A (2001), or API 620. However, Cheniere promotes the epoxy repair as a sufficiently reliable method to prevent vapor from escaping from the tank bottom. Cheniere's solution relies on the pile cap functioning as a pressure containing element for years (and potentially decades) to come. If a crack were to develop in the pile cap, the existing pressure within the annulus would (assuming the epoxy seal continued to hold) create a flow path for vapor to flow from the annulus of the tank, through the crack(s) in the bottom of Tank S-101, and ultimately escape through cracks or breaches in the pile cap structure. The risk of such a containment breach is heightened due to the fact that none of these structural elements are designed to withstand long-term exposure to low temperature LNG vapor flows.

The epoxy solution and the Structural Integrity Report are the sum total of Cheniere's response to a major operational upset that resulted in damage to Tank S-101. Cheniere's proposed solution fails to repair the known damage to the failed carbon steel floor plate of the outer tank, and it fails to mitigate the unknown risks associated with this damage.[29] The unknown risks include present and future risks that could arise over decades. Cheniere is proposing to put Tank S-101 back into service without inspecting the damage, and then living with the uncertainty risk for the next 30 to 50^{+} years. These unknown risks could be mitigated by doing a thorough inspection of the damaged area and permanently repairing any identified defects or damage.

In light of the foregoing analysis, Cheniere's proposed solution does not adequately address the risks associated with the decision not to fully investigate the damage caused by the LNG spill. The risk of not undertaking available inspection and repair actions unnecessarily presents a continuing public safety threat over the years and decades to come. Accordingly, Cheniere must thoroughly inspect the damage to Tank S-101 in a manner consistent with the remediation process for Tank S-103. This approach will ensure that known defects and damage to Tank S-101 are repaired in accordance with the construction and repair criteria contained in 49 CFR Part 193. Once the repair

[29] Cheniere provided a Structural Integrity Report by Stress Engineering Services, Inc. (SES) for Tank S-101 to justify its position that the damage to Tank S-101 would not compromise the structural integrity of the tank. This SES Report contains an important disclaimer on page 23 (at the end of Section 8) that it is impossible to assess the structural integrity without performing an inspection of the affected area. The disclaimer introduces an element of uncertainty that other defects more severe than those included in the listed scenarios may exist. Additionally, the Report's conclusions are based on the assumption that the existing construction materials satisfy the strength properties noted for ASTM A36 Mod 2 plate material, and assumes that no corrosion, pits, or other flaws could contribute to a failure mode other than global plastic collapse. If any of these assumptions are incorrect, the Report's conclusions would need to be reevaluated.

process is complete, Cheniere is directed to submit to the Director an additional fitness-for-service evaluation plan that meets the requirements of API RP 579-1/ASME FFS11.[30]

Conclusion

For the reasons stated above, I hereby find that the July 20, 2018 Work Plan for Tank S-101 submitted by Cheniere was insufficient and, therefore, was properly rejected by the Director. The terms and conditions of this Final Determination are effective upon service in accordance with 49 CFR § 190.5.

Alan K. Mayberry
Associate Administrator
for Pipeline Safety

DATED IN WASHINGTON, DC ON THIS 11th DAY OF FEBRUARY, 2019.

[30] A review of the record indicates that the temperature excursions within the annulus of the LNG storage tanks were identified in the Matrix PDM Report during the 2016-2017 timeframe for Tank S-103. Subsequently, Cheniere apparently did not take adequate steps to ensure that LNG did not flow from the Tank S-103 bottom fill line to Tank S-103 annulus causing damage to the carbon steel tank wall and bottom plate. The RCFA observes that Cheniere did not adequately communicate the problems to operations personnel, so that when the temperature excursions occurred in other LNG storage tanks, including Tank S-101, the control room personnel could have identified the new problem that was occurring so that proactive measures could have been taken. The RCFA discusses a number of recommendations Cheniere should consider incorporating into operating procedures.