PUGET SOUND ENERGY

Puget Sound Energy
P.O. Box 97034
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PSE.com

May 22, 2017

BY HAND DELIVERY

Ms. Carole Cenci, P.E.
Compliance Manager
Puget Sound Clean Air Agency
1904 3rd Avenue, Suite 105
Seattle, WA 98101-3317

Re: NOV No. 3-008343

Dear Ms. Cenci:

Puget Sound Energy ("PSE") is pleased to submit the enclosed Notice of Construction application for our proposed Tacoma LNG facility. The facility will serve PSE's existing customers by providing a dependable and cost-effective natural gas source during times of peak demand. The LNG produced at the facility will also provide a cleaner fuel alternative for regional businesses, including TOTE, a local shipping company operating cargo ships between Tacoma and Alaska. This innovative step will help them comply with new, stricter federal low-sulfur emission requirements.

The proposed Tacoma LNG facility will be subject to a variety of local, state and federal requirements discussed in the application, including, but not limited to, the application of Best Available Control Technology. As a result, the facility will have low emissions and will be a minor source of regulated air pollutants.

Enclosed with the application is a check for $1,150 as required by Regulation I, Section 6.04. Please let me know immediately if we have miscalculated the necessary fees to process this application.

As our permitting team has previously discussed with you and Mr. Hess, we will submit the ambient air quality impact analysis under separate cover on or before June 22, 2017. Other than the ambient air quality impact analysis, we believe that the NOC application is complete. We note that the Tacoma LNG project has complied with the State Environmental Policy Act based on the Final Environmental Impact Statement issued by the City of Tacoma on November 9, 2015.

PUGET SOUND ENERGY
The Energy To Do Great Things

Puget Sound Energy
P.O. Box 97034
Bellevue, WA 98009-9734
PSE.com

Please do not hesitate to contact me if you have any questions regarding this application.

Sincerely,

Roger Garratt
Director, Strategic Initiatives

Cc (by email):
- Rick Hess (RickH@pscleanair.org)
- Jim Hogan
- Lorna Luebbe
- Keith Faretra
- Bill Steiner
- Tom Wood

Notice of Construction Application
Supporting Information Report
Tacoma Liquefied Natural Gas Facility
Tacoma, Washington

May 22, 2017

Prepared for

Puget Sound Energy
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Bellevue, Washington 98004

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Notice of Construction Application Supporting Information Report
Tacoma Liquefied Natural Gas Facility
Tacoma, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

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Project Manager

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Project Coordinator:	Christopher C. Young

Landau Associates

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LIST OF ABBREVIATIONS AND ACRONYMS

ASIL	Acceptable Source Impact Level
BACT	Best Available Control Technology
Btu	British thermal unit
BTEX	benzene, toluene, ethylbenzene, and xylenes
BOG	boil-off gas
CAA	Clean Air Act
CAS	Chemical Abstract Service
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
EIS	Environmental Impact Statement
EPA	US Environmental Protection Agency
°F	degrees Fahrenheit
HAP	Hazardous Air Pollutant
HC	hydrocarbon
H_2S	hydrogen sulfide
hr	hour
kPa	kilopascal
kW	kilowatt
LAI	Landau Associates, Inc.
LAER	lowest achievable emission rate
LDAR	leak detection and repair
LNG	liquefied natural gas
min	minutes
MMBtu	million British thermal units
MMscfd	million standard cubic feet per day
MW	megawatt
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOC	Notice of Construction
NO_x	nitrogen oxides
NSPS	New Source Performance Standard
NSR	New Source Review
PM	particulate matter
$PM_{2.5}$	PM with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10}	PM with an aerodynamic diameter less than or equal to 10 microns
ppm	parts per million
ppmw	parts per million (by weight)

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

PSCAA .... Puget Sound Clean Air Agency
PSD .... Prevention of Significant Deterioration
PSE .... Puget Sound Energy
psi .... pounds per square inch
psia .... pounds per square inch absolute
psig .... pounds per square inch (as gauge pressure)
RACT .... reasonably available control technology
RBLC .... RACT/BACT/LAER clearinghouse
SCAQMD .... South Coast Air Quality Management District
scf .... standard cubic feet
scfd .... standard cubic feet per day
SEPA .... State Environmental Policy Act
SO_2 .... sulfur dioxide
SQER .... Small-Quantity Emission Rate
TAP .... Toxic Air Pollutant
TCEQ .... Texas Commission for Environmental Quality
TOTE .... Totem Ocean Trailer Express
tpy .... tons per year
tBACT .... BACT for Toxic Air Pollutants
VOC .... volatile organic compound
WAAQS .... Washington Ambient Air Quality Standards
WAC .... Washington Administrative Code
WPG .... water propylene glycol

1.0 INTRODUCTION

Landau Associates, Inc. (LAI) prepared this document on behalf of Puget Sound Energy (PSE) to support the submittal of PSE's Notice of Construction (NOC) application for installation and operation of a new Tacoma Liquefied Natural Gas (LNG) Facility (LNG Facility) and Totem Ocean Trailer Express Marine Vessel LNG Fueling System (TOTE Fueling System). This proposed stationary source of air emissions would be installed as part of the Tacoma LNG Project located on land leased from the Port of Tacoma within the city of Tacoma, Washington (Figure 1).

The Tacoma LNG Project has three main elements: 1) Tacoma LNG Facility, 2) TOTE Fueling System, and 3) associated improvements to the existing PSE Natural Gas Distribution System that would deliver natural gas from the Williams Natural Gas Pipeline to the LNG Facility. The LNG Facility and adjacent TOTE Fueling System are the elements subject to minor source New Source Review (NSR) permitting under air quality regulations promulgated by the Puget Sound Clean Air Agency (PSCAA) and Washington State Department of Ecology.

The Tacoma LNG Project was issued a Final Environmental Impact Statement (EIS) by the City of Tacoma on November 9, 2015. On November 9, 2015, the City of Tacoma approved the final EIS, which satisfies the requirements of the Washington State Environmental Policy Act for this project.

PSCAA's required application form is provided in Appendix A.

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2.0 PROJECT DESCRIPTION AND ESTIMATED EMISSIONS

The LNG Facility and TOTE Fueling System would be located on land leased from the Port of Tacoma (see Figure 1), which is zoned as Port Maritime Industrial. The general location of the LNG Facility is north of East 11th Street, east of Alexander Avenue, south of Commencement Bay, and on the west shoreline of the Hylebos Waterway in Tacoma, Washington. The LNG Facility would receive natural gas from Williams Northwest Pipeline via PSE's distribution system, process and liquefy (chill) the natural gas to produce up to 250,000 gallons of fuel-grade (to satisfy PSE's supply agreement with TOTE) LNG per day, and store up to 8 million gallons of LNG on site. The LNG Facility would be staffed with approximately 16 to 18 full-time employees 24 hours per day, 365 days a year. The LNG would be distributed to TOTE ships through the TOTE Fueling System and other industry customers through a tanker truck loading system. The LNG could also be re-gasified for reinjection into the PSE natural gas distribution system to help meet peak-day needs of PSE's natural gas customers. Peak-day loads on the natural gas distribution system typically occur during the coldest winter days. During peak shaving, the LNG liquefaction system will be shut down, but the facility can continuously liquefy gas while simultaneously bunkering LNG to ships or loading trucks.

The TOTE Fueling System would be located at the TOTE terminal, which is across Alexander Avenue south of the LNG Facility. The TOTE Fueling System would consist of a cryogenic pipeline and fuel loading (bunkering) equipment to deliver LNG to TOTE's ships. The TOTE Fueling System is located within a portion of TOTE's existing terminal that would be leased and operated by PSE.

Detailed engineering of the project is still in progress. Make and model information presented in this application support document is subject to change, but specifications for final equipment selections will be equivalent or better.

The proposed site plan is shown on Figure 2. Figure 3 provides an overview of the facility process and the associated sources of emissions.

2.1 Process Description

Natural gas would enter the facility through the metering and odorant area. A single underground pipeline would connect the LNG Facility to PSE's natural gas distribution system. Metered natural gas entering the facility for liquefaction would be first routed to an inlet filter separator to remove small particles and liquid droplets to protect downstream boost compression and the pre-treatment system. Natural gas entering the LNG Facility can vary between 150 and 240 pounds per square inch gage (psig) with a typical operating range of 170 to 225 psig. To facilitate effective pre-treatment contaminant removal and to maintain a relatively constant and efficient liquefaction pressure, the feed gas would be boosted in pressure to approximately 525 psig by an electric motor-driven, two-stage, integrally geared centrifugal compressor. Fugitive leakage from the feed gas compressor's seals would be captured and sent to the enclosed ground flare.

2.1.1 Amine Pretreatment System

Natural gas entering the LNG facility will be composed primarily of methane, but will also contain ethane, propane, butane, and other heavy end hydrocarbons. In addition, quantities of nitrogen, carbon dioxide (CO_2), sulfur compounds (H_2S and odorants), and water will be present in the feed gas stream entering the plant. CO_2 and water would freeze within the liquefaction process and must be removed to sufficient levels to avoid riming of the platefin heat exchangers. Although measurable quantities of mercury are not anticipated in the feed gas, even small quantities can aggressively attack the brazed aluminum liquefaction platefin heat exchangers. A mercury removal system would be installed to remove mercury to a concentration equal to or less than 10 nanograms per normalized cubic meter. CO_2, water, some sulfur based components, and any trace amounts of mercury would be removed from the feed gas by an Amine Pretreatment System. The Amine Pretreatment System would consist of amine gas treating and regeneration, a gas dehydration system, outlet gas filtration, a mercury removal system, and an intermediate heat transfer fluid system.

An aqueous amine solution would absorb CO_2 and hydrogen sulfide (H_2S) from the natural gas through a chemical reaction, resulting in a "sweet" gas with less than 50 parts per million (ppm) of CO_2 and a "rich" amine solution that contains the CO_2 and H_2S. The "rich" aqueous amine solution would then be heated in a regenerator to remove the CO_2 and H_2S, resulting in a "lean" amine solution that would be reused in the process. An enclosed ground flare would be used to control emissions from the amine regenerator by oxidizing H_2S, odorants, and volatile organic compounds (VOCs) at high temperature into water, CO_2, and sulfur dioxide (SO_2).

The next step in the preparation of the feed gas is processing the gas through a molecular sieve dehydration system. After passing through the aqueous amine solution for removal of CO_2, the gas would be saturated with water. The gas would then be passed through molecular sieve beds, which adsorb the water onto an alumina silicate crystal, leaving less than 1 ppm of water in the gas. The beds would then be regenerated by a reverse flow of heated dry gas on a rotation cycle. The condensed water that would be removed is reused as make-up water for the amine system.

The Amine Pretreatment System will be designed to treat up to 26 million standard cubic feet per day (MMscfd) of inlet gas with a 2 percent CO_2 concentration so as to not limit the capacity of the liquefaction system.

2.1.2 Heavy Hydrocarbon Removal

After pretreatment, but prior to liquefaction of the natural gas, heavy hydrocarbons that may freeze at the cryogenic temperatures encountered downstream would be removed by partial refrigeration. A portion of the removed hydrocarbons would be stored as a liquid at ambient temperature on site in a horizontal pressure vessel and periodically trucked off site using a centrifugal heavies loading pump. Nitrogen would be used to purge the truck loading hoses and facilitate liquid draining and then be routed to the flare. The remainder of the removed hydrocarbons would either be used as fuel gas on site or disposed of via the enclosed ground flare. Flash gases from the heavy hydrocarbon storage vessel would be sent to the flare.

2.1.3 Liquefaction

After the heavy hydrocarbon removal process, the natural gas would be mixed with compressed boil-off gas (BOG) and condensed to a liquid by cooling the gas to approximately –260 degrees Fahrenheit (°F) in a brazed aluminum heat exchanger using a mixed refrigerant (composed of methane, ethylene, propane, isopentane, and nitrogen). The refrigeration cycle would use a 13,000-horsepower, electric motor-driven, three-stage, integrally geared centrifugal compressor and eject heat to the atmosphere via forced draft fin-fan heat exchangers. The constituents of the refrigerant would be delivered to the site by truck once per year and mixed on site. Compressor seal leakage would be captured and sent to the enclosed ground flare. Liquefaction is expected to typically occur during 51 weeks of the year. During the remaining 7 days, the facility is expected to operate in a holding mode while LNG is vaporized (see Section 2.1.5.1). Liquefaction does not occur at the same time as vaporization.

2.1.4 LNG Storage

The liquefied natural gas would then be stored in an 8 million gallon (net), low-pressure LNG storage tank at less than 3 psig. The LNG storage tank would be a full containment structure consisting of a steel inner tank and a pre-stressed concrete outer tank. The storage tank would be vapor- and liquid-tight without losses to the environment. Insulating material would be placed between the inner and outer tanks to minimize heat gain and boil-off. The temperature of the LNG would be maintained below –260°F to keep the treated natural gas in a liquid state using an auto-refrigeration process. Inside the tank, vapor pressure above the liquid is kept constant so the temperature is maintained. When LNG temperature increases, vapors are created from the boiling liquid (i.e., BOG). In order to avoid pressure build-up within the tank, BOG would be collected in the BOG Recovery System. The BOG Recovery System would warm the gas and boost its pressure using two, three-stage reciprocating compressors to sufficient pressure for either re-liquefaction and return to the storage tank, or for discharge to the distribution system whenever liquefaction is not occurring. In the highly unlikely event that a process upset situation occurs, excess LNG vapors would vent to the flare.

2.1.5 LNG Product Delivery

LNG would be pumped out from the LNG Facility's storage tank to one of three systems: LNG vaporizer, TOTE Fueling System, or tanker truck loading bay. LNG would be removed from the storage tank by way of submerged motor in-tank pumps. The submerged motor LNG pumps would be contained within the enclosed LNG tank and therefore are not a source of fugitive emissions.

2.1.5.1 LNG Vaporization

The LNG vaporization system would produce natural gas for customers connected to PSE's existing distribution system during peak demand periods. This is commonly referred to as peak shaving. A vaporization pump would boost the pressure of the LNG from the storage tank to a sufficient level for vaporization. The vaporization pump would be a pot-mounted, submerged motor pump outside the LNG storage tank, which would be fed from the in-tank pumps. The pump would feed the vaporizer, a natural gas-fired horizontal fire-tube water bath heater equipped with vaporizing LNG coils and a circulation pump. The LNG vaporizer bath would be filled with an intermediate fluid consisting of 40 percent mixture by weight of propylene glycol with 60 percent by weight of water. This common heat transfer fluid has a low freezing point, which eliminates the need for bath freeze protection while idle.

The vaporization system would have the capacity to deliver 66,000 decatherms per day (approximately 64.2 MMscfd) of vaporized natural gas at a temperature of 65°F and a pressure range between 150 psig and 249 psig to the metering area. An odorizer would add odorant to the natural gas before it enters the pipeline. PSE estimates that the vaporization system would operate for up to 10 days per year during peak natural gas usage times in the winter months.

2.1.5.2 Marine Bunkering

The LNG would be conveyed via cryogenic pipeline to the TOTE Fueling System. The LNG pipeline would extend 1,200 feet from the LNG facility storage tank, traveling below the Alexander Avenue right-of-way, above ground along the TOTE terminal access trestle, and end at a loading arm on a bunkering platform in the Blair Waterway. Accidental releases of LNG would be collected by a concrete spillway and conveyed to an onshore containment basin. Ship bunkering would occur up to twice per week, for a period of 4 hours each, or a total of 8 hours per week.

Marine vessels would be bunkered with LNG for fuel using a dedicated marine bunkering arm equipped with a piggyback vapor return line. The arm is hydraulically maneuvered and includes swivel joints that would be swept with nitrogen to prevent ingress of moisture that could freeze and impede arm movement. When connected to the receiving vessel, the LNG bunkering arm and connected piping would be purged with nitrogen, which would be routed to the enclosed ground flare. Once purged, LNG would be bunkered onto the receiving vessel at a maximum design rate of 2,640 gallons per minute. Once bunkering is complete, the liquid in the bunkering arm and in the adjacent piping would be drained back to the LNG storage tank. After draining, the arm and connected piping would be purged with nitrogen again, which would be routed to the enclosed ground flare and then depressurized prior to disconnection.

The LNG bunkering arm would be stored under a nitrogen atmosphere. The bunkering arm has the capability to return vapor from the receiving vessel to the LNG storage tank and/or to the enclosed ground flare. However, the LNG fuel tanks on the ships are designed to operate at 100 pounds per square inch (psi). LNG stored on the ship is subcooled and acts to collapse vapor pressure in the ship tanks during fueling (reducing the pressure), hence the vapor return system would not normally be used during bunkering.

2.1.5.3 Truck Loading

Two loading bays on the west side of the facility would load LNG to 10,000-gallon capacity tanker trucks. The loading bays would be designed to fill a tanker truck at a rate of 300 gallons per minute. Truck loading can be functionally undertaken concurrently with liquefaction, marine loading, or sending out to the pipeline. The loading area would be paved and graded to a spill trough to carry any accidental liquid spills to a containment sump.

Each truck bay would have a liquid supply and vapor return hose. The hoses would be 3 inches in diameter and 20 feet long and made from corrugated braided stainless steel with connections suited for LNG trailers. After truck loading, the liquid hose would be drained to a common, closed truck station sump connected to the facility vapor handling system where it would be allowed to boil off and be re-liquefied or sent to the pipeline. Nitrogen would be used to purge the hoses and facilitate liquid draining and would then be routed to the flare. PSE has committed approximately half of the 250,000 gallon per day LNG production to TOTE. The other half is available to load on to trucks or regasification and send out to the natural gas pipeline.

2.2 Air Emissions

The following equipment proposed as part of the project would have the potential for air emissions:

- **LNG Vaporizer:** A 66 million British thermal units per hour (MMBtu/hr) water heater burning natural gas
- **Enclosed Ground Flare:** With two burners designed to combust between 2.5 and 46 MMBtu/hr of waste gas and two pilot flames combusting 5 standard cubic feet per minute (scf/min) of natural gas each
- **Fluid conveyance:** Fugitive vapor emissions from equipment leaks (i.e., valves, flanges, and seals)
- **Emergency generator:** 1,500-kilowatt (kW) emergency generator burning ultra-low sulfur diesel fuel
- **Water Propylene Glycol Pretreatment Heater:** 9 MMBtu/hr heater burning natural gas for regeneration of the aqueous amine solution described in Section 2.1.1
- **Regeneration Pretreatment Heater:** 1.6 MMBtu/hr heater burning natural gas to regenerate (desorb water) from the dehydration beds as described in Section 2.1.1.

The following self-contained pressurized vessels will not be emission sources:

- Propane Storage Vessel: 1,000 gallons
- Iso-Pentane Storage Vessel: 1,000 gallons
- Ethylene Storage Vessel: 2,760 gallons
- Heavies Storage Vessel: 4,650 gallons.

The following equipment vessel, while not pressurized, is designed to have no emissions under normal operations and so will not be an emissions source:

- LNG Storage Tank – 8 million gallons.

All other process equipment and vessels would not produce emissions due to the control systems in place (e.g., nitrogen purge or capture and routing to the flare). Filling of the refrigerant storage vessels by truck would occur approximately once per year, comply with all standards, and would be a negligible source of fugitive emissions. The emergency generator, both pretreatment heaters, and the refrigerant and heavies storage vessels are exempt from NOC and Order of Approval requirements due to their size and nature per PSCAA Regulation I Section 6.03(c)(1), (3), and (78) for natural gas combustion devices less than 10 MMBtu/hr heat input; standby stationary internal combustion engines that operate less than 500 hours per year; and storage tanks with a rated capacity less than 20,000 gallons. Therefore, this NOC application does not address emissions from those units. See Section 3.0 for further discussion of regulatory applicability.

The following subsections provide additional information on each emission source that requires an NOC and assumptions used in emission calculations. The location of each emission source (except for the fugitive VOC leaks) is shown on Figure 2. Detailed emission calculations are provided in Appendix B and vendor data are provided in Appendix C.

2.2.1 Vaporizer

The vaporizer would use a natural gas-burning, fire-tube type water heater. The heated water and propylene glycol mixture would be used to vaporize LNG to a gaseous state. The vaporizer would use an ultra-low nitrogen oxides (NO_X) burner that would have a maximum design heat input capacity of 66 MMBtu/hr. The LNG Facility would use the vaporized LNG and BOG for fuel as much as possible. However, when those fuels are not available, natural gas from the pipeline would be used as fuel. As a conservative approach for the emissions calculations, we assume all combustible waste gases generated on site are sent to the flare and all process equipment combusts natural gas from the pipeline. The vaporizer would operate when natural gas demand peaks on PSE’s existing distribution system, which typically occurs when the ambient temperature drops below 20°F, usually between the months of November and April. As such, the vaporizer is expected to operate up to 240 hours per year. Specifications for the proposed vaporizer burner are provided in Table 1 below.

Table 1: Vaporizer Specifications

Parameter	Value
Date of manufacture	September 2017
Rated capacity	66 MMBtu/hr
Fuel	Natural gas
Hours of operation	240 hours per year
Estimated installation date	January 2018
Make and model	Cryoquip VFTU-2I-2886-1IC-35 (or equivalent)
Emission controls	Ultra-Low NO_X burner, oxygen trim system

The burner in the vaporizer would produce emissions from natural gas combustion. Estimated emissions of NO_X and carbon monoxide (CO) from the burner are based on manufacturer specifications. Emissions of particulate matter (PM) with an aerodynamic diameter less than or equal to 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), VOCs, and Hazardous Air Pollutants (HAPs) are based on emission factors from the US Environmental Protection Agency's (EPA's) AP-42, Volume I, Chapter 1.4 (EPA 1995a) and the rated fuel usage of the burner. Emissions of SO_2 are calculated using a mass balance approach assuming all sulfur contained in the fuel is converted to SO_2. The estimated maximum concentration of untreated natural gas is 166 parts per million by weight (ppmw) sulfur.[1] SO_2 emissions would be reduced when the LNG Facility is able to combust fuel gas, which has been treated on site to remove sulfur compounds and has an estimated design sulfur content of approximately 22 ppmw.

2.2.2 Enclosed Ground Flare

The enclosed ground flare would be an air-assisted dual burner flare designed for smokeless operation while maintaining a controlled stack temperature and retention time for achieving a 99 percent destruction efficiency of total hydrocarbons and entrained VOCs.[2] The flare would include two continuous flame pilots, burning 5 scf/min of natural gas each, at the flare tip monitored by thermocouples. An intermittent spark ignition pilot would be used during system startup. An integral air blower mounted on the flare will deliver primary combustion air while actuated air louvers would provide quench air to the combustion zone to maintain optimum combustion temperature.

The dual burner assembly would be mounted inside a 9-foot-diameter and 45-foot-tall enclosure. The burner assembly includes one annular 30-inch burner for combusting waste gases from normal

1 Assumed sulfur content used by CB&I for facility design, which is based on the sulfur content tariff for the Williams Northwest Pipeline.

2 Note: The manufacturer design basis is for a 99.5 percent destruction efficiency on average. We have conservatively assumed a lower efficiency for the purpose of the emission calculations in case actual conditions do not match the engineering estimates.

operations (warm gases) and one annular 29-inch burner for combusting cryogenic gas during plant upset conditions.

The cryogenic burner would accept boil-off gas from the LNG storage tank in the highly unlikely event of potential overpressure under upset conditions and has a capacity of 46 MMBtu/hr. The cryogenic burner would also be used to dispose of depressurization and nitrogen purge gases from the marine bunkering arm, the LNG truck loading hoses, refrigerant (ethylene, propane, and isopentane) receiving hoses, and heavies truck load hose prior to disconnection. Liquid would be drained from the bunkering arm back to storage using nitrogen. This nitrogen would be subsequently depressurized and routed to the enclosed ground flare, and may have trace amounts of remaining hydrocarbons.

The warm gas burner would be used to destroy the following commingled waste gas streams:

- Gas chromatograph speed loops
- Flare header sweeps
- Seal vents from one feed gas compressor and one refrigerant compressor
- Acid gases from the pretreatment system
- Heavy hydrocarbon storage flash gas
- Heavy hydrocarbon fuel gas (to be conservative, all fuel gas is assumed to be combusted in the flare instead of used in onsite combustion devices).

Specifications for the proposed enclosed ground flare are provided in Table 2 below.

Table 2: Enclosed Ground Flare Specifications

Parameter	Liquefaction Mode	Not Liquefying
Destruction efficiency	99%	
Waste gas flow rate (scf/hr)	5,833 to 40,417	958
Number of pilots	2	
Pilot fuel flow rate	5 scf/min each	
Waste gas stream characteristics		
Heat content (Btu/scf)	330 to 1,821	1,096
Oxygen (%)	12 to 13	12
Average molecular weight	33.4 to 39.1	19.1
Estimated installation date	January 2018	
Assist system	Combustion Air Louvers, Combustion Air Blower	
Ignition system	Spark Plug	
Pilot flame monitor	Type "K" duel element thermocouples	

The characteristics of the combined waste gas including flow, heat content, and pollutant composition would change depending on the LNG Facility operations and the quality of the feed gas from the natural gas pipeline. Waste gas characteristics for five different scenarios during LNG production (liquefaction mode) were developed and reviewed for their emission profiles. Some waste gas from process equipment (gas chromatograph speed loops, flare header sweeps, and compressor seals) would still vent to the flare when not liquefying. The estimated total gas flow to the flare would be reduced to 958 scf/hr when not liquefying. The LNG Facility cannot liquefy and vaporize at the same time so this holding scenario would occur when the vaporizer is running, which is estimated to occur less than 10 days per year. The amount of time vaporization and reinjection of natural gas would occur is unknown and the worst-case emissions would occur when the LNG Facility is in liquefaction mode and producing LNG. Therefore, for the purposes of the emissions calculations for the ground flare and process heaters, we conservatively assume that operations for liquefaction will occur every hour of the year (8,760 hours per year).

The flare would produce emissions from combustion of the waste gas and supplemental gas as well as natural gas combustion in the pilot flames. Emission estimates from the flare burners (combusting waste gas) and pilots (combusting natural gas) are based on the heat input rate for each waste gas scenario and the following emission factors:

- NO_X and CO from manufacturer specifications.
- VOCs and benzene, toluene, ethylbenzene, and xylenes (BTEX) based on composition of the waste gas and destruction efficiency of 99 percent. We conservatively assume that all BTEX in

the natural gas feed will be sent to the flare (some BTEX would also partition into the heavy hydrocarbons, but the fraction is unknown and it is more conservative for emission estimation purposes to assume that all BTEX will go to the in gases flare).

- PM_{10}, $PM_{2.5}$, and other HAPs from AP-42 Chapter 1.4 (EPA 1995a).
- H_2S and SO_2 from mass balance using the sulfur content of the waste gas and assuming that 99 percent is oxidized to SO_2. For the pilots, the estimated maximum sulfur content of the natural gas fuel is 166 ppmw.

2.2.3 Fugitives from Equipment Leaks

Process fugitive VOC emissions can occur from leaks in valves, pump seals, flanges, connectors, and compressor seals. As noted above, though, all of the proposed pumps used, with the exception of the hydrocarbon liquid pump, will be submerged inside enclosed liquid storage tanks and would have no fugitive leaks to the atmosphere. Also, there would be a seal leak recovery system for the refrigerant compressor that captures 90 percent of the leak losses, with the remaining 10 percent sent to the flare. Leaks from the feed gas compressor seals would also be captured and vented to the flare. The compressor seals for mixed refrigerant storage, the regeneration pretreatment system, and BOG would have fugitive emissions vented to the atmosphere. In addition, there are several valves, relief valves, and flanged connectors for conveyance of various process fluids that have the potential for fugitive leaks. LNG bunkering of ships at the TOTE terminal would not produce any fugitive emissions (as discussed in the process description above). However, there are four swivel joints that have seals with the potential to leak LNG. We assume that the leak rate of the swivel joints would be similar to that of the pump seals. Component counts by fluid service are provided in Table 3 below.

Table 3: Inventory of Fugitive Equipment Leak Components

Component	Acid gas	BOG	Ethylene	Fuel Gas	HC Liquid	Liquefied NG	Mixed Refrigerant	NG	Untreated NG
Valves	39	9	12	36	33	244	112	185	30
Pressure Relief Valves	3	--	1	3	1	19	8	9	2
Flanges/ Connectors	--	7	2	15	6	114	28	77	15
Pump Seals	--	--	--		1	--	--	--	--
Compressor Seals	--	2	--	--	--	--	1	1	--
Swivel Joints						4			

HC = hydrocarbon
NG = natural gas

Emission factors for “Terminal/Depot” emission sources were obtained from South Coast Air Quality Management District's (SCAQMD’s) Guidelines for Fugitive Emissions Calculations (SCAQMD 2003). In this guidance, SCAQMD updated emission factors that were identified in the EPA's Protocol for

Equipment Leak Emission Estimates (EPA 1995b). Emission factors are higher for light liquid service than for heavy liquid; therefore, the hydrocarbon (HC) liquid and LNG fluids are conservatively assumed to be in light liquid service. PSE would commit to a voluntary leak detection and repair (LDAR) program to reduce emissions from equipment leaks (see measures outlined in Appendix D). The EPA found that this program achieves emission reductions of 88 percent for light liquid service and 92 percent for gas service compared to uncontrolled emission factors in the EPA's 1995 protocol. Considering that the emission factors in the SCAQMD's guidance are lower than the EPA's, a lower control effectiveness from the Texas Commission for Environmental Quality's (TCEQ's) 28M LDAR program would be used. Emission reductions expected from the TCEQ 28M LDAR program are 75 percent for valves, pumps, compressors, and relief valves, and 30 percent for flanges for both gas and light liquid service.

Although neither methane nor ethane are regulated as VOCs at the federal level or in Washington State, we conservatively assume that 100 percent of the leak emissions would be VOCs. For simplicity, we assume that the entire BTEX concentration in the natural gas feed is present in every fluid serviced by these equipment.

2.2.4 Project Emissions Summary

The resultant potential-to-emit for the project (minus the exempt units) is provided in Table B-11 of Appendix B and summarized below.

Table 4: Potential Annual Emissions Summary

Pollutant	Vaporizer (tpy)	Enclosed Ground Flare (tpy)	Fugitives (tpy)	Project Total (tpy)
$PM_{10}/PM_{2.5}$	0.055	1.2	--	**1.3**
SO_2	0.11	8.9	--	**9.0**
NO_x	0.086	9.9	--	**10**
CO	0.29	33	--	**33**
VOCs	0.040	45	4.2	**49**
Lead	3.6E-06	8.1E-05	--	**8.5E-05**
Total TAPs/HAPs	0.014	0.37	3.43E-05	**0.38**

tpy = tons per year
TAP = Toxic Air Pollutant

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3.0 REGULATORY APPLICABILITY REVIEW

This section describes the regulations applicable to the proposed Tacoma LNG Project. The applicability determination conducted in this analysis is pursuant to the Major and Minor NSR regulations, National Emissions Standards for Hazardous Air Pollutants (NESHAP), New Source Performance Standards (NSPS), federal Clean Air Act (CAA) Title V Operating Permit, CAA Chemical Accident Prevention programs, and PSCAA regulations.

3.1 Major Source New Source Review (40 CFR 52.21 and WAC 400-720)

The Tacoma LNG Project is proposed to be located in an area that is in attainment or unclassified for all National Ambient Air Quality Standards (NAAQS).[3] Therefore, Nonattainment New Source Review requirements do not apply.

The Tacoma LNG Project will not be a Major Stationary Source as that term is defined in Washington Administrative Code (WAC) 173-400-710 because the Tacoma LNG Project is not in one of the designated source categories and potential emissions of all regulated NSR pollutants are well below the 250 tons per year threshold for non-designated source categories. Therefore, Prevention of Significant Deterioration (PSD) New Source Review requirements do not apply.

3.2 Minor New Source Review (PSCAA Reg I; Section 6.03)

As explained in Section 2 of this application, the Tacoma LNG Project will consist of multiple different pieces of process equipment, some of which are emitting units and some of which are non-emitting units. Per PSCAA Regulation I Section 6.03, an NOC permit application must be filed and an Order of Approval issued by the PSCAA prior to beginning construction of any emitting unit absent the applicability of an exemption. The following emission sources are considered subject to the NOC process and are addressed in detail in this application.

- LNG vaporizer
- Enclosed ground flare
- Fugitive vapor emissions from equipment leaks (i.e., valves, flanges, seals).

Table 5 below identifies additional equipment to be installed as part of the Tacoma LNG Project that is not subject to the NOC process and provides an explanation for why.

[3] Effective March 12, 2015, the EPA redesignated the Tacoma-Pierce County area to attainment for the 2006 24-hour fine particle National Ambient Air Quality Standard.

Table 5: Exempt Equipment Summary

Equipment Description	Basis for Not Being Subject to NOC Process
LNG Storage Tank	No emissions under normal operations Exemptions 78(A) and 78(F)
Water/Propylene Glycol Pretreatment Heater	Exemption (1)(A) (natural gas-fired unit < 10 MMBtu/hr)
Regeneration Pretreatment Heater	Exemption (1)(A) (natural gas-fired unit < 10 MMBtu/hr)
Emergency Generator	Exemption (3)(C) (standby unit operated <500 hr/year)
Propane Storage Vessel	Exemption (78)(D) (Organic liquid [other than gasoline or asphalt] storage tanks with rated capacity <20,000 gallons)
Iso-Pentane Storage Vessel	Exemption (78)(D) (Organic liquid [other than gasoline or asphalt] storage tanks with rated capacity <20,000 gallons)
Ethylene Storage Vessel	Exemption (78)(D) (Organic liquid [other than gasoline or asphalt] storage tanks with rated capacity <20,000 gallons)
Heavies Storage Vessel	Exemption (78)(D) (Organic liquid [other than gasoline or asphalt] storage tanks with rated capacity <20,000 gallons)
Facility Cooling Water System	Exemption (91) (Water cooling tower not used for evaporative cooling of process water and in which no chromium compounds are contained)
Power Distribution Center	No emissions

This application describes all of the units (emitting and non-emitting) and presents the necessary pre-construction assessment for those emitting units not covered by an exemption.

3.3 Operating Permit Program (40 CFR 70 and WAC 173-401)

The Tacoma LNG Project will not be a Major Stationary Source as that term is defined in WAC 173-401-200(19) as the potential-to-emit any regulated air pollutant (as that term is defined in WAC 173-401-200[35]) from the facility (including all exempt units) will be less than 100 tons/year and the potential-to-emit HAPs is less than 10 tons/year for any individual HAP and less than 25 tons/year for aggregate HAPs. Therefore, the Operating Permit regulations in WAC 173-401 are not applicable.

3.4 New Source Performance Standards (40 CFR 60 and WAC 400-115)

New Source Performance Standards (NSPS), located in Title 40 of the Code of Federal Regulations Part 60 (40 CFR 60) and adopted by reference in WAC 400-115, require new, modified, or reconstructed sources in applicable source categories to control emissions to the level achievable by the best demonstrated technology as specified in the applicable provisions. Any source that is subject to provisions under an NSPS subpart is also subject to the general provisions of NSPS Subpart A, except as noted in the applicable subpart. This section outlines the applicability of NSPS subparts that are potentially applicable to the Tacoma LNG Project.

3.4.1 Subpart Dc: Steam Generating Units

NSPS Subpart Dc—Standards of Performance for Small Industrial-Commercial-Institutional Steam Generating Units—applies to each steam generating unit for which construction, modification, or reconstruction is commenced after June 9, 1989 and that has a maximum design heat input capacity of 29 megawatts (MW) (100 MMBtu/hr) or less, but greater than or equal to 2.9 MW (10 MMBtu/hr). The term "steam-generating unit" is defined in 40 CFR 60.41c as "a device that combusts any fuel and produces steam or heats water or any other heat transfer medium."

The Tacoma LNG Project will include three combustion devices that heat a heat transfer medium. These are identified in the table below along with their maximum design heat input capacity.

Table 6: Combustion Devices Heating a Heat Transfer Medium

Unit	Maximum Design Heat Input Capacity (MMBtu/hr)
Water Propylene Glycol (WPG) Heater	9
Pretreatment Regeneration Heater	1.6
LNG Vaporizer	66

As shown in Table 6, only the LNG Vaporizer exceeds the maximum design heat input capacity threshold of 10 MMBtu/hr. Therefore, the WPG heater and the pretreatment regeneration heater are not subject to the steam-generating unit NSPS.

While the LNG vaporizer does not produce steam, it does combust fuel to heat a transfer medium. Therefore, it is within the scope of the definition of steam-generating unit. As the vaporizer will be a new unit installed after June 9, 1989 with a maximum design heat input capacity greater than 10 MMBtu/hr, the LNG vaporizer is considered an affected facility subject to the Subpart Dc NSPS. Subpart Dc imposes no substantive requirements on exclusively gas-fired units other than to file an initial notification and to keep records of the volume of natural gas fuel combusted in the unit.

3.4.2 Subpart Kb: Ambient Pressure Storage Tanks (Not Applicable)

3.4.2.1 LNG Storage Tank

NSPS Subpart Kb—Standards of Performance for Volatile Organic Liquid Storage Vessels (Including Petroleum Liquid Storage Vessels) for which Construction, Reconstruction, or Modification Commenced After July 23, 1984—applies to all storage vessels with a capacity greater than or equal to 75 cubic meters (20,000 gallons) that are used to store volatile organic liquids unless otherwise exempted. One exemption (40 CFR 60.110b[b]) is for storage tanks with a capacity greater than or equal to 151 cubic meters (40,000 gallons) and that store a liquid with a maximum true vapor pressure of less than 3.5 kPa (0.5 psia). The LNG storage tank will have a working capacity of 8 million gallons (the only storage tank on site with a capacity of 20,000 gallons or more). By definition, the maximum true vapor pressure is the equilibrium partial pressure exerted by the VOCs in the stored volatile organic liquid. The partial pressure of the volatile components of LNG maintained at –260°F is less than 3.5 kPa (0.5 psia). Therefore, the Subpart Kb NSPS does not apply to the LNG storage tank.

3.4.2.2 Propane, Isopentane, Ethylene, and Heavies Storage Tanks

The propane, isopentane, ethylene, and heavies storage tanks are exempt from Subpart Kb because their storage capacity is substantially less than 75 cubic meters (20,000 gallons). Tanks smaller than 20,000 gallons are not subject to the Subpart Kb NSPS.

3.4.3 Subpart LLL: Onshore Natural Gas Processing (Not Applicable)

NSPS Subpart LLL—Standards of Performance for Onshore Natural Gas Processing: SO_2 Emissions—applies to sweetening units and sweetening units followed by a sulfur recovery unit at onshore natural gas processing facilities. The Tacoma LNG Project design includes an amine unit that could be considered a sweetening unit under Subpart LLL. However, the Tacoma LNG Project is not a natural gas processing facility. Therefore, the requirements of NSPS Subpart LLL are not applicable.

3.4.4 Subpart IIII: Emergency Generator

NSPS Subpart IIII—Standards of Performance for Stationary Compression Ignition Internal Combustion Engines—applies to stationary compression ignition internal combustion engines that are manufactured after April 1, 2006 and ordered after July 11, 2005. The Tacoma LNG Project will include a 1.5-MW diesel-fired emergency generator. This unit will be purchased as new for the Tacoma LNG Project and so the requirements of NSPS Subpart IIII relevant to emergency engines are applicable to the Tacoma LNG Project's emergency generator.

Engine manufacturers are required to certify new engines for prescribed NO_x, PM, CO, and VOC emission standards, and operators are required to follow manufacturers' operation and maintenance instructions. Subpart IIII also limits emergency engines to 100 hours per year of non-emergency operation (e.g., maintenance and testing). Emergency use is not restricted. The Tacoma LNG Project's emergency engines will be purchased new, will be certified for NSPS Subpart IIII compliance, and will operate a maximum of 52 hours per year for non-emergency purposes.

3.4.5 Subpart OOOOa: Natural Gas Production, Transmission, and Distribution (Not Applicable)

NSPS Subpart OOOOa—Standards of Performance for Crude Oil and Natural Gas Production Facilities for which Construction, Modification or Reconstruction Commenced After September 18, 2015—applies to certain equipment within the crude oil and natural gas source category that are constructed, modified, or reconstructed after September 18, 2015. The term "crude oil and natural gas source category" is defined in relation to natural gas as "Natural gas production, processing, transmission, and storage, which include the well and extend to, but do not include, the local distribution company custody transfer station." The term "local distribution company custody transfer station" is defined as "a metering station where the LDC receives a natural gas supply from an upstream supplier, which may be an interstate transmission pipeline or a local natural gas producer, for delivery to customers through the LDC's intrastate transmission or distribution lines." As these terms demonstrate, the Subpart OOOOa NSPS applies from natural gas wellhead to immediately upstream of the local distribution company custody transfer station. The Tacoma LNG Project is situated downstream of the local distribution company (i.e., PSE) custody transfer station. Therefore, NSPS Subpart OOOOa is not applicable to the Tacoma LNG Project.

3.5 National Emission Standards for Hazardous Air Pollutants (40 CFR 61 and 63)

The Tacoma LNG Project will not be a Major Source of HAPs. Potential emissions are below the 10 tons-per-year (tpy) single HAP and 25 tpy total HAPs thresholds. Thus, the Tacoma LNG Project qualifies as an "area source" under the following NESHAP rules.

3.5.1 Subpart ZZZZ: National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines

NESHAP Subpart ZZZZ for reciprocating internal combustion engines will apply to the Tacoma LNG Project's backup generator. Operation of the emergency generator will qualify under Subpart ZZZZ's provisions for emergency engines. Compliance with NSPS Subpart IIII requirements satisfies applicable Subpart ZZZZ requirements.

3.5.2 Subpart Y: National Emissions Standards for Hazardous Air Pollutants for Marine Tank Vessel Loading Operations (Not Applicable)

NESHAP Subpart Y requirements for marine tank vessel loading apply to area HAP sources with an initial startup date after September 20, 1999 barring some exemption. However, this rule applies exclusively to marine tank vessel loading operations. The Tacoma LNG Project will only be fueling vessels, not filling tank ships or tank barges that transport bulk LNG. Therefore, the Tacoma LNG Project will not be engaged in marine tank vessel loading operations and so this NESHAP does not apply.

3.5.3 Subparts HH and HHH: National Emissions Standards for Hazardous Air Pollutants for Oil and Natural Gas Production and Natural Gas Transmission and Storage (Not Applicable)

NESHAP Subpart HH applies to gases up to the point of custody transfer at the production field where gases enter the pipeline for transmission. As the Tacoma LNG Project is well downstream of the point of custody transfer at the production field, this NESHAP does not apply.

NESHAP Subpart HHH applies to natural gas transmission and storage facilities that transport or store natural gas prior to entering the pipeline to a local distribution company or to a final end user (if there is no local distribution company), and that are major HAP sources. The Tacoma LNG Project will be an area HAP source. In addition, LNG storage associated with the Tacoma LNG Project will occur downstream of the point of custody transfer from the transmission company to the local distribution company (PSE). PSE operates no natural gas transmission facilities. For both of these reasons, this NESHAP does not apply.

3.5.4 Subpart JJJJJJ: National Emissions Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers Area Sources (Not Applicable)

NESHAP Subpart JJJJJJ applies to area source boilers combusting certain types of fuel. Boilers burning exclusively natural gas are exempt from coverage and process heaters are not within the definition of boilers. Therefore, the Tacoma LNG Project's two heaters and LNG vaporizer, which are exclusively gas-fired, are not subject to this NESHAP.

3.6 Toxic Air Pollutants and tBACT

As a new source, the Tacoma LNG Project is required to conduct a Toxic Air Pollutant (TAP) evaluation if maximum uncontrolled emissions of TAPs would be greater than the *de minimis* values identified in WAC 173-460-150, as adopted in Regulation III, Section 2.07. Each listed TAP has an established *de minimis* level, a Small-Quantity Emission Rate (SQER), and an Acceptable Source Impact Level (ASIL). If the TAP emission rate from a source is above its *de minimis* level and SQER, further determination of compliance with the ASIL is required.

Table 7 below shows the estimated TAP emission rate and *de minimis* value for each pollutant (further details on the emission calculations are provided in Section 2 and Appendix B). As shown in Table 5, emission estimates indicate that 12 TAPs require review for the Tacoma LNG Project under Chapter 173-460 WAC. Best Available Control Technology (BACT) for TAPs (tBACT) requirements are addressed in Section 4 and the ambient air quality assessment is addressed in Section 5.

Table 7: Project Emissions Compared to Small-Quantity Emission Rates

Pollutant	CAS Number	Averaging Period	Emission Rate	*De Minimis*[a]	SQER[a]	Review Required?
			(pounds per averaging period)			
3-Methylchloranthrene	56-49-5	Year	0.00061	0.00153	0.0305	--
7,12-Dimethylbenz(a)anthracene	57-97-6	Year	0.0054	0.000135	0.00271	Yes
Benzo(a)anthracene	56-55-3	Year	0.00061	0.0872	1.74	--
Benzene	71-43-2	Year	56	0.331	6.62	Yes
Benzo(a)pyrene	50-32-8	Year	0.00041	0.00872	0.174	--
Benzo(b)fluoranthene	205-99-2	Year	0.00061	0.0872	1.74	--
Benzo(k)fluoranthene	207-08-9	Year	0.00061	0.0872	1.74	--

Pollutant	CAS Number	Averaging Period	Emission Rate	*De Minimis*[a]	SQER[a]	Review Required?
			(pounds per averaging period)			
Chrysene	218-01-9	Year	0.00062	0.0872	1.74	--
Dibenz(a,h)anthracene	53-70-3	Year	0.00042	0.00799	0.16	--
Ethylbenzene	100-41-4	Year	3.1	3.84	76.8	--
Formaldehyde	50-00-0	Year	34	1.6	32	Yes
n-Hexane	110-54-3	24-hour	1.9	4.6	92	--
Hydrogen sulfide	7783-06-4	24-hour	0.26	0.0131	0.263	Yes
Indeno(1,2,3-cd)pyrene	193-39-5	Year	0.00069	0.0872	1.74	--
Naphthalene	91-20-3	Year	0.20	0.282	5.64	--
Toluene	108-88-3	24-hour	0.16	32.9	657	--
m-Xylene	108-38-3	24-hour	0.050	1.45	29	--
o-Xylene	95-47-6	24-hour	0.0084	1.45	29	--
p-Xylene	106-42-3	24-hour	0.050	1.45	29	--
Arsenic	--	Year	0.068	0.00291	0.0581	Yes
Beryllium	--	Year	0.0041	0.004	0.08	Yes
Cadmium	7440-43-9	Year	0.37	0.00228	0.0457	Yes
Cobalt	7440-48-4	24-hour	0.000075	0.000657	0.013	--
Copper	--	1-hour	3.2E-05	0.011	0.219	--
Lead and compounds	--	Year	0.17	10	16	--
Manganese	--	24-hour	0.00034	0.000263	0.00526	Yes
Mercury	7439-97-6	24-hour	0.00026	0.000591	0.0118	--
Selenium	--	24-hour	7.0E-05	0.131	2.63	--
Vanadium	7440-62-2	24-hour	0.0020	0.00131	0.0263	Yes
Carbon monoxide	630-08-0	1-hour	9.9	1.14	50.4	Yes
Nitrogen dioxide	10102-44-0	1-hour	3.0	0.457	1.03	Yes
Sulfur dioxide	7446-09-05	1-hour	3.0	0.457	1.45	Yes

[a] WAC 173-460-150

3.7 Chemical Accident Prevention (40 CFR 68) (Not Applicable)

Federal Risk Management Program requirements do not apply to LNG facilities that transport or store incident to such transport-regulated substances. As the EPA has explained:

> EPA has expressly provided that the RMP regulations do not apply to on-shore LNG facilities to the extent they transport or store incident to such transport regulated

> substances. In 1996, EPA defined “stationary source,” the legal prerequisite for being subject to the RMP regulations, as “excluding transportation, including storage incident to transportation, provided such transportation is regulated under 49 CFR Part 192, 193, or 195… as well as transportation subject to natural gas or hazardous liquid programs for which a state has in effect a certification under 49 U.S.C. section 60105.” 61 Fed. Reg. at 16,601. In 1998, EPA clarified that the “transportation exemption” was not limited to just sources regulated by DOT, but included transportation and storage incident to transportation generally. 63 Fed. Reg. at 642. It also reiterated that the exemption “applies to liquefied natural gas (LNG) facilities subject to [DOT] oversight or regulation…or a state natural gas or hazardous liquid program.” *Id*. EPA made clear that it promulgated such a definition of “stationary source,” i.e., one that excludes transportation and storage incident to transportation, including LNG facilities, to be “consistent with Congressional intent.” *See* RTC at 21. As discussed in greater detail below, EPA did not suggest that it was narrowly interpreting the statutory definition of “stationary source” for RMP regulatory purposes.[4]

Siting, design, construction, operation, and maintenance of the Tacoma LNG Project are federally regulated by the Pipeline Hazardous Materials Safety Administration (PHMSA) under LNG Facilities, specifically Federal Safety Standards (49 CFR 193 et al.), which incorporate by reference the National Fire Protection Association (NFPA) Standard for the Production, Storage, and Handling of LNG (NFPA 59A), in addition to many other national standards. The Tacoma LNG Project is not subject to the EPA’s Chemical Accident Prevention Program as the facility transports and stores incident to transportation and therefore is regulated under 49 CFR 193.

3.8 State Environmental Policy Act

The City of Tacoma issued a Final EIS for the Tacoma LNG Project on November 9, 2015, which satisfies the State Environmental Policy Act (SEPA) requirements for this project. In the cover letter accompanying the Final EIS, the City of Tacoma described the Final EIS as “adequate for SEPA compliance and permit and approval decision making…” PSCAA may rely on the Final EIS in assessing and taking action on this application.

3.9 PSCAA Local Regulations

The Tacoma LNG Project will be subject to and comply with a variety of PSCAA regulations including the following:

- <u>Opacity</u>. No air contaminant source shall exceed opacity of 20 percent for more than 3 minutes in a given hour as specified in PSCAA Regulation I Section 9.03.
- <u>Nuisance</u>. No air contaminant shall be emitted in sufficient quantities and of such characteristics and duration as is, or is likely to be, injurious to human health, plant or animal

[4] Memorandum, Ann R. Klee, General Counsel, to Granta Nakayama, Assistant Administrator, Office of Enforcement and Compliance Assistance, and Susan Bodine, Assistant Administrator, Office of Solid Waste and Emergency Response, “Applicability of Clean Air Act Section 112(r)(1) General Duty Clause and Section 112(r)(7) Risk Management Program to Liquefied Natural Gas Facilities” (March 6, 2006).

life, or property, or which unreasonably interferes with enjoyment of life and property as specified in PSCAA Regulation I Section 9.11.

- Fugitive Dust. No visible emissions of fugitive dust shall be caused or allowed unless reasonable precautions are taken to minimize the emissions as specified in PSCAA Regulation I Section 9.15.
- Proper Operations. No features, devices, control equipment, or machines shall operate unless such equipment are maintained in good working order as specified in PSCAA Regulation I Section 9.20.

The Tacoma LNG Project will not be subject to PSCAA Regulation II, Section 3.02 (Volatile Organic Compound Storage Tanks), which applies to stationary storage tanks with a capacity of 40,000 gallons or greater storing VOCs with a true vapor pressure of 1.5 psi (10.5 kPa) or greater at actual monthly average storage temperatures. The LNG storage tank will be the only stationary storage tank with a capacity of 40,000 gallons or greater at the Tacoma LNG Facility. The maximum true vapor pressure of the VOC components of the LNG in the storage tank (where temperature will be maintained at –260°F or lower) is less than 1.5 psi (10.5 kPa). Therefore, this rule does not apply.

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4.0 BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

As mentioned above, the proposed project would not be a Major Stationary Source and would not trigger Prevention of Significant Deterioration (PSD) review. Therefore, PSD Best Available Control Technology (BACT) requirements do not apply to this project. However, PSCAA requirements for criteria pollutant BACT and tBACT apply to all emission sources that undergo Washington NSR.

BACT is an emission limitation based on case-by-case review of the maximum degree of reduction that can be feasibly and economically achieved for each criteria air pollutant that would be emitted from any new or modified stationary source. BACT is usually determined using a "top-down" approach as described in the EPA's draft New Source Review Workshop Manual: Prevention of Significant Deterioration and Non-Attainment Area Permitting (EPA 1990). Comprehensive BACT analyses for natural gas-fired heaters, enclosed flares, and fugitive emission sources at petroleum-related facilities have been extensively conducted and no new control technologies have emerged. Therefore, a qualitative approach was used for the BACT assessment and proposed determinations are subject to PSCAA's review and approval.

BACT emission limits proposed in this NOC application for each of the LNG Project's non-exempt emission units were identified based on a review of BACT determinations listed on the EPA's RACT/BACT/LAER Clearinghouse (RBLC) website.[5] A summary of RBLC listings for similar sources is provided in Appendix E.

4.1 Best Available Control Technology

4.1.1 Vaporizer

The LNG Facility's vaporizer would use a natural gas-burning fire-tube water heater with a heat input capacity of 66 MMBtu/hr (see vendor data in Appendix C). A search of the RBLC database was conducted to identify recent BACT determinations for heaters of comparable size and use. Based on our review of the RBLC, add-on control devices for similar heaters have not been demonstrated in practice and therefore are not considered feasible, and were removed from consideration as BACT. Control technologies that were found to be available and feasible for the vaporizer heater are provided in Table 8 below.

[5] The RBLC database refers to the EPA's Reasonably Available Control Technology (RACT)/Best Available Control Technology (BACT)/Lowest Achievable Emission Rate (LAER) Clearinghouse.

Table 8: Available and Feasible Control Technologies for Vaporizer Heater

Pollutant	Control Technology
NO_X	Good Combustion Practices/Low or Ultra-Low NO_X Burners
CO	Good Combustion Practices
PM, PM_{10}, $PM_{2.5}$	Good Combustion Practices, Fuel Selection
VOCs	Good Combustion Practices

As specified in Table 8, good combustion practices, fuel selection, and a low or ultra-low nitrogen oxides (NO_x) burner are the only control options feasible for this emission unit. PSE proposes to voluntarily equip the vaporizer heater with ultra-low NO_x burner technology, implement good combustion practices, and burn clean, locally available natural gas, which collectively constitute BACT for this emission unit, subject to PSCAA's review and approval.

The proposed BACT emission limits, which are based on the heater manufacturer's guarantee for NO_X and CO, fuel sulfur content for SO_2, and AP-42 for VOCs and PM, are summarized in Table 9 below.

Table 9: Proposed BACT Emission Limits for Vaporizer Heater

Pollutant	Emission Limit
NO_X	12 lb/MMcf
CO	40 lb/MMcf
VOCs	5.5 lb/MMcf
SO_2	15 lb/MMcf
$PM/PM_{10}/PM_{2.5}$ (total)	7.6 lb/MMcf

4.1.2 Enclosed Ground Flare

The proposed enclosed ground flare would have two natural gas pilots (5 scf/min each) to provide a continuous ignition source for reliable vapor combustion. As described in Section 2.2.2, the following process streams would be sent to the enclosed flare:

- Seal vents from one feed gas compressor and one refrigerant compressor
- Acid gases from the pretreatment system
- Heavy hydrocarbon storage flash gas
- Heavy hydrocarbon fuel gas
- Emergency venting of the LNG storage tank during upset conditions.

Additionally, based on an RBLC search of recent BACT determinations for enclosed flares, add-on control devices have not been demonstrated in practice and therefore are not considered feasible, and are removed from consideration as BACT.

The available and feasible control technologies identified during RBLC review for the enclosed ground flare are provided in Table 10 below.

Table 10: Available and Feasible Control Technologies for Enclosed Ground Flare

Pollutant	Control Technology
NO_X	Good Combustion Practices/Low NO_X Burners
CO	Good Combustion Practices
VOCs	Good Combustion Practices

Note, the RBLC database search for enclosed ground flares was focused on flares that are burning similar gas streams. For example, BACT determinations for landfill gas flares were not considered relevant or comparable. RBLC database entries for enclosed flares were also screened out if insufficient information is provided to allow for comparison to the proposed project (e.g., mass emission limits with no throughput information provided, etc.). As shown in Table 10, good combustion practices and low-NO_x burner design are the only control options feasible for the enclosed flare. Based on a review of the EPA's RBLC database, the only example of a BACT determination for an enclosed flare that specifies low-NO_x burner design is for a horizontal enclosed flare that burns oil or field gas and is twice the size of the flare PSE proposes for this project. Therefore, good combustion practices constitute BACT for this emission unit, subject to PSCAA's review and approval.

The proposed BACT emission limits, which are based on the flare burner manufacturer's specifications, are summarized in Table 11 below.

Table 11: Proposed BACT Emission Limits for Enclosed Ground Flare

Pollutant	Emission Limit
NO_X	0.06 lb/MMBtu
CO	0.2 lb/MMBtu
VOCs	Destruction Efficiency of at least 99%

4.1.3 Fugitive Emissions

Fugitive VOC emissions occur from leaks in valves, pump seals, flanges, connectors, and compressor seals. Methods of controlling fugitive VOC emissions include efficiently capturing and controlling fugitive emissions from process equipment, ship bunkering, and truck loading operations. Additionally, use of an LDAR system can ensure that fugitive emissions are minimized by identifying and repairing leaking equipment.

The available and feasible control options for fugitive VOC sources are provided in Table 12 below.

Table 12: Available and Feasible Control Technologies for Fugitive Emissions

Pollutant	Control Technology
VOC	Efficient Capture and Control/LDAR Measures

As described in Section 2.1.5, the ship bunkering connection point piping would be purged with nitrogen prior to disconnection and the contents sent to the flare. A vapor return line is not required during bunkering because the LNG is subcooled, which collapses vapor in the fuel tank on the ship during fueling. A vapor return hose would capture fugitive emissions from vapor displacement during loading of trucks and would send the vapors preferentially to the BOG handling system or to the flare. Prior to disconnecting the truck loading hose, the truck tank would be closed, and the loading hose liquid contents would be sent back to the LNG tank prior to disconnect. PSE would voluntarily implement LDAR measures for all equipment with potential for leaks. A summary of PSE's proposed LDAR program is provided in Appendix D. Therefore, efficient vapor capture and control and the use of LDAR measures constitute BACT for fugitive emissions, subject to PSCAA's review and approval.

4.2 Toxics Best Available Control Technology

The proposed project would satisfy the tBACT requirements of WAC 173-460-060 by applying design and operational measures that are also described in Section 2.0 of this document, including:

- Purchase and installation of new modern pumps, compressors, valves, and flanges/fittings
- Vapor return system for truck loading and onboard vapor condensing systems during ship bunkering
- An efficient flare with an average guaranteed destruction efficiency of 99 percent for volatile TAPs
- Use of natural gas fuel for the LNG Facility's enclosed flare pilot and vaporizer heater
- Transfer and processing of LNG that would contain low levels of toxic compounds.

These measures, in combination with PSE's voluntary LDAR measures, would achieve tBACT, subject to PSCAA's review and approval.

5.0 AMBIENT AIR QUALITY ANALYSIS

Air quality modeling inputs are currently being prepared and emission source characteristics such as stack parameters are being developed. Once modeling is completed, this section will discuss the air dispersion modeling parameters, inputs, assumptions and results, and will provide a comparison with National Ambient Air Quality Standards (NAAQS) and Washington Ambient Air Quality Standards (WAAQS) for criteria pollutants and Acceptable Source Impact Levels (ASILs) for TAPs. As agreed upon with the PSCAA, the analysis report will be submitted on or before June 22, 2017.

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6.0 USE OF THIS REPORT

This Notice of Construction Application Supporting Information Report has been prepared for the exclusive use of Puget Sound Energy (client), the Puget Sound Clean Air Agency, and any other applicable regulatory agencies for specific application to the Tacoma Liquefied Natural Gas Project. The reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau Associates, shall be at the user's sole risk.

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7.0 REFERENCES

EPA. 1990. New Source Review Workshop Manual: Prevention of Significant Deterioration and Nonattainment Area Permitting. Office of Air Quality Planning and Standards, US Environmental Protection Agency. October.

EPA. 1995a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources. AP-42. 5th ed. Office of Air Quality Planning and Standards, US Environmental Protection Agency. January.

EPA. 1995b. Protocol for Equipment Leak Emission Estimates. EPA-453/R-95-017. US Environmental Protection Agency. November.

Haass, C.C., J.L. Kovach, S.E. Kelly, and D.A. Turner. 2010. Evaluation of Best Available Control Technology for Toxics (tBACT), Double Shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations. US Department of Energy. June 3.

SCAQMD. 2003. Guidelines for Fugitive Emissions Calculations. South Coast Air Quality Management District. June.

Data Source: Esri 2012

G:\Projects\130\015\F01VicMap.mxd 5/12/2017

LANDAU ASSOCIATES

Puget Sound Energy Liquefied Natural Gas Project Notice of Construction Application Tacoma, Washington	**Vicinity Map**	Figure 1

CLIENT DWG NO:

NOTES

ROBERT JACOB WALTER · STATE OF WASHINGTON · 53142 · STRUCTURAL ENGINEER · PROFESSIONAL ENGINEER

2MAR17

REV	REVISION	DRAWN	CK'D	APPD	DATE
D	ISSUED FOR AGENCY REVIEW	ND	SAB	FH	02MAR17
C	ISSUED FOR AGENCY REVIEW	ND	SAB	FH	22FEB17
B	ISSUED FOR CLIENT REVIEW	ND	SAB	FH	20JAN17
A	ISSUED FOR REVIEW	ND	SAB	FH	08DEC16

PUGET SOUND ENERGY

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DRAWN: ND | CK'D: SAB | APPD: FH | DATE: 08DEC16 | SCALE: AS SHOWN

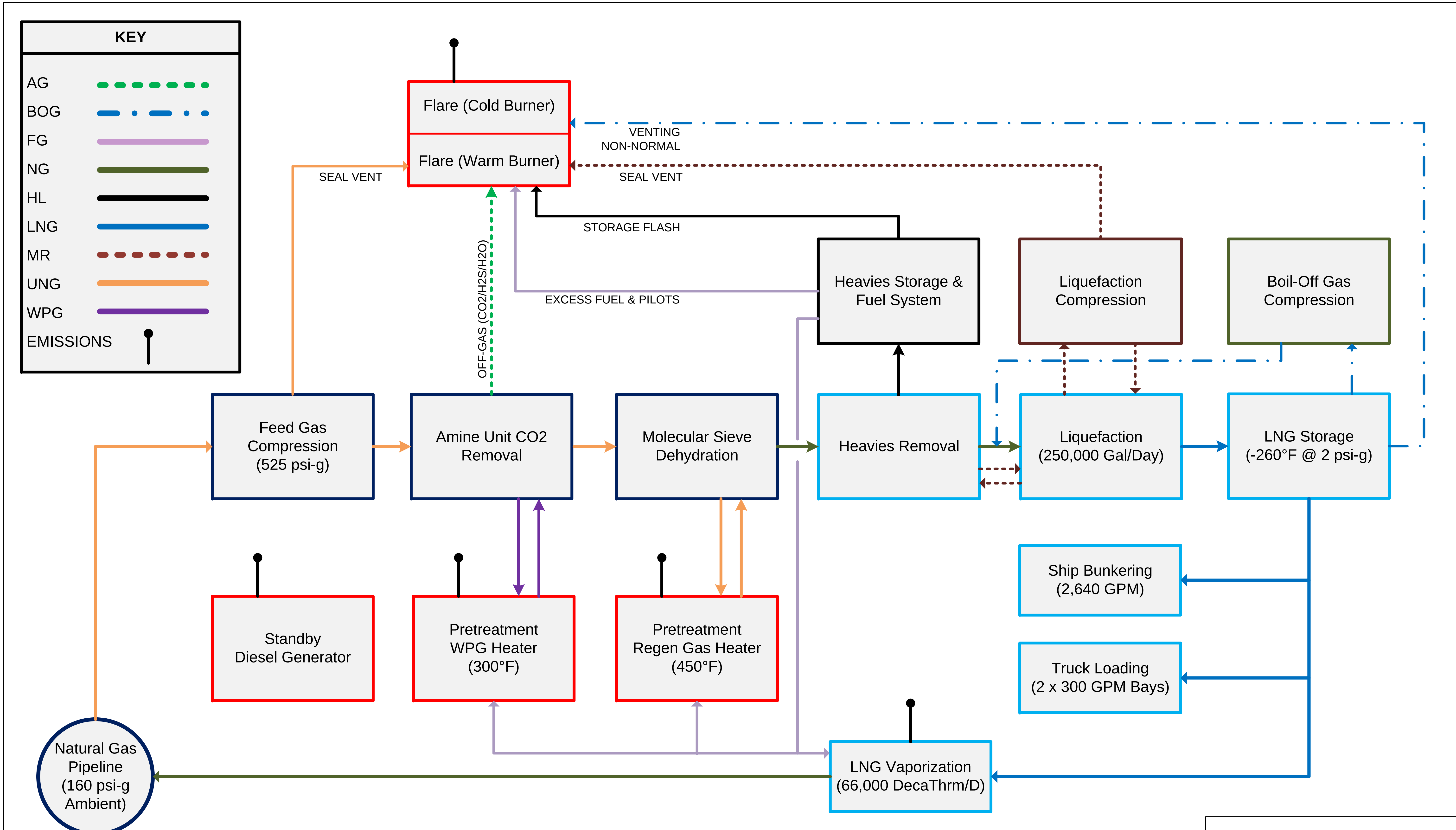
SITE PLAN

TACOMA LNG
1001 E. ALEXANDER AVE, TACOMA, WA 98421

FOR: PUGET SOUND ENERGY | PROJECT NO: 210140

DWG NO: 210140-000-CV-03-000001 | REV: D

H:\Project\210140 - Tacoma LNG\05 Engineering\5.13 Drawings\5.13.02 Sitework\210140-000-CV-03-000001.dgn



NOTES

REFERENCE DRAWINGS

NO.	REVISION	DRAWN	CK'D	APPD	DATE
A	FOR INFORMATION	T. MULLEN	M. STOBART		10-MAY-17

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DRAWN: | CHKD: | APPD: | DATE: | SCALE: N/A

CLIENT DRAWING:

FACILITY BLOCK FLOW EMISSIONS DIAGRAM

PUGET SOUND ENERGY
TACOMA LNG PROJECT
TACOMA, WASHINGTON

FOR: TACOMA LNG PROJECT

PROJECT: 210140 | DWG NO: 210140-000-PR-05-00001 | REV:

FILE LOCATION =

APPENDIX A

PSCAA Form P

pscleanair.org
Puget Sound Clean Air Agency

PUGET SOUND CLEAN AIR AGENCY
1904 3rd Ave Ste 105
Seattle WA 98101-3317
(206) 689-4052 Fax: (206) 343-7522 www.pscleanair.org

NOTICE OF CONSTRUCTION AND APPLICATION FOR APPROVAL

Incomplete applications delay Agency review, so please fill out your application thoroughly. Instructions for filling out the application are available on the NOC Permit Application Instructions webpage.

GENERAL EQUIPMENT FORM — FORM P

AGENCY USE ONLY	Date:	Reg No.:	NOC No.:

Type of business: (check)
- [ ] new
- [X] existing

Status of equipment (check):
- [X] new
- [ ] existing
- [ ] altered
- [ ] relocation

Applicant Name & Mailing Address:
Puget Sound Energy
c/o Keith Faretra, Mailstop PSE-09S
10885 NE 4th Street
Bellevue, WA 98004

Phone No.: 425-456-2561

Fax No.: 425-462-3223

Email Address: keith.faretra@pse.com

North American Industry Classification System (NAICS) Code:
221210 - Natural Gas Distribution

Company (or owner) name & mailing address:
Puget Sound Energy
10885 NE 4th Street
Bellevue, WA 98004

Nature of Business / Type of Process:
Natural gas processing and liquefaction, LNG storage, ship fueling and truck loading.

Installation address (Include city & zip code):
East 11th Street, east of Alexander Avenue, south of Commencement Bay, and on the west shoreline of the Hylebos Waterway in Tacoma, WA 98424

PROCESS EQUIPMENT AND CONTROL EQUIPMENT

Process Equipment		Air Pollution Control Equipment	
# Units	Equipment Type	# Units	Equipment Type
1	Vaporizer Heater		
1	Enclosed Ground Flare		
See attachment	Valves, Flanges, and Seals		
	(Exempt equipment is described in attached process description.)		

- [X] Attach a process flow diagram
- [X] Attach a project description

PREPARER'S CERTIFICATION STATEMENT

I, the undersigned, certify that the information contained in this application and the accompanying forms, plans, and supplemental data described herein is to the best of my knowledge, accurate and complete.

Signature:		Date:	May 19, 2017
Type or print name: Roger Garratt	Title: Director, Strategic Initiatiaves	Phone:	(425) 462-3470
Prepared by (signature and title):	Keith Faretra	Senior Resource Scientist 425-456-2561	

Your application will not be processed unless you mail a $1,150 filing fee payment *along with this application*. Additional fees may apply after application review. An Environmental Checklist form and additional equipment specific forms may also be needed. These forms are available on the Agency's Regulatory Forms webpage. See the NOC Permit Application Instructions webpage for instructions on filling out the permit application. To pay by credit card, check here ☐ and an accounting technician will contact you.

Form No. 50-125P (06/02/15 *ns*)

APPENDIX B

Detailed Emission Calculations

APPENDIX B
LIST OF ABBREVIATIONS AND ACRONYMS

µg .... microgram
Btu .... British thermal unit
cf .... cubic feet
CO .... carbon monoxide
dscf .... dry standard cubic feet
ft^3 .... cubic feet
g .... gram
HAP .... hazardous air pollutant
H_2S .... hydrogen sulfide
hr .... hour
lb .... pound
LDAR .... leak detection and repair
m^3 .... cubic meter
min .... minutes
MMBtu .... million British thermal units
MMcf .... million cubic feet
MMscf .... million standard cubic feet
NO_x .... nitrogen oxides
PM .... particulate matter
$PM_{2.5}$ .... PM with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10} .... PM with an aerodynamic diameter less than or equal to 10 microns
ppmw .... parts per million (by weight)
scf .... standard cubic feet
SO_2 .... sulfur dioxide
TAP .... toxic air pollutant
tpy .... tons per year
VOC .... volatile organic compound
wt .... weight
yr .... year

Table B-1
Emission Unit Inventory and Rates
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Equipment	Rate[a]		Hours of Operation[a]	Fuel
Vaporizer	66	MMBtu/hr	240	Natural Gas
Enclosed Ground Flare				
Case 1				
Waste Gas Flow	30,833	scf/hr	8,760	Waste Gas
Waste Gas Heat Input	10.2	MMBtu/hr		
Case 2				
Waste Gas Flow	5,833	scf/hr	8,760	Waste Gas
Waste Gas Heat Input	2.5	MMBtu/hr		
Case 3				
Waste Gas Flow	20,833	scf/hr	8,760	Waste Gas
Waste Gas Heat Input	34.5	MMBtu/hr		
Case 4				
Waste Gas Flow	40,417	scf/hr	8,760	Waste Gas
Waste Gas Heat Input	35.6	MMBtu/hr		
Case 5				
Waste Gas Flow	20,417	scf/hr	8,760	Waste Gas
Waste Gas Heat Input	37.2	MMBtu/hr		
Pilots	10	scf/min	8,760	Natural Gas
Fugitives	--		8,760	--

Notes:

[a] Provided by CB&I.

Table B-2
Combusted Gas Characteristics
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Parameters	Natural Gas[a]	Flared Waste Gas[a]				
		Case 1	Case 2	Case 3	Case 4	Case 5
Heat Content (Btu/scf)	1,093	330	427	1,654	882	1,821
Density (lb/scf)	0.046	0.103	0.083	0.090	0.099	0.088
Sulfur Content (ppmw)	166	41	36	527	257	192
VOC Content (wt%)	NA	9.4%	14%	51%	25%	58%
Benzene Concentration ($\mu g/m^3$)[b]	2,980	2,980	2,980	2,980	2,980	2,980
Ethylbenzene Concentration ($\mu g/m^3$)[b]	144	144	144	144	144	144
m,p-Xylene Concentration ($\mu g/m^3$)[b]	986	986	986	986	986	986
o-Xylene Concentration ($\mu g/m^3$)[b]	165	165	165	165	165	165
Toluene Concentration ($\mu g/m^3$)[b]	2,570	2,570	2,570	2,570	2,570	2,570

Notes:

[a] Provided by CB&I.

[b] From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most hazardous air pollutants (HAPs) will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we conservatively assume the waste gas has the full concentration of HAP.

Table B-3
Potential Emissions from Vaporizer
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)	Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants			
$PM/PM_{10}/PM_{2.5}$	7.6 (1)	0.46	0.055
SO_2	15 [c]	0.9	0.11
NO_x	12 (2)	0.72	0.086
CO	40 (2)	2.4	0.29
VOCs	5.5 (1)	0.33	0.040
Lead	0.0005 (1)	3.0E-05	3.6E-06
Hazardous Air Pollutants/Toxic Air Pollutants			
Arsenic	2.0E-04 (3)	1.3E-08	1.4E-06
Benzene	2.1E-03 (3)	1.4E-07	1.5E-05
Beryllium	1.2E-05 (3)	7.9E-10	8.7E-08
Cadmium	1.1E-03 (3)	7.3E-08	8.0E-06
Chromium(total)	1.4E-03 (3)	9.2E-08	1.0E-05
Cobalt	8.4E-05 (3)	5.5E-09	6.1E-07
Copper	8.5E-04 (3)	5.6E-08	6.2E-06
Formaldehyde	7.5E-02 (3)	5.0E-06	5.4E-04
Hexane	1.8E+00 (3)	1.2E-04	1.3E-02
Lead	5.0E-04 (1)	3.3E-08	3.6E-06
Manganese	3.8E-04 (3)	2.5E-08	2.8E-06
Mercury	2.6E-04 (3)	1.7E-08	1.9E-06
Naphthalene	6.1E-04 (3)	4.0E-08	4.4E-06
Nickel	2.1E-03 (3)	1.4E-07	1.5E-05
Polycyclic Organic Matter	7.0E-04 (3)	4.6E-08	5.1E-06
2-Methylnaphthalene	*2.4E-05 (3)*	*1.6E-09*	*1.7E-07*
3-Methylchloranthrene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
7,12-Dimethylbenz(a)anthracene	*1.6E-05 (3)*	*1.1E-09*	*1.2E-07*
Acenaphthene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Acenaphthylene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Anthracene	*2.4E-06 (3)*	*1.6E-10*	*1.7E-08*
Benz(a)anthracene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Benzo(a)pyrene	*1.2E-06 (3)*	*7.9E-11*	*8.7E-09*
Benzo(b)fluoranthene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Benzo(g,h,i)perylene	*1.2E-06 (3)*	*7.9E-11*	*8.7E-09*
Benzo(k)fluoranthene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Chrysene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Dibenzo(a,h)anthracene	*1.2E-06 (3)*	*7.9E-11*	*8.7E-09*
Fluoranthene	*3.0E-06 (3)*	*2.0E-10*	*2.2E-08*
Fluorene	*2.8E-06 (3)*	*1.8E-10*	*2.0E-08*
Indeno(1,2,3-cd)pyrene	*1.8E-06 (3)*	*1.2E-10*	*1.3E-08*
Naphthalene	*6.1E-04 (3)*	*4.0E-08*	*4.4E-06*
Phenanathrene	*1.7E-05 (3)*	*1.1E-09*	*1.2E-07*
Pyrene	*5.0E-06 (3)*	*3.3E-10*	*3.6E-08*
Selenium	2.4E-05 (3)	1.6E-09	1.7E-07
Vanadium	2.3E-03 (3)	1.5E-07	1.7E-05
Toluene	3.4E-03 (3)	2.2E-07	2.5E-05
Total HAPs		**0.00012**	**0.014**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Heat Input (MMBtu/hr)] / [Fuel Heating Value (Btu/scf)] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Maximum Heat Input (MMBtu/hr) =	66	(4)
Fuel Heating Value (Btu/scf) =	1,093	(5)
Projected Hours of Operation (hrs/yr) =	240	(4)

[c] SO_2 Emission Factor (lb/MMcf) = [Natural Gas Density (lb/cf)] x [Sulfur Content (ppm)] / 10^6 x [2 g-SO_2/g-S] x [10^6 cf/MMcf]

Natural gas density (lb/cf) =	0.046	(5)
Sulfur Content of Fuel (ppmw) =	166	(5)

[d] Pollutant Emission Rate (lb/MMscf) = [Pollutant concentration by volume, dry basis (ppm_{dv})] x ([Maximum Fuel Usage (scf/hr)] x [Fuel Heating Value (Btu/scf)] x [Combustion Gas Generated (dscf/MMBtu)] x [Pollutant Molecular Weight (lb/lb-mole)] x [2.59×10^{-9} lb-mole/dscf per ppm] + [CO_2 Volume in Waste Gas (dscf/hr)]) x [20.9 / (20.9 - Percent Oxygen)]

Pollutant Concentration NO_X (ppm) =	9	(2)
Pollutant Concentration CO (ppm) =	50	(2)
Percent Oxygen =	3	(2)
Flue Gas Generated (dscf/MMBtu) =	8,710	(6)

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42.
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.
(6) NSPS Subpart D.

Table B-4
Case 1: Potential Emissions from Enclosed Ground Flare Burners
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMBtu)			Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants					
$PM/PM_{10}/PM_{2.5}$	0.0075	lb/MMBtu	(1)	0.076	0.33
SO_2	8.4	lb/MMscf	c	0.26	1.1
NO_x	0.06	lb/MMBtu	(2)	0.61	2.7
CO	0.2	lb/MMBtu	(2)	2.0	8.9
VOCs	97	lb/MMscf	d	3.0	13
Lead	4.9E-07	lb/MMBtu	(1)	5.0E-06	2.2E-05
Hazardous Air Pollutants/Toxic Air Pollutants					
Arsenic	2.0E-07	lb/MMBtu	(3)	2.0E-06	8.7E-06
Benzene	1.7E-04	lb/MMBtu	e	1.7E-03	7.6E-03
Beryllium	1.2E-08	lb/MMBtu	(3)	1.2E-07	5.2E-07
Cadmium	1.1E-06	lb/MMBtu	(3)	1.1E-05	4.8E-05
Chromium(total)	1.4E-06	lb/MMBtu	(3)	1.4E-05	6.1E-05
Cobalt	8.2E-08	lb/MMBtu	(3)	8.4E-07	3.7E-06
Copper	8.3E-07	lb/MMBtu	(3)	8.5E-06	3.7E-05
Ethylbenzene	8.2E-06	lb/MMBtu	e	8.4E-05	3.7E-04
Formaldehyde	7.4E-05	lb/MMBtu	(3)	7.5E-04	3.3E-03
Hexane	1.8E-03	lb/MMBtu	(3)	1.8E-02	7.9E-02
Hydrogen sulfide	4.5E-02	lb/MMscf	f	1.4E-03	6.1E-03
Lead	4.9E-07	lb/MMBtu	(1)	5.0E-06	2.2E-05
Manganese	3.7E-07	lb/MMBtu	(3)	3.8E-06	1.7E-05
Mercury	2.5E-07	lb/MMBtu	(3)	2.6E-06	1.1E-05
Naphthalene	6.0E-07	lb/MMBtu	(3)	6.1E-06	2.7E-05
Nickel	2.1E-06	lb/MMBtu	(3)	2.1E-05	9.2E-05
Polycyclic Organic Matter	6.8E-07	lb/MMBtu	(3)	7.0E-06	3.1E-05
2-Methylnaphthalene	*2.4E-08*	*lb/MMBtu*	*(3)*	*2.4E-07*	*1.0E-06*
3-Methylchloranthrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
7,12-Dimethylbenz(a)anthracene	*1.6E-08*	*lb/MMBtu*	*(3)*	*1.6E-07*	*7.0E-07*
Acenaphthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Acenaphthylene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Anthracene	*2.4E-09*	*lb/MMBtu*	*(3)*	*2.4E-08*	*1.0E-07*
Benz(a)anthracene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Benzo(a)pyrene	*1.2E-09*	*lb/MMBtu*	*(3)*	*1.2E-08*	*5.2E-08*
Benzo(b)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Benzo(g,h,i)perylene	*1.2E-09*	*lb/MMBtu*	*(3)*	*1.2E-08*	*5.2E-08*
Benzo(k)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Chrysene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Dibenzo(a,h)anthracene	*1.2E-09*	*lb/MMBtu*	*(3)*	*1.2E-08*	*5.2E-08*
Fluoranthene	*2.9E-09*	*lb/MMBtu*	*(3)*	*3.0E-08*	*1.3E-07*
Fluorene	*2.7E-09*	*lb/MMBtu*	*(3)*	*2.8E-08*	*1.2E-07*
Indeno(1,2,3-cd)pyrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*1.8E-08*	*7.9E-08*
Naphthalene	*6.0E-07*	*lb/MMBtu*	*(3)*	*6.1E-06*	*2.7E-05*
Phenanathrene	*1.7E-08*	*lb/MMBtu*	*(3)*	*1.7E-07*	*7.4E-07*
Pyrene	*4.9E-09*	*lb/MMBtu*	*(3)*	*5.0E-08*	*2.2E-07*
Selenium	2.4E-08	lb/MMBtu	(3)	2.4E-07	1.0E-06
Toluene	1.5E-04	lb/MMBtu	e	1.5E-03	6.5E-03
Vanadium	2.3E-06	lb/MMBtu	(3)	2.3E-05	1.0E-04
m,p-Xylene	5.6E-05	lb/MMBtu	e	5.7E-04	2.5E-03
o-Xylene	9.4E-06	lb/MMBtu	e	9.6E-05	4.2E-04
Total HAPs				**0.023**	**0.10**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Heat Input (MMBtu/hr) =	10	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)
Maximum Gas Flow (scf/hr) =	30,833	(4)

[c] SO_2 Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [64 g-SO_2/32 g-S] x [Destruction Efficiency (%)] x [10^6 cf/MMcf]

Gas Density (lb/cf) =	0.103	(5)
Sulfur Content of Gas (ppmw) =	41	(5)
Destruction Efficiency (%) =	99%	(2)

[d] Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [VOC Content (wt%)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

VOC Concentration (wt%) =	9.4%	(5)

[e] Emission Factor (lb/MMBtu) = [Gas Density (lb/cf)] x [Pollutant Concentration ($\mu g/m^3$)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Natural Gas Heating Value (Btu/scf)] x [1 - Destruction Efficiency (%)] x [10^6 Btu/MMBtu]

Benzene Concentration ($\mu g/m^3$) =	2,980	(5)
Ethylbenzene Concentration ($\mu g/m^3$) =	144	(5)
m,p-Xylene Concentration ($\mu g/m^3$) =	986	(5)
o-Xylene Concentration ($\mu g/m^3$) =	165	(5)
Toluene Concentration ($\mu g/m^3$) =	2,570	(5)
Natural Gas Heating Value (Btu/scf) =	1,093	(5)

[f] H_2S Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [34 g-H_2S/32 g-S] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air Quality Planning and Standards, US
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-5
Case 2: Potential Emissions from Enclosed Ground Flare Burners
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)			Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants					
$PM/PM_{10}/PM_{2.5}$	0.0075	lb/MMBtu	(1)	0.019	0.081
SO_2	6.0	lb/MMscf	c	0.035	0.15
NO_X	0.06	lb/MMBtu	(2)	0.15	0.65
CO	0.2	lb/MMBtu	(2)	0.50	2.2
VOCs	118	lb/MMscf	d	0.69	3.0
Lead	4.90E-07	lb/MMBtu	(1)	1.2E-06	5.3E-06
Hazardous Air Pollutants/Toxic Air Pollutants					
Arsenic	2.0E-07	lb/MMBtu	(3)	4.9E-07	2.1E-06
Benzene	1.7E-04	lb/MMBtu	e	4.2E-04	1.9E-03
Beryllium	1.2E-08	lb/MMBtu	(3)	2.9E-08	1.3E-07
Cadmium	1.1E-06	lb/MMBtu	(3)	2.7E-06	1.2E-05
Chromium(total)	1.4E-06	lb/MMBtu	(3)	3.4E-06	1.5E-05
Cobalt	8.2E-08	lb/MMBtu	(3)	2.1E-07	9.0E-07
Copper	8.3E-07	lb/MMBtu	(3)	2.1E-06	9.1E-06
Ethylbenzene	8.2E-06	lb/MMBtu	e	2.0E-05	9.0E-05
Formaldehyde	7.4E-05	lb/MMBtu	(3)	1.8E-04	8.0E-04
Hexane	1.8E-03	lb/MMBtu	(3)	4.4E-03	1.9E-02
Hydrogen sulfide	3.2E-02	lb/MMscf	f	1.9E-04	8.2E-04
Lead	4.9E-07	lb/MMBtu	(1)	1.2E-06	5.3E-06
Manganese	3.7E-07	lb/MMBtu	(3)	9.3E-07	4.1E-06
Mercury	2.5E-07	lb/MMBtu	(3)	6.3E-07	2.8E-06
Naphthalene	6.0E-07	lb/MMBtu	(3)	1.5E-06	6.5E-06
Nickel	2.1E-06	lb/MMBtu	(3)	5.1E-06	2.2E-05
Polycyclic Organic Matter	6.8E-07	lb/MMBtu	(3)	1.7E-06	7.5E-06
2-Methylnaphthalene	*2.4E-08*	*lb/MMBtu*	*(3)*	*5.9E-08*	*2.6E-07*
3-Methylchloranthrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
7,12-Dimethylbenz(a)anthracene	*1.6E-08*	*lb/MMBtu*	*(3)*	*3.9E-08*	*1.7E-07*
Acenaphthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Acenaphthylene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Anthracene	*2.4E-09*	*lb/MMBtu*	*(3)*	*5.9E-09*	*2.6E-08*
Benz(a)anthracene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Benzo(a)pyrene	*1.2E-09*	*lb/MMBtu*	*(3)*	*2.9E-09*	*1.3E-08*
Benzo(b)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Benzo(g,h,i)perylene	*1.2E-09*	*lb/MMBtu*	*(3)*	*2.9E-09*	*1.3E-08*
Benzo(k)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Chrysene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Dibenzo(a,h)anthracene	*1.2E-09*	*lb/MMBtu*	*(3)*	*2.9E-09*	*1.3E-08*
Fluoranthene	*2.9E-09*	*lb/MMBtu*	*(3)*	*7.3E-09*	*3.2E-08*
Fluorene	*2.7E-09*	*lb/MMBtu*	*(3)*	*6.8E-09*	*3.0E-08*
Indeno(1,2,3-cd)pyrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*4.4E-09*	*1.9E-08*
Naphthalene	*6.0E-07*	*lb/MMBtu*	*(3)*	*1.5E-06*	*6.5E-06*
Phenanathrene	*1.7E-08*	*lb/MMBtu*	*(3)*	*4.2E-08*	*1.8E-07*
Pyrene	*4.9E-09*	*lb/MMBtu*	*(3)*	*1.2E-08*	*5.3E-08*
Selenium	2.4E-08	lb/MMBtu	(3)	5.9E-08	2.6E-07
Toluene	1.5E-04	lb/MMBtu	e	3.7E-04	1.6E-03
Vanadium	2.3E-06	lb/MMBtu	(3)	5.6E-06	2.5E-05
m,p-Xylene	5.6E-05	lb/MMBtu	e	1.4E-04	6.1E-04
o-Xylene	9.4E-06	lb/MMBtu	e	2.3E-05	1.0E-04
Total HAPs				**0.006**	**0.02**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Heat Input (MMBtu/hr) =	2.5	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)
Maximum Gas Flow (scf/hr) =	5,833	

[c] SO_2 Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [64 g-SO_2/32 g-S] x [Destruction Efficiency (%)] x [10^6 cf/MMcf]

Gas Density (lb/cf) =	0.083	(5)
Sulfur Content of Gas (ppmw) =	36	(5)
Destruction Efficiency (%) =	99%	(2)

[d] Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [VOC Content (wt%)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

VOC Concentration (wt%) = 14% (5)

[e] Emission Factor (lb/MMBtu) = [Gas Density (lb/cf)] x [Pollutant Concentration ($\mu g/m^3$)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Natural Gas Heating Value (Btu/scf)] x [1 - Destruction Efficiency (%)] x [10^6 Btu/MMBtu]

Benzene Concentration ($\mu g/m^3$) =	2,980	(5)
Ethylbenzene Concentration ($\mu g/m^3$) =	144	(5)
m,p-Xylene Concentration ($\mu g/m^3$) =	986	(5)
o-Xylene Concentration ($\mu g/m^3$) =	165	(5)
Toluene Concentration ($\mu g/m^3$) =	2,570	(5)
Natural Gas Heating Value (Btu/scf) =	1,093	(5)

[f] H_2S Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [34 g-H_2S/32 g-S] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-6
Case 3: Potential Emissions from Enclosed Ground Flare Burners
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)			Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants					
$PM/PM_{10}/PM_{2.5}$	0.0075	lb/MMBtu	(1)	0.26	1.1
SO_2	94	lb/MMscf	c	2.0	8.5
NO_x	0.06	lb/MMBtu	(2)	2.1	9.1
CO	0.2	lb/MMBtu	(2)	6.9	30
VOCs	459	lb/MMscf	d	9.6	42
Lead	4.90E-07	lb/MMBtu	(1)	1.7E-05	7.4E-05
Hazardous Air Pollutants/Toxic Air Pollutants					
Arsenic	2.0E-07	lb/MMBtu	(3)	6.8E-06	3.0E-05
Benzene	1.7E-04	lb/MMBtu	e	5.9E-03	2.6E-02
Beryllium	1.2E-08	lb/MMBtu	(3)	4.1E-07	1.8E-06
Cadmium	1.1E-06	lb/MMBtu	(3)	3.7E-05	1.6E-04
Chromium(total)	1.4E-06	lb/MMBtu	(3)	4.7E-05	2.1E-04
Cobalt	8.2E-08	lb/MMBtu	(3)	2.8E-06	1.2E-05
Copper	8.3E-07	lb/MMBtu	(3)	2.9E-05	1.3E-04
Ethylbenzene	8.2E-06	lb/MMBtu	e	2.8E-04	1.2E-03
Formaldehyde	7.4E-05	lb/MMBtu	(3)	2.5E-03	1.1E-02
Hexane	1.8E-03	lb/MMBtu	(3)	6.1E-02	2.7E-01
Hydrogen sulfide	5.0E-01	lb/MMscf	f	1.0E-02	4.6E-02
Lead	4.9E-07	lb/MMBtu	(1)	1.7E-05	7.4E-05
Manganese	3.7E-07	lb/MMBtu	(3)	1.3E-05	5.6E-05
Mercury	2.5E-07	lb/MMBtu	(3)	8.8E-06	3.8E-05
Naphthalene	6.0E-07	lb/MMBtu	(3)	2.1E-05	9.0E-05
Nickel	2.1E-06	lb/MMBtu	(3)	7.1E-05	3.1E-04
Polycyclic Organic Matter	6.8E-07	lb/MMBtu	(3)	2.4E-05	1.0E-04
2-Methylnaphthalene	*2.4E-08*	*lb/MMBtu*	*(3)*	*8.1E-07*	*3.6E-06*
3-Methylchloranthrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
7,12-Dimethylbenz(a)anthracene	*1.6E-08*	*lb/MMBtu*	*(3)*	*5.4E-07*	*2.4E-06*
Acenaphthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Acenaphthylene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Anthracene	*2.4E-09*	*lb/MMBtu*	*(3)*	*8.1E-08*	*3.6E-07*
Benz(a)anthracene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Benzo(a)pyrene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.1E-08*	*1.8E-07*
Benzo(b)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Benzo(g,h,i)perylene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.1E-08*	*1.8E-07*
Benzo(k)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Chrysene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Dibenzo(a,h)anthracene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.1E-08*	*1.8E-07*
Fluoranthene	*2.9E-09*	*lb/MMBtu*	*(3)*	*1.0E-07*	*4.4E-07*
Fluorene	*2.7E-09*	*lb/MMBtu*	*(3)*	*9.5E-08*	*4.1E-07*
Indeno(1,2,3-cd)pyrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.1E-08*	*2.7E-07*
Naphthalene	*6.0E-07*	*lb/MMBtu*	*(3)*	*2.1E-05*	*9.0E-05*
Phenanathrene	*1.7E-08*	*lb/MMBtu*	*(3)*	*5.7E-07*	*2.5E-06*
Pyrene	*4.9E-09*	*lb/MMBtu*	*(3)*	*1.7E-07*	*7.4E-07*
Selenium	2.4E-08	lb/MMBtu	(3)	8.1E-07	3.6E-06
Toluene	1.5E-04	lb/MMBtu	e	5.1E-03	2.2E-02
Vanadium	2.3E-06	lb/MMBtu	(3)	7.8E-05	3.4E-04
m,p-Xylene	5.6E-05	lb/MMBtu	e	1.9E-03	8.5E-03
o-Xylene	9.4E-06	lb/MMBtu	e	3.2E-04	1.4E-03
Total HAPs				**0.077**	**0.34**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Heat Input (MMBtu/hr) =	34	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)
Maximum Gas Flow (scf/hr) =	20,833	

[c] SO_2 Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [64 g-SO_2/32 g-S] x [Destruction Efficiency (%)] x [10^6 cf/MMcf]

Gas Density (lb/cf) =	0.090	(5)
Sulfur Content of Gas (ppmw) =	527	(5)
Destruction Efficiency (%) =	99%	(2)

[d] Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [VOC Content (wt%)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

VOC Concentration (wt%) =	51%	(5)

[e] Emission Factor (lb/MMBtu) = [Gas Density (lb/cf)] x [Pollutant Concentration ($\mu g/m^3$)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Natural Gas Heating Value (Btu/scf)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Benzene Concentration ($\mu g/m^3$) =	2,980	(5)
Ethylbenzene Concentration ($\mu g/m^3$) =	144	(5)
m,p-Xylene Concentration ($\mu g/m^3$) =	986	(5)
o-Xylene Concentration ($\mu g/m^3$) =	165	(5)
Toluene Concentration ($\mu g/m^3$) =	2,570	(5)
Natural Gas Heating Value (Btu/scf) =	1,093	(5)

[f] H_2S Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [34 g-H_2S/32 g-S] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air Quality Planning and Standards, US
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-7
Case 4: Potential Emissions from Enclosed Ground Flare Burners
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)			Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants					
$PM/PM_{10}/PM_{2.5}$	0.0075	lb/MMBtu	(1)	0.27	1.2
SO_2	50	lb/MMscf	c	2.0	8.9
NO_x	0.06	lb/MMBtu	(2)	2.1	9.4
CO	0.2	lb/MMBtu	(2)	7.1	31
VOCs	245	lb/MMscf	d	9.9	43
Lead	4.9E-07	lb/MMBtu	(1)	1.7E-05	7.7E-05
Hazardous Air Pollutants/Toxic Air Pollutants					
Arsenic	2.0E-07	lb/MMBtu	(3)	7.0E-06	3.1E-05
Benzene	1.7E-04	lb/MMBtu	e	6.1E-03	2.7E-02
Beryllium	1.2E-08	lb/MMBtu	(3)	4.2E-07	1.8E-06
Cadmium	1.1E-06	lb/MMBtu	(3)	3.8E-05	1.7E-04
Chromium(total)	1.4E-06	lb/MMBtu	(3)	4.9E-05	2.1E-04
Cobalt	8.2E-08	lb/MMBtu	(3)	2.9E-06	1.3E-05
Copper	8.3E-07	lb/MMBtu	(3)	3.0E-05	1.3E-04
Ethylbenzene	8.2E-06	lb/MMBtu	e	2.9E-04	1.3E-03
Formaldehyde	7.4E-05	lb/MMBtu	(3)	2.6E-03	1.1E-02
Hexane	1.8E-03	lb/MMBtu	(3)	6.3E-02	2.8E-01
Hydrogen sulfide	2.7E-01	lb/MMscf	f	1.1E-02	4.8E-02
Lead	4.9E-07	lb/MMBtu	(1)	1.7E-05	7.7E-05
Manganese	3.7E-07	lb/MMBtu	(3)	1.3E-05	5.8E-05
Mercury	2.5E-07	lb/MMBtu	(3)	9.1E-06	4.0E-05
Naphthalene	6.0E-07	lb/MMBtu	(3)	2.1E-05	9.3E-05
Nickel	2.1E-06	lb/MMBtu	(3)	7.3E-05	3.2E-04
Polycyclic Organic Matter	6.8E-07	lb/MMBtu	(3)	2.4E-05	1.1E-04
2-Methylnaphthalene	*2.4E-08*	*lb/MMBtu*	*(3)*	*8.4E-07*	*3.7E-06*
3-Methylchloranthrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
7,12-Dimethylbenz(a)anthracene	*1.6E-08*	*lb/MMBtu*	*(3)*	*5.6E-07*	*2.4E-06*
Acenaphthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Acenaphthylene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Anthracene	*2.4E-09*	*lb/MMBtu*	*(3)*	*8.4E-08*	*3.7E-07*
Benz(a)anthracene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Benzo(a)pyrene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.2E-08*	*1.8E-07*
Benzo(b)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Benzo(g,h,i)perylene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.2E-08*	*1.8E-07*
Benzo(k)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Chrysene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Dibenzo(a,h)anthracene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.2E-08*	*1.8E-07*
Fluoranthene	*2.9E-09*	*lb/MMBtu*	*(3)*	*1.0E-07*	*4.6E-07*
Fluorene	*2.7E-09*	*lb/MMBtu*	*(3)*	*9.8E-08*	*4.3E-07*
Indeno(1,2,3-cd)pyrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.3E-08*	*2.8E-07*
Naphthalene	*6.0E-07*	*lb/MMBtu*	*(3)*	*2.1E-05*	*9.3E-05*
Phenanathrene	*1.7E-08*	*lb/MMBtu*	*(3)*	*5.9E-07*	*2.6E-06*
Pyrene	*4.9E-09*	*lb/MMBtu*	*(3)*	*1.7E-07*	*7.7E-07*
Selenium	2.4E-08	lb/MMBtu	(3)	8.4E-07	3.7E-06
Toluene	1.5E-04	lb/MMBtu	e	5.2E-03	2.3E-02
Vanadium	2.3E-06	lb/MMBtu	(3)	8.0E-05	3.5E-04
m,p-Xylene	5.6E-05	lb/MMBtu	e	2.0E-03	8.8E-03
o-Xylene	9.4E-06	lb/MMBtu	e	3.4E-04	1.5E-03
Total HAPs				**0.080**	**0.35**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Heat Input (MMBtu/hr) =	36	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)
Maximum Gas Flow (scf/hr) =	40,417	

[c] SO_2 Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [64 g-SO_2/32 g-S] x [Destruction Efficiency (%)] x [10^6 cf/MMcf]

Gas Density (lb/cf) =	0.099	(5)
Sulfur Content of Gas (ppmw) =	257	(5)
Destruction Efficiency (%) =	99%	(2)

[d] Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [VOC Content (wt%)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

VOC Concentration (wt%) =	25%	(5)

[e] Emission Factor (lb/MMBtu) = [Gas Density (lb/cf)] x [Pollutant Concentration ($\mu g/m^3$)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Natural Gas Heating Value (Btu/scf)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Benzene Concentration ($\mu g/m^3$) =	2,980	(5)
Ethylbenzene Concentration ($\mu g/m^3$) =	144	(5)
m,p-Xylene Concentration ($\mu g/m^3$) =	986	(5)
o-Xylene Concentration ($\mu g/m^3$) =	165	(5)
Toluene Concentration ($\mu g/m^3$) =	2,570	(5)
Natural Gas Heating Value (Btu/scf) =	1,093	(5)

[f] H_2S Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [34 g-H_2S/32 g-S] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air Quality Planning and Standards, US
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-8
Case 5: Potential Emissions from Enclosed Ground Flare Burners
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)			Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants					
$PM/PM_{10}/PM_{2.5}$	0.0075	lb/MMBtu	(1)	0.28	1.2
SO_2	33	lb/MMscf	c	0.68	3.0
NO_x	0.06	lb/MMBtu	(2)	2.2	9.8
CO	0.2	lb/MMBtu	(2)	7.4	33
VOCs	505	lb/MMscf	d	10.3	45
Lead	4.90E-07	lb/MMBtu	(1)	1.8E-05	8.0E-05
Hazardous Air Pollutants/Toxic Air Pollutants					
Arsenic	2.0E-07	lb/MMBtu	(3)	7.3E-06	3.2E-05
Benzene	1.7E-04	lb/MMBtu	e	6.3E-03	2.8E-02
Beryllium	1.2E-08	lb/MMBtu	(3)	4.4E-07	1.9E-06
Cadmium	1.1E-06	lb/MMBtu	(3)	4.0E-05	1.8E-04
Chromium(total)	1.4E-06	lb/MMBtu	(3)	5.1E-05	2.2E-04
Cobalt	8.2E-08	lb/MMBtu	(3)	3.1E-06	1.3E-05
Copper	8.3E-07	lb/MMBtu	(3)	3.1E-05	1.4E-04
Ethylbenzene	8.2E-06	lb/MMBtu	e	3.1E-04	1.3E-03
Formaldehyde	7.4E-05	lb/MMBtu	(3)	2.7E-03	1.2E-02
Hexane	1.8E-03	lb/MMBtu	(3)	6.6E-02	2.9E-01
Hydrogen sulfide	1.8E-01	lb/MMscf	f	3.7E-03	1.6E-02
Lead	4.9E-07	lb/MMBtu	(1)	1.8E-05	8.0E-05
Manganese	3.7E-07	lb/MMBtu	(3)	1.4E-05	6.1E-05
Mercury	2.5E-07	lb/MMBtu	(3)	9.5E-06	4.2E-05
Naphthalene	6.0E-07	lb/MMBtu	(3)	2.2E-05	9.7E-05
Nickel	2.1E-06	lb/MMBtu	(3)	7.7E-05	3.4E-04
Polycyclic Organic Matter	6.8E-07	lb/MMBtu	(3)	2.5E-05	1.1E-04
2-Methylnaphthalene	*2.4E-08*	*lb/MMBtu*	*(3)*	*8.7E-07*	*3.8E-06*
3-Methylchloranthrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
7,12-Dimethylbenz(a)anthracene	*1.6E-08*	*lb/MMBtu*	*(3)*	*5.8E-07*	*2.6E-06*
Acenaphthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Acenaphthylene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Anthracene	*2.4E-09*	*lb/MMBtu*	*(3)*	*8.7E-08*	*3.8E-07*
Benz(a)anthracene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Benzo(a)pyrene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.4E-08*	*1.9E-07*
Benzo(b)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Benzo(g,h,i)perylene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.4E-08*	*1.9E-07*
Benzo(k)fluoranthene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Chrysene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Dibenzo(a,h)anthracene	*1.2E-09*	*lb/MMBtu*	*(3)*	*4.4E-08*	*1.9E-07*
Fluoranthene	*2.9E-09*	*lb/MMBtu*	*(3)*	*1.1E-07*	*4.8E-07*
Fluorene	*2.7E-09*	*lb/MMBtu*	*(3)*	*1.0E-07*	*4.5E-07*
Indeno(1,2,3-cd)pyrene	*1.8E-09*	*lb/MMBtu*	*(3)*	*6.6E-08*	*2.9E-07*
Naphthalene	*6.0E-07*	*lb/MMBtu*	*(3)*	*2.2E-05*	*9.7E-05*
Phenanathrene	*1.7E-08*	*lb/MMBtu*	*(3)*	*6.2E-07*	*2.7E-06*
Pyrene	*4.9E-09*	*lb/MMBtu*	*(3)*	*1.8E-07*	*8.0E-07*
Selenium	2.4E-08	lb/MMBtu	(3)	8.7E-07	3.8E-06
Toluene	1.5E-04	lb/MMBtu	e	5.5E-03	2.4E-02
Vanadium	2.3E-06	lb/MMBtu	(3)	8.4E-05	3.7E-04
m,p-Xylene	5.6E-05	lb/MMBtu	e	2.1E-03	9.2E-03
o-Xylene	9.4E-06	lb/MMBtu	e	3.5E-04	1.5E-03
Total HAPs				**0.083**	**0.36**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Heat Input (MMBtu/hr) =	37	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)
Maximum Gas Flow (scf/hr) =	20,417	

[c] SO_2 Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [64 g-SO_2/32 g-S] x [Destruction Efficiency (%)] x [10^6 cf/MMcf]

Gas Density (lb/cf) =	0.088	(5)
Sulfur Content of Gas (ppmw) =	192	(5)
Destruction Efficiency (%) =	99%	(2)

[d] Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [VOC Content (wt%)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

VOC Concentration (wt%) = 58% (5)

[e] Emission Factor (lb/MMBtu) = [Gas Density (lb/cf)] x [Pollutant Concentration ($\mu g/m^3$)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Natural Gas Heating Value (Btu/scf)] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Benzene Concentration ($\mu g/m^3$) =	2,980	(5)
Ethylbenzene Concentration ($\mu g/m^3$) =	144	(5)
m,p-Xylene Concentration ($\mu g/m^3$) =	986	(5)
o-Xylene Concentration ($\mu g/m^3$) =	165	(5)
Toluene Concentration ($\mu g/m^3$) =	2,570	(5)
Natural Gas Heating Value (Btu/scf) =	1,093	(5)

[f] H_2S Emission Factor (lb/MMcf) = [Gas Density (lb/cf)] x [S Content (ppmw)] / 10^6 x [34 g-H_2S/32 g-S] x [1 - Destruction Efficiency (%)] x [10^6 cf/MMcf]

Notes:

(1) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42. Office of Air Quality Planning and
(2) Vendor design specifications provided by CB&I.
(3) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air Quality Planning and Standards, US
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-9
Potential Emissions from Enclosed Ground Flare Pilots
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Emission Factor (lb/MMcf)	Potential Emissions Hourly[a] (lbs/hr)	Potential Emissions Annual[b] (tons/yr)
Criteria Pollutants			
$PM/PM_{10}/PM_{2.5}$	7.6 (1)	0.0046	0.020
SO_2	15 [c]	0.009	0.040
NO_x	50 (2)	0.030	0.13
CO	84 (2)	0.050	0.22
VOCs	5.5 (1)	0.0033	0.014
Lead	0.0005 (1)	3.0E-07	1.3E-06
Hazardous Air Pollutants/Toxic Air Pollutants			
Arsenic	2.0E-04 (3)	1.2E-07	5.3E-07
Benzene	2.1E-03 (3)	1.3E-06	5.5E-06
Beryllium	1.2E-05 (3)	7.2E-09	3.2E-08
Cadmium	1.1E-03 (3)	6.6E-07	2.9E-06
Chromium(total)	1.4E-03 (3)	8.4E-07	3.7E-06
Cobalt	8.4E-05 (3)	5.0E-08	2.2E-07
Copper	8.5E-04 (3)	5.1E-07	2.2E-06
Formaldehyde	7.5E-02 (3)	4.5E-05	2.0E-04
Hexane	1.8E+00 (3)	1.1E-03	4.7E-03
Lead	5.0E-04 (1)	3.0E-07	1.3E-06
Manganese	3.8E-04 (3)	2.3E-07	1.0E-06
Mercury	2.6E-04 (3)	1.6E-07	6.8E-07
Naphthalene	6.1E-04 (3)	3.7E-07	1.6E-06
Nickel	2.1E-03 (3)	1.3E-06	5.5E-06
Polycyclic Organic Matter	7.0E-04 (3)	4.2E-07	1.8E-06
2-Methylnaphthalene	*2.4E-05 (3)*	*1.4E-08*	*6.3E-08*
3-Methylchloranthrene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
7,12-Dimethylbenz(a)anthracene	*1.6E-05 (3)*	*9.6E-09*	*4.2E-08*
Acenaphthene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Acenaphthylene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Anthracene	*2.4E-06 (3)*	*1.4E-09*	*6.3E-09*
Benz(a)anthracene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Benzo(a)pyrene	*1.2E-06 (3)*	*7.2E-10*	*3.2E-09*
Benzo(b)fluoranthene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Benzo(g,h,i)perylene	*1.2E-06 (3)*	*7.2E-10*	*3.2E-09*
Benzo(k)fluoranthene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Chrysene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Dibenzo(a,h)anthracene	*1.2E-06 (3)*	*7.2E-10*	*3.2E-09*
Fluoranthene	*3.0E-06 (3)*	*1.8E-09*	*7.9E-09*
Fluorene	*2.8E-06 (3)*	*1.7E-09*	*7.4E-09*
Indeno(1,2,3-cd)pyrene	*1.8E-06 (3)*	*1.1E-09*	*4.7E-09*
Naphthalene	*6.1E-04 (3)*	*3.7E-07*	*1.6E-06*
Phenanathrene	*1.7E-05 (3)*	*1.0E-08*	*4.5E-08*
Pyrene	*5.0E-06 (3)*	*3.0E-09*	*1.3E-08*
Selenium	2.4E-05 (3)	1.4E-08	6.3E-08
Vanadium	2.3E-03 (3)	1.4E-06	6.0E-06
Toluene	3.4E-03 (3)	2.0E-06	8.9E-06
Total HAPs		**0.0011**	**0.0050**

Calculations:

[a] Hourly Emissions (lb/hr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)]

[b] Annual Emissions (tons/yr) = [Maximum Fuel Usage (scf/hr)] x [1 MMscf/1,000,000 scf] x [Emission Factor (lb/MMcf)] x [Operating Hours (hrs/yr)] / [2,000 lbs/ton]

Maximum Fuel Usage (scf/hr) =	600	(4)
Projected Hours of Operation (hrs/yr) =	8,760	(4)

[c] SO_2 Emission Factor (lb/MMcf) = [Natural Gas Density (lb/cf)] x [Sulfur Content (ppm)] / 10^6 x [2 g-SO_2/g-S] x [10^6 cf/MMcf]

Natural gas density (lb/cf) =	0.046	(5)
Sulfur Content of Fuel (ppm) =	166	(5)

Notes:

(1) EPA. 1998b. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-2: Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion. AP-42.
(2) EPA. 1998a. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-1: Emission Factors for Nitrogen Oxides and Carbon Monoxide from Natural Gas Combustion. AP-42.
(3) EPA. 1998c. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 1.4, Table 1.4-3: Emission Factors for Speciated Organic Compounds from Natural Combustion. AP-42. Office of Air
(4) See rates in Table B-1.
(5) See fuel characteristics in Table B-2.

Table B-10
Fugitive Emissions from Equipment Leaks
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

EQUIPMENT INFORMATION (1)

Component	Phase	Fluid Serviced									VOC Emission Factors (3) (lb/hr per component)	LDAR Control Efficiency (4)
		Acid gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas		
Valves	Gas/Vapor	39	9	12	36			112	185	30	0.00137	75%
	Light Liquid					33	244				0.00537	75%
Pump Seals	Light Liquid					1	4				0.0493	75%
Flanges/Connectors	Gas/Vapor	0	7	2	15			28	77	15	0.000559	30%
	Light Liquid					6	114				0.000559	30%
Compressor Seals	Gas/Vapor	0	2	0	0	0	0	1	1	0	0.0166	75%
Relief Valves	Gas/Vapor	3	0	1	3	1	19	8	9	2	0.0220	75%
Swivel Joints	Light Liquid						4				0.0493	75%

FLUID HAP/TAP CONTENT

Pollutant	Fluid								
	Acid gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas
VOC Content (%wt) (1)	100%	100%	100%	100%	100%	100%	100%	100%	100%
n-Hexane (ppmw) (1)	70	5.7E-10		1,185	210,669	27		1,185	1,185
Hydrogen sulfide (ppmw) (1)	3,128	0.00035		22	0.010	0.21		22	166
Benzene (ppmw)[b]	4.0	4.0		4.0	4.0	4.0		4.0	4.0
Ethylbenzene (ppmw)[b]	0.20	0.20		0.20	0.20	0.20		0.20	0.20
m,p-Xylene (ppmw)[b]	1.3	1.3		1.3	1.3	1.3		1.3	1.3
o-Xylene (ppmw)[b]	0.22	0.22		0.22	0.22	0.22		0.22	0.22
Toluene (ppmw)[b]	3.5	3.5		3.5	3.5	3.5		3.5	3.5

Table B-10
Fugitive Emissions from Equipment Leaks
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

POTENTIAL EMISSIONS

Pollutant	Acid gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas	Total
Hourly Emissions (lb/hr)										
VOCs	0.030	0.014	0.010	0.035	0.064	0.58	0.098	0.15	0.027	**1.0**
n-Hexane	2.1E-06	8.1E-18	0	4.1E-05	0.014	1.6E-05	0	1.7E-04	3.2E-05	**0.014**
Hydrogen sulfide	9.3E-05	4.9E-12	0	7.5E-07	6.61E-10	1.2E-07	0	3.2E-06	4.5E-06	**0.00010**
Benzene	1.2E-07	5.7E-08	0	1.4E-07	2.6E-07	2.3E-06	0	5.9E-07	1.1E-07	**3.6E-06**
Ethylbenzene	5.8E-09	2.7E-09	0	6.8E-09	1.3E-08	1.1E-07	0	2.9E-08	5.3E-09	**1.7E-07**
m,p-Xylene	4.0E-08	1.9E-08	0	4.6E-08	8.6E-08	7.7E-07	0	2.0E-07	3.6E-08	**1.2E-06**
o-Xylene	6.7E-09	3.2E-09	0	7.8E-09	1.4E-08	1.3E-07	0	3.3E-08	6.1E-09	**2.0E-07**
Toluene	1.0E-07	4.9E-08	0	1.2E-07	2.2E-07	2.0E-06	0	5.1E-07	9.5E-08	**3.1E-06**
Total HAPs	2.8E-07	1.3E-07	0	3.2E-07	6.0E-07	5.3E-06	0	1.4E-06	2.5E-07	**8.3E-06**
Annual Emissions (tpy)										
VOCs	0.13	0.062	0.046	0.15	0.28	2.5	0.43	0.64	0.12	**4.4**
n-Hexane	9.1E-06	3.5E-17	0	0.00018	0.060	6.9E-05	0	0.00076	0.00014	**0.061**
Hydrogen sulfide	0.00041	2.1E-11	0	3.3E-06	2.9E-09	5.3E-07	0	1.4E-05	2.0E-05	**0.00045**
Benzene	5.3E-07	2.5E-07	0	6.1E-07	1.1E-06	1.0E-05	0	2.6E-06	4.8E-07	**1.6E-05**
Ethylbenzene	2.6E-08	1.2E-08	0	3.0E-08	5.5E-08	4.9E-07	0	1.3E-07	2.3E-08	**7.6E-07**
m,p-Xylene	1.7E-07	8.2E-08	0	2.0E-07	3.8E-07	3.4E-06	0	8.6E-07	1.6E-07	**5.2E-06**
o-Xylene	2.9E-08	1.4E-08	0	3.4E-08	6.3E-08	5.6E-07	0	1.4E-07	2.7E-08	**8.7E-07**
Toluene	4.6E-07	2.1E-07	0	5.3E-07	9.8E-07	8.8E-06	0	2.2E-06	4.1E-07	**1.4E-05**
Total HAPs	1.2E-06	5.7E-07	0	1.4E-06	2.6E-06	2.3E-05	0	6.0E-06	1.1E-06	**3.6E-05**

Calculations:

[a] Hourly Emissions (lb/hr) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)]

Annual Emissions (tpy) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)] x [Hours of Operation (hrs/yr)] / [2,000 lb/ton]

Hours of Operation (hrs/yr) = 8,760

[b] Pollutant Concentration (ppmw) = [Pollutant Concentration (μg/m^3)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Gas Density (lb/cf)] x 10^6

Benzene Concentration (μg/m^3) =	2,980	(5)
Ethylbenzene Concentration (μg/m^3) =	144	(5)
m,p-Xylene Concentration (μg/m^3) =	986	(5)
o-Xylene Concentration (μg/m^3) =	165	(5)
Toluene Concentration (μg/m^3) =	2,570	(5)
Natural Gas Density (lb/scf) =	0.046	(5)

Notes:

(1) Provided by CB&I.

(2) From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most HAPs will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we assume each fluid has the full concentration of HAP to provide a conservative emissions estimate.

(3) Terminal/Depot factors from South Coast Air Quality Management District's "Guidelines for Fugitive Emissions Calculations" (June 2003). In this guidance, the District updated emissions factors that were identified in the EPA's "Protocol for Equipment Leak Emission Estimates (November 1995).

(4) Control effectiveness from Texas Commission for Environmental Quality (TCEQ) "Control Efficiencies for TCEQ Leak Detection and Repair Programs" (July 2011) for its 28M fugitive leak detection program.

(5) See fuel characteristics in Table B-2.

Table B-11
Project Emissions Summary
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Pollutant	Vaporizer		Enclosed Ground Flare (Worst-case)		Fugitives		Total	
	(lb/hr)	(tpy)	(lb/hr)	(tpy)	(lb/hr)	(tpy)	(lb/hr)	(tpy)
Criteria Pollutants								
$PM/PM_{10}/PM_{2.5}$	0.46	0.055	0.28	1.2	--	--	**0.74**	**1.3**
SO_2	0.93	0.11	2.0	8.9	--	--	**3.0**	**9.0**
NO_x	0.72	0.086	2.3	9.9	--	--	**3.0**	**10**
CO	2.4	0.29	7.5	33	--	--	**9.9**	**33**
VOCs	0.33	0.040	10	45	1.0	4.4	**12**	**50**
Lead	3.0E-05	3.6E-06	1.9E-05	8.1E-05	--	--	**4.9E-05**	**8.5E-05**
Hazardous Air Pollutants	**0.00012**	**0.014**	**0.084**	**0.37**	**8.3E-06**	**3.6E-05**	**0.084**	**0.38**

APPENDIX C

Manufacturer Specification Sheets

210140 - Tacoma LNG
Warm Flare Operating/Design Scenarios

CASE DESCRIPTION	Low Flow Low BTU	High Flow Mid BTU	Normal Flow High BTU	High Flow Low BTU	Highest BTU
	2B	4	3	1A	5
COMPOSITION, MOL%					
NITROGEN (N2)	26.56	0.05	0.10	4.95	0.11
CARBON DIOXIDE (CO2)	43.37	48.46	12.08	69.37	4.42
WATER VAPOR (H2O)	4.85	5.33	1.39	7.63	0.51
METHANE (C1)	13.46	18.40	34.37	9.23	37.57
ETHANE (C2)	2.28	9.85	18.47	2.25	20.35
ETHYLENE (C2=)	1.78	0.08	0.15	0.33	0.17
PROPANE (C3)	2.99	9.73	18.26	2.49	20.16
BUTANE (C4)	2.42	6.39	11.99	2.34	13.24
i-PENTANE (i-C5)	1.72	1.41	2.64	1.03	2.91
HEXANE PLUS (C6+)	0.58	0.26	0.49	0.40	0.54
HYDROGEN SULFIDE (H2S)	0.004	0.030	0.056	0.005	0.020
			0.00		
CAPACITY, LB/HR	483	3,994	1,871	3,189	1,792
CAPACITY, MMSCFD	**0.14**	**0.97**	**0.50**	**0.74**	**0.49**
CAPACITY, MMBTU/HR (LHV)	**2.4**	**32.7**	**31.6**	**9.6**	**34.0**
MOLE WEIGHT	35.21	37.50	34.09	39.09	33.44
LOWER HEATING VALUE, BTU/SCF	417	810	1518	309	1672
HIGHER HEATING VALUE, BTU/SCF	427	882	1654	330	1821

NOTES:

1) FLARE MUST BE HYDRAULICALLY DESIGNED TO PASS THE HIGHEST FLOW CASE 4.
2) FLARE MUST BE DESIGNED TO EFFECTIVELY OXIDZIE THE HIGHEST BTU CASE WITH NO LESS THAN 99.5% EFFICIENCY.
3) FLARE SHALL BE SMOKELESS WITHOUT A VISIBLE FLAME ACROSS THE ENTIRETY OF THE OPERATING RANGE.
4) THE FLARE MUST BE CAPABLE OF EFFECTIVELY OXIDIZING FLOWS FROM THE LOW BTU/LOW FLOW CASE, UP THROUGH THE HIGHEST BTU CASE.
5) THE AGGREGATE BTUS FOR DISPOSAL DO NOT EXCEED CASE 5. AS FLOW TO THE FLARE INCREASES, THE RESULTING SPECIFIC HEATING VALUE FALLS.

Updated 3 April 2017.
T. Mullen

Case Assumptions

2B (Prior Case) This is the feed flow to facility turndown case with the original average supply composition (~0.5% CO2) with blending to get >300 BTU/SCF with a 16% assist gas to total gas flow.
4 (New Case) This is the maximum flow case to the flare. It assumes that we've normalized 2% CO2 in the feed with a heavy composition resulting in high BTU vapor to the flare. Used to set the flare hydraulic design.
3 (New Case) This it the "Normal" case based on the new proposed design composition including the (~0.2% CO2) to flare. Assumes we heat the liquids going to the heavies drum V-802 to 50F.
1A (Prior Case) This is the prior high flow/low BTU case (2% CO2) with blending to get >300 BTU/SCF with a 16% assist gas to total flow. This was the previous highest flow case to the flare.
5 (New Case) This is the highest specific BTU/SCF case. This assumes that only 33% of the rate of overheads from the pretreatment unit is blended with the balance of the heavies. Want to assure we have approriate assist air to get smokeless flaring.

Puget Sound Energy

Enclosed Flare Case 1A **High Flow-Low Btu**

Gas Flow (MMCFD) **0.74**

Fuel Data:	**Gas Composition**
	%
Butane n-C4H10	2.34
Carbon Dioxide CO2	69.37
Ethane C2H6	2.25
Ethylene C2H4	0.33
n-Hexane C6H14	0.4
Hydrogen Sulfide H2S	0.005
Methane CH4	9.23
Nitrogen N2	4.95
n-Pentane C5H12	1.03
Propane C3H8	2.49
Water H2O	7.63
Total	**100.0**

Inlet Gas Net Heating Value (Btu/cf)	310			
Inlet Gas Flow (scfm)	514			
Inlet Gas Flow (lbs/hr)	3202			
Flare Emissions:				
Excess Air %=	178			
Combustion Air (scfm)	4708			
CO2 (scfm)	552	11%		
H2O (scfm)	330	6%		
N2 (scfm)	3645	71%		
O2 (scfm)	613	12%		
Exhaust Gas Flow (scfm)	5140			
Exhaust Gas Flow (scfh)	**308425**			
Heat Rel from Waste Gas(MMBtu/hr)	9.56			
CO emissions (lbs/MMBtu)	0.2000	or	1.912	lbs/hr
NOx Emissions (lbs/MMBtu)	0.0600		0.574	lbs/hr
H2S Emissions (lbs/hr)	0.0028		0.000	
SO2 Emissions (lbs/hr)	0.2554		0.000	
Exhaust Temperature (ºF)	**1600**			
Flare Data:				
Flare Diameter	9	ft		
Flare Height	45	ft		
Flare effective Height	38	ft		
Stack Exit Cross Section	57.86	sq ft		
Flare effective Volume	2198.80	ft^3		
Exhaust Gas Velocity	5	ft/sec		
Gas Ret. Time	7.13	sec		

Puget Sound Energy
Enclosed Flare Case 2B **Low Flow-Low Btu**
Gas Flow (MMCFD) **0.14**

Fuel Data:	**Gas Composition**
	%
Butane n-C4H10	2.42
Carbon Dioxide CO2	43.37
Ethane C2H6	2.28
Ethylene C2H4	1.78
n-Hexane C6H14	0.58
Hydrogen Sulfide H2S	0.004
Methane CH4	13.46
Nitrogen N2	26.56
n-Pentane C5H12	1.72
Propane C3H8	2.99
Water H2O	4.85
Total	**100.0**

Inlet Gas Net Heating Value (Btu/cf)	419			
Inlet Gas Flow (scfm)	97	Too Low		
Inlet Gas Flow (lbs/hr)	545			
Flare Emissions:				
Excess Air %=	178			
Combustion Air (scfm)	1174			
CO2 (scfm)	90	7%		
H2O (scfm)	78	6%		
N2 (scfm)	947	75%		
O2 (scfm)	156	12%		
Exhaust Gas Flow (scfm)	1271			
Exhaust Gas Flow (scfh)	**76280**			
Heat Rel from Waste Gas(MMBtu/hr)	2.44	Too Low		
CO emissions (lbs/MMBtu)	0.2000	or	0.489	lbs/hr
NOx Emissions (lbs/MMBtu)	0.0600		0.147	lbs/hr
H2S Emissions (lbs/hr)	0.0004		0.000	
SO2 Emissions (lbs/hr)	0.0387		0.000	
Exhaust Temperature (ºF)	**1600**			
Flare Data:				
Flare Diameter	9	ft		
Flare Height	45	ft		
Flare effective Height	38	ft		
Stack Exit Cross Section	57.86	sq ft		
Flare effective Volume	2198.80	ft^3		
Exhaust Gas Velocity	1	ft/sec		
Gas Ret. Time	28.83	sec		

Note: Flare requires a minimum heat input of 5.0 MMBtu/hr
to maintan temperature and destruction efficiency

Puget Sound Energy
Enclosed Flare Case 3 **Normal Flow-High Btu**
Gas Flow (MMCFD) **0.5**

Fuel Data:	**Gas Composition**
	%
Butane n-C4H10	11.99
Carbon Dioxide CO2	12.08
Ethane C2H6	18.47
Ethylene C2H4	0.15
n-Hexane C6H14	0.49
Hydrogen Sulfide H2S	0.056
Methane CH4	34.37
Nitrogen N2	0.1
n-Pentane C5H12	2.64
Propane C3H8	18.27
Water H2O	1.39
Total	**100.0**

Inlet Gas Net Heating Value (Btu/cf)	1521			
Inlet Gas Flow (scfm)	347			
Inlet Gas Flow (lbs/hr)	1890			
Flare Emissions:				
Excess Air %=	178			
Combustion Air (scfm)	15054			
CO2 (scfm)	702	4%		
H2O (scfm)	966	6%		
N2 (scfm)	12004	76%		
O2 (scfm)	2033	13%		
Exhaust Gas Flow (scfm)	15706			
Exhaust Gas Flow (scfh)	**942338**			
Heat Rel from Waste Gas(MMBtu/hr)	31.69			
CO emissions (lbs/MMBtu)	0.2000	or	6.338	lbs/hr
NOx Emissions (lbs/MMBtu)	0.0600		1.901	lbs/hr
H2S Emissions (lbs/hr)	0.0210		0.000	
SO2 Emissions (lbs/hr)	1.9326		0.000	
Exhaust Temperature (ºF)	**1600**			
Flare Data:				
Flare Diameter	9	ft		
Flare Height	45	ft		
Flare effective Height	38	ft		
Stack Exit Cross Section	57.86	sq ft		
Flare effective Volume	2198.80	ft^3		
Exhaust Gas Velocity	16	ft/sec		
Gas Ret. Time	2.33	sec		

Puget Sound Energy
Enclosed Flare Case 4 **High Flow-Mid Btu**
Gas Flow (MMCFD) **0.97**

Fuel Data:	**Gas Composition**
	%
Butane n-C4H10	6.39
Carbon Dioxide CO2	48.46
Ethane C2H6	9.85
Ethylene C2H4	0.08
n-Hexane C6H14	0.26
Hydrogen Sulfide H2S	0.03
Methane CH4	18.4
Nitrogen N2	0.05
n-Pentane C5H12	1.41
Propane C3H8	9.73
Water H2O	5.33
Total	**100.0**
Inlet Gas Net Heating Value (Btu/cf)	811
Inlet Gas Flow (scfm)	674
Inlet Gas Flow (lbs/hr)	4030

Flare Emissions:

Excess Air %=	178			
Combustion Air (scfm)	15884			
CO2 (scfm)	1010	6%		
H2O (scfm)	1031	6%		
N2 (scfm)	12423	75%		
O2 (scfm)	2104	13%		
Exhaust Gas Flow (scfm)	16568			
Exhaust Gas Flow (scfh)	**994065**			
Heat Rel from Waste Gas(MMBtu/hr)	32.79			
CO emissions (lbs/MMBtu)	0.2000	or	6.559	lbs/hr
NOx Emissions (lbs/MMBtu)	0.0600		1.968	lbs/hr
H2S Emissions (lbs/hr)	0.0218		0.000	
SO2 Emissions (lbs/hr)	2.0086		0.000	
Exhaust Temperature (ºF)	**1600**			

Flare Data:

Flare Diameter	9	ft
Flare Height	45	ft
Flare effective Height	38	ft
Stack Exit Cross Section	57.86	sq ft
Flare effective Volume	2198.80	ft^3
Exhaust Gas Velocity	17	ft/sec
Gas Ret. Time	2.21	sec

Puget Sound Energy
Enclosed Flare Case 5 **Highest Btu**
Gas Flow (MMCFD) **0.49**

Fuel Data:	**Gas Composition**
	%
Butane n-C4H10	13.24
Carbon Dioxide CO2	4.42
Ethane C2H6	20.35
Ethylene C2H4	0.17
n-Hexane C6H14	0.54
Hydrogen Sulfide H2S	0.02
Methane CH4	37.57
Nitrogen N2	0.11
n-Pentane C5H12	2.91
Propane C3H8	20.16
Water H2O	0.51
Total	**100.0**

Inlet Gas Net Heating Value (Btu/cf)	1675			
Inlet Gas Flow (scfm)	340			
Inlet Gas Flow (lbs/hr)	1817			
Flare Emissions:				
Excess Air %=	178			
Combustion Air (scfm)	16529			
CO2 (scfm)	728	4%		
H2O (scfm)	1038	6%		
N2 (scfm)	12951	77%		
O2 (scfm)	2194	13%		
Exhaust Gas Flow (scfm)	16911			
Exhaust Gas Flow (scfh)	**1014651**			
Heat Rel from Waste Gas(MMBtu/hr)	34.19			
CO emissions (lbs/MMBtu)	0.2000	or	6.838	lbs/hr
NOx Emissions (lbs/MMBtu)	0.0600		2.051	lbs/hr
H2S Emissions (lbs/hr)	0.0073		0.000	
SO2 Emissions (lbs/hr)	0.6764		0.000	
Exhaust Temperature (ºF)	**1600**			
Flare Data:				
Flare Diameter	9	ft		
Flare Height	45	ft		
Flare effective Height	38	ft		
Stack Exit Cross Section	57.86	sq ft		
Flare effective Volume	2198.80	ft^3		
Exhaust Gas Velocity	18	ft/sec		
Gas Ret. Time	2.17	sec		

Enclosed Flare Maintenance

An LFG Specialties enclosed flare and controller system requires very little maintenance. A few preventative maintenance steps should be taken, however, to insure the life of the flare and proper operation of the system. These steps include:

1. Maintain the finish on the flare stack by cleaning any scratches or chipping with a wire brush and repainting with touch-up paint supplied. Note: no maintenance is required on the stainless steel portion of the flare.
2. Inspect all wiring and connections for any wear and replace as necessary.
3. Inspect spark plug igniter for electrode wear and replace as necessary.
4. Check pilot nozzle for obstructions and clean as necessary. Pilot nozzle is a small jet, which may require a fine wire, needle or brake cleaner to aid in cleaning.
5. Check all piping connections for tightness and leaks, replace gaskets as necessary and retorque bolts.
6. Lubricate the blower and motor bearings as specified by manufacturer.

Flare Routine Maintenance Schedule

Standard Components	Frequency of Service						
	Daily	Weekly	Monthly	Bi-Monthly	Semi-annually	Annually	As Needed
Air Blower							
Check Bearing Temperature		√					
Check Vibration Levels		√					
Grease Bearing per Mfr. Recommendations			√				
Inspect Drive Belts and Coupling, if applicable				√			
Clean or replace air filter				√			√
Lubricate Motor Bearings per Manufacturers Recommendations				√			√
Check Blower Motor Alignment						√	
Piping							
Check all Valves for Proper Operation			√				
Check all Flange Gaskets for Leakage						√	
Flow Meter							
Clean Flow Meter Probe						√	√
Calibrate Flow Meter						√	√
Flame Arrester							
Check Back Pressure			√				
Clean Element per Mfr. Recommendations							√

Standard Components	Frequency of Service						
	Daily	Weekly	Monthly	Bi-Monthly	Semi-annually	Annually	As Needed
Pilot System							
Check Fuel Supply		√					
Check Fuel Supply Pressure (3-6 psig)		√					
Clean Solenoid per Mfr. Recommendations					√		
Clean Pressure Regulator Vent					√		
Check all Connections for Leaks					√		
Enclosed Flare Assembly, if applicable							
Check Linkage Condition & Tightness on Linkage Connections; Lubricate Air Louver Bearings			√				
Check Purge Flow Switch for Proper Operation					√		
Inspect Condition of Insulation, Pins, & Keepers						√	
Instrumentation							
Remove and Clean UV Scanner				√			
Check Voltage UV Scanner (Min. 2.25VDC)					√		
Inspect Igniter Plug, Lead-wire, & Connections						√	√
Check Thermocouple Elements					√		
Check Pressure, Vacuum & Temp. Gauges				√			

LFG Specialties

(a CB&I Company)

Budgetary Proposal & Pricing

Enclosed Ground Flare

Prepared for:
William Patterson
Senior Buyer
CB&I
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(815) 439-6122
wpatterson@cbi.com

Reference: **Tacoma LNG Project**
CB&I RFQ # 210140-MR-11470-01
Tacoma, Washington

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LFGS Reference #: 121606R3
April 5, 2017

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SALES AGREEMENT

This sale agreement "Agreement" which includes the Equipment Specification and Terms and Conditions of Sale below is entered into on the undersigned date, by and between the seller, LFG Specialties, L.L.C. ("LFG Specialties") a Louisiana limited liability company, and purchaser, CB&I LLC (hereinafter "Purchaser"). LFG Specialties, L.L.C. agrees to perform these services subject to the terms and conditions in accordance of an intercompany agreement.

A. LFG Specialties is the manufacturer of certain flares and control systems "Equipment" more fully described in paragraph 1. below, "Equipment Quote".

B. Purchaser wishes to purchase from LFG Specialties such Equipment on the terms and conditions set forth herein.

Therefore, in consideration of the covenants contained herein and for other good and valuable consideration, the legal sufficiency of which is acknowledged, the parties wishing to be legally bound agree as follows:

I. EQUIPMENT SPECIFICATION

Purchaser hereby agrees to purchase from LFG Specialties such Equipment and Services as described in this Agreement per the following:

A. Equipment Scope:

Waste gas enclosed flare system with air-assisted burner designed to accept two hydrocarbon gas streams. Case A – warm gas stream with varying heating content with LHV maintained between 300 and 1672 Btu/SCF. Case B – methane rich vapor from LNG loading and LNG Storage. Both gas streams will be combusted in an air-assisted dual nozzle burner assembly. This dual burner system will be designed for smokeless operation while maintaining controlled stack temperature and retention time for achieving the required destruction efficiency of total hydrocarbons and entrained VOC's.

This enclosed flare system will be designed for the following gas flow conditions:

Case A: Warm Gas Stream combined with assist gas:

Gas flow range	0.14 to 0.97 MMSCFD, (97 to 673 SCFM)
Heat Loading Capacity	2.4 to 34.0 MMBtu/hr (LHV)
Inlet gas temperature	120 °F
Inlet back pressure	0 to 1.5 PSIG

Gas molecular Weight 35 to 40

Gas Lower Heating Value 309 to 1672 Btu/CF

Case B: Cryogenic Vapor Stream:

Gas flow range 0 to 1.1 MMSCFD, (764 SCFM)

Heat Loading Capacity up to 32.7 MMBtu/hr (LHV)

Inlet gas temperature -240 °F

Inlet back pressure 0 to 0.5 PSIG

Gas molecular Weight 18.63

Gas Heat Value 714 to 1000 Btu/CF

Note: Air-assisted gas burner will be used for this gas stream.

Equipment Description:

This petroleum waste gas combustor consists of a 9 ft. diameter by 45 ft. overall height enclosed flare stack with two (2) flanged gas inlet connections. An integral air blower mounted to the side of the stack will deliver primary combustion air to the air assisted waste gas burner. Two actuated air louvers at the base of the stack will admit quench air to the combustion zone in order to maintain the optimum combustion temperature for the required emissions control. The flare is designed for installation to a concrete foundation by others. Flare controls will be mounted to a self-standing control rack for remote installation in a Class 1, Group C/D, Div. 2 location.

This petroleum waste gas combustor can operate under a wide gas flow range up to the specified maximum design capacity. The air blower will purge the stack prior to ignition. An intermittent spark ignition pilot will be utilized during system start up. The ignition system lights two continuous flame pilots installed at the flare tip which will maintain flare operation during minimum flow or no flow conditions. Each continuous flame pilot will burn approximately 3 to 5 scfm of natural gas and will be monitored using two type “K” dual elements thermocouples to verify the presence of flame at all times during flare operation.

1. The LFG Specialties petroleum waste gas enclosed flare will include:

   - One 9 ft. diameter x 45 ft. OAH flare constructed of A-36 carbon steel stack fully lined with two layers of refractory ceramic blanket insulation and Inconel pins and keepers.

   - One annular 30” diameter warm gas burner for (Case A) warm gas stream providing nozzle mix of gas and primary air for improved gas combustion efficiency.

- One annular 29" diameter, high Btu gas burner assembly for the cryogenic stream (Case B) gas providing nozzle mix of gas and primary air for improved gas combustion efficiency.
- One primary combustion air blower controlled to maintain consistent air to fuel ratio. Natural draft air from the air dampers will quench the flame and maintain the optimal stack combustion temperature.
- One igniter/pilot assembly with pressure regulator and solenoid valve. Pilot assembly is accessible from ground level for ease of maintenance
- Two Venturi style continuous pilots to maintain flare operation and flame stability during no flow or reduced flow conditions.
- Two automatic air dampers/louvers to maintain flare temperature during varying flow operation
- Three type K thermocouples for stack temperature monitoring and control. Sensors will be installed at 10 ft. vertical spacing down the flare stack starting at ½ diameter from the flare top
- Four each 4 in. sample ports with caps installed ½ diameter from top of flare stack at 90 degrees spacing for emissions testing if needed.
- One 4", 150# flanged waste gas connection for Case A warm gas stream. A 4" Enardo or equal deflagration flame arrester will be installed to this inlet with stainless steel Group D flame cell elements, drain, pressure, and temperature ports.
- One 4", 150# flanged gas connection for the Case B cryogenic gas stream. A 4" Enardo or equal deflagration flame arrester will be installed to this inlet with stainless steel Group D flame cell elements, drain, pressure, and temperature ports.
- One gas flow meter using a multivariable flow transmitter with Anubar or equal installed on the Case B cryogenic waste gas line.
- Two 4" butterfly valves with fail-close automatic control actuators in NEMA 7 enclosures. The valves will be installed at Case A and case B gas inlets to block gas flow during flare shutdowns.
- Two 4" butterfly valves with fail-open automatic control actuators in NEMA 7 enclosures. The valves will be installed to the emergency vent line at Case A and Case B gas inlets to divert gas to a 4" vent pipe outside the flare stack during flare shutdown.
- One vent gas flame arrester installed at the end of the emergency vent stack
- One 8 ft. wide by 10 ft. long structural steel skid with pipe rack to mount the flare inlet piping, valves, pilot fuel train and associated system controls and instrumentations. All equipment wiring will be terminated to a junction box with terminal strip for ease of field installation
- Flare stack and all the flare carbon steel components will be sandblasted, and painted with two coats of Sherwin William Zinc Clad II high zinc galvanizing paint system.

- Axial air blower mounted to the side of the stack and connected to the flare air-assisted burner to provide purge and combustion air. The combustion air blower will be driven by 20 HP, 460 Volts, 3 phase, TEFC electric motor.

2. One self-standing control rack including:

- Flare controller mounted in a NEMA 4X enclosure. Controller will automatically light the intermittent pilot which will light the continuous pilots and maintain the flare operation. The continuous pilots will be monitored by two type "K" thermocouples at the flare burner. The thermocouples will sense the pilot flame and trigger the intermittent pilot to relight the flare should the temperature drop to a minimum control setting. The air blower will continue to run as long as the flare operation is maintained.
- Gas flow signals for Case A or Case B waste gas streams will be utilized to control the air blower speed and provide air to gas mixture ratio based on the waste gas flow and waste gas stream type reference (gas heating value signals will be advantageous for the system to control the assist air needed during flare operation for improved combustion efficiency).
- Optimum combustion temperature will be maintained through the control of the air louvers. Induced natural draft air flow will maintain the flare stack temperature to the desired operator selected set point.
- Control interface signals will be available for client use including flare status, flare temperature, flare alarm and command signals to start or stop the flare. Additional signals identified during submittals can be communicated using MODBUS or hard wired contacts
- Two high temperature alarm sensors installed at the gas inlets to turn off the air assist blower and trigger an alarm in case of higher temperature or flame flash back.
- A flare stack high temperature alarm is provided to shut the flare down should the temperature exceed the allowable operational setting.
- Alarm contacts for the flare will be available for remote monitoring.
- One air blower motor variable frequency drive (VFD) with harmonic filters and circuit protection disconnect breaker in a NEMA 4X outdoor rated enclosure.
- Control system to be UL inspected and certified.
- 460 Volts three phase power is required to operate the flare controls and air blower.
- One 460VAC to 120VAC control power transformer with circuit protection for control panel.

3. One set of flare spare parts including:

a. Parts recommended (~3-5 months):

- (2) Spark plugs – ESPI64 80.00/ea

- (2) U.V. flame detectors-EUVSNRA 295.00/ea
- (2) Pilot gas thermocouples- 376.00/ea
- (2) Flare stack thermocouples- ETCA20W24IK 350.00/ea
- (2) Tubes of air blower bearing grease- GREASE-SHC100 15.00/ea

b. Parts could be considered Capital Spares:

- (1) Digital I/O card- EPLCIO20I12O 303.50/ea
- (1) Analog I/O card- EPLCAMOD4I2O 517.00/ea
- (1) Bases for I/O cards- EPLCIOMNT 82.00/ea
- (1) T/C card- EPLCTCMOD7I 763.50/ea
- (1) Base for T/C card- EPLCTCMNT 87.50/ea
- (1) PLC power supply- EPLCPWRSPLY 91.00/ea
- (1) DC power supply- EPS120V55W 312.00/ea

Technical Notes:

1. Clean fuel gas supply to flare pilot at a supply pressure between 40-60 psig is required during flare operation.
2. Estimated shipping weight of flare is 30,000 lbs.
3. Estimated shipping weight of piping skid and control rack is 4,500 lbs.
4. Flare is designed to operate in automatic unattended mode; however, it is recommended that operator be present to monitor system during start-up.
5. A properly designed liquid removal system must be in place upstream of the flare system for reliable operation.
6. The flare system must be supplied power from a stable energy source with a voltage deviation of no more than 7%.

B. Budgetary Price Schedule:

LFG Specialties Enclosed Flare System as described in Section A, items 1 and 2 FOB Findlay, OH, excluding tax, is

Five days of start-up assistance and training (travel and living expenses are included)

*NOTE: Should the system not be commissioned by LFG Specialties, the warranty will be void.

Options:

LFG Specialties Enclosed Flare System spare parts as described in Section A, item 3 FOB Findlay, OH, excluding tax, is

Parts recommended (~3-5 months)

- (2) Spark plugs – ESPI64
- (2) U.V. flame detectors-EUVSNRA
- (2) Pilot gas thermocouples
- (2) Flare stack thermocouples- ETCA20W24IK
- (2) Tubes of air blower bearing grease- GREASE-SHC100

Parts could be considered Capital Spares

- (1) Digital I/O card- EPLCIO20I12O
- (1) Analog I/O card- EPLCAMOD4I2O
- (1) Bases for I/O cards- EPLCIOMNT
- (1) T/C card- EPLCTCMOD7I
- (1) Base for T/C card- EPLCTCMNT
- (1) PLC power supply- EPLCPWRSPLY
- (1) DC power supply- EPS120V55W

Extended warranty until end of July 2019

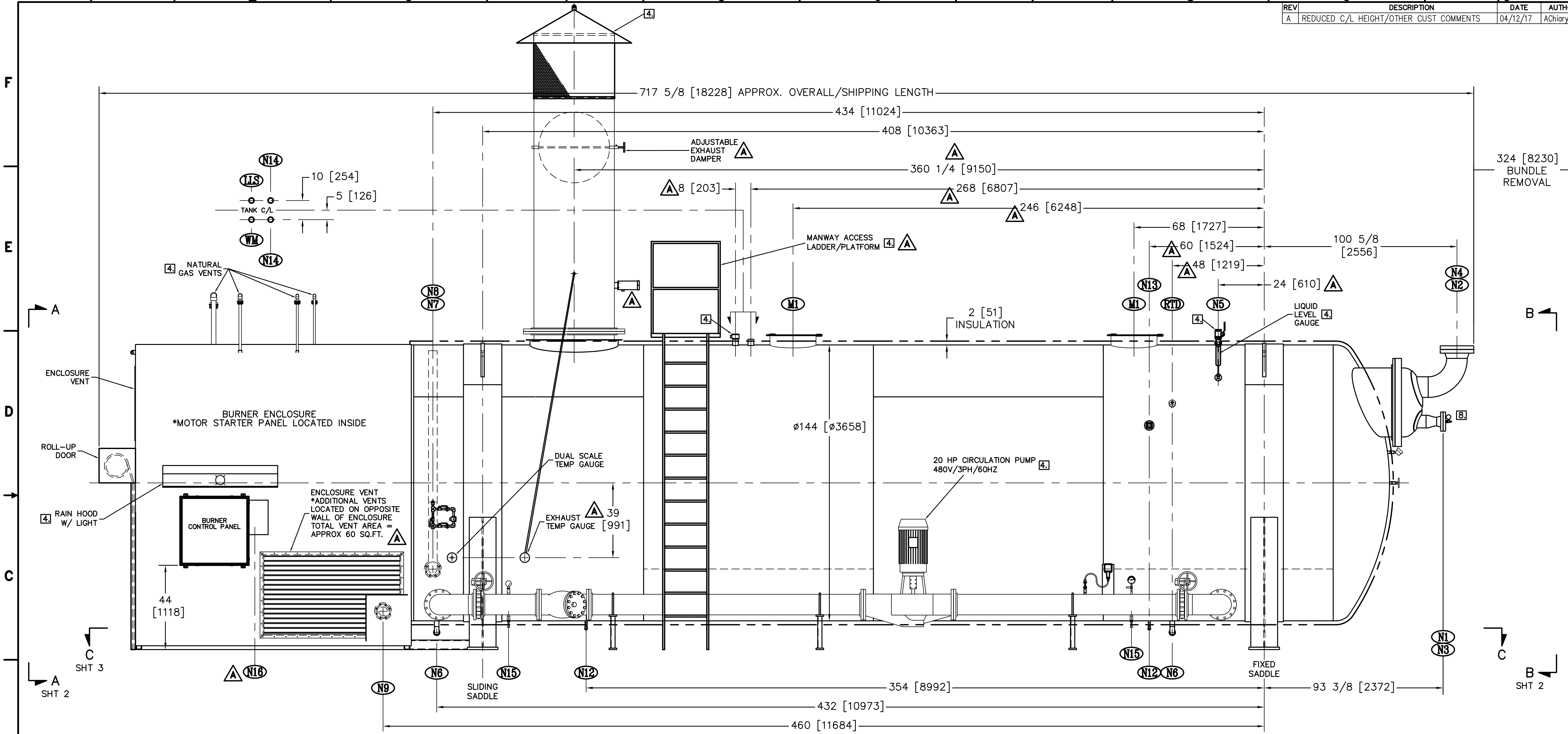
ALL PRICING IS FOB — FINDLAY, OHIO

C. Shipment Schedule:

LFG Specialties makes every effort to meet our Customers delivery requests and special requirements. Shipment for the flare system outlined in this Agreement is:

Submittal drawings:	4 weeks after receipt of PO
Equipment delivery:	16-18 weeks after receipt of submittals approval.

REV	DESCRIPTION	DATE	AUTHOR
A	REDUCED C/L HEIGHT/OTHER CUST COMMENTS	04/12/17	AChiary



*NOTES ON SHEET 3

CONNECTION SCHEDULE

NOZ.	SERVICE	SIZE	TYPE	RATING	lbF [N]	lb*ft [N*m]
N10	BURNER EXHAUST	42"	–	–	–	–
N9	NATURAL GAS INLET	4"	R.F.S.O. FLG.	150# ASME B16.5-2009	1773 [7888]	1145 [1551]
N8	TANK WATER MAKE-UP	1/2"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–
N7	TANK OVERFLOW	4"	R.F.S.O. FLG.	150# ASME B16.5-2009	1773 [7888]	1145 [1551]
N6	TANK DRAIN W/ VALVE (2)	2"	N.P.T.F.	150# W.O.G.	–	–
N5	TANK FILL W/ VALVE	2"	N.P.T.F.	150# W.O.G.	–	–
N4	PROCESS OUTLET	10"	R.F.W.N. FLG.	300# ASME B16.5-2009	3213 [14292]	1893 [2385]
N3	PROCESS INLET	4"	R.F.W.N. FLG.	300# ASME B16.5-2009	1773 [7888]	1145 [1551]
N2	PROCESS OUTLET	10"	R.F.W.N. FLG.	300# ASME B16.5-2009	3213 [14292]	1893 [2385]
N1	PROCESS INLET	4"	R.F.W.N. FLG.	300# ASME B16.5-2009	1773 [7888]	1145 [1551]

NOZ.	SERVICE	SIZE	TYPE	RATING	lbF [N]	lb*ft [N*m]
LLS	BURNER WARNING/SHUTDOWN SW.	2"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–
WM	WATER MAKE-UP ON/OFF SW.	2"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–
M1	MANWAY/VENTS (2)	24"	–	–	–	–
N16	Z-PURGE INSTRUMENT AIR PORT	1/4"	TUBE	TUBE COMPRESSION FITTING	–	–
N15	PUMP DRAIN W/ LOCKING VALVE (2)	1/4"	N.P.T.F.	3000# W.O.G.	–	–
N14	SPARE (2)	2"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–
N13	SPARE INSTRUMENT PORT	1 1/2"	R.F.S.O. FLG.	150# ASME B16.5-2009	443 [1969]	260 [352]
N12	COMBUSTION CHAMBER DRAIN W/VALVE (2)	1/2"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–
N11	EXHAUST SAMPLE PORT	3/4"	N.P.T.F.	3000# CPLG. B16.11-2011	–	–

MAXIMUM ALLOWABLE PIPING LOAD COMBINATIONS (THERMAL EXPANSION, DEAD WEIGHT AND SEISMIC MOVEMENT) SHALL NOT EXCEED THE FOLLOWING RELATIONSHIP FOR EACH NOZZLE:

$$\frac{F_I}{F_O} + \frac{M_I}{M_O} \leq 1$$

WHERE FI (LBS) IS THE MAXIMUM OF THE THREE ORTHOGONAL FORCES (Fx, Fy, Fz) AND MI (FT. LBS) IS THE MAXIMUM OF ANY OF THE THREE ORTHOGONAL MOMENTS (Mx, My, Mz) FOR THE SAME REFERENCE COORDINATES.

DO NOT SCALE DRAWING

INTERPRET DRAWING IN ACCORDANCE WITH DOD-STD-100

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

DECIMALS	ANGLES
.X ± .1	± 1°
.XX ± .03	FRACTIONS
.XXX ± .010	± 1"[25]

THIRD ANGLE PROJECTION

CONTRACT NUMBER

SIGNATURES		DATE
DRAWN	A.CHIARY	03/09/17
CHECK		
ENGR		
APPD		

APPROVED

FILE NAME: 500007001.DWG

CRYOQUIP MURRIETA, CA 92562 USA

OUTLINE, VFTU-21-2886-11C-35, GAS FIRED WATER BATH VAPORIZER

SIZE B | 7X733 | DWG NO 50000700 | REV A

CAD REF. SCALE 1/48 | WEIGHT | SHEET 1 OF 3

SEE SEPARATE BOM FOR PARTS LIST

DWG NO. 50000700 SHEET 1 REV A

CAD ORIGINATED DRAWING. REVISION UPDATES RESTRICTED TO CAD SYSTEM ONLY. NO MANUAL UPDATES.

NOTICE: THIS DRAWING IS A PRINTED VERSION OF AN ELECTRONIC RECORD AND SERVES AS AN ILLUSTRATION TO THE ELECTRONIC LIST OF MATERIALS (LM). THE LM GOVERNS FOR ANY CONFLICT BETWEEN THE DRAWING AND THE LM. THE LM RECORD REFERENCES THE LATEST REVISION LEVEL FOR BOTH THE LM AND THE DRAWING. THE REVISION OF THE DRAWING RECORD AND THE LM RECORD MAY BE DIFFERENT. PRINTED LM OR DRAWING COPIES MUST BE VERIFIED WITH THE ELECTRONIC VERSION AND REVISION LEVEL BEFORE USE.
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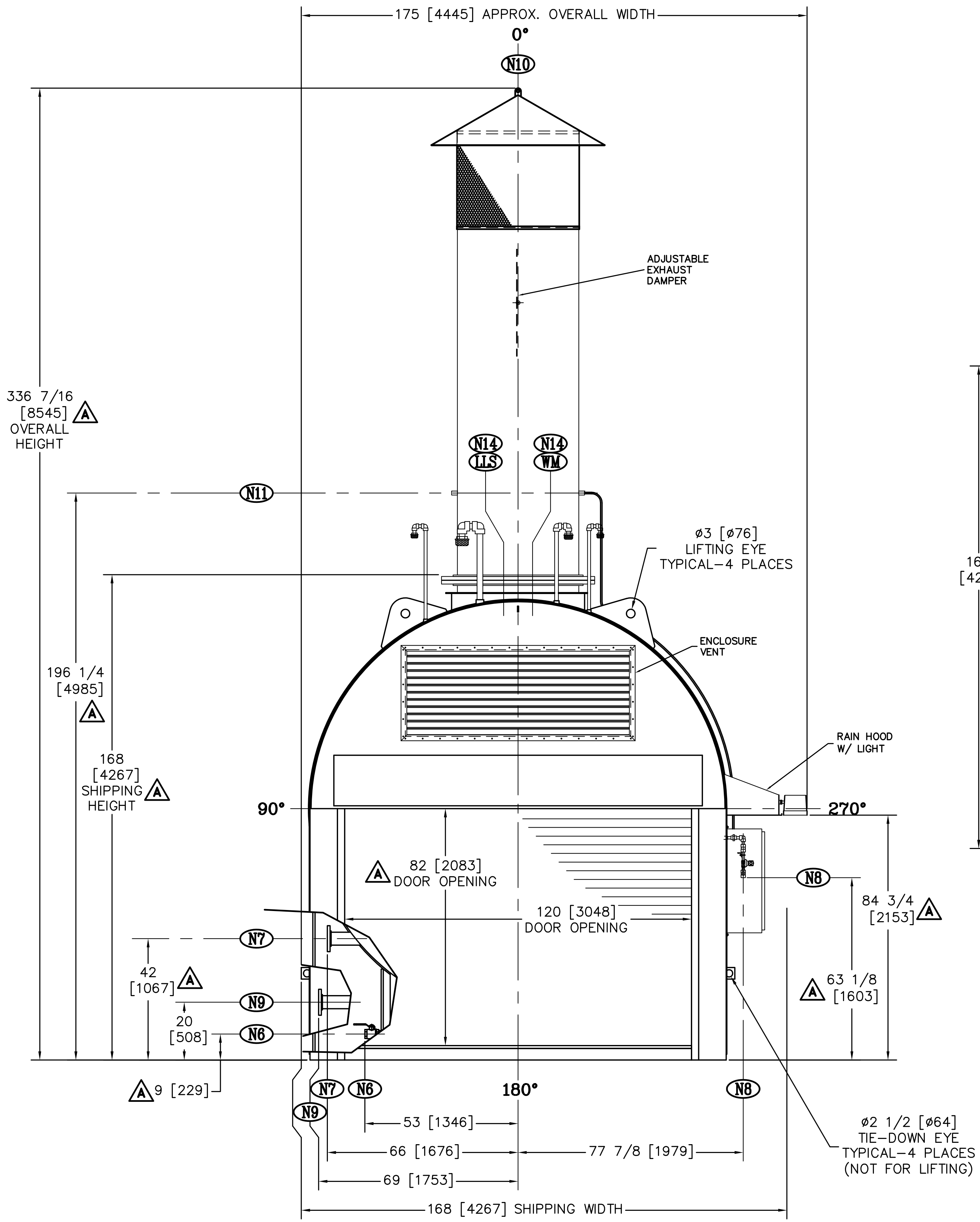
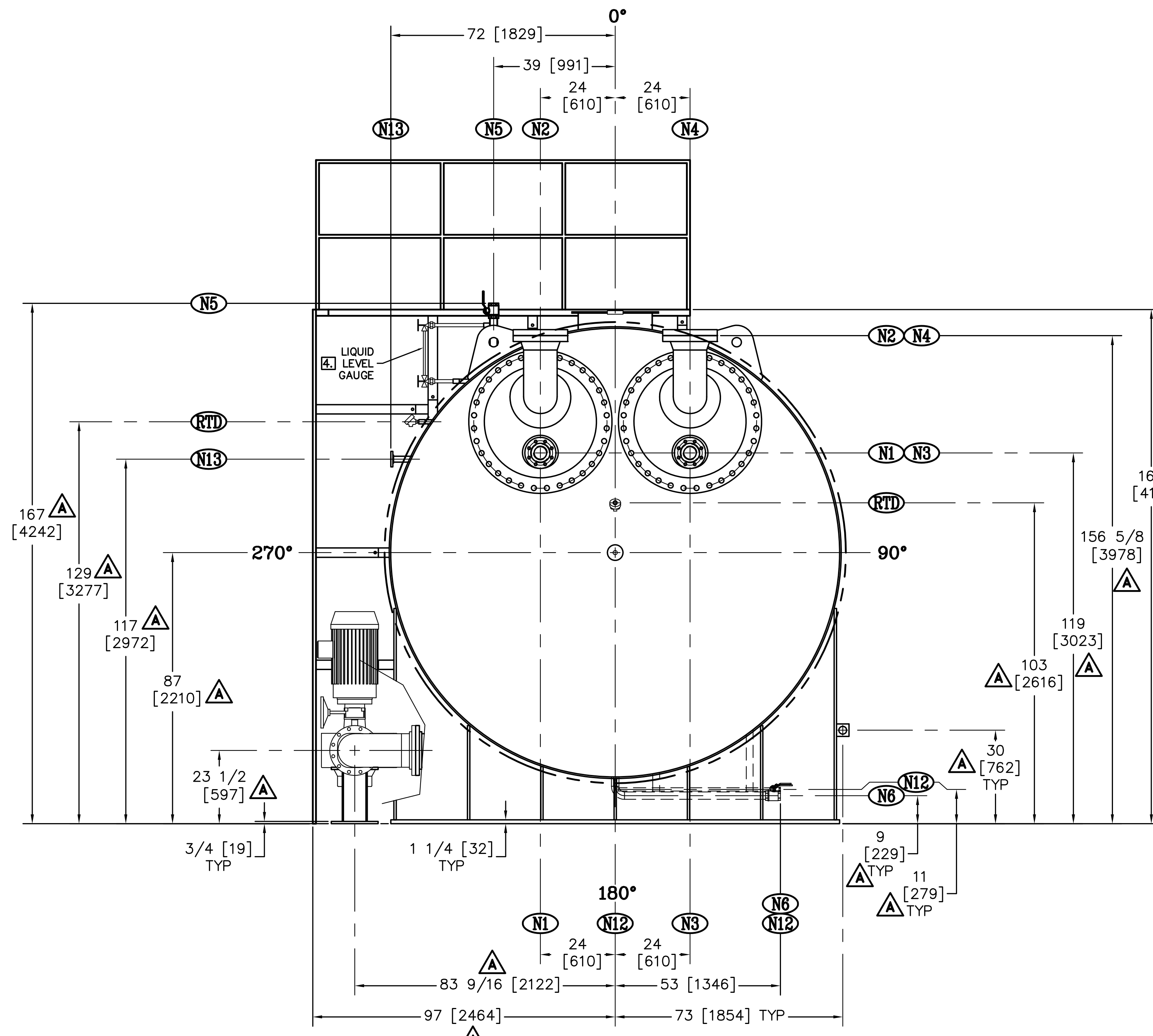
REV	DESCRIPTION	DATE	AUTHOR
A	SEE SHEET 1	04/12/17	AChiary

DWG NO. 50000700 SHEET 2 REV A



VIEW A–A



VIEW B–B

CAD ORIGINATED DRAWING. REVISION UPDATES RESTRICTED TO CAD SYSTEM ONLY. NO MANUAL UPDATES.

DO NOT SCALE DRAWING	CONTRACT NUMBER			CRYOQUIP MURRIETA, CA 92562 USA
INTERPRET DRAWING IN ACCORDANCE WITH DOD–STD–100	SIGNATURES		DATE	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	DRAWN	A.CHIARY	03/09/17	OUTLINE, VFTU–21–2886–1IC–35, GAS FIRED WATER BATH VAPORIZER
TOLERANCES ON DECIMALS .X ± .1 .XX ± .03 .XXX ± .010 ANGLES ± 1° FRACTIONS ± 1"[25]	CHECK			
	ENGR			
	APPD			
	APPROVED			SIZE B 7X733 DWG NO 50000700 REV A
THIRD ANGLE PROJECTION	FILE NAME: 500007001.DWG			CAD REF. SCALE 1/42 WEIGHT SHEET 2 OF 3

SEE SEPARATE BOM FOR PARTS LIST

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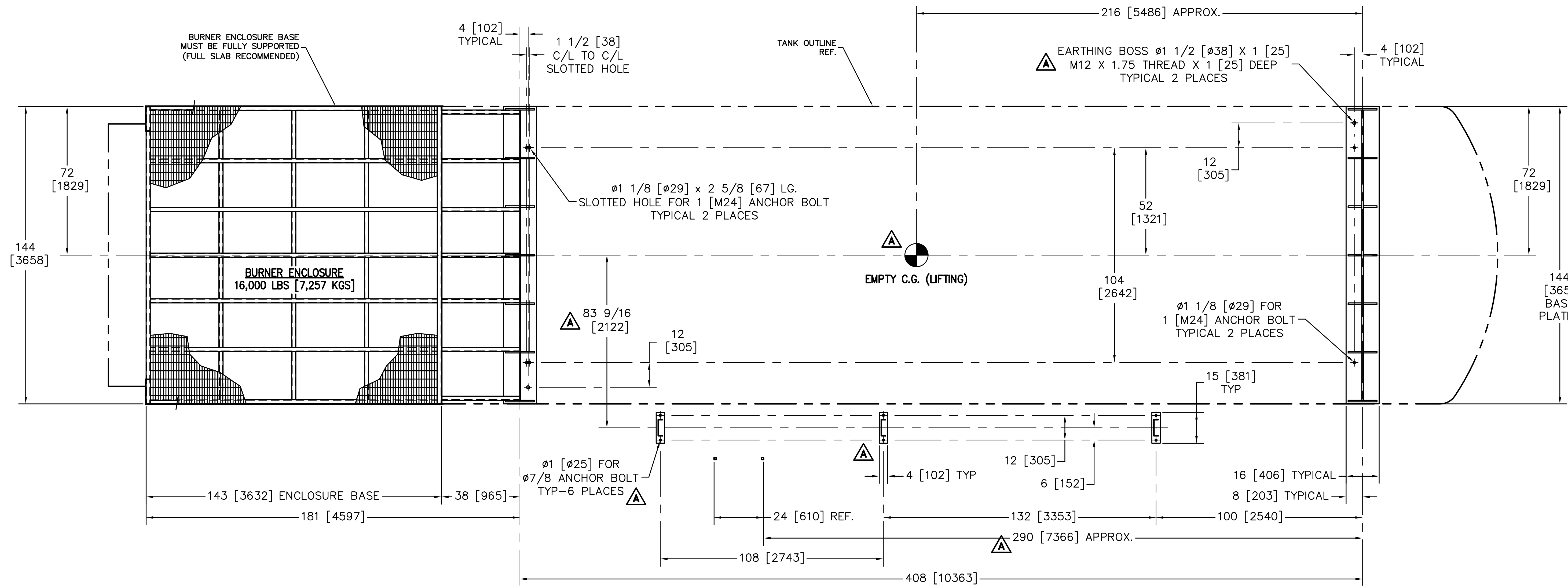
REV	DESCRIPTION	DATE	AUTHOR
A	SEE SHEET 1	04/12/17	AChiary



SLIDING SADDLE
84,893 LB [38,507 KG] EMPTY WEIGHT (LIFTING)
182,542 LBS [82,800 KGS] OPERATING WEIGHT

MAXIMUM FOUNDATION LOADS
WIND SHEAR: 5,821 LB
WIND MOMENT: 42,202 FT*LB
SEISMIC SHEAR: 82,172 LB
SEISMIC MOMENT: 595,747 FT*LB

SECTION C–C
FOUNDATION & LOADING
160,175 LB [72,654 KG] EMPTY WEIGHT
392,375 LB [177,978 KG] OPERATING WEIGHT

FIXED SADDLE
75,282 LB [34,147 KG] EMPTY WEIGHT (LIFTING)
193,833 LB [87,921 KG] OPERATING WEIGHT

MAXIMUM FOUNDATION LOADS
WIND SHEAR: 5,821 LB
WIND MOMENT: 42,202 FT*LB
SEISMIC SHEAR: 82,172 LB
SEISMIC MOMENT: 595,747 FT*LB

NOTES:

1. FLANGE BOLT HOLES STRADDLE CENTERLINES.
2. TANK WATER VOLUME: 35,000 GAL [132,489 L] GROSS.
3. APPROXIMATE VAPORIZER WEIGHT:
   VWU-362 = 9,370 LBS [4,250 KGS] EMPTY (EACH)
   TOTAL EMPTY: 160,175 LBS [72,654 KG]
   TOTAL FULL W/ WATER: 392,375 LBS [177,978 KG]
4. ITEMS REMOVED FOR SHIPPING.
5. DIMENSIONS IN [ ] ARE IN MILLIMETERS.
6. ALL EXTERIOR CARBON STEEL SURFACES SHALL BE SANDBLASTED, PRIMED AND FINISH PAINTED PER CRYOQUIP SPEC SP-09-26, COLOR GRAY.
7. DESIGN DATA: TUBEBUNDLES: ASME SECT VIII, DIV. 1, "U" STAMP & TEMA "R"
   VWU-362 : +420 PSIG [29 BARG] @ -320/+212°F (-196/+100°C).
8. TUBEBUNDLES TO BE PURGED WITH 5/10 PSI NITROGEN FOR SHIPPING. WARNING SIGN INDICATING PURGED BUNDLE SUPPLIED.
9. TANK DESIGN PRESSURE/TEMPERATURE = ATMOSPHERIC @ -20/212°F (-29/100°C)
10. FOUNDATION LOADS CALCULATED USING ASCE-7 2010 DESIGN CODE WITH THE FOLLOWING PARAMETERS:
    WIND: 118 MPH, CATEGORY D, IMPORTANCE FACTOR 1.0
    SEISMIC: SITE CLASS D, IMPORTANCE FACTOR 1.25
    Sds = 0.8, Sd1 = 0.48
11. ALL COMPONENTS SHALL BE DESIGNED AND RATED TO NEC 500, CLASS 1, DIV. 2, GROUP C/D CLASSIFIED AREA.

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DECIMALS: .X ± .1 / .XX ± .03 / .XXX ± .010
ANGLES: ± 1°
FRACTIONS: ± 1"[25]
THIRD ANGLE PROJECTION

CONTRACT NUMBER

SIGNATURES		DATE
DRAWN	A.CHIARY	03/09/17
CHECK		
ENGR		
APPD		
APPROVED		

FILE NAME: 500007001.DWG

CRYOQUIP MURRIETA, CA 92562 USA

OUTLINE, VFTU-2I-2886-1IC-35, GAS FIRED WATER BATH VAPORIZER

SIZE B | 7X733 | DWG NO 50000700 | REV A
CAD REF. SCALE 1/48 | WEIGHT | SHEET 3 OF 3
SEE SEPARATE BOM FOR PARTS LIST

DWG NO. 50000700 | SHEET 3 | REV A

CAD ORIGINATED DRAWING. REVISION UPDATES RESTRICTED TO CAD SYSTEM ONLY. NO MANUAL UPDATES.

Sub Supplier List					
Supplier Name	**Scope of Supply**	**Address**	**Phone Number**	**Fax Number**	**Website**
Industrial Combustion	Natural Gas Burner System	351 21st St., Monroe, WI 53566	608.325.3141	608.325.4379	ind-comb.com

50000798

REVISIONS

CRYOQUIP LLC.
MURRIETA, CALIFORNIA

ITEM	VAPORIZER	FLUID	LNG
MODEL	VFTU-2I-2886-1IC-35	MAWP	420 PSIG
RATING	2,886,000 SCFH	K.W.	–
P/N	50000701–1	AMPS	150
S/N	500007–1–1	VOLTS	480
YEAR	2017	PHASE	3

BLANK P/N 190946–1

ORIGINAL DATE OF DRAWING:	04/05/17	DATA NAMEPLATE	CRYOQUIP MURRIETA, CALIFORNIA
DRAWN:	A.CHIARY		DWG.50000798 .
CHECKED:			SHEET 1 OF 1
APPROVAL:			

EF–50

INDUSTRIAL COMBUSTION

Customer:	Cryoquip	**Job Name:**	Tacoma
		Date:	May 9, 2017
		By:	Eng
Burner Model:	MTH-660		
Max. Firing Rate:	66.0 mmBTU/hr		
Gas Flow:	66,000 scfh		
Fuel:	Natural Gas		

Application Details:

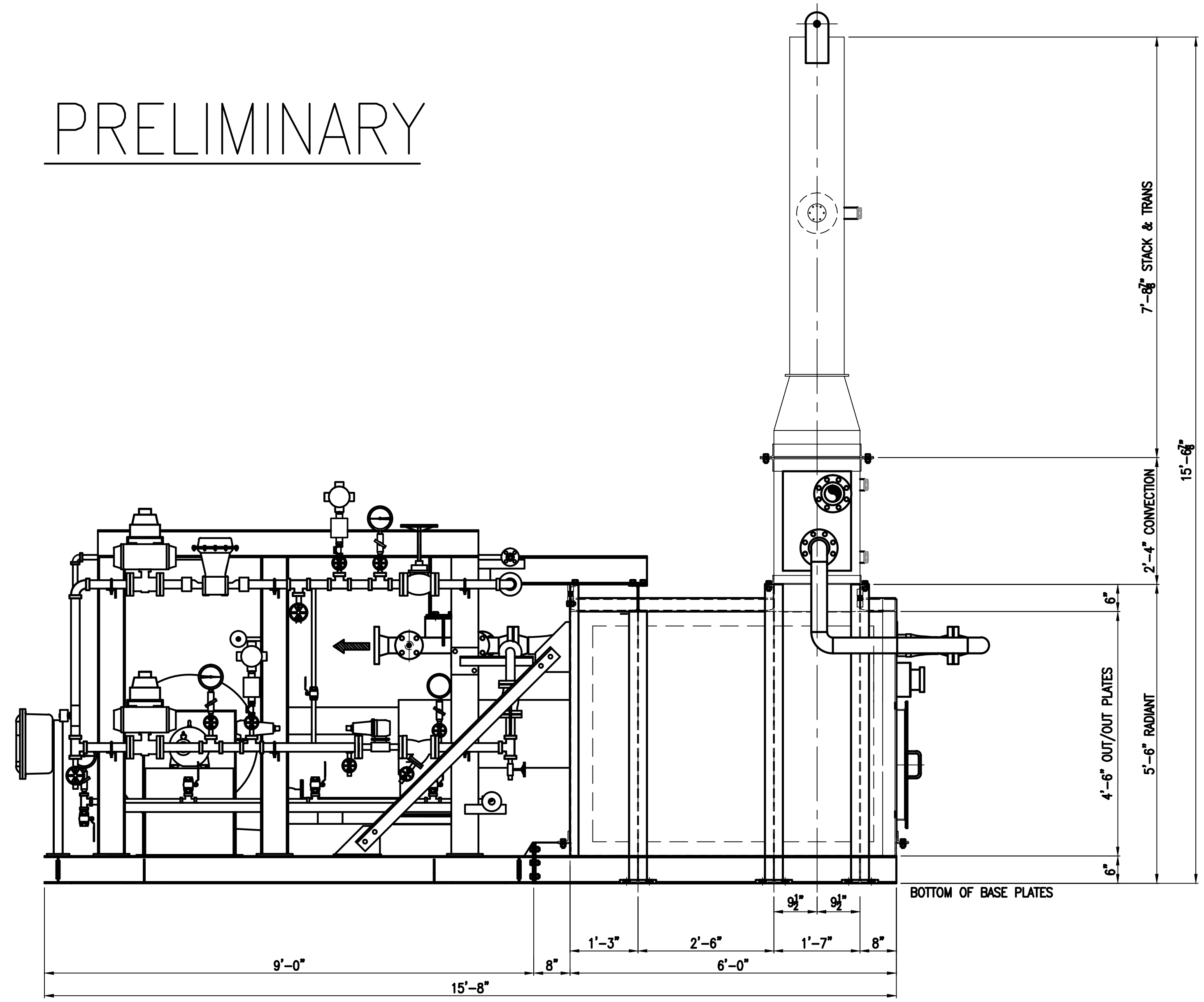
	ppm-vol.dry (at 3% O2)	Pounds per 1,000,000 BTU's	TOTAL Pounds / Hour @ 100% Firing Rate
PM-10 (Particulate)	--	0.0076	**0.502**
CO (Carbon Monoxide)	50	0.0370	**2.440**
SOx (<18 ppm Sulfur in Fuel)	1	0.0017	**0.112**
VOC (Non-Methane)	--	0.0055	**0.363**
NOx (Nitrogen Compounds)	9	0.0109	**0.721**
CO2 (Carbon Dioxide)	--	114.75	**7,574**
H2O (Water)	--	91.35	**6,029**

Based on AP-42 (table 1.4-2)

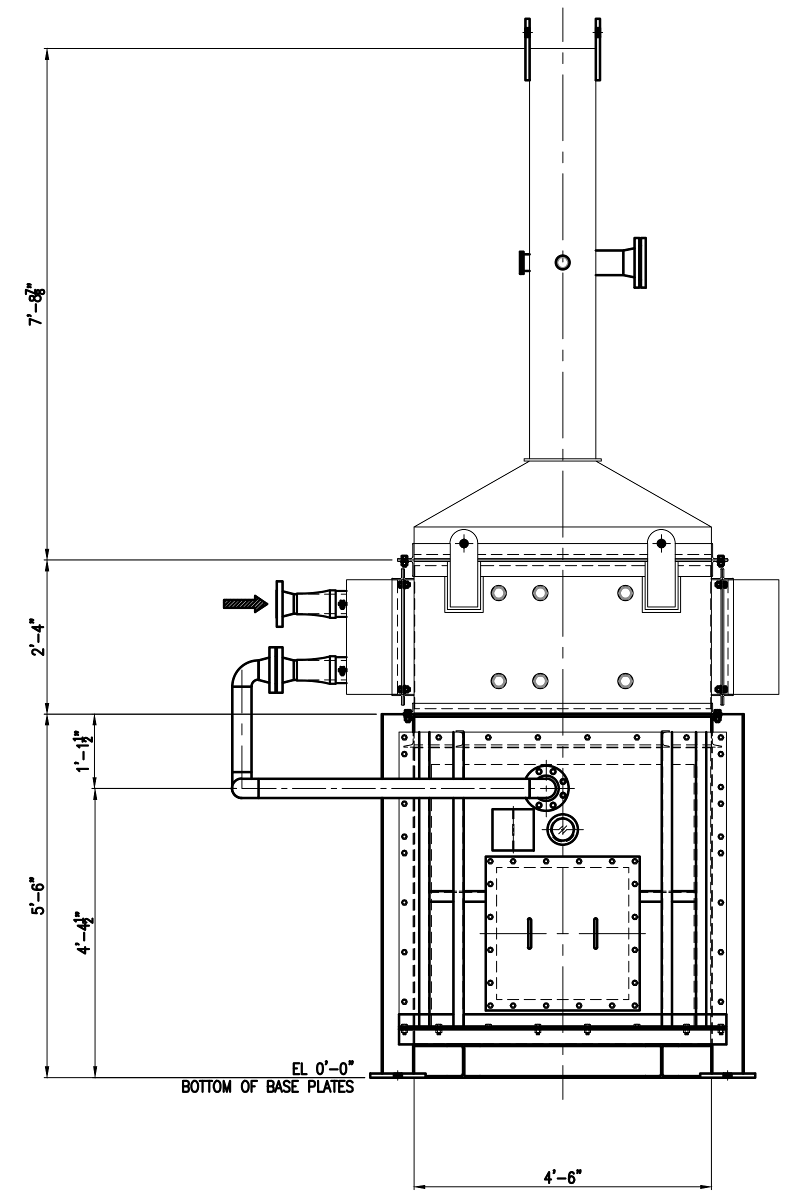
Based on AP-42 (table 1.4-2)

Based on AP-42 (table 1.4-2)

PRELIMINARY



SIDE ELEVATION



ARCH END VIEW

PROPRIETARY INFORMATION

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Customer:

LOCATION :
UNIT :
SERVICE :
EQUIPMENT No. :
P.O. No. :

Rev.	Date	By	Revision Description

THM TULSA HEATERS MIDSTREAM

Title: GENERAL ARRANGEMENT			
Drawn By: GP	Date: 11/5/15	Job No.:	
Checked By	Date	Drawing No.: SHO 100	Rev.: 0
Approved By	Certified By		

PERFORMANCE DATA[DM8260]

October 17, 2014

Performance Number: DM8260 **Change Level: 04**

SALES MODEL:	3512C
ENGINE POWER (BHP):	2,206
GEN POWER WITH FAN (EKW):	1,500.0
COMPRESSION RATIO:	14.7
RATING LEVEL:	STANDBY
PUMP QUANTITY:	2
FUEL TYPE:	DIESEL
MANIFOLD TYPE:	DRY
GOVERNOR TYPE:	ADEM3
ELECTRONICS TYPE:	ADEM3
CAMSHAFT TYPE:	STANDARD
IGNITION TYPE:	CI
INJECTOR TYPE:	EUI
FUEL INJECTOR:	2664387
UNIT INJECTOR TIMING (IN):	64.34
REF EXH STACK DIAMETER (IN):	10
MAX OPERATING ALTITUDE (FT):	3,937
COMBUSTION:	DI
ENGINE SPEED (RPM):	1,800
HERTZ:	60
FAN POWER (HP):	88.5
ASPIRATION:	TA
AFTERCOOLER TYPE:	ATAAC
AFTERCOOLER CIRCUIT TYPE:	JW+OC, ATAAC
INLET MANIFOLD AIR TEMP (F):	122
JACKET WATER TEMP (F):	210.2
TURBO CONFIGURATION:	PARALLEL
TURBO QUANTITY:	4
TURBOCHARGER MODEL:	GTB4708BN-52T-0.96
CERTIFICATION YEAR:	2006
CRANKCASE BLOWBY RATE (FT3/HR):	2,203.4
FUEL RATE (RATED RPM) NO LOAD (GAL/HR):	9.9
PISTON SPD @ RATED ENG SPD (FT/MIN):	2,244.1

INDUSTRY	SUBINDUSTRY	APPLICATION
OIL AND GAS	LAND PRODUCTION	PACKAGED GENSET
ELECTRIC POWER	STANDARD	PACKAGED GENSET

General Performance Data

GENSET POWER WITH FAN	PERCENT LOAD	ENGINE POWER	BRAKE MEAN EFF PRES (BMEP)	BRAKE SPEC FUEL CONSUMPTN (BSFC)	VOL FUEL CONSUMPTN (VFC)	INLET MFLD PRES	INLET MFLD TEMP	EXH MFLD TEMP	EXH MFLD PRES	ENGINE OUTLET TEMP
EKW	%	BHP	PSI	LB/BHP-HR	GAL/HR	IN-HG	DEG F	DEG F	IN-HG	DEG F
1,500.0	100	2,206	307	0.332	104.6	77.5	120.9	1,145.6	74.6	759.0
1,350.0	90	1,983	276	0.336	95.2	72.2	116.1	1,102.7	68.8	726.8
1,200.0	80	1,768	246	0.343	86.6	66.9	113.2	1,069.1	63.1	708.7
1,125.0	75	1,662	232	0.346	82.0	63.4	111.5	1,052.3	59.5	700.6
1,050.0	70	1,556	217	0.348	77.4	59.7	109.8	1,035.3	55.8	693.6
900.0	60	1,349	188	0.352	67.9	51.1	107.1	1,000.5	47.6	682.5
750.0	50	1,144	159	0.355	58.1	40.6	107.5	963.7	38.4	686.4
600.0	40	940	131	0.359	48.2	30.0	108.4	921.9	29.4	686.0
450.0	30	736	103	0.368	38.6	20.9	107.1	856.1	21.9	667.6
375.0	25	632	88	0.376	33.9	16.9	106.2	809.6	18.8	648.1
300.0	20	527	73	0.388	29.2	13.3	105.2	754.6	16.0	621.1
150.0	10	312	43	0.443	19.7	7.3	103.2	609.7	11.4	526.2

GENSET POWER WITH FAN	PERCENT LOAD	ENGINE POWER	COMPRESSOR OUTLET PRES	COMPRESSOR OUTLET TEMP	WET INLET AIR VOL FLOW RATE	ENGINE OUTLET WET EXH GAS VOL FLOW RATE	WET INLET AIR MASS FLOW RATE	WET EXH GAS MASS FLOW RATE	WET EXH VOL FLOW RATE (32 DEG F AND 29.98 IN HG)	DRY EXH VOL FLOW RATE (32 DEG F AND 29.98 IN HG)
EKW	%	BHP	IN-HG	DEG F	CFM	CFM	LB/HR	LB/HR	FT3/MIN	FT3/MIN
1,500.0	100	2,206	82	449.8	4,570.7	10,909.2	20,179.4	20,912.0	4,401.2	3,984.7
1,350.0	90	1,983	77	428.8	4,387.3	10,167.0	19,354.1	20,020.6	4,213.1	3,825.4
1,200.0	80	1,768	71	409.0	4,190.2	9,533.7	18,456.0	19,062.3	4,012.0	3,655.5
1,125.0	75	1,662	68	396.6	4,062.8	9,156.1	17,861.1	18,435.5	3,879.9	3,539.6
1,050.0	70	1,556	64	382.7	3,917.6	8,750.8	17,185.6	17,727.5	3,730.8	3,407.5
900.0	60	1,349	55	350.3	3,576.3	7,863.4	15,607.1	16,082.3	3,384.9	3,097.2
750.0	50	1,144	44	309.9	3,132.5	6,856.9	13,608.7	14,015.1	2,941.7	2,693.8
600.0	40	940	33	266.6	2,669.6	5,821.5	11,547.1	11,884.6	2,498.4	2,290.8
450.0	30	736	23	224.6	2,255.4	4,830.1	9,719.1	9,989.4	2,106.6	1,937.5
375.0	25	632	19	204.3	2,072.0	4,354.9	8,915.9	9,153.2	1,932.9	1,782.3
300.0	20	527	15	184.3	1,901.9	3,888.6	8,175.8	8,380.0	1,769.0	1,636.5
150.0	10	312	9	148.8	1,629.0	3,012.8	6,991.2	7,129.2	1,502.5	1,404.3

Heat Rejection Data

GENSET POWER WITH FAN	PERCENT LOAD	ENGINE POWER	REJECTION TO JACKET WATER	REJECTION TO ATMOSPHERE	REJECTION TO EXH	EXHUAST RECOVERY TO 350F	FROM OIL COOLER	FROM AFTERCOOLER	WORK ENERGY	LOW HEAT VALUE ENERGY	HIGH HEAT VALUE ENERGY
EKW	%	BHP	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN
1,500.0	100	2,206	35,045	7,072	75,190	35,916	11,958	27,337	93,547	224,502	239,151
1,350.0	90	1,983	32,811	6,707	68,272	31,548	10,884	24,908	84,110	204,338	217,671
1,200.0	80	1,768	30,708	6,394	62,804	28,510	9,899	22,371	74,958	185,849	197,976
1,125.0	75	1,662	29,571	6,250	59,771	26,919	9,378	20,805	70,466	176,063	187,551
1,050.0	70	1,556	28,384	6,110	56,659	25,337	8,847	19,142	66,004	166,092	176,930
900.0	60	1,349	25,881	5,841	50,233	22,204	7,761	15,544	57,205	145,705	155,213
750.0	50	1,144	23,184	5,565	43,580	19,571	6,637	11,412	48,509	124,605	132,736
600.0	40	940	20,363	5,287	36,864	16,564	5,513	7,503	39,882	103,503	110,257
450.0	30	736	17,435	4,840	29,997	13,124	4,417	4,600	31,201	82,927	88,339
375.0	25	632	15,907	4,570	26,510	11,255	3,877	3,492	26,809	72,781	77,530
300.0	20	527	14,318	4,299	22,979	9,339	3,336	2,570	22,353	62,636	66,723
150.0	10	312	10,869	3,818	15,812	5,101	2,253	1,253	13,214	42,305	45,066

PERFORMANCE DATA[DM8260]

October 17, 2014

Emissions Data

RATED SPEED POTENTIAL SITE VARIATION: 1800 RPM

GENSET POWER WITH FAN		EKW	1,500.0	1,125.0	750.0	375.0	150.0
PERCENT LOAD		%	100	75	50	25	10
ENGINE POWER		BHP	2,206	1,662	1,144	632	312
TOTAL NOX (AS NO2)		G/HR	13,311	6,733	4,486	3,351	2,583
TOTAL CO		G/HR	1,745	1,092	1,544	1,806	1,733
TOTAL HC		G/HR	326	354	333	263	302
PART MATTER		G/HR	90.5	92.4	140.5	169.6	102.7
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	2,631.0	1,672.1	1,552.2	2,038.1	2,711.4
TOTAL CO	(CORR 5% O2)	MG/NM3	394.6	312.6	662.4	1,129.4	2,176.8
TOTAL HC	(CORR 5% O2)	MG/NM3	63.8	89.0	114.9	162.2	330.4
PART MATTER	(CORR 5% O2)	MG/NM3	16.8	22.3	50.7	100.7	105.3
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,282	814	756	993	1,321
TOTAL CO	(CORR 5% O2)	PPM	316	250	530	903	1,741
TOTAL HC	(CORR 5% O2)	PPM	119	166	215	303	617
TOTAL NOX (AS NO2)		G/HP-HR	6.09	4.09	3.95	5.33	8.34
TOTAL CO		G/HP-HR	0.80	0.66	1.36	2.88	5.59
TOTAL HC		G/HP-HR	0.15	0.22	0.29	0.42	0.97
PART MATTER		G/HP-HR	0.04	0.06	0.12	0.27	0.33
TOTAL NOX (AS NO2)		LB/HR	29.35	14.84	9.89	7.39	5.70
TOTAL CO		LB/HR	3.85	2.41	3.40	3.98	3.82
TOTAL HC		LB/HR	0.72	0.78	0.73	0.58	0.66
PART MATTER		LB/HR	0.20	0.20	0.31	0.37	0.23

RATED SPEED NOMINAL DATA: 1800 RPM

GENSET POWER WITH FAN		EKW	1,500.0	1,125.0	750.0	375.0	150.0
PERCENT LOAD		%	100	75	50	25	10
ENGINE POWER		BHP	2,206	1,662	1,144	632	312
TOTAL NOX (AS NO2)		G/HR	11,092	5,610	3,738	2,793	2,153
TOTAL CO		G/HR	969	607	858	1,003	963
TOTAL HC		G/HR	245	267	251	197	227
TOTAL CO2		KG/HR	1,012	791	557	324	186
PART MATTER		G/HR	64.7	66.0	100.4	121.1	73.3
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	2,192.5	1,393.4	1,293.5	1,698.4	2,259.5
TOTAL CO	(CORR 5% O2)	MG/NM3	219.2	173.7	368.0	627.4	1,209.3
TOTAL HC	(CORR 5% O2)	MG/NM3	48.0	66.9	86.4	121.9	248.4
PART MATTER	(CORR 5% O2)	MG/NM3	12.0	15.9	36.2	72.0	75.2
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,068	679	630	827	1,101
TOTAL CO	(CORR 5% O2)	PPM	175	139	294	502	967
TOTAL HC	(CORR 5% O2)	PPM	90	125	161	228	464
TOTAL NOX (AS NO2)		G/HP-HR	5.08	3.41	3.29	4.45	6.95
TOTAL CO		G/HP-HR	0.44	0.37	0.76	1.60	3.11
TOTAL HC		G/HP-HR	0.11	0.16	0.22	0.31	0.73
PART MATTER		G/HP-HR	0.03	0.04	0.09	0.19	0.24
TOTAL NOX (AS NO2)		LB/HR	24.45	12.37	8.24	6.16	4.75
TOTAL CO		LB/HR	2.14	1.34	1.89	2.21	2.12
TOTAL HC		LB/HR	0.54	0.59	0.55	0.44	0.50
TOTAL CO2		LB/HR	2,230	1,743	1,228	714	409
PART MATTER		LB/HR	0.14	0.15	0.22	0.27	0.16
OXYGEN IN EXH		%	10.4	11.6	12.3	13.3	15.3
DRY SMOKE OPACITY		%	1.0	1.3	2.9	5.0	3.0
BOSCH SMOKE NUMBER			0.37	0.45	1.06	1.60	1.11

Regulatory Information

EPA TIER 2		2006 - 2010		
GASEOUS EMISSIONS DATA MEASUREMENTS PROVIDED TO THE EPA ARE CONSISTENT WITH THOSE DESCRIBED IN EPA 40 CFR PART 89 SUBPART D AND ISO 8178 FOR MEASURING HC, CO, PM, AND NOX. THE "MAX LIMITS" SHOWN BELOW ARE WEIGHTED CYCLE AVERAGES AND ARE IN COMPLIANCE WITH THE NON-ROAD REGULATIONS.				
Locality	**Agency**	**Regulation**	**Tier/Stage**	**Max Limits - G/BKW - HR**
U.S. (INCL CALIF)	EPA	NON-ROAD	TIER 2	CO: 3.5 NOx + HC: 6.4 PM: 0.20

EPA EMERGENCY STATIONARY		2011 - ----		
GASEOUS EMISSIONS DATA MEASUREMENTS PROVIDED TO THE EPA ARE CONSISTENT WITH THOSE DESCRIBED IN EPA 40 CFR PART 60 SUBPART IIII AND ISO 8178 FOR MEASURING HC, CO, PM, AND NOX. THE "MAX LIMITS" SHOWN BELOW ARE WEIGHTED CYCLE AVERAGES AND ARE IN COMPLIANCE WITH THE EMERGENCY STATIONARY REGULATIONS.				
Locality	**Agency**	**Regulation**	**Tier/Stage**	**Max Limits - G/BKW - HR**
U.S. (INCL CALIF)	EPA	STATIONARY	EMERGENCY STATIONARY	CO: 3.5 NOx + HC: 6.4 PM: 0.20

Altitude Derate Data

ALTITUDE CORRECTED POWER CAPABILITY (BHP)

AMBIENT OPERATING TEMP (F)	30	40	50	60	70	80	90	100	110	120	130	140	NORMAL
ALTITUDE (FT)													
0	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,096	2,206
1,000	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,162	2,074	2,206
2,000	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,176	2,118	2,007	2,206
3,000	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,173	2,135	2,098	2,052	1,919	2,206
4,000	2,201	2,201	2,201	2,201	2,201	2,171	2,132	2,094	2,057	2,021	1,963	1,831	2,201
5,000	2,129	2,129	2,129	2,129	2,129	2,092	2,054	2,017	1,982	1,947	1,853	1,677	2,129
6,000	2,059	2,059	2,059	2,059	2,053	2,015	1,978	1,943	1,909	1,876	1,699	1,522	2,059
7,000	1,992	1,992	1,992	1,992	1,976	1,940	1,904	1,870	1,838	1,787	1,522	1,368	1,992
8,000	1,927	1,927	1,927	1,927	1,902	1,867	1,833	1,800	1,769	1,699	1,368	1,213	1,927
9,000	1,865	1,865	1,865	1,865	1,831	1,797	1,764	1,733	1,699	1,610	1,235	1,081	1,865
10,000	1,805	1,805	1,805	1,795	1,761	1,729	1,697	1,667	1,610	1,522	1,081	949	1,805
11,000	1,522	1,522	1,522	1,522	1,522	1,500	1,390	1,279	1,191	1,081	971	838	1,522
12,000	1,478	1,478	1,478	1,478	1,434	1,346	1,235	1,147	1,037	971	860	772	1,478
13,000	1,434	1,434	1,434	1,390	1,279	1,191	1,103	1,015	927	860	772	706	1,434
14,000	1,390	1,390	1,346	1,235	1,147	1,059	971	882	816	772	706	640	1,390
15,000	1,346	1,302	1,191	1,103	1,015	927	860	794	750	706	662	596	1,346

Cross Reference

Engine Arrangement			
Arrangement Number	Effective Serial Number	Engineering Model	Engineering Model Version
2673949	EBG00001	GS335	-
3869723	CT200001	GS656	LS

Test Specification Data						
Test Spec	Setting	Effective Serial Number	Engine Arrangement	Governor Type	Default Low Idle Speed	Default High Idle Speed
0K7015	GG0288	EBG00001	2673949	ADEM3		
4183066	GG0760	CT200001	3869723	ADEM3		

Supplementary Data

Type	Classification	Performance Number
SOUND	SOUND PRESSURE	DM8779

General Notes

General Notes DM8260 - 04
SOUND PRESSURE DATA FOR THIS RATING CAN BE FOUND IN PERFORMANCE NUMBER - DM8779

Performance Parameter Reference

Parameters Reference:DM9600-06
PERFORMANCE DEFINITIONS

PERFORMANCE DEFINITIONS DM9600

APPLICATION:
Engine performance tolerance values below are representative of a typical production engine tested in a calibrated dynamometer test cell at SAE J1995 standard reference conditions. Caterpillar maintains ISO9001:2000 certified quality management systems for engine test Facilities to assure accurate calibration of test equipment. Engine test data is corrected in accordance with SAE J1995. Additional reference material SAE J1228, J1349, ISO 8665, 3046-1:2002E, 3046-3:1989, 1585, 2534, 2288, and 9249 may apply in part or are similar to SAE J1995. Special engine rating request (SERR) test data shall be noted.

PERFORMANCE PARAMETER TOLERANCE FACTORS:

Power	+/- 3%
Torque	+/- 3%
Exhaust stack temperature	+/- 8%
Inlet airflow	+/- 5%
Intake manifold pressure-gage	+/- 10%
Exhaust flow	+/- 6%
Specific fuel consumption	+/- 3%
Fuel rate	+/- 5%
Specific DEF consumption	+/- 3%
DEF rate	+/- 5%
Heat rejection	+/- 5%
Heat rejection exhaust only	+/- 10%
Heat rejection CEM only	+/- 10%

Heat Rejection values based on using treated water.

Torque is included for truck and industrial applications, do not use for Gen Set or steady state applications.

On C7 - C18 engines, at speeds of 1100 RPM and under these values are provided for reference only, and may not meet the tolerance listed.

These values do not apply to C280/3600. For these models, see the tolerances listed below.

C280/3600 HEAT REJECTION TOLERANCE FACTORS:

Heat rejection	+/- 10%
Heat rejection to Atmosphere	+/- 50%
Heat rejection to Lube Oil	+/- 20%
Heat rejection to Aftercooler	+/- 5%

TEST CELL TRANSDUCER TOLERANCE FACTORS:

Torque	+/- 0.5%
Speed	+/- 0.2%
Fuel flow	+/- 1.0%
Temperature	+/- 2.0 C degrees
Intake manifold pressure	+/- 0.1 kPa

OBSERVED ENGINE PERFORMANCE IS CORRECTED TO SAE J1995 REFERENCE AIR AND FUEL CONDITIONS.

REFERENCE ATMOSPHERIC INLET AIR

FOR 3500 ENGINES AND SMALLER
SAE J1228 AUG2002 for marine engines, and J1995 JAN2014 for other engines, reference atmospheric pressure is 100 KPA (29.61 in hg), and standard temperature is 25deg C (77 deg F) at 30% relative humidity at the stated aftercooler water temp, or inlet manifold temp.

FOR 3600 ENGINES
Engine rating obtained and presented in accordance with ISO 3046/1 and SAE J1995 JANJAN2014 reference atmospheric pressure is 100 KPA (29.61 in hg), and standard temperature is 25deg C (77 deg F) at 30% relative humidity and 150M altitude at the stated aftercooler

water temperature.

MEASUREMENT LOCATION FOR INLET AIR TEMPERATURE
Location for air temperature measurement air cleaner inlet at stabilized operating conditions.

REFERENCE EXHAUST STACK DIAMETER
The Reference Exhaust Stack Diameter published with this dataset is only used for the calculation of Smoke Opacity values displayed in this dataset. This value does not necessarily represent the actual stack diameter of the engine due to the variety of exhaust stack adapter options available. Consult the price list, engine order or general dimension drawings for the actual stack diameter size ordered or options available.

REFERENCE FUEL

DIESEL
Reference fuel is #2 distillate diesel with a 35API gravity;
A lower heating value is 42,780 KJ/KG (18,390 BTU/LB) when used at 29 (84.2), where the density is 838.9 G/Liter (7.001 Lbs/Gal).

GAS
Reference natural gas fuel has a lower heating value of 33.74 KJ/L (905 BTU/CU Ft). Low BTU ratings are based on 18.64 KJ/L (500 BTU/CU FT) lower heating value gas. Propane ratings are based on 87.56 KJ/L (2350 BTU/CU Ft) lower heating value gas.

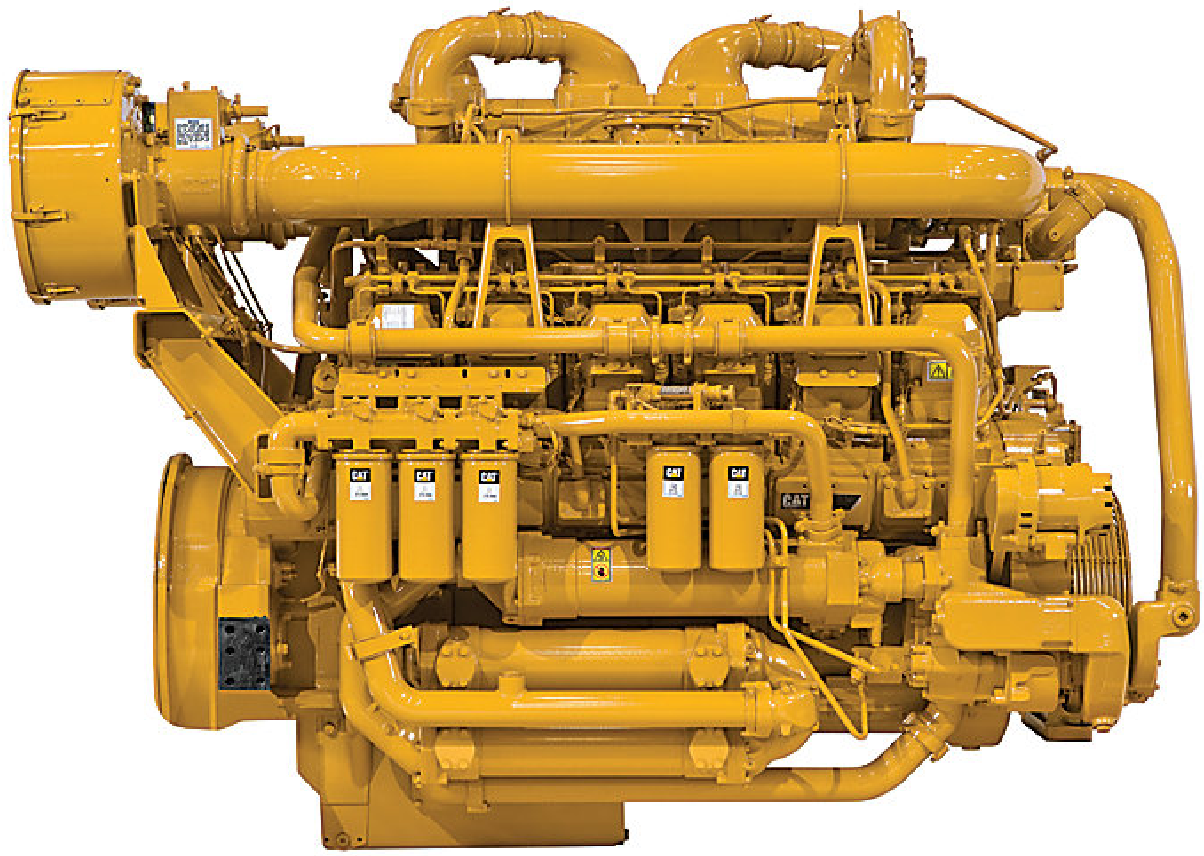
ENGINE POWER (NET) IS THE CORRECTED FLYWHEEL POWER (GROSS) LESS EXTERNAL AUXILIARY LOAD
Engine corrected gross output includes the power required to drive standard equipment; lube oil, scavenge lube oil, fuel transfer, common rail fuel, separate circuit aftercooler and jacket water pumps. Engine net power available for the external (flywheel) load is calculated by subtracting the sum of auxiliary load from the corrected gross flywheel out put power. Typical auxiliary loads are radiator cooling fans, hydraulic pumps, air compressors and battery charging alternators. For Tier 4 ratings additional Parasitic losses would also include Intake, and Exhaust Restrictions.

ALTITUDE CAPABILITY
Altitude capability is the maximum altitude above sea level at standard temperature and standard pressure at which the engine could develop full rated output power on the current performance data set. Standard temperature values versus altitude could be seen on TM2001. When viewing the altitude capability chart the ambient temperature is the inlet air temp at the compressor inlet.

Engines with ADEM MEUI and HEUI fuel systems operating at conditions above the defined altitude capability derate for atmospheric pressure and temperature conditions outside the values defined, see TM2001. Mechanical governor controlled unit injector engines require a setting change for operation at conditions above the altitude defined on the engine performance sheet. See your Caterpillar technical representative for non standard ratings.

REGULATIONS AND PRODUCT COMPLIANCE
TMI Emissions information is presented at 'nominal' and 'Potential Site Variation' values for standard ratings. No tolerances are applied to the emissions data. These values are subject to change at any time. The controlling federal and local emission requirements need to be verified by your Caterpillar technical representative. Log on to the Technology and Solutions Divisions (T&SD) web page (https://pdgt.cat.com/cda/layout) for information including federal regulation applicability and time lines for implementation. Information for labeling and tagging requirements is also provided.

NOTES:
Regulation watch covers regulations in effect and future regulation changes for world, federal, state and local. This page includes



3512C LRC

SPECIFICATIONS BENEFITS & FEATURES EQUIPMENT

OVERVIEW

For your largest power needs in any environment, Cat® 3512C Industrial Diesel Engines offer the unsurpassed performance and durability your customers need to keep their industrial applications and operations running. They deliver high power output, proven reliability and excellent fuel efficiency. These engines maintain low operating costs to keep your customers profitable for years to come. Industries and applications powered by 3512C engines include Bore/Drill Rigs, Chippers/Grinders, Construction, Cranes, Dredgers, Forestry, General Industrial, Material Handling, Mining, Mobile Earthmoving Equipment, Pumps, Shovels/Draglines, Surface Hauling Equipment and Trenchers. The 3512C engine, with a rating of 1120 bkW (1500 bhp) @ 1800 rpm, is U.S. EPA Tier 2 equivalent. It is available using U.S. EPA Flexibility, and for other regulated and non-regulated areas.

POWER RATING UNITS: US METRIC

Minimum Power	1500.0 bhp
Maximum Power	1500.0 bhp
Rated Speeds	1800 rpm

EMISSION STANDARDS

Emissions	U.S. EPA Tier 2 Equivalent

GENERAL

Engine Configuration	V-12, 4-Stroke-Cycle Diesel
Bore	170 mm (6.7 in)
Stroke	190 mm (7.5 in)
Displacement	51.8 L (3158 in^3)
Aspiration	Turbocharged Aftercooled
Rotation (from flywheel end)	Counterclockwise

ENGINE DIMENSIONS (APPROXIMATE. FINAL DIMENSIONS DEPENDENT ON SELECTED OPTIONS)

Length	3067 mm (120.8 in)
Width	1785 mm (70.3 in)
Height	1806 mm (71.1 in)

Weight, Net Dry (Basic Operating Engine Without Optional Attachments)	6078 kg (13,400 lb)

APPENDIX D

Proposed Voluntary LDAR Program

APPENDIX D
PROPOSED VOLUNTARY LDAR PROGRAM

In order to reduce potential volatile organic compound (VOC) emissions, Puget Sound Energy (PSE) proposes to voluntarily implement the use of a Leak Detection and Repair (LDAR) program. As shown in Table B-10 of the Appendix B emission calculations, the proposed voluntary LDAR program is assumed to achieve a 75 percent control efficiency for all valves, pump seals, and compressor seals; and a 30 percent control efficiency for all flanges and connectors.[1] This control level is lower than the 88 percent control efficiency for valves in light liquid service and 92 percent control efficiency for valves in gaseous service that the US Environmental Protection Agency determined for sources subject to the Synthetic Organic Chemical Manufacturing Industry (SOCMI) National Emission Standards for Hazardous Air Pollutants (NESHAP) on which PSE's LDAR program is based.[2]

Proposed voluntary LDAR measures for the Tacoma LNG Terminal's equipment include:

- Monthly monitoring of equipment and repair of any detected leaks (>500 ppm) within 15 days (unless a unit shutdown is required).
- If a unit shutdown is required to make a repair, the repair will be made at the next shutdown.
- Equipment monitoring will be delayed if past monitoring shows low leak rates per the following schedule:
  - If the overall unit equipment leak rate is < 2%, the facility may monitor only quarterly
  - Leak rate < 1%, monitor only semiannually
  - Leak rate < 0.5%, monitor annually
  - Equipment that is difficult to monitor may be monitored annually instead of the above schedule if the following conditions are met:
    - The equipment cannot be monitored without elevating the monitoring personnel more than 2 meters above a support surface or it is not accessible at any time in a safe manner
    - The total number of such equipment does not exceed 3 percent of the total equipment at the source.

These proposed measures will be implemented upon startup and throughout the facility's operating life unless/until the permit is modified. PSE will prepare a Tacoma LNG Project LDAR program

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1 EPA. 1995. Protocol for Equipment Leak Emission Estimates. Research Triangle Park, NC: US Environmental Protection Agency.

2. TCEQ. 2011. Control Efficiencies for TCEQ Leak Detection and Repair Programs. Texas Commission on Environmental Quality. July. While PSE's proposed voluntary LDAR measures would be based on the substantive requirements of the SOCMI maximum achievable control technology in 40 CFR 63 Subpart H, which apply only to major hazardous air pollutant (HAP) sources, it is important to note that Subpart H does not apply to the proposed Tacoma LNG Terminal, which will not be a major source of HAPs. With or without LDAR, the LNG Facility will not be a major source of HAPs or criteria pollutants.

implementation manual for review and approval by PSCAA. The LDAR program will reflect the requirements in the following (inapplicable) regulations:

- Definitions under 40 CFR 63.16
- General requirements under 40 CFR 63.162(a), (c), (d), (f), (g), and (h)
- Monitoring provisions for equipment gas/vapor and light liquid service under 40 CFR 63.163 to 174, using the 500-ppm leak rate definition immediately upon startup
- Method 21 test methods and procedures (40 CFR part 60, Appendix A),
- Delay of repair provisions under 40 CFR 63.171
- The alternative quality improvement program for equipment described in 40 CFR 63.175 and 176, in lieu of related 40 CFR 63.168 and 163 requirements, upon written notification 30 days in advance and approval by PSCAA
- Recordkeeping provisions for equipment in VOC service under 40 CFR 63.181
- Records will be available for inspection by PSCAA.

APPENDIX E

RBLC Search Summary

Table E-1
RBLC Search Summary
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

Emission Unit	RBLC Listed Process	RBLC ID	Permit Issuance Date	Throughput	Primary Fuel	Process Code	Pollutant	Control Technology Type	Emission Limits	Case-by-case Basis
Vaporizer	Submerged combustion vaporizer nos. 1-21	LA-0219	08/15/2007	108 MMBtu/hr (ea)	LNG	19.9	CO	Good combustion practices	9.47 lb/hr hourly maximum; 31.22 tpy annual maximum; 80 ppmvd@5% O_2 [a]	BACT-PSD
							NO_x	Low NO_x burners with water injection and good combustion practices	4.5 lb/hr hourly maximum; 17.5 tpy annual maximum; 30 ppmvd@5% O_2 [b]	BACT-PSD
							PM_{10}	Good combustion practices	0.15 lb/hr hourly maximum; 0.66 tpy annual maximum; 0.0014 lb/MMBtu	BACT-PSD
							VOCs	Good combustion practices	0.32 lb/hr hourly maximum; 1.42 tpy annual maximum	BACT-PSD
	Heater	TX-0657 [(c)]	5/16/2014	45 MMBtu/hr	Natural Gas & Plant Gas	50.002	CO	Good Combustion Practices	50 ppm annual; 3.45 tpy	BACT-PSD
							NO_x	Ultra-low NO_x burners	0.0360 lb/MMBTU, 3.92 tpy	BACT-PSD
							PM, PM_{10}, $PM_{2.5}$	Good combustion practices and fuel selection	0.81 tpy	BACT-PSD
							VOCs	Good combustion practices	0.59 tpy	BACT-PSD
Enclosed Ground Flare	Enclosed ground flare	CA-1187	1/24/2012	17 MMBtu/hr	Field gas	19.39	NO_x	Burner design, premix, and combustion temperature control	15 ppmvd@3% O_2 40 minutes [d]	Other, unknown
							VOCs	Burner design, premix, and combustion temperature control	10 ppmvd@3% O_2 40 minutes	Other, unknown
	Horizontal Enclosed Flare	CA-1235	8/28/2009	62 MMBTU/H	Field gas	19.33	CO	Forced draft enclosed flare with ultra-low NO_x burner	0.0371 lb/MMBtu	Other, unknown [c]
							NO_x	Forced draft enclosed flare with ultra-low NO_x burner	0.0146 lb/MMBtu	
							VOCs	Forced draft enclosed flare with ultra-low NO_x burner	0.0013 lb/MMBtu	
Fugitives	Fugitives	TX-0723	11/21/2014	--	--	50.002	VOCs	Piping, valves, pumps, compressors, and other fittings will be subject to a leak detection and repair program with some directed to flare control as minor vents. 28 LAER will be implemented.	--	LAER
	Fugitives	OK-0148 c	09/12/2012	--	--	50.002	VOCs	LDAR	--	BACT-PSD

Notes:

[a] The RBLC database reported a CO limit of 80 ppmvd at 5 percent O_2 for this emission unit. However, for project comparability purposes, the limit was converted to 0.049 lb/MMBtu using the equations in EPA Method 19.

[b] The RBLC database reported a NO_x limit of 30 ppmvd at 5 percent O_2 for this emission unit. However, for project comparability purposes, the limit was converted to 0.031 lb/MMBtu using the equations in EPA Method 19.

[c] RBLC ID was marked as a draft determination.

[d] The RBLC database reported a NO_x limit of 15 ppmvd at 3 percent O_2 for this emission unit. However, for project comparability purposes, the limit was converted to 0.015 lb/MMBtu using the equations in EPA Method 19.