Public

Alaska LNG Liquefaction Plant Construction Permit Application

Project Information Form Attachment 8:

AERMOD Sensitivity Liquefaction Plant

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Since the submittal of the Liquefaction Facility Air Quality Modeling Report Supporting Resource Report No. 9 (Resource Report No. 9 Appendix D), dated October 11, 2016[1], USEPA promulgated new versions of AERMINUTE (updated from v.14337 to v. 15272), AERMET (updated from v. 15181 to v. 16216) and AERMOD (updated from version 15181 to version 16216r). This analysis describes a study conducted to demonstrate that assessments conducted with the superseded versions of AERMET and AERMOD yield the same results as those conducted with the current versions, obviating the need to revise all analyses conducted with the previous versions of AERMINUTE, AERMET and AERMOD.

To conduct this study, meteorology data was reprocessed using v15272 of AERMINUTE and v16216 of AERMET. This new meteorological dataset was used in conjunction with v16216r of AERMOD to perform sensitivity tests on the cumulative LNG NAAQS/AAAQS Air Quality Compliance Normal Operations modeling found in Table 7-3 of Resource Report No. 9 Appendix D. For this study impacts were predicted with the latest model versions for two pollutants and averaging periods: 1-hour NO_2 and 24-hour $PM_{2.5}$. These pollutants and averaging periods were selected because 1) both generally result in the smallest compliance margins, and 2) together they demonstrate potential sensitivities associated with modeling inert and reactive pollutants.

Results from this study are shown in Table 1 and compared to respective results found in Resource Report No. 9 Appendix D. These results indicate there are virtually no differences to the AERMOD predicted 1-hour NO_2 and 24-hour $PM_{2.5}$ impacts when the latest AERMOD modeling system model versions are used provided modeling is conducted with the same in-stack ratio (ISR) assumptions. Given that AERMOD treats all reactive and inert pollutants the same, the differences shown in Table 1 will be typical of all pollutants and averaging periods.

Table 1: Sensitivity of the Cumulative LNG Impacts for Normal Operations to the most recent version of AERMOD and AERMET

Pollutant and Averaging Period	Modeled Period	Model Predicted Impacts from Resource Report No. 9 Appendix D Table 7-3 Using AERMOD Version 15181[1,3]	Modeled Impact Using AERMOD Version 16216r[1,2]
1-Hour NO_2 (Highest-8th-High Rank)	2011-2015	149.47826	149.49961
24-Hour $PM_{2.5}$ (Highest-8th-High Rank)	2011-2015	6.38954	6.38955

[1] Meteorology data utilized in AERMOD run was processed using AERMINUTE v 14337 and AERMET v. 15181.
[2] Meteorology data utilized in AERMOD run was processed using AERMINUTE v 15272 and AERMET v. 16216.
[3] For this analysis, the In-Stack Ratios (ISRs) in v1616r were manually set to match the default ISR of 0.2 utilized in the v15181 runs found in Resource Report No. 9 Appendix D.

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[1] Alaska LNG. 2016. Liquefaction Facility Air Quality Modeling Report Supporting Resource Report No. 9. Appendix D. Document No. USAL-P1-SRZZZ-00-000001-000. October 11, 2016.

There is one significant difference between AERMOD model version v16216r and v15121 that deserves additional discussion and is not apparent in the 1-hour NO_2 results presented in Table 1 because they were obtained by manually setting the minimum ambient ratio to 0.2 in both versions. The minimum ambient ratio is set on a source-wide basis and is equivalent to the minimum in-stack ratio (ISR) representative of sources dominating impacts. AERMOD v16216r utilizes a default source wide ISR of 0.5, and v15121 utilizes a default ISR of 0.2. As a result, if a comparison were done using default settings with these two versions, differences in NO_2 predictions would occur solely due to the ISR defaults. Results predicted with default settings (i.e., difference ISR values) show a difference in predicted 1-hour NO_2 concentrations of approximately 7%. Therefore, in order to justify the 1-hour NO_2 comparisons found in Table 1 the same ISR must be used with each model version and:

1. a case must be made to justify a source-wide ISR of 0.2 when running AERMOD version v16216r; or
2. a demonstration must be made showing that impacts do not change when the source-wide ISR is increased to 0.5 when running v15121; or
3. a case must be made to justify a source-wide ISR somewhere between 0.2 and 0.5 to use with both versions that still demonstrates compliance with AERMOD v15121.

Neither 1 nor 2 can be done easily leaving option 3. To make this demonstration, modeling was performed at source-wide ISRs of 0.2, 0.3 and 0.5 using AERMOD v15121. The results of this ISR sensitivity modeling are shown in Table 2 and show results predicted are virtually the same and show compliance using an ISR of 0.3 and an ISR of 0.2. It is not until the source-wide ISR is increased to above 0.3 do modeled concentrations increase. With this demonstration made, all that is required is justifying the use of a source-wide ISR of 0.3 with AERMOD v16216r.

Table 3 shows ISRs by source category for the types of sources present in the LNG facility modeling. This table shows that with the exception of flares, on-site and offsite sources do have ISRs of 0.3 or less. Justifications of these ISRs were determined primarily though research of USEPA and/or ADEC databases and are found in Attachment A. While the flares have an ISR of 0.5, the dispersion properties of this source group are so different from the rest that the flares do not contribute to maximum impacts in the modeled domain. A culpability analysis of several modeled maximum impact locations showed that only a small number sources contribute significantly to the increases in pollutant concentrations which occur when the ISR is increased above 0.3. These sources include:

- Tesoro Refinery Tanker Hoteling Engines
- Agrium Kenai Nitrogen Operations Ammonia Vessel Hoteling Engines (900 kW)
- Agrium Kenai Nitrogen Operations Urea Vessel Hoteling Engines (240 kW)
- Kenai Liquefaction Facility Tanker Hoteling Engines
- Alaska LNG LNG Carriers
- Agrium Kenai Nitrogen Operations Turbines

Table 3 shows that all of these sources are expected to have ISRs of 0.3 or less. The culpability analysis showed that altering the ISR of sources other than these had little or no effect on maximum impacts.

Based on the results shown in Table 2, AERMOD v16216r and v15121 both yield the same results using an ISR of 0.3. Furthermore, an ISR of 0.3 is justified for use with AERMOD v16216r and using an ISR of 0.3 with AERMOD v15121 demonstrates compliance with roughly the same compliance margin as those documented in Resource Report No. 9 Appendix D. Therefore, this analysis shows that the results documented in Resource Report No. 9 Appendix D are not sensitive to recent changes in the AERMOD modeling system.

Table 2: In-Stack Ratio Sensitivity Analysis

Pollutant and Averaging Period	Year	ISR = 0.5		ISR = 0.2 or 0.3	
		15181[1]	16216r[2]	15181[1]	16216r[2]
1-Hour NO_2 (Highest-8th-High Rank)	2011-2015	159.96962	159.96962	149.47826	149.49961
24-Hour $PM_{2.5}$ (Highest-8th-High Rank)	2010[3]	12.53668	12.53107	12.53668	12.53107

[1] Meteorology data utilized in AERMOD run was processed using AERMINUTE v 14337 and AERMET v. 15181.

[2] Meteorology data utilized in AERMOD run was processed using AERMINUTE v 15272 and AERMET v. 16216.

[3] Sensitivity analysis was performed in the year which was shown to have maximum impact in the five individual years run in Resource Report No. 9 Appendix D.

Table 3: In-Stack Ratio by Source Category according to Attachment A

Source Category	ISR	Examples of Sources from the Alaska LNG Liquefaction Facility Modeling
Diesel-Fired Heaters/Boilers	<0.1	Package boiler, waste heat boiler, recycle gas heater, crude heater and glycol heater
Natural Gas-Fired Heaters/Boilers	<0.1	
Small Diesel-Fired Internal Combustion Engines (<600 hp)	<0.1	Firewater pump, auxiliary air compressor, LNG carrier engines, Tesoro tanker engines, Agrium Kenai Nitrogen Operations ammonia vessel engines[1] and Urea Vessel engines[1]
Diesel-Fired Internal Combustion Engines (>600 hp)	<0.2	
Gas-Fired Turbine Engines	<0.3	Compression turbines and power generator turbines
Gas-Fired Reciprocating Internal Combustion Engines (RICE)	<0.3	No modeled sources
Diesel-Fired Nonroad Engines Associated with Construction Equipment	<0.2	No modeled sources
Onroad Mobile Sources	<0.2	No modeled sources
Flares[2]	0.5	High pressure and low pressure flares at all facilities

[1] In the September 2014 Dispersion Modeling Analysis - Agrium Kenai Nitrogen Operations Facility Report, these sources were modeled with an ISR of 0.22.

[2] Not included in Appendix A. Based on USEPA Default.

ATTACHMENT A

Survey of Typical Emission Unit In-Stack NO_2 to NO_x Ratios

INTRODUCTION

Representative emission unit exhaust in-stack NO_2/NO_x Ratios selected for refined 1-hour NO_2 dispersion modeling were determined based on a survey of data available from the following:

- USEPA Technology Transfer Network (TTN) Support Center for Regulatory Atmospheric Modeling (SCRAM) database (http://www.epa.gov/ttn/scram/no2_isr_database.htm). The data used is contained in the spreadsheet named NO2_ISR_alpha_database.xlsx (herein referred to as "USEPA Database") and available on that web site. This data represents values collected by various Regional, State, and Local air permitting offices prior to the formal collection which has been initiated by the Office of Air Quality Planning and Standards (OAQPS) and represents the largest database available at this time.
- Alaska Department of Environmental Conservation (ADEC) Air Dispersion Modeling data base publically available at (http://dec.alaska.gov/air/ap/modeling.htm). This data represents values collected by ADEC from source tests conducted on emission units within the state. The following presents a review of available data and justification for the NO_2/NO_x Ratios selected for modeling based on emission unit type.

For onroad mobile sources, the following peer-reviewed papers were used:

- P G Boulter, I S McCrae, and J Green, Transportation research Laboratory, "Primary NO_2 Emissions From Road Vehicles in the Hatfield and Bell Commons Tunnels", July 2007.
- X Yao, N T Lau, C K Chan, and M Fang, Atmospheric Chemistry and Physics Discussions, "The use of tunnel concentration profile data to determine the ratio of NO2/NOx directly emitted from vehicles", December 2005.
- G A Bishop and D H Stedman, Air Pollution XVI 247, Department of Chemistry and Biochemistry, University of Denver, WIT Transactions on Ecology and the Environment, Vol 116, "Emissions of Nitrogen Dioxide from Modern Diesel Vehicles".

The following presents a review of available data and justification for the NO_2/NO_x Ratios selected for modeling based on emission unit type.

Diesel-Fired Heaters/Boilers

Entries of exhaust NO_2/NO_X ratio data from the USEPA database were summarized for diesel fired "small" heaters and boilers, i.e., units less than 10 MMBtu/hour heat input. Only units for which the heat input information was available were taken into consideration. The results are summarized in Table A-1. As shown in the table, only two data points were found for NO_x and NO_2 emissions test data collected from small, diesel-fired, uncontrolled boilers. Both the boilers were tested at a 100% load only, and therefore, NO_2/NO_x ratios across various load cases could not be determined.

A similar database developed by the Alaska Department of Environmental Conservation (ADEC) was also referenced. The search returned one 29.3 MMBtu/hour Cleaver-Brooks Fire Tube Boiler at the Dutch

Harbor Seafood Processing Facility - Captain's Bay Plant. Four tests were run on this boiler at 4 load points between 20% and 100% load. These tests all yielded a NO_2/NO_x in-stack ratio of less than 0.01.

Based on this analysis, an NO_2/NO_X in-stack ratio lower than 0.05 is justifiable for modeling small diesel fired boilers.

Table A-1: NO_2/NO_x In-Stack Ratios for Uncontrolled Diesel Boilers from USEPA Database

Load	No. of Data Points	Average	Maximum	Minimum
100%	2	0.0409	0.0476	0.0341

Natural Gas-Fired Heaters/Boilers

Exhaust NO_2/NO_x in-stack ratio data were summarized for natural gas-fired heaters and boilers. Entries of exhaust NO_2/NO_x in-stack ratio data from the USEPA database were summarized for natural gas fired heaters and boilers in Table A-2. As shown in the table, two natural gas-fired boilers with no controls with NO_x and NO_2 emissions test data from the John Bean Tech Corporation Facility were found. The heat input information was not available for these boilers in the database. Both the boilers were tested at four different loads, and therefore, NO_2/NO_x ratios across various load cases were determined. Test results for zero load were assumed erroneous and ignored.

Table A-2: NO_2/NO_X In-Stack Ratios for Natural Gas-Fired Boilers from USEPA Database

Load	No. of Data Points	Average	Maximum	Minimum
25%	2	0.017	0.020	0.015
50%	2	0.016	0.018	0.014
75%	2	0.031	0.035	0.027
100%	3	0.030	0.034	0.026
Overall Maximum			0.034	

A similar database developed by the Alaska Department of Environmental Conservation (ADEC) was also reviewed. The search returned one 30 MMBtu/hr Zeeco boiler (Model GLSFWB12) equipped with a low NO_x burner installed at BP's Milne Point Unit (MPU) facility in Alaska. The results are summarized in Table A-3. As shown in the table, the boiler was tested at two load conditions: 40% load and 60% load.

Table A-3: NO_2/NO_X In-Stack Ratios for Natural Gas-Fired Boilers from USEPA Database

Load	No. of Data Points	Average	Maximum	Minimum
60%	1	0.05	0.05	0.05
40%	1	0.34	0.34	0.34
Overall Maximum			0.34	

The size of the boilers for the USEPA database was not provided. However, an internet search of the boiler models (KEWANEE BOILER KF15-1562-6 and CLAYTON BOILER EO-200-3FM) reveals that these boilers are sized less than 30 MMBtu/hour. The USEPA database contains multiple data points at various loads with good continuity among the test data. The ADEC data for the 30 MMBtu/hour Zeeco boiler at 40% load seems to be an outlier in comparison to all other available data points.

The maximum in-stack ratio based on the USEPA data is 0.035 and 0.05 for the ADEC data (excluding the outlier point at 40% load). As such, a 0.10 in-stack ratio upper limit is justifiable. This value is conservative as it is a factor of 2 higher than the highest non-outlier in-stack ratio between the USEPA and ADEC database.

Small Diesel-Fired Internal Combustion Engines

Exhaust NO_2/NO_x in-stack ratio data were summarized from the USEPA database for small (less than or equal to 600 hp), uncontrolled diesel-fired reciprocating, internal-combustion engines (RICE). Data was available from the Harvey Explorer facility containing values for three (3) different load categories for a 540 hp Caterpillar/3412EDITA RICE and values at 90-100% load for three (3) 320 kW Caterpillar/3406CDITA RICE. NO_2/NO_x in-stack ratio values ranged between 0.05 and 0.08. These data are summarized in Table A-4.

An examination of the ADEC data did not reveal differences in the average NO_2/NO_x in-stack ratio (data not shown). The average in-stack ratio value was 0.05, with only one data point within the subset of ADEC data for small diesel reciprocating engines.

Based on this analysis, an upper limit NO_2/NO_x in-stack ratio of 0.10 for the purposes of modeling small (<600 hp) diesel-fired RICE is justifiable. The maximum observed value across all loads is less than that, at 0.08.

Table A-4: NO_2/NO_X In-Stack Ratios by Load for Uncontrolled Small Diesel RICE Emission Test Results from USEPA Database

Load	No. of Data Points	Average	Maximum	Minimum
90-100%	3	0.06	0.07	0.06
80%	1	0.08	0.08	0.08
60%	1	0.05	0.05	0.05
30%	1	0.08	0.08	0.08
Overall Maximum			0.08	

Diesel-Fired Internal Combustion Engines Associated with Power Generation

Exhaust stack NO_2/NO_x in-stack ratio data were summarized for emissions test data for large (greater than 600 hp), diesel-fired reciprocating, internal-combustion engines (RICE) for which load information was available. Data for the one or more Caterpillar 3406B RICE associated with the City of LeMoore were eliminated from consideration due to lack of information concerning equipment size and load. Removal of these data resulted in the loss of 41 data points. Data from the AEL&P Lemon Creek facility appeared to contain emission results for three runs; therefore, data were reduced to one average value for each load category presented contributing three data points for the data analysis. This reduced the total number of available data points by six (6). Average NO_2/NO_x in-stack ratio values ranged between 0.06 and 0.10, ranging between 0.05 and 0.11 when taking into consideration information such as the standard deviation and number of data points (i.e. generating confidence intervals based on 95th percentile). These data are summarized in Table A-5.

Table A-5: Average NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Diesel RICE Emission Test Results from USEPA Database

Load Class	No. of data Points	Upper Confidence Limit	Average	Lower Confidence Limit
90-100%	7	0.08	0.06	0.05
70-89%	10	0.11	0.08	0.05
50-69%	13	0.11	0.10	0.08
Less than 50%	8	0.11	0.10	0.08
All	**38**	**0.09**	**0.09**	**0.08**

An examination of the ADEC data did not reveal differences in the average NO_2/NO_x in-stack ratio by load class. The average ratio value was 0.04 across all load classes. The maximum and minimum values observed for the uncontrolled ADEC NO_2/NO_x Ratio data were 0.05 and 0.03, respectively. The total number of data points within the subset of ADEC data in which emission controls were not installed was six (6).

In addition to generating average values, the maximum and minimum values observed by load class and for all data points combined were examined as well. Based on this analysis, the maximum NO_2/NO_x in-stack ratio observed was 0.19 and the minimum ratio value observed was 0.01 (See Table A-6).

Table A-6: Range of NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Diesel RICE Emission Test Results from USEPA Database

Load Class	No. of data Points	Maximum	Minimum
90-100%	7	0.10	0.02
70-89%	10	0.15	0.01
50-69%	13	0.19	0.06
Less than 50%	8	0.14	0.08
All	**38**	**0.19**	**0.01**

Based on the above analysis, an NO_2/NO_x in-stack ratio of 0.2 or above for the purposes of modeling diesel fired RICE is both conservative and justifiable. This is particularly the case when the maximum and minimum observed values are taken into consideration. Clearly the maximum observed value across the 38 data points demonstrates that 0.20 is just above the range of values expected for the NO_2/NO_x in-stack ratio of diesel-fired RICE engines.

Gas-Fired Turbine Engines

Exhaust stack NO_2/NO_x in-stack ratio data were summarized for emissions test data for natural gas-fired turbines for which load information was available. Only one set of data was available for a dual-fired unit, while combusting diesel fuel. Therefore, this analysis is limited to the gas turbine engine emission test results. There were a total of 16 different emission units and 42 data points. USEPA data were screened for quality and completeness and only four data points from one unit could be used. The one viable turbine test run from the USEPA average ratio values ranged between 0.06 and 0.10, ranging between 0.06 and 0.49 when taking into consideration information such as the standard deviation and number of data points (i.e. generating confidence intervals). These data are summarized in Table A-7.

Based on this analysis, an NO_2/NO_x in-stack ratio of 0.3 for the purposes of modeling the natural gas fired turbines is both conservative and justifiable. This is particularly the case when the maximum and minimum observed values are taken into consideration. Clearly, the maximum observed value across the 42 data points demonstrates that 0.3 is within the range of values expected for the NO_2/NO_x in-stack ratio of gas-fired turbines.

Table A-7: Average NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Natural Gas Turbine Emission Test Results from USEPA Database

Load Class	Number of Data Points	Upper Confidence Limit	Average	Lower Confidence Limit
90-100%	13	0.15	0.11	0.06
70-89%	11	0.26	0.18	0.10
50-69%	9	0.16	0.14	0.12
Less than 50%	9	0.49	0.35	0.21
All	**42**	**0.24**	**0.19**	**0.14**

Gas-Fired Reciprocating Internal Combustion Engines (RICE) by Control

Exhaust stack NO_2/NO_x in-stack ratio data were summarized for emissions test data for gas-fired RICE for which input rating information was available. Data for the natural gas-fired RICE that lacked information on the engine input rating were eliminated from consideration. Removal of these data resulted in the loss of 595 data points. A majority of the remaining data did not have load information associated with it; therefore, a comparison of NO_2/NO_x in-stack ratios across loads was not determined. The only other data field that could provide a distinction across data points was the primary control field. For this reason, ratios were compared across primary control equipment type installed on the engines. Average ratio values ranged between 0.14 and 0.26 across all control classes. These data are summarized in Table A-8.

Table A-8: Average NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Natural Gas RICE Emission Test Results from USEPA Database

Control Equipment Class	Number of Data Points	Upper Confidence Limit	Average	Lower Confidence Limit
No Controls	3	0.26	0.22	0.18
SCR Only	238	0.20	0.19	0.19
All	**241**	**0.20**	**0.19**	**0.19**

Natural Gas-Fired Internal Combustion Engines by Load

Exhaust NO_2/NO_x in-stack ratio data were summarized from the USEPA database for natural gas-fired reciprocating, internal-combustion engines (RICE) for which size and load information was available. Data from the CenterPoint Energy facility containing three tests, two for a 4,000 hp Cooper-Bessemer RICE and one test for a 1,500 hp Cooper-Bessemer RICE, was the only data available. NO_2/NO_x in-stack ratio values ranged between 0.18 and 0.24. These data are summarized in Table A-9. As can be seen, a NO_2/NO_x in-stack ratio between 0.2 and 0.3 is justifiable for dispersion modeling purposes.

An examination of the ADEC data revealed only one data point within the subset of ADEC data for natural gas reciprocating engines, a 740 hp Waukesha F3514GSI engine. This emission unit had an average NO_2/NO_x in stack ratio of 0.05. However, note that this was a controlled engine and this low value was not included in the analysis.

Table A-9: Average NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Natural Gas RICE Emission Test Results from USEPA Database

Load	No. of Data Points	Average	Maximum	Minimum
100%	1	0.24	0.24	0.24
95%	1	0.24	0.24	0.24
90%	1	0.18	0.18	0.18
Overall Maximum			**0.24**	

Diesel-Fired Nonroad Engines Associated with Construction Equipment

The USEPA database was researched to evaluate instances of diesel-fired RICE specifically used in construction service. Engines serving equipment such as cranes, bulldozers, excavators, front-end loaders, winches etc. would fall under this category. Two entries for nonroad construction engines were found in the USEPA database. Two 250 hp Caterpillar C7 diesel engine powered logging winches were each tested at 50% load and 80% load. A 365 hp Caterpillar D343 diesel engine powered crane was also tested at 60% load and 80% load. The test data are summarized in Table A-10.

Based on this analysis, a NO_2/NO_x in-stack ratio of 0.20 is justifiable for the purposes of modeling diesel fired engines used in construction service.

Table A-10: Range of NO_2/NO_x In-Stack Ratios by Load for Uncontrolled Construction Equipment Diesel RICE Emission Test Results from USEPA Database

Load Class	No. of data Points	Average	Maximum	Minimum
70-89%	3	0.1354	0.1811	0.0965
50-69%	3	0.1496	0.1669	0.1209
Overall Maximum			**0.1811**	

Onroad Mobile Sources

The USEPA and ADEC databases contained test information for stationary and nonroad sources only. Therefore, a web search was conducted to research NO_2/NO_x in-stack ratios for light/medium duty and heavy duty diesel vehicles. The findings are presented in Table A-11. The maximum NO_2/NO_x in-stack ratio for light and medium duty diesel and gasoline vehicles is 0.25; whereas, that for heavy duty diesel vehicles is 0.11. Based on Table A-11, a proposed NO_2/NO_x in-stack ratio of 0.01 or more for heavy duty diesel vehicles and 0.20 or more for light and medium duty diesel vehicles for the purposes of modeling is conservative. For a mixed fleet, a value of 0.15 should be conservative assuming that most of the fuel consumed will be in the larger engines.

Table A-11: Range of NO_2/NO_x In-Stack Ratios for Onroad Source

Vehicle Class	Average	Maximum	Minimum
Light and Medium Duty Gasoline / Diesel Vehicles [1]	0.18	0.25	0.16
Heavy Duty Diesel Vehicles [1]	0.085	0.11	0.06

[1] Ranges of NO_2/NO_x in-stack ratios obtained from - P G Boulter, I S McCrae, and J Green, Transportation research Laboratory, "Primary NO_2 Emissions From Road Vehicles in the Hatfield and Bell Commons Tunnels", July 2007.