Dodge Cove Improvement District comment on Aurora Application
Calculation of NO2 concentrations over residential areas

We are concerned that Aurora underestimated NO2 concentrations over Dodge Cove in their Application by using 10% in-stack NO2/NOx conversion ratios for turbines where it would have been more appropriate to use 30%

We were alerted to a possible underestimation of NO2 concentrations over the residential area of Dodge Cove as a result of the Aurora Application using the Ozone Limiting Method (OLM) with 10% in stack NO2/NOx conversion ratio (ISR) instead of 30%. We asked Trinity Consultants to provide comments on the appropriate NO2/NOX in-stack ratio (ISR) for a Siemens Trent 60 turbine with dry low emission (DLE) technology for use with the ozone limiting method (OLM). We knew this was the turbine Aurora was planning to use:

> *"4.1 Compressor Gas Turbine Drivers*
> *At full buildout, 16 Siemens Trent 60 gas turbines equipped with dry low NOX emission (DLE) combustors will be used as refrigerant compressor drivers."* –pg. 191 Aurora Application Appendix A Air Quality

Trinity Consultants responded:

> *"While this turbine is not the same model turbine as identified by the District, it is a Siemens turbine (same make) that uses the same dry low emissions combustion technology, so it is likely the NO2/NOX ISRs of the turbines are comparable. Based on the available test data, it would be most appropriate to apply the conservative ratio of 0.32 (or 32% NO2)."*-see attached letter Trinity Consultants [following in this pdf is their full letter and following that is their company experience]

We know that Aurora used 10% (not 30% as Trinity suggests would be correct for this make of turbine)

> *"3.7 NOx to NO2 Conversion*
> *The oxidation of NO to NO2 by ozone was predicted by use of the Ozone Limiting Method (OLM). The OLM assumes that the conversion of NO to NO2 in the atmosphere is limited by the ambient ozone concentrations in the atmosphere. <u>The approach assumes that 10% (on a volume basis) of the NOx is converted to NO2 prior to discharge into the atmosphere</u>. For the remaining NO, the following is adopted:*
> *--If 0.9 (NOx) is greater than the ambient O3 concentration then NO2 = 0.1 (NOx) + 0.9 (O3). For this case, the conversion is not complete.*
> *-- If 0.9 (NOx) is less than the ambient O3 concentration then NO2 = 0.1 (NOx) + 0.9 (NOx) = NOx. This is equivalent to the total conversion approach, since there is sufficient ozone to effect the complete conversion.*

The Detailed Model Plan (Appendix 1 of the Air Quality TDR) proposing the above method was approved by BC MOE (Stantec 2015). For this assessment, the maximum hourly O3 value of 50 ppb measured at Prince Rupert airshed for 2011-2013 was used (W. McCormick (BC MOE) pers.comm. January 7, 2016).” –Page 296 Aurora Application Appendix A Air Quality

Another study which calculated NO2 concentrations from Aurora, PNW and PR LNG plants was the Prince Rupert Airshed Study. It used 30% ISR in its OLM calculation for these three LNG plants:

“NO2/NOx Ratios for RIVAD
NOx emissions will be speciated into NO and NO2 emissions based on in-stack ratio data.
All sources except turbines will assume 10% NO2 and 90% NO (i.e. 0.1 in-stack NO2/NOx ratio).
Turbines with DLE (or SoLoNox) will use data from Solar indicated at 30% NO2 ***(or a 0.3 in stack NO2/NOx ratio)*** *[DLE is dry low emissions]*
Data for in-stack ratios for turbines with SCR also uses the 0.3 in stack NO2/NOx ratio”-PRAS page 425 http://www.bcairquality.ca/airsheds/docs/PR-Airshed-Study-Report-Summ.pdf

Table 16 from page 34 Appendix A. Air Quality in the Aurora Application shows the three LNG plants Aurora, PNW and PR emit about 10,000 t/y NOx; about half the total NOx emissions forecast for the area. An underestimation of the NO2 which would be produced from this large an amount of NOx is a very serious issue. NO2 is a serious human health concern and the public needs to have an accurate estimation of the concentrations which will exist over residential areas in order to assess the risk from the Aurora Application.

Trinity Consultant letter

following

20819 72nd Avenue South | Suite 610 | Kent, WA 98032 | P (253) 867-5600 | F (253) 867-5601
trinityconsultants.com

Trinity Consultants

VIA E-MAIL

March 9, 2017

Dodge Cove Improvement District
Box 742 Prince Rupert, V8J 3S1
attn: Carol Brown

RE: Comments on the appropriate NO_2/NO_X in-stack ratio for a Siemens Trent 60 turbine with dry low emission technology

Dear Ms. Brown:

Dodge Cove Improvement District (the District) has requested that Trinity Consultants provide comments on the appropriate NO_2/NO_X in-stack ratio (ISR) for a Siemens Trent 60 turbine with dry low emission (DLE) technology for use with the ozone limiting method (OLM). The OLM is used to model the conversion of nitric oxide (NO) to nitrogen dioxide (NO_2) to predict or estimate NO_2 concentrations in the atmosphere from emissions of NOX (combination of NO and NO_2). In addition to the ozone value, the NO_2/NO_X ISR is a critical input to the OLM calculations, and variations in this input value can result in drastically different predicted NO_2 concentrations. The District has also requested that Trinity to comment on the guidance for selecting and documenting the appropriate NO_2/NO_X ISR.

US EPA GUIDANCE FOR NO2/NOX IN-STACK RATIOS

US EPA guidance[1] states that the default in-stack ratio is 0.5, and that use of lower ratios should be justified based on source-specific test data:

> *The national default for ARM2 includes a minimum ambient NO2/ NOX ratio of 0.5 and a maximum ambient ratio of 0.9. The reviewing agency may establish alternative minimum ambient NO2/ NOX values based on the source's in-stack emissions ratios, with alternative minimum ambient ratios reflecting the source's in-stack NO2/NOX ratios. Preferably, alternative minimum ambient NO2/NOX ratios should be based on source-specific data which satisfies all quality assurance procedures that ensure data accuracy for both NO2 and NOX within the typical range of measured values. However, alternate information may be used to justify a source's anticipated NO2/NOX in-stack ratios, such as manufacturer test data, state or local agency guidance, peer-reviewed literature, and/or the EPA's NO2/NOX ratio database.*

Note that the discussion above relates to Tier 2, but it also applies to Tier 3 guidance (for OLM), as 0.5 is also the default in-stack ratio for Tier 3 methods (e.g., OLM). Additionally, earlier, more detailed guidance specifically recommends this 0.5 default, generally accepted ISR *in the absence of more appropriate source-specific information on in-stack ratios* for the Tier 3 methods.[2]

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[1]Federal Register / Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations 5211. https://www3.epa.gov/ttn/scram/appendix_w/2016/AppendixW_2017.pdf. Accessed March 8, 2017.
[2] U.S. EPA, 2011: Additional Clarification Regarding the Application of Appendix W Modeling

NO_2/NO_X RATIOS FOR TURBINES

The vast majority of NO_X emissions result from combustion activities. Nitrogen in the combustion air reacts to form NO and NO_2 due to the high combustion temperatures. In typical external combustion, the majority of the NO_X emitted from the stack or tailpipe is in the form of NO, and only about 10% or less is in the form of NO_2. However, for combustion sources employing various technologies to control or reduce NO_X emissions, the amount of NO_2 compared to total NO_X is often higher than 10%, because the reduction technology may reduce more NO than NO_2 or the formation of NO may be limited more than the formation of NO_2. For this reason, it is particularly important to obtain source-specific NO_2/NO_X ISR information for combustion sources that use any type of NO_X control or reduction technology. In the absence of source specific information, information from similar sources may be accepted by the reviewing authority on a case-by-case basis.

Source specific information for the Siemens Trent 60 turbine with DLE was not immediately available. However, the US EPA database referenced in the quotation in the previous section (available at https://www3.epa.gov/scram001/no2_isr_database.htm) includes one (and only one) set of NO_2/NO_X data for gas turbines identified as having DLE technology. Table 1 below summarizes the relevant sections of the EPA database. The summary below lists four separate tests on the same turbine (Emission unit 18). This turbine's tested NO_2/NOx ratio ranges from 0.07 to 0.32.

Guidance for the 1-hr NO2 National Ambient Air Quality Standard. Tyler Fox Memorandum dated March 1, 2011, Research Triangle Park, North Carolina 27711. https://www.epa.gov/sites/production/files/2015-07/documents/appwno2_2.pdf. Accessed March 8, 2017.
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Table 1. NO2/NOX data for gas turbines with DLE[3]

Site Name	Facility Description	Equipment description	Fuel Type	Equipment manufacturer & model	Emission Unit No.	Equipment capacity	Control Equipment 1	Output units	Avg. NO2	Avg NO	Avg Nox	Ratio	Comments
Alyeska Pump Station #	Pipeline Pump Station	Siemens SGT 400 Turbine	Natural Gas	Siemens SGT 400 Turbine	18	12,900 kW	Not listed - provide details in comments	ppmv	0.7		10	0.07	Dry Low Emissions combustion technology
Alyeska Pump Station #	Pipeline Pump Station	Siemens SGT 400 Turbine	Natural Gas	Siemens SGT 400 Turbine	18	12,900 kW	Not listed - provide details in comments	ppmv	2.8		23	0.1217	Dry Low Emissions combustion technology
Alyeska Pump Station #	Pipeline Pump Station	Siemens SGT 400 Turbine	Natural Gas	Siemens SGT 400 Turbine	18	12,900 kW	Not listed - provide details in comments	ppmv	5.5		17	0.3235	Dry Low Emissions combustion technology
Alyeska Pump Station #	Pipeline Pump Station	Siemens SGT 400 Turbine	Natural Gas	Siemens SGT 400 Turbine	18	12,900 kW	Not listed - provide details in comments	ppmv	2.6		13	0.2	

[3] https://www3.epa.gov/scram001/no2_isr_database.htm

While this turbine is not the same model turbine as identified by the District, it is a Siemens turbine (same make) that uses the same dry low emissions combustion technology, so it is likely the NO_2/NO_X ISRs of the turbines are comparable. Based on the available test data, it would be most appropriate to apply the conservative ratio of 0.32 (or 32% NO_2). If a proponent were to propose to use a lower NO_2/NO_X ISR for a future development for which it is not possible to obtain source-specific test data, obtaining test data for the specific model turbine from the manufacturer would be important to document that the appropriate model input values are applied.

Sincerely,

Trinity Consultants

Anna Henolson, P.E.
Managing Consultant

Trinity Consultants Experience

following

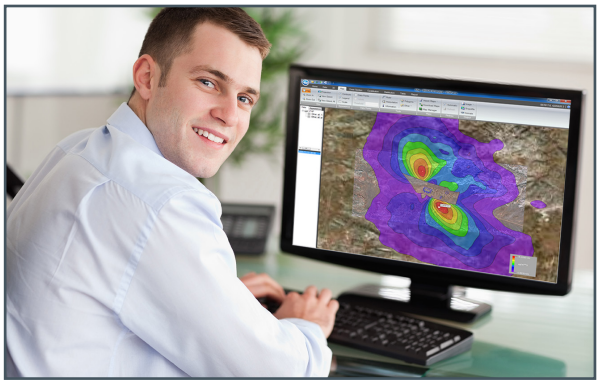
REGULATORY ASSISTANCE

> Air Dispersion Modeling

For more than 40 years, Trinity Consultants has performed air dispersion modeling for industrial facilities, utilities, and government agencies. Trinity is recognized nationally and internationally for our skills and advanced modeling software/infrastructure, enabling Trinity to formulate and conduct dispersion modeling studies for numerous applications.

With the implementation of new, state-of-the-science dispersion models, and more companies realizing the value of dispersion modeling as a planning tool to assess the feasibility of major capital projects, optimize operations, and mitigate risk, Trinity provides unparalleled expertise and service for regulatory situations as well as specialized, often technically challenging scenarios:

- Assessing impacts of air emissions from a single site or cumulative sites to demonstrate compliance with ambient air quality standards and other air quality-related values (acid deposition, visibility, regional haze, etc.) utilizing U.S. EPA preferred models (e.g., AERMOD) and beta-version AERCOARE (the marine environment version of AERMOD)
- Assessing impacts of offshore emissions on the air quality of coastal regions using the Offshore and Coastal Dispersion (OCD) model
- Assessing visible plumes, icing, and fogging impacts due to high water-content air emissions using specialized models such as FOG, SACTI, and CALPUFF
- Performing off-site consequence analyses for risk management planning and meeting state and local air toxic modeling requirements using EPA dispersion, fire, and explosion models included in BREEZE Incident Analyst
- Evaluating individual and cumulative human and ecological risk, and performing probabilistic risk analyses using various modeling tools including BREEZE Risk Analyst and other risk modeling tools
- Conducting off-site impact and deposition studies to support litigation activities
- Performing fatal flaw analyses for siting considerations
- Predicting the impact of roadway air emissions with MOVES and AERMOD (EPA is proposing to replace CALINE as a preferred roadway model)



- Conducting regional modeling studies with the Community Multi-scale Air Quality (CMAQ) model and the Comprehensive Air-quality Model with extensions (CAMx, a photochemical model) for regional haze analyses, control strategy evaluations, ozone/$PM_{2.5}$ impact assessments, and inter-pollutant credit demonstrations in support of nonattainment new source review permitting
- Conducting odor concentration modeling and predicting the effect of different abatement strategies using SCREEN3, AERSCREEN, AERMOD, and CALPUFF
- Analyzing potential risks associated with release of liquefied fuel gas (LFG) and liquefied natural gas (LNG) using BREEZE LFG Fire/Risk and Incident Analyst
- Predicting structural damage and personnel injury from the detonation of high explosives and vapor cloud explosions with BREEZE ExDAM, and illustrating setup and results in powerful 3D graphs and animations
- Processing model-ready meteorological data from surface/upper air observations as well as prognostic meso-scale meteorological models (WRF/MM5) to support to various dispersion models (AERMOD, CALPUFF, CMAQ, CAMx, OCD, etc.)

Air Dispersion Modeling Services

Trinity provides a wide range of air quality modeling consulting services for regulatory applications, emergency planning, and human health assessments.

Trinity Consultants

trinityconsultants.com

Regulatory Air Dispersion Modeling
Trinity is a global provider of air dispersion modeling, air quality compliance services, and software solutions to regulated air emissions sources of all varieties. Trinity is a leader in the practical use of AERMOD, CALPUFF, and other dispersion models, and has developed numerous tools to aid in identifying subtle anomalies in modeled results that can often be challenged in a regulatory context.

Class I Area PSD Impact and Regional Haze Analyses
Trinity has performed numerous Class I area analyses in support of Prevention of Significant Deterioration (PSD) permit applications including PSD Class I Increment and Air Quality Related Value (AQRV) analyses, i.e., visibility and acidic deposition using CALPUFF. In addition, Trinity has completed visibility assessments using VISCREEN and PLUVUE and regional haze analyses for Best Available Retrofit Technology (BART) and Reasonable Progress evaluations in support of the Regional Haze Rule with CMAQ/CAMx. CALPUFF and CAMQ/CAMx modeling requires far more sophisticated analysis than typical near-field models. Because CALPUFF may soon be demoted by EPA as a preferred model, Trinity is increasingly using CMAQ/CAMx for BART and Reasonable Progress evaluations. CAMx has gained favor because of its superior consideration of chemical reactivity as well as other options. We are also versed in the use of SCICHEM, another possible alternative to CALPUFF.

Multi-Pathway Risk Assessment Dispersion Modeling
Trinity has assisted industry, regulatory agencies, and trade associations with technical and modeling support to conduct human health and ecological risk assessments. These projects have included National Environmental Policy Act (NEPA) projects such as coal-gasification plants, MACT residual risk assessments, risk assessments to support RCRA facility permitting for hazardous waste incineration or that utilize hazardous waste derived fuel, and other air quality assessment studies with both inhalation and ingestion pathway assessments. These specialized studies employ a combination of BREEZE AERMOD/ISC, BREEZE Risk Analyst, and other risk modeling tools to account for inhalation and ingestion pathways for maximum exposed individuals and overall population impacts.

Emergency Response Planning and Associated Acute Risks
Trinity performs many health effects impact studies for actual and potential releases of toxic and hazardous air pollutants. These studies have included emissions estimations, acute toxicity evaluations for comparison to threshold limit value-based concentration limits, cancer risk assessment, and ambient monitoring studies. Trinity's staff has considerable experience modeling emissions from accidental releases of liquid spills and spills of liquefied gases using dense gas models including DEGADIS, SLAB, ExDAM, VASDIP, and HEXFRAG. Both BREEZE Incident Analyst and BREEZE ExDAM contain a suite of agency-recognized and industry-standard models that can be utilized in various scenarios.

High Performance Computing Solutions

Trinity provides true high performance computing (HPC) solutions for models such as AERMOD and CALPUFF. The BREEZE Remote Modeling System (or BRMS), delivers runtimes up to 100 times faster (e.g., 8 hour runs reduced to 5 minutes) than standard desktop computing. The BRMS for AERMOD operates on a massively parallel computer cluster that harnesses the processing power of multiple multi-core computers. Users can submit data online, anytime, and receive email notification when model results are available. The BRMS utilizes the BREEZE AERMOD Parallel Fortran application, which produces identical results to EPA's public air dispersion model.

Model Development and Training

Since 1983, Trinity has provided market leading PC-based BREEZE® air dispersion modeling software to environmental professionals. Trinity also provides professional training courses in dispersion modeling, taught by senior-level consultants who are dispersion modeling experts. In addition, Trinity develops customized modeling applications and teaches custom courses to meet the needs of individual organizations.

Why Choose Trinity

In short, there's no better choice for your dispersion modeling needs. Our experience is multi-faceted and extensive. Our strategies are innovative, time saving, and cost-effective. Our staff and tools are the best in the business.

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