POLLUTION CONTROL HEARINGS BOARD

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ADVOCATES FOR A CLEANER TACOMA; SIERRA CLUB; WASHINGTON ENVIRONMENTAL COUNCIL; WASHINGTON PHYSICIANS FOR SOCIAL RESPONSIBILITY; STAND.EARTH, and THE PUYALLUP TRIBE OF INDIANS, Appellants, v. PUGET SOUND CLEAN AIR AGENCY, PUGET SOUND ENERGY Respondents.	)	PCHB NO. P19-087c DECLARATION OF THOMAS O. SPICER

INTRODUCTION

1. My name is Thomas O. Spicer. My curriculum vitae is attached as Exhibit A to this testimony. I currently serve as Professor in the Ralph E. Martin Department of Chemical Engineering at the University of Arkansas, and have taught as a faculty member in this department for 35 years. Recently, my course work focus has been in the areas of chemical process control and chemical process safety. During my career at the University of Arkansas, I have acted as a consulting engineer for government and industry clients including the U.S. Environmental Protection Agency, the Department of Homeland Security, Exxon, Mitsubishi Heavy Industries, and the American Petroleum Institute. My areas of expertise include fire and explosion hazard assessment, atmospheric dispersion of toxic and flammable air-borne contaminants, and computational fluid dynamics, among others.

2. I helped develop the methodology for the Degadis vapor dispersion method and have published numerous peer-reviewed articles, book chapters, and publications on fire and

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explosion risk assessment, and atmospheric vapor dispersion modeling. I direct the Chemical Hazards Research Center (CHRC) at the University of Arkansas. The CHRC conducts major research programs to develop and verify mathematical and wind tunnel models of the atmospheric dispersion of hazardous chemicals. The CHRC houses an ultra-low-speed environmental wind tunnel — presently the largest in the world. This tunnel was built to investigate atmospheric dispersion processes at extremely low wind conditions, which frequently define worst case conditions for atmospheric dispersion. I am also a member of the Safety and Chemical Engineering Education (SACHE) Committee of the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers (AICHE); SACHE develops course material for safety education in chemical engineering. In 2018, the Safety and Health Division of AICHE awarded me with the Norton H. Walton – Russell L. Miller Award that recognizes outstanding achievements in contributions to chemical engineering in the fields of loss prevention, safety, and health.

3. Included below is a non-exhaustive list of the documents specific to this project that I have reviewed:

a. *Final Environmental Impact Statement for the Proposed Tacoma LNG Project*, published on November 9, 2015 ("Final EIS").

b. *Tacoma LNG Siting Study Report*, Doc. No. 186512-000-SE-RP-00001, issued on July 16, 2015 ("2015 Siting Study"), and accompanying appendices.

c. CB&I Services, Inc., COR-110 Alternate Feed Gas Composition (Option 6A) Scope Definition, Doc. No. 210140-PE-PC-00171.0030 (Jul. 14, 2017).

d. Alternate Feed Gas Composition Review, Doc. No. 210140-000-PR-TN-00002, Rev. A, Mar. 13, 2017.

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[redacted]

f. Project Design Basis, Rev. C, CBI Doc. No. 186512-000-PR-DV-00001, Sept. 14, 2015.

g. Project Design Basis, Rev. 2, Doc. No. 210140-000-PR-BD-00001, Jun. 28, 2017.

[redacted]

i. The Overall Plot Plan for the Main LNG Plant, including the preliminary design, and Revision 1.

j. *Tacoma LNG Fire Thermal Radiation Calculation Storage Area Truck Connection Station Local Spill Impoundment Supplement*, Doc. No. 210140-000-SE-RP-00002, Issued on November 1, 2018 ("2018 CB&I Supplemental Study").

k. *Tacoma LNG – Dispersion Modeling – Supplemental Report*, Ref. No. GexCon-18-P515018-R-1, Rev. 01, Issued Nov. 2, 2018 ("2018 Gexcon Supplemental Study").

l. Puget Sound Clean Air Agency, Final Supplemental Environmental Impact Statement: Proposed Tacoma Liquified Natural Gas Project, March 30, 2018 ("SEIS").

m. Deposition of Jim Hogan, Responsive Witness for ACT's 30(b)(6) deposition Notice, December 14, 2020.

4. Additionally, below is a non-exhaustive list of references I relied upon to prepare this declaration:

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a. Center for Chemical Process Safety, Guidelines for Vapor Cloud Explosion, Pressure Vessel Burst, BLEVE, and Flash Fire Hazards, American Institute of Chemical Engineers, John Wiley and Sons, 2010 ("*CCPS Guidelines*").

b. NFPA 59A, Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG), National Fire Protection Association, 2019.

c. NFPA 68, Standard on Explosion Protection by Deflagration Venting, National Fire Protection Association, 2018 ("NFPA 68").

d. U.S. DOT/PHMSA Final Decision on Det Norske Veritas Petition for Approval of Alternative Gas Dispersion Model, Oct. 7, 2011, http://www.regulations.gov/document?D=PHMSA-2011-0075-0025 last accessed on Jan. 6, 2021.

e. Coldrick, C., C.J. Lea, and M.J. Ivings, Validation Database for Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities, Guide to the LNG Model Validation Database, Fire Protection Research Foundation, May 2010.

ANALYSIS

I. BACKGROUND

5. The Tacoma LNG Facility would receive raw natural gas that contains ethane, propane, butane, and other heavy hydrocarbons. Hasselman Decl., Ex. 32 (Project Design Basis Rev. 2 at 3, 7). This raw natural gas would be processed on site into commercial natural gas, and then liquefied and stored onsite in the storage tank. *Id*. Processing the raw natural gas requires removing heavy hydrocarbons from the gas stream. SEIS at 2-3.

6. The Tacoma LNG Project would use and store heavy hydrocarbons. These heavy hydrocarbons include: (1) mixed refrigerant liquids including propane and isopentane, and (2) natural gas liquids removed from the raw gas stream which contain a mixture of different heavy

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hydrocarbons (including propane, i-butane, n-butane, i-pentane, n-pentane, n-hexane, n-heptane, n-octane). Hasselman Decl., Ex. 34 (2018 CB&I Supplemental Siting Report at 4); *id*., at Ex. 33 (2018 Gexcon Study at 11-12) (describing composition of natural gas liquids that could be spilled). The original facility design was based on raw natural gas feedstock, which contained minimal heavy liquid hydrocarbons, but the design basis revised in July 2017 was based on a raw natural gas feedstock reflecting a substantial increase in heavy hydrocarbons. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 3); *id.* at Ex. 32 (Project Design Basis, Rev. 2 at 7) (describing feed gas composition with a much higher content of ethane, propane, butane, and pentane).

7. Refrigerant liquids and natural gas liquids contain highly flammable chemicals, and a leak of these hazardous chemicals could pose a fire or vapor cloud explosion hazard. Methane, a single carbon hydrocarbon, is a low reactivity fuel, but other alkanes, with two carbons or higher, are classified as medium reactivity fuels.[1] Per NFPA 59A, evaluating the consequences of a fire or vapor cloud explosion requires modeling radiant heat flux, vapor dispersion, and overpressure.[2] Overpressure is the pressure caused by a flame front over and above normal atmospheric pressure caused by a deflagration or detonation.

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[1] NFPA 68, at Table D.1(a) (listing fundamental burning velocities of various substances including alkanes (all with burning velocities greater than 40 cm/s)); *CCPS Guidelines*, at 197 (stating that fuels are conservatively classified as medium reactivity for burning velocities between 40 and 75 cm/s except methane which is listed as an example of a low reactivity fuel).

[2] PHMSA requires considering explosion risks when evaluating safety hazards:

> According to NFPA 59A-2001 Paragraph 2.1.1(d), (incorporated by reference in 49 CFR Part 193), all hazards that can affect the safety of the public or plant personnel are to be considered. In addition to LNG, the applicant should consider hazards associated with flammable gases, flammable refrigerants, flammable or combustible liquids, or acutely toxic materials. If present at the LNG plant, hazards including vapor dispersion

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8. Calculating overpressure is required when evaluating the dangers posed by a vapor cloud explosion. When a flammable vapor is released, its mixture with air will form a flammable vapor cloud. If ignited, the flame speed can accelerate to high velocities and produce significant overpressure especially in areas of containment or congestion. A leak of refrigerants or heavy hydrocarbons from the Tacoma LNG Facility creates the possibility that such an explosion could occur.

9. The Final Environmental Impact Statement ("EIS")[3] relied upon the CB&I Siting and Safety Study prepared in 2015 to evaluate health and safety hazards. Hasselman Decl., Ex. 3 (Final EIS at 3) ("Preliminary siting studies were performed for Tacoma LNG using basic modeling tools, Degadis for vapor dispersion, and LNG Fire III for thermal radiation."). The Final EIS noted that the project would require further review once a more detailed engineering design is available. *Id*. ("More advanced modeling is required later in detailed engineering when the design is further defined using Computational Fluid Dynamic (CFD) software.").

10. After publication of the Final EIS, PSE made the following changes to the design of the Tacoma LNG Project:

> from liquid pools, vapor dispersion from jetting and flashing phenomena, thermal radiation from pool fires, thermal radiation from fires involving jetting and flashing phenomena (jet fires), overpressure from vapor cloud ignitions, toxic gas dispersion, and boiling liquid expanding vapor explosions (BLEVEs) involving pressurized storage vessels should be included in an LNG plant's hazard evaluation.

U.S. Pipeline and Hazardous Materials Safety Administration, "LNG Plant Requirements: Frequently Asked Questions," https://www.phmsa.dot.gov/pipeline/liquified-natural-gas/lng-plant-requirements-frequently-asked-questions#h1, last accessed on Dec. 18, 2020.

[3] City of Tacoma, Puget Sound Energy Proposed Tacoma Liquefied Natural Gas Project Final Environmental Impact Statement, Nov. 9, 2015, https://cms.cityoftacoma.org/planning/pse/Reissued%20Final%20Tacoma%20LNG%20EIS%20(11-9-15).pdf.

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a. Relocating equipment in the liquefaction area near Vessel V-204 in a manner that could affect areas of congestion. A leak from Vessel V-204 was evaluated for the risk of causing a vapor cloud explosion. Hasselman Decl., Ex. 28 (2015 Siting Study at 16).

b. In July 2017, PSE redesigned the Tacoma LNG facility to handle incoming natural gas with a much higher content of heavy hydrocarbons than previously anticipated. Hasselman Decl., Ex. 30 (Change Order 110). This redesign added new equipment that will receive and process flammable and explosive materials. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 3-8). Processing feed gas with a higher content of heavy hydrocarbons would also require more frequent removal of natural gas liquids by truck. Hasselman Decl., Ex. 32 (Project Design Basis Rev. 2 at 12).

11. Below, I describe potentially significant unexamined health and safety adverse consequences associated with these design changes.

II. CATASTROPIC FAILURE OF VESSEL V-204 PRESENTS PREVIOUSLY UNIDENTIFIED HAZARDS.

A. <u>The 2015 Siting Study identified the liquefaction area as a location where a vapor cloud explosion could occur.</u>

12. In the time period between preparation of the 2015 Siting Study and the final drawings issued for construction at the Tacoma LNG Facility, some equipment was moved and re-sized, particularly in the liquefaction area. The liquefaction area was identified as an area of concern in the 2015 Siting Study. Hasselman Decl., Ex. 28 (2015 Siting Study at 16).

13. The 2015 Siting Study determined there was a credible scenario for a flammable vapor cloud if there is a release of mixed refrigerants from vessel V-204, which is located in the plant's liquefaction area. Hasselman Decl., Ex. 28 (2015 Siting Study at 16). Accordingly, the

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study identified areas of congestion and confinement where a leak of mixed refrigerants from vessel V-204 could create the risk of an explosion. *Id*. An area of congestion (obstacles or blockage in a moving gas that can generate turbulence and enhance mixing) and confinement (solid surfaces that prohibit gas movement in one or more directions) creates the circumstances found to be important in characterizing the overpressure damage due to an explosion.

14. The 2015 Siting Study relied upon a preliminary design of the plot plan for the Tacoma LNG Project as the basis for its analysis. Hasselman Decl., Ex. 28 (2015 Siting Study at 5) (relying on Revision P of the Overall Plot Plan of the Main LNG Plant). The study relied on the preliminary plot plan to assess possible areas of congestion and confinement, and identified two areas that have the potential to retain flammable vapor.

B. <u>Although the 2015 Siting Study evaluated the catastrophic rupture of vessel V-204 for vapor dispersion, it never evaluated this scenario for explosion consequences.</u>

15. The 2015 Siting Study listed lines that carry flammable or hazardous materials, and evaluated whether these lines exceeded the probability of failure threshold. Hasselman Decl., Ex. 28 (2015 Siting Study, Appendix A, B). Where a line failure exceeded the probability of failure threshold, it was modeled for vapor dispersion hazard extent using PHAST, a modeling software Approved by PHMSA for modeling vapor dispersion. Hasselman Decl., Ex. 28 (2015 Siting Study, Appendices E and L).

16. In all of the equipment spill cases except one, the 2015 Siting Study determined that the line failure scenario release rates were significantly larger than the quantity of liquid held in the equipment listed. Hasselman Decl., Ex. 28 (2015 Siting Study at 7). The exception was the MRL Condensate Separator (V-204), and the study considered two scenarios consisting of a catastrophic rupture of the vessel and a 0.4 inch diameter hole. Hasselman Decl., Ex. 28 (2015 Siting Study at 7).

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17. Appendix E includes PHAST calculations with the Effect Zone shown on facility drawings for the two cases. In Appendix E, the vapor dispersion calculations show that the scenario made using a 0.4 inch hole has a larger Effect Zone than the catastrophic failure of V-204. This 0.4 inch hole scenario has a larger Effect Zone because the release from a hole is simulated as a continuous release while the catastrophic failure of the vessel is simulated as an instantaneous release of the vessel contents without any additional leak.

18. The 2015 Siting Study evaluated the vapor dispersion hazard extent associated with a catastrophic failure of the vessel containing mixed refrigerant liquids (V-204) using PHAST version 7.01.

19. Det Norske Veritas (USA), Inc. (DNV) PHAST-UDM versions 6.6 and 6.7 were approved by PHMSA for evaluating vapor dispersion hazard extents. The supporting documentation required by PHMSA is based on comparison between model predictions and established data sets for continuous releases only. Because the PHMSA approval process does not consider modeling instantaneous releases, the vapor cloud extent of the catastrophic failure of V-204 could be larger than predicted by PHAST version 7.01. A larger vapor cloud results in a larger predicted impact of a vapor cloud explosion.

20. The 2015 Siting Study did not evaluate the overpressure associated with a catastrophic failure of V-204. It is unclear why overpressure was not evaluated.

21. In consideration of the extent of overpressure due to catastrophic failure of V-204, it should be recognized that flows into V-204 would continue at the same rate if there was a catastrophic failure of V-204, and the flow rate from the loss of primary containment would be much larger than a 0.4 inch diameter hole. A larger vapor cloud results in a larger predicted impact of a vapor cloud explosion.

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C. <u>Equipment changed location in the liquefaction area, changing the potential areas of congestion at the facility.</u>

22. In the preliminary plot plan, the liquefaction heat exchanger was located (plant) south of vessel V-204 (the MRL Condensate Separator), and (plant) south of the MRL condenser. Hasselman Decl., Ex. 41 (2015 Plot Plan, Revision P) (location of equipment Nos. 17 and 19). However, in the final plot plan issued for construction, PSE flipped the location of this equipment so that the liquefaction heat exchanger is now located (plant) north of vessel V-204, and (plant) north of the MRL condenser. *Compare* Hasselman Decl., Ex. 42 (2018 Plot Plan, Revision 1) (location of equipment Nos. 17 and 19); *id*. at Ex. 43 (2017 Overall Plot Plan) (same). The liquefaction heat exchanger is a large piece of equipment – approximately 15 feet by 25 feet. Hogan Depo., Dec. 14, 2020 at 72.

23. The areas of congestion and confinement identified in the 2015 Piping Study and used in the Final EIS were identified before the changes to equipment location were made. The Final EIS clearly states that hazard assessment should be re-evaluated when equipment layout has been finalized. The changes in equipment locations could change the identified areas of confinement and congestion.

D. <u>Catastrophic failure of V-204 identified as appropriate for consideration in the Tacoma LNG Siting Study Report presents a foreseeable consequence of a boiling liquid expanding vapor explosion.</u>

24. The catastrophic failure of V-204 presents a foreseeable and serious consequence of fire and explosion hazard due to a boiling liquid expanding vapor explosion or BLEVE. A BLEVE is the result of a rupture of a pressure vessel containing a liquid above its atmospheric boiling point. V-204 separates vapor and liquid mixed refrigerant liquids [redacted] and a catastrophic failure of V-204 would result in a BLEVE.

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[redacted] This new adverse consequence was not evaluated in the 2015 Siting Study.

25. A BLEVE presents several potential hazards including damaging overpressure and a fireball that could have detrimental effect on adjacent equipment that could compromise containment of other flammable fuel (knock on events).

III. DESIGN CHANGES TO ACCOMMODATE A DIFFERENT RAW NATURAL GAS FEEDSTOCK COMPOSITION CREATED UNEXAMINED POTENTIAL ADVERSE CONSEQUENCES.

26. In 2017, PSE changed the design of the Tacoma LNG project to accommodate raw gas feedstock with a different composition. Hasselman Decl., Ex. 31 (Option 6A Scoping Document); *id*. at Ex. 32 (Project Design Basis, Rev. 2 at 7). The new raw gas composition would contain more heavy hydrocarbons, and thus required PSE to change equipment at the facility to enable it to process, store, and transport larger quantities of natural gas liquids removed from the gas stream. *Id*.

27. Changes to the facility include, but are not limited to: modifying a vessel in the amine processing unit to remove heavy hydrocarbons before liquefaction of the raw natural gas stream. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 3-4). Adding a new pipe that connects to the amine flash drum, which is 2 inches in diameter, 100 feet long, and carries natural gas liquids (NGL) which is flammable. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 5). Increasing the vessel storage capacity (V-801), adding a new NGL stored liquids heater, and increasing the capacity of associated piping that holds NGL before going to a storage vessel at the truck loading station. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 6-7). Adding a new pipe 2 inches in diameter that runs the length of the facility (approximately 550 ft) from the amine processing unit to the natural gas liquids storage vessel near the truck loading station. Hasselman Decl., Ex. 31 (Option 6A Scoping Document at 7).

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This 550 foot pipe would be located above ground on a pipe rack. Hogan Depo., Dec. 14, 2020, at 157.

28. PSE stated that it never prepared a supplement to its original 2015 Siting Study to evaluate the risks associated with these changes to equipment and design. Hogan Depo., Dec. 14, 2020, at 154.

29. This is a problem because when the 2015 Siting Study was prepared, the biggest safety concern at the facility was from the liquefaction process. *See* Hasselman Decl., Ex. 28 (2015 Siting Study at 1-16). However, design changes to accommodate the new raw gas feedstock created new and significant potential for a fire or explosion caused by the processing and storing of natural gas liquids at the facility.

30. Vapor dispersion calculations made in the 2015 Siting Study are no longer applicable in light of design changes that increase the flow rate and capacity of lines carrying heavy hydrocarbons. When flow rates and line capacities were increased in these design changes, the amount of hazardous materials to be considered in assessment of the consequences of a release will be increased which results in an increase of extent of the fire or explosion hazards.

31. In particular, one of the lines identified 2015 Siting Study as exceeding the probability of failure threshold, would now have an increased flow rate because of the new raw natural gas feedstock. Hasselman Decl., Ex. 45 Redacted [redacted] The 2015 Siting Study evaluated vapor dispersion for Redacted [redacted] because it exceeded the probability of failure threshold. Hasselman Decl., Ex. 28 (2015 Siting Study at 7). Redacted [redacted] carries natural gas liquids. Hasselman Decl., Ex. 28 (2015 Siting Study, Appendix A). Because this line will

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now have an increased flow rate, it would also have a larger vapor dispersion extent. Further, a spill from this line could pose an explosion hazard due to the flammability of natural gas liquids, and the overpressure for a spill from this line should be evaluated.

32. Further, adding a new pipeline that carries heavy hydrocarbons Redacted [redacted] (approximately 550 ft) creates a new wholly unexamined hazard which could create additional risk since it is Redacted. The capacity of vessel V-801 which carries heavy hydrocarbons, was also substantially increased and this change should be evaluated to determine whether increasing the capacity of this vessel would present new unexamined hazards.

33. Accordingly, changes to the design of the Tacoma LNG Project accommodating a different raw natural gas feedstock pose new and unexamined consequences of a damaging fire or explosion.

IV. THE 2018 SUPPLEMENTAL SAFETY STUDIES FAIL TO EVALUTE ALL FIRE AND OVERPRESSURE HAZARDS.

34. In November 2018, Puget Sound Energy's contractors prepared two new studies evaluating safety concerns. As described in the 2018 Gexcon Supplemental Study: "This Supplemental Report is intended to reevaluate certain spill scenarios within the facility that *may have changed as a result of modifications* to the final Plot Plan layout of the facility. It also evaluates *newly identified* spills of either refrigerants or heavy hydrocarbons into the spill containment sump located at the storage area truck connection station." Hasselman Decl., Ex. 33 (2018 Gexcon Supplemental Study at 2) (emphasis added). However, these reports do not evaluate changes to equipment or flow rates in other areas for processing and storing heavy hydrocarbons onsite. *See id*.

35. PSE anticipates that changes to the design of the facility will require increased removal of accumulated natural gas liquids by truck. Hogan Depo., December 14, 2020, at 96-

98; 121-124; 154; 176-177. Almost three times as many truck trips will be required than previously anticipated. Hogan Depo., December 14, 2020, at 123. Trucks will need to remove accumulated natural gas liquids every five days under the alternate feed gas scenario. Hogan Depo., December 14, 2020, at 124. The original design only required removal of natural gas liquids by truck every fourteen days. Hogan Depo., December 14, 2020 at 123.

36. As discussed above, the Final EIS states that "[t]he design should be reviewed when complete to confirm that all conditions for the installation have been met." Hasselman, Ex. 3 (Final EIS at 3). The 2018 supplemental studies do begin to address this recommendation with regard to the hazard of a spill at truck connection station, but no address is given to other issues that can be identified in the current design in the supplemental studies.

37. Further, these supplemental studies do not consider the hazards posed when these heavy hydrocarbons are transported offsite. As with consideration of the consequences of a spill onsite, a spill offsite will have consequences that are not mitigated by measures employed onsite such as the use of a sump in the truck loading area. In addition to fire hazards, the degree of confinement and congestion cannot be determined for the unknown location of an accident during transport offsite.

V. CONCLUSION

38. PSE changed the location of equipment in the liquefaction area, which was evaluated for the risk of a vapor cloud explosion in the event of a spill of refrigerants from vessel V-204. This change in equipment could affect where areas of congestion or confinement occur.

39. PSE considered the hazard associated with catastrophic failure of vessel V-204, but the assessment failed to recognize that a catastrophic failure would cause a boiling liquid expanding vapor explosion, or BLEVE. This is a significant hazard, which could have knock on effects that damage nearby equipment handling flammable materials.

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40. PSE changed the design of the Tacoma LNG project to accommodate a raw feed gas composition with a greater heavy hydrocarbon content. Any equipment that handles hazardous materials should be assessed to determine whether it poses a fire or explosion hazard. This change in the design of the Tacoma LNG project, adding equipment and expanding the capacity of existing equipment that handles heavy hydrocarbons, would pose a potential fire and explosion hazards that have not been assessed.

41. Changes to the facility design to accommodate a new feed gas composition, would also require more frequent removal by truck of accumulated natural gas liquids. Natural gas liquids are flammable. More frequent trucking of these materials increases the likelihood of an offsite spill of these materials, which presents a potentially serious fire or explosion hazard.

I declare under penalty of perjury that the foregoing is true and correct.

Executed this 8th day of January, 2021.

Tom O. Spicer, III Digitally signed by Tom O. Spicer, III
Date: 2021.01.08 08:05:22 -06'00'

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