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4.4 AIR QUALITY

4.4.1 Setting

The MBGF would be located in the City of Santa Clara, which is in the San Francisco Bay Area Air Basin. Overall air quality in the San Francisco Bay Area Air Basin is better regions. This is due to a more favorable climate, with cooler temperatures and better ventilation. Although air quality improvements have occurred, violations and exceedances of the State and Federal ozone and PM standards continue to persist in the San Francisco Bay Area Air Basin, and still pose challenges to State and local air pollution control agencies.

The MBGF is within the air permitting jurisdiction of the Bay Area Air Quality Management District (BAAQMD). The federal and state attainment status of criteria pollutants in the region are summarized in Table 4.4-1.

Table 4.4-1
Attainment Status of San Francisco Bay Area Air Basin
Bay Area Air Quality Management District

Pollutants	State Classification	Federal Classification
Ozone (1-hr)	Nonattainment	No Federal Standard
Ozone (8-hr)	Nonattainment	Nonattainment
PM10	Nonattainment	Unclassified
PM2.5	Nonattainment	Nonattainment
CO	Attainment	Attainment
NO2	Attainment	Unclassified
SO2	Attainment	Attainment

Source: http://www.baaqmd.gov/research-and-data/air-quality-standards-and-attainment-status

4.4.2 Project Changes Relevant to MBGF

The MND for the MDC site evaluated two generator yards and 32 generators as part of the MDC. The MBGF is an expansion of the backup generating facilities to include 1~~6~~5 additional backup generators located with an additional generator yard and the addition of three life safety generators (one in each generator yard). The configuration and the locations of the generators have been modified as described in Section 2 and the only ground disturbing activities would be limited underground trenching to support underground cabling for its electrical interconnection to each MDC building served by each generator yard.

4.4.3 Environmental Impact Evaluation

The following summarizes the results of an Air Quality and Greenhouse Gas Technical Report (AQTR) and an Air Dispersion Modeling Report For One-Hour NO2 Standard prepared by Ramboll Environ. Both reports are included in Appendix E-1. As described in this SPPE, the MND prepared by the City evaluated the MDC including 32 backup generators. For comparison purposes, the AQTR has evaluated the total emissions from full buildout of the MBGF, in addition to identifying the emission increases resulting from the addition of 1~~6~~5 backup generators and three life safety generators.

Table 4.4-2 shows the previous generator and updated MBGF emissions and the BAAQMD CEQA thresholds.

Table 4.4-2
Summary of Backup Generator Operational Emissions

	ROG	**NOx**	**PM_{10}**	**$PM_{2.5}$**
Operational Daily Emissions (lb/day)				
Previous Generator Emissions	2.1	178	0.43	0.43
Updated Generator Emissions	~~3.3~~3.6	~~263~~220	~~0.63~~0.81	~~0.63~~0.81
Percent change from MND	~~57~~71%	~~48~~24%	~~47~~88%	~~47~~88%
BAAQMD CEQA Thresholds	***54***	***54***	***82***	***54***
Operational Annual Emissions (tpy)				
Previous Generator Emissions	0.38	33	0.08	0.08
Updated Generator Emissions	~~0.60~~0.66	~~34.9~~40[1]	~~0.12~~0.15	~~0.12~~0.15

[1] Proposed as an overall cap for NOx for the site to the BAAQMD.

Percent change from MND	~~58~~71%	~~6~~24%	~~50~~88%	~~50~~88%
BAAQMD CEQA Thresholds	***10***	***10***	***15***	***10***

The MBGF, as modified, will not exceed the BAAQMD CEQA thresholds except for NOx. As described in the MND, per BAAQMD's Rule 2-2, new sources that emit more than 10 tons per year of NOx but less than 35 tons of NOx must fully offset emissions to net zero using the BAAQMD small facility bank. If emissions from any facility are greater than 35 tons per year, the operator must provide offsets to zero. Due to the acceptance of a limit on average aggregate operating hours for the generators at the MBGF, annual NOx emissions from the MBGF are less than 35 tons per year, and would total 40~~34.9~~ tons per year[2], as shown in Table 4.4-2. Accordingly, the BAAQMD will provide offsets for NOx emissions from the backup generators from the BAAQMD small facility bank.

As described more fully in the AQTR, MBGF operations would contribute maximum local CO concentrations of 0.33~~67~~ parts per million (ppm) on a 1-hour average and 0.28~~39~~ ppm on an 8-hour average. These impacts are below the respective BAAQMD thresholds of significance of 20.0 ppm and 9.0 ppm. Dispersion modelling demonstrated compliance with the 1-hour NO_2 NAAQS and CAAQS. More detail on the 1-hour NO_2 model can be found in the air quality technical reports in Appendix E-1.

Therefore, the MBGF would not result in significant air quality impacts and therefore would comply with the Bay Area Clean Air Plan.

Additionally, the AQTR contains a health risk assessment for the MBGF. The results are presented in Table 4.4-3 and demonstrate that the MBGF will not result in significant public health impacts.

Table 4.4-3

Summary of Backup Generator Operational Health Impacts at the Maximally Exposed Individual Sensitive Receptor (MEISR)

	Excess Lifetime Cancer Risk in one million	**Noncancer Chronic HI (unitless)**	**Noncancer Acute HI (unitless)**	**$PM_{2.5}$ Concentration (µg/m^3)**
Project Operational Health Impacts				
Previous Generator Impact	0.30	0.000079	0.67	0.00039

2 Proposed as an overall cap for NOx for the site to the BAAQMD.

Updated Generator Impact	~~0.42~~0.69	~~0.00011~~0.00018	~~0.84~~0.84	~~0.00055~~0.00091
Percent change from MND	~~40~~130%	~~39~~128%	~~25~~25%	~~41~~133%
BAAQMD CEQA Thresholds	***10***	***1***	***1***	***0.3***

4.4.4 Mitigation Measures

No mitigation measures are proposed beyond those included in the MND and the overall emission's cap for NOx proposed to the BAAQMD.

4.4.5 Governmental Agencies

The BAAQMD has authority to implement the air quality LORS and permits for the MBGF. Vantage has filed an application with the BAAQMD for an Authority To Construct (ATC) 31 of the 47 generators and one of the life safety generators. ATC Applications for the remaining generators will be filed in time to support full buildout of the MDC phases. A copy of the recently filed BAAQMD application for ATC is included in - Appendix E 2.

Appendix E-1

Revised Air Quality Technical Reports

Prepared for
Vantage Data Centers
Santa Clara, California

Prepared by
Ramboll ~~Environ~~ US Corporation
San Francisco, California

Project Number
~~03-41184B~~1690006450

~~Date~~
~~January~~May, 2018

AIR QUALITY AND GREENHOUSE GAS TECHNICAL REPORT – BACKUP GENERATORS ONLY

VANTAGE DATA CENTERS
SANTA CLARA, CALIFORNIA

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ACRONYMS AND ABBREVIATIONS

AERMOD	American Meteorological Society/Environmental Protection Agency regulatory air dispersion model
AQ	Air Quality
ARB	California Air Resources Board
aREL	Acute Reference Exposure Level
ASF	Age Sensitivity Factor
BAAQMD	Bay Area Air Quality Management District
Cal/EPA	California Environmental Protection Agency
CAP	Criteria Air Pollutant
CEQA	California Environmental Quality Act
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
CPF	Cancer Potency Factor
cREL	Chronic Reference Exposure Level
DPF	Diesel Particulate Filter
DPM	Diesel Particulate Matter
GHG	Greenhouse Gas
HI	Hazard Index
HQ	Hazard Quotient
HRA	Health Risk Assessment
MAF	Modelling Adjustment Factor
MEIR	Maximally Exposed Individual Resident
MEISR	Maximally Exposed Individual Sensitive Receptor
MEIW	Maximally Exposed Individual Worker
MESCR	Maximally Exposed Soccer Child Receptor
N_2O	Nitrogen Dioxide
NOx	Nitrous Oxide
OEHHA	Office of Environmental Health Hazard Assessment
$PM_{2.5}$	Fine Particulate Matter Less than 2.5 Micrometers in Aerodynamic Diameter

PM_{10}	Respirable Particulate Matter Less than 10 Micrometers in Aerodynamic Diameter
PMI	Point of Maximum Impact
ppm	part per million
REL	Reference Exposure Level
ROG	Reactive Organic Gas
RPS	Renewables Portfolio Standard
TAC	Toxic Air Contaminant
TOG	Total Organic Gas
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Units

g	Gram
kg	Kilogram
m	Meter
MT	Metric Ton
MW	Megawatts
MWh	Megawatts Hour
µg	Microgram
$\mu g/m^3$	Micrograms per cubic meter
m^3/kg-day	Milligrams per kilogram per day
m^3	Cubic meters
mg	Milligram
s	Second
tpy	Ton per Year
yr	Year

EXECUTIVE SUMMARY

Vantage Data Centers' Mathew Street development ("the Project") is a proposed new data center in Santa Clara, California. The Project would be located on a 8.97-acre plot bounded by existing occupied buildings to the West, rail tracks to the East, a Home Depot location to the North and Mathew Street to the South. The proposed plan for the Project includes forty-seven (47) 2.75~~3~~-megawatts (MW) emergency generators and three~~one~~ (3~~1~~) 6~~5~~00-kilowatts (kW) life safety generators to provide back-up power for the data center which may draw up to 74 MW critical and 99.8 MW total of power from the grid. This report evaluates the air quality (AQ) and greenhouse gas (GHG) impacts, together with risks and hazards associated with the Project backup generators (the "power plant").

At the request of Vantage Data Centers, Ramboll ~~Environ~~ US Corporation (Ramboll~~Environ~~) conducted a California Environmental Quality Act (CEQA) analysis of criteria air pollutants (CAPs) and precursor emissions associated with the proposed operation of the backup generators in 2016. Ramboll~~Environ~~ also estimated GHG emissions from operation of the backup generators and performed a health risk assessment (HRA) of operation of the backup generators. This report serves as an update to the previous analysis in 2016 using updated project descriptions and characteristics and only evaluates the changes associated with the Project power plant. The local air agency, the Bay Area Air Quality Management District (BAAQMD) has published CEQA Guidelines for use in determining significance, which will apply here for AQ and GHG (BAAQMD 2011).[1] As shown in **Table ES-1**, the relevant thresholds for the Project are:

- Operational CAP and precursor emissions
- Local carbon monoxide (CO) concentrations
- Operational GHG emissions
- Excess lifetime cancer risk, chronic HI, acute HI, and $PM_{2.5}$ concentrations from operation on off-site receptors; and
- Cumulative excess lifetime cancer risk, chronic HI, and $PM_{2.5}$ concentration from construction and surrounding sources on off-site receptors.

Since construction emissions associated with the grading, concrete pad construction, and placement of the backup generators are negligible, construction emissions and relevant thresholds are not being evaluated. Project health impacts from diesel particulate matter and speciated on-road total organic gas (TOG) emissions were calculated consistent with guidance in BAAQMD's 2011 CEQA guidelines (BAAQMD 2011) and the 2015 California Environmental Protection Agency (Cal/EPA) Office of Environmental Health Hazard Assessment (OEHHA) Hot Spots Guidance (2015). Consistent with BAAQMD and OEHHA Hot Spots guidance, health impacts were based on emissions of toxic air contaminants (TACs). Concentrations of TACs were estimated using AERMOD, a Gaussian air dispersion model recommended by United States Environmental Protection Agency (USEPA), California Air

[1] A March 2012 Alameda County Superior Court judgment determined that the BAAQMD had failed to evaluate the environmental impacts of the land use development patterns that would result from adoption of the thresholds and ordered the thresholds set aside. The Court of Appeal reversed that judgment and the California Supreme Court decided the limited issue that CEQA does not require an analysis of the environment's impact on a project, with the exception of schools.

Resources Board (ARB), and BAAQMD for use in preparing environmental documentation for stationary sources. Health impacts were calculated using the TAC concentrations and TAC toxicities and exposure assumptions consistent with the 2015 OEHHA Hot Spots guidance.

Table ES-1 shows the previous and updated Project emissions and the BAAQMD CEQA thresholds. Updated Project operational GHG emissions are ~~5,460~~5,044 metric tonnes per year (MT/yr), a ~~32~~22% percent change from the previous Project description.

Table ES-1: Summary of Backup Generator Operational Emissions				
	ROG	**NOx [2]**	**PM_{10}**	**$PM_{2.5}$**
Operational Daily Emissions (lb/day)				
Previous Generator Emissions	2.1	178	0.43	0.43
Updated Generator Emissions	~~3.3~~3.6	~~262~~220	~~0.63~~0.81	~~0.63~~0.81
Percent change from MND	~~57~~71%	~~48~~24%	~~47~~88%	~~47~~88%
BAAQMD CEQA Thresholds	***54***	***54***	***82***	***54***
Operational Annual Emissions (tpy)				
Previous Generator Emissions	0.38	33	0.08	0.08
Updated Generator Emissions	0.~~60~~66	~~48~~40	0.~~12~~15	0.~~12~~15
Percent change from MND	~~58~~74%	~~45~~21%	~~50~~88%	~~50~~88%
BAAQMD CEQA Thresholds	***10***	***10***	***15***	***10***

Project operations would contribute maximum local CO concentrations of 0.~~55~~ 33 parts per million (ppm) on a 1-hour average and 0.~~40~~ 23 ppm on an 8-hour average. These impacts are below the respective BAAQMD thresholds of significance of 20.0 ppm and 9.0 ppm.

[2] NOx emissions will be capped or offset through the air permitting process with the BAAQMD.

Table ES-2 shows the previous and updated Project health impacts and the BAAQMD CEQA thresholds. Only the Executive Summary of this report outlines the changes in results due to changes in the project description/master plan (comparing to numbers from the Mitigated Negative Declaration (MND)). The remainder of this report only discusses methodologies and results of the updated Project description.

Table ES-2: Summary of Backup Generator Operational Health Impacts at the Maximally Exposed Individual Sensitive Receptor (MEISR)

	Excess Lifetime Cancer Risk in one million	**Noncancer Chronic HI (unitless)**	**Noncancer Acute HI (unitless)**	**$PM_{2.5}$ Concentration ($\mu g/m^3$)**
Project Operational Health Impacts				
Previous Generator Impact	0.30	0.000079	0.67	0.00039
Updated Generator Impact	0.69~~0.4077~~	0.00018~~0.000110.00020~~	0.~~68~~84	~~0.00053~~0.00091
Percent change from MND	~~33~~130%	~~39~~128%	25~~2~~%	~~36~~133%
BAAQMD CEQA Thresholds	***10***	***1***	***1***	***0.3***

1. INTRODUCTION

This report replaces the previously submitted Air Quality Technical Report in Appendix E. Changes in the project description are reflected in this redline version of the latest submitted version of the Air Quality Technical Report. ~~The previous version of the report was completed prior to the 1-hour NO_2 analysis. A refined 1-hour NO_2 modelling analysis revealed the need to update the designed generator stack heights.~~ This report provides an updated model (modeling files attached separately) ~~that is consistent with the stack parameters presented in the 1-hour NO_2 model (and SPPE application)~~ and also provides updated health risk impacts based on the new ~~stack heights~~project description. This report also reflects analytical changes to respond to comments from the CEC.

~~Additionally, this report has corrected some errors in language identified within the previous report. The AERMOD version used for modeling was previously defined as version 15181 and has been corrected to state that AERMOD version 16216r was used. The text also previously stated that there were four construction phases, this has been corrected to state that there are three construction phases.~~

At the request of Vantage Data Centers, Ramboll~~ Environ~~ US Corporation (Ramboll~~ Environ~~) has prepared this technical report documenting air quality (AQ) and greenhouse gas (GHG) analyses for the construction and operational activities of the proposed data center, located on three land parcels on Mathew Street, in Santa Clara, California (referred to as the "Project"). The analyses follows the Bay Area Air Quality Management District (BAAQMD) California Environmental Quality Act (CEQA) Guidelines released in 2011 (BAAQMD 2011).[3]

1.1 Project Description

The proposed Project spans from 651 to 825 Mathew Street and is bounded by Lafayette Street to the West, rail tracks to the East, a Home Depot location to the North and Mathew Street to the South in Santa Clara, California. The property is an approximately 8.97-acre lot. The proposed location and boundary are shown in **Figure 1**. The proposed Project will be a data center developed over three construction phases from 2017 to 2022. At full build-out, the project will include forty-seven (47) 2.75~~3~~-megawatts (MW) capacity Tier-2 emergency generators with diesel particulate filters (DPF) (a total backup capacity of 99.5~~6~~ MW), three~~one~~ 6~~5~~00-kilowatts (kW) life safety generators, three office buildings, surface street parking spaces, 72 adiabatic air-cooled chillers, and 12 direct expansion make-up air units. This report is only assessing impacts from operations of the backup generators (the "power plant").

1.2 Objective and Methodology

The BAAQMD 2011 CEQA Guidelines contain recommended thresholds for operational criteria air pollutant (CAP) and precursor emissions, GHG emissions, and risks and hazards associated with toxic air contaminant (TAC) emissions from an individual project (BAAQMD 2011). This report evaluates the AQ and GHG impacts, together with risks and hazards associated with backup generator operational activities, on off-site receptors and the

[3] A March 2012 Alameda County Superior Court judgment determined that the BAAQMD had failed to evaluate the environmental impacts of the land use development patterns that would result from adoption of the thresholds and ordered the thresholds set aside. The Court of Appeal reversed that judgment and the California Supreme Court decided the limited issue that CEQA does not require an analysis of the environment's impact on a project, with the exception of schools.

cumulative impact to off-site sensitive receptors from backup generator operations and surrounding sources.

1.3 Thresholds Evaluated

The AQ analysis of this report evaluates the daily and annual regional emissions of criteria pollutants and precursors from operation of the backup generators and evaluates these emissions against BAAQMD's May 2011 significance thresholds for emissions (BAAQMD 2011). These thresholds are as follows:

Operational CAP Emissions:

- Average daily emissions of ROG greater than 54 lb/day, or maximum annual emissions of 10 tons per year (tpy);
- Average daily emissions of NOx greater than 54 lb/day, or maximum annual emissions of 10 tpy;
- Average daily emissions of PM_{10} greater than 82 lb/day, or maximum annual emissions of 10 tpy; and
- Average daily emissions of $PM_{2.5}$ greater than 54 lb/day, or maximum annual emissions of 10 tpy.

Local carbon monoxide (CO) concentrations:

- 8-hour average concentration of 9.0 parts per million (ppm)
- 1-hour average concentration of 20.0 ppm

The GHG analysis of this report evaluates the GHG emissions from operation of the Project and evaluates these emissions against BAAQMD's May 2011 significance thresholds for emissions. These thresholds are as follows:

- Stationary source direct GHG emissions of 10,000 metric tonnes per year (MT/yr)

The health risk assessment (HRA) in this report evaluates the estimated cancer risk, noncancer chronic hazard index (HI), acute HI, and $PM_{2.5}$ concentration associated with construction and operation of the Project's emissions of Toxic Air Contaminants (TACs). The Toxic Air Contaminants considered are those included in BAAQMD Rule 2-5, New Source Review of Toxic Air Contaminants. No chronic or acute health impacts are shown for CAPs, including NO_2, consistent with BAAQMD CEQA guidance. The HRA evaluates potential sensitive receptor locations including:

- "Residential dwellings, including apartments, houses, condominiums;
- Schools, colleges, and universities;
- Daycares;
- Hospitals; and
- Senior-care facilities." (BAAQMD 2012a)

Ramboll ~~Environ~~ conducted a sensitive receptor search within the 1,000-foot zone of influence, and determined that the only sensitive receptors are residential dwellings to the southwest of the Project site. However, for completeness, Ramboll ~~Environ~~ also included a nearby soccer facility directly south of the Project site as a potential sensitive receptor.

To meet the above stated objectives, this HRA was conducted consistent with the following guidance:

- Air Toxics Hot Spots Program Risk Assessment Guidelines (Office of Environmental Health Hazard Assessment [OEHHA] 2015);
- May 2011 BAAQMD CEQA Guidelines (BAAQMD 2011); and
- BAAQMD Recommended Methods for Screening and Modeling Local Risks and Hazards (BAAQMD 2012a).

Ramboll ~~Environ~~ compared the results of emissions and health risk analyses to the BAAQMD 2011 CEQA significance thresholds. Operational health impacts of the backup generators were compared against the BAAQMD 2011 CEQA single source thresholds. The thresholds are:

Single Source Impacts:

- An excess lifetime cancer risk level of more than 10 in one million;
- A noncancer chronic HI greater than 1.0;
- A noncancer acute HI greater than 1.0; and
- An incremental increase in the annual average $PM_{2.5}$ concentration of greater than 0.3 micrograms per cubic meter ($\mu g/m^3$).

If a project does not exceed the identified significance thresholds, its emissions would not be cumulatively considerable. For reference, the BAAQMD 2011 cumulative CEQA significance thresholds are:

- An excess lifetime cancer risk level of more than 100 in one million;
- A noncancer chronic HI greater than 10.0; and
- An annual average $PM_{2.5}$ concentration of greater than 0.8 micrograms per cubic meter ($\mu g/m^3$).

1.4 Report Organization

This technical report is divided into eight sections as follows:

Section 1.0 – Introduction: describes the purpose and scope of this technical report, the objectives and methodology used in this technical report, and the report organization.

Section 2.0 – Emission Estimates: describes the methods used to estimate the emissions of CAPs, GHGs, and TACs from the Project;

Section 3.0 – Estimated Air Concentrations: discusses the air dispersion modeling, the selection of the dispersion models, the data used in the dispersion models (e.g., terrain, meteorology, source characterization), and the identification of residential and sensitive locations evaluated in this technical report.

Section 4.0 – Risk Characterization Methods: provides an overview of the methodology for conducting the HRA.

Section 5.0 – Project Health Risk Assessment: presents the estimated emissions of CAPs and GHGs, estimated excess lifetime cancer risks, chronic noncancer HIs, acute noncancer HIs, and $PM_{2.5}$ concentrations for the Project.

Section 6.0 – References: includes a listing of all references cited in this report.

2. EMISSION ESTIMATES

Ramboll ~~Environ~~ estimated CAP, GHG, and TAC emissions from the operation of the backup generators. The CAPs of interest include ROG, NOx, $PM_{2.5}$ and PM_{10}. There is no mass emissions threshold for CO, although the mass emissions are necessary for CO concentration impact modeling, so Ramboll ~~Environ~~ also estimated CO emissions from operation of the Project. The GHGs of interest include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are commonly combined by global warming potential-weighted average into carbon dioxide equivalents (CO_2e). One of the TACs of interest is diesel particulate matter (DPM), emissions of which are assumed to be equal to exhaust PM_{10} from backup diesel engines during operation. Other TACs are speciated from TOG from on-road emissions from gasoline vehicles. These emissions estimates were used to compare to BAAQMD thresholds and as inputs to the HRA. The methodologies used by Ramboll ~~Environ~~ are summarized below.

Tables 1a and **1b** present the backup generator characteristics and assumptions used in the emissions estimation.

2.1 Calculation Methodologies for Operational Emissions

Emissions from backup generator operations were estimated using manufacturer's data for stationary sources (emergency generators).

2.1.1 Stationary Sources

The proposed Project includes 50~~48~~ diesel back-up generators including three~~one~~ life safety generators, the locations of which are shown in **Figure 2~~3~~**. **Table 1a and Table 1b** presents controlled emission factors used to calculate daily and annual criteria pollutant emission rates as well as uncontrolled emission factors and DPF abatement efficiencies used to calculate the controlled emission factors. Ramboll ~~Environ~~ used United States Environmental Protection Agency (USEPA) D2 Certification Cycle emissions factors with reductions, based on the information provided by project sponsor. Engine emissions are based on non-emergency operations (primarily the schedule of testing that is required for the generators) and the planned number of hours of non-emergency operations (in accordance with BAAQMD Regulation 2, Rule 5). Consistent with BAAQMD permitting methods, no load factor is applied. Annual non-emergency operation is limited to 50 hours, as stated in the Airborne Toxic Control Measure for Stationary Toxic Compression Ignition Engines (Section 93115, Title 17, CCR). Emission rates were averaged over the period of a year since the emergency generators could potentially be tested at any time of day or day of year. **Tables 2** and **3** present the daily and annual CAP emissions from non-emergency operation of the backup engines, and **Table 4** reports the operational mass emissions of CAP including BAAQMD stationary source offsets. Annual GHG emissions are presented in **Table 5**. ~~and with annual GHG emissions also presented in **Table 5**.~~ GHG emissions were calculated following the same methodology as described above for CAPs. The USEPA engine certification emission factors include CO_2. Ramboll ~~Environ~~ used the USEPA Mandatory Reporting Rule emission factors for CH_4 and N_2O emissions (USEPA 2013), which were added to develop a carbon dioxide equivalent (CO_2e) emission factor using the same global warming potentials as in CalEEMod®.

2.1.2 Summary of Project Operational GHG Emissions

GHG emissions from the emergency generators are subject to the BAAQMD CEQA threshold for stationary sources. GHG emissions for backup generator operations are presented in **Table 5**. Based on the maximum allowable hours of operation annually, generators are estimated to emit 5,~~460~~ 044 MT CO_2e/yr, below the BAAQMD stationary source threshold of 10,000 MT CO_2e/yr.

3. ESTIMATED AIR CONCENTRATIONS

Backup generator operational activities will generate emissions that will be transported outside of the physical boundaries of the Project site, potentially impacting nearby sensitive receptors such as residential areas. Methodologies to estimate concentrations resulting from generator operational activities are provided below. Ramboll ~~Environ~~ performed a refined HRA for non-emergency operation of the emergency generators.

3.1 Chemical Selection

The cancer risk, chronic, and acute hazards in the HRA for the Project construction and stationary source operation were based on TAC emissions from the Project. Modeled sources of TACs include on-road construction traffic, off-road construction equipment, and diesel-powered emergency generators. Accordingly, the chemicals to be evaluated in the HRA were DPM, speciated total organic gases (TOG) in diesel exhaust, and speciated evaporative and exhaust TOGs from gasoline vehicles. DPM emissions are assumed to be equal to Exhaust PM_{10} from on- and off-road construction equipment, and exhaust PM_{10} from backup diesel engines during operation. Other TACs are speciated from total organic gases (TOG) from on-road emissions from gasoline vehicles.

Diesel exhaust, a complex mixture that includes hundreds of individual constituents, is identified by the State of California as a known carcinogen (California Environmental Protection Agency [Cal/EPA] 1998). Under California regulatory guidelines, DPM is used as a surrogate measure of exposure for the mixture of chemicals that make up diesel exhaust as a whole. Cal/EPA and other proponents of using the surrogate approach to quantifying cancer risks associated with the diesel mixture indicate that this method is preferable to use of a component-based approach. A component-based approach involves estimating risks for each of the individual components of a mixture. Critics of the component-based approach believe it will underestimate the risks associated with diesel as a whole mixture because the identity of all chemicals in the mixture may not be known and/or exposure and health effects information for all chemicals identified within the mixture may not be available. Furthermore, Cal/EPA has concluded that "potential cancer risk from inhalation exposure to whole diesel exhaust will outweigh the multi-pathway cancer risk from the speciated components" (OEHHA 2003). The DPM analyses for cancer and chronic hazards will be based on the surrogate approach, as recommended by Cal/EPA. In the absence of an acute toxicity value for diesel exhaust, speciated TOG will be used as a conservative estimate.

For the analysis of local CO concentrations, Ramboll ~~Environ~~ used operational CO emissions from stationary sources during project operation.

3.2 Sources of Emissions

The relevant emissions sources of TACs for the refined HRA are off-road equipment and on-road trucks during construction and emergency generators during operation. Emissions estimates for operational mobile sources are not included in the refined HRA since BAAQMD screening tools are used to assess operational mobile source health impacts. Emissions of CO from project operation are from emergency generators only. The screening level for operational traffic is 44,000 vehicles per hour (BAAQMD 2011), which is 100 times higher than total daily trip generation from the project. As such operational traffic is a *de minimis* contributor to operational CO emissions. **Table 11** shows the maximum CO emissions per generator, using the USEPA engine certification emission factor. The CO concentrations analysis is conservative in that it assumes all 50~~48~~ emergency generators are in use at the same time during the worst meteorological conditions for the respective averaging periods.

3.3 Air Dispersion Modeling

~~The latest version of~~ AERMOD ~~(~~Version 16216r~~)~~ was used to evaluate ambient air concentrations of CO, DPM, $PM_{2.5}$ and TOG at off-site receptors from ~~both~~ Project ~~construction sources and the~~ non-emergency use of the backup generators. For each receptor location, the model generates air concentrations that result from emissions from multiple sources. If unit emissions (i.e., 1 g/s) are modelled, the resultant value for each receptor location is called the air dispersion factor.

Air dispersion models such as AERMOD require a variety of inputs such as source parameters, meteorological conditions, topographical information, and receptor parameters. Modeling parameters are shown in **Table 6**. ~~Construction source parameters are from BAAQMD modeling performed in support of the San Francisco Community Risk Reduction Plan (SF CRRP) (Bay Area Air Quality Management District, San Francisco Department of Public health, San Francisco Planning Department 2012).~~ The Project boundary is shown in **Figure 1**.

Meteorological data: Air dispersion modeling requires the use of meteorological data that ideally are spatially and temporally representative of conditions in the immediate vicinity of the site under consideration. Ramboll ~~Environ~~ used surface meteorological data from the San Jose Airport for years 2013~~09~~ through 2017~~3~~, with upper air data collected at the Oakland Airport for the same time period. Data were processed using AERMINUTE (15272) and AERMET (16216). The meteorological data was processed using the ADJ_U* option that reduces overprediction of modeled concentrations that occur in stable conditions with low wind speeds due to underprediction of the surface friction velocity (u*). Underprediction of u* results in an underestimation of the mechanical mixing height and thus overprediction of ambient concentrations. The ADJ_U* option is now considered a regulatory default option with the recent update to Appendix W.

Terrain considerations: Elevation and land use data were imported from the National Elevation Dataset maintained by the United States Geological Survey (USGS 2013). An important consideration in an air dispersion modeling analysis is the selection of whether or not to model an urban area. Here the model assumes an urban land use as has been done for similar projects in the area. Ramboll ~~Environ~~ will use 1,664,496~~126,251~~, the 2010~~2014~~ population of ~~the City of Santa Clara~~San Jose, as the urban population in AERMOD (US Census Bureau 2014). This is a conservative underestimate of the population that contributes to the urban heat island effect in the vicinity of the Project.

Emission rates: Emissions were modeled using the unit rate emissions method for all but CO, such that each source has a unit emission rate (i.e., 1 gram per second [g/s]) and the model estimates dispersion factors with units of ($\mu g/m^3$)/(g/s). Actual emissions were multiplied by the dispersion factors to obtain concentrations. CO modeling used actual emission rates in g/s.

~~Emitting activities were modeled to reflect the actual hours of operation. For Project construction, emissions were modeled to occur between 7 AM and 4 PM, a span of 9 hours, although equipment operation may total less than 9 hours.~~ For Project operation, generators were modeled as if they could operate at any hour of the day.

For annual average ambient air concentrations, the estimated annual average dispersion factors were multiplied by the annual average emission rates. For maximum hourly ambient air concentrations, the estimated maximum hourly dispersion factors were multiplied by the maximum hourly emission rates.

Source parameters: Source locations and parameters are necessary to model the dispersion of air emissions. Operational source locations are shown in **Figure 2**. At full buildout, there are twenty-~~three~~ five generators on the ground-level that will be double ~~stacked at double height on top of~~stacked along with twenty-four generators on ~~ground-level~~a podium and one of the ~~the~~ life safety generators will be single stacked on the ground-level~~, so~~. **Figure 2** shows locations for all 50~~48~~ generators. Source parameters are detailed in **Table 6**.

The operational sources (i.e., emergency generators) were represented by point sources with identical exit temperatures, exit velocities and exit diameters (~~750.85~~753.71 degrees K, ~~59.2~~29.93 meter (m)/s and 0.~~51~~ 66 m, respectively), based on manufacturer information. The life safety generators were~~as~~ represented as~~ an~~ individual point sources with a stack temperature of ~~823.15~~807.76 degrees K, stack velocity of ~~49.34~~ 22.736 m/s and exit diameter of 0.~~2~~ 36 meters, based on manufacturer information. The stack heights for the generators were provided by the Project Sponsor. All stack heights, for both single and double storied generators, will be at the same height. The modeled stack height for all generators is ~~13.77~~14.55 meters above ground.

Receptors: Nearby sensitive receptor populations were identified within a 1,000-m buffer of the Project site, which is larger than the Project's 1,000-foot zone of influence. As discussed above, sensitive receptors include residents to the southwest of the Project site and a soccer facility south of the Project site. A receptor grid was created to cover all potential sensitive receptors within 1,000-m of the Project site. A fine grid of receptors with 25-m spacing was modeled out to 500 m, and a coarse grid with 50-m spacing was modeled out to 1,000 m. Modeled off-site receptors are shown in **Figure 3~~4~~.** Receptors were modeled at 1.8 meters of height, consistent with BAAQMD guidance for breathing height. As discussed previously, average annual and maximum hourly dispersion factors were estimated for each receptor location.

Concentrations: As discussed above, for all but CO modeling emissions were modeled using the unit rate emission factor method, such that the model estimates dispersion factors based on an emission rate of 1 g/s and the dispersion factors have units of [μg/m^3]/[g/s]. Estimated emissions were multiplied by the dispersion factors to obtain concentrations. CO modeling used maximum 1-hour and 8-hour emissions from emergency generator use.

Modeling Adjustment Factor: OEHHA (2015) recommends applying an adjustment factor to the annual average concentration modeled assuming continuous emissions (i.e., 24 hours per day, seven days per week), when the actual emissions are less than 24 hours per day and exposures are concurrent with the emitting activities. Operational emissions for the Project are modeled with the assumption that they can occur at any hour of the day. MAFs are shown in **Table 7**.

4. RISK CHARACTERIZATION METHODS

The following sections discuss in detail the various components required to conduct the HRA.

4.1 Project Sources Evaluated

As discussed in Section 1.3, excess lifetime cancer risk, chronic and acute HIs, and $PM_{2.5}$ concentrations were evaluated for off-site sensitive receptor exposures to emissions from Project construction and operation. The TACs of concern are those in BAAQMD Rule 2-5, so no health impacts from CAPs are considered in this analysis, consistent with BAAQMD CEQA Guidance.

4.2 Exposure Assessment

Potentially Exposed Populations: This assessment evaluated off-site receptors potentially exposed to Project emissions from operational activities. These exposed populations include residential and recreational receptors at a nearby soccer field. Both long-term health impacts (cancer risk, chronic HI, and $PM_{2.5}$ concentration) and acute hazards were evaluated for the residential and recreational locations.

Exposure Assumptions: The exposure parameters used to estimate excess lifetime cancer risks due to operational activities were obtained using risk assessment guidelines from OEHHA (2015) and draft guidelines from the BAAQMD that indicate how the BAAQMD would integrate the 2015 OEHHA Guidelines (BAAQMD 2016), unless otherwise noted, and are presented in **Table 7**. Based on the TACs considered, the only relevant exposure pathway is inhalation, so this HRA considers inhalation exposure only.

For offsite residential receptors, Ramboll ~~Environ~~ selected conservative exposure parameters assuming that exposure would begin during the third trimester of a residential child's life. Ramboll ~~Environ~~ used 95th percentile breathing rates up to age 2, and 80th percentile breathing rates above age 2, consistent with BAAQMD guidance (2016). For operation, off-site residents were assumed to be present at one location for a 30-year period, beginning with exposure in the third trimester.

For offsite recreational soccer receptors, Ramboll ~~Environ~~ selected exposure parameters using the conservative assumption that a child would be located at the soccer facility starting at age 2, then that same child would continue to be exposed by participating in activities at the facility as they got older. For operation, the child was assumed to be present one day a week for one hour per day for a full 30 years. Operational exposures used the 95th percentile 8-hour moderate intensity breathing rate from the OEHHA guidelines.

For offsite receptors, including fenceline and adjacent sidewalk receptors, Ramboll adopted the Commission Staff-requested methodology of assigning a worker exposure parameters to those locations for assessment of the point of maximum impact. Ramboll is not in agreement with this methodology and believes every receptor should be assigned exposure parameters based on existing conditions and land uses or what could feasibly occur at each receptor over the duration of the project. It is not reasonable that a worker will be present for 25-30 years on the fenceline of the Site or the adjacent sidewalk. However, consistent with the Staff's request, Ramboll has provided results of an analysis that assumes every receptor that is not classified as a resident or soccer child is assumed to have worker exposure parameters. This includes all receptors on the fenceline and all other public spaces adjacent to the project site. Operational exposure for a worker used the 95th percentile 8–hour breathing rate from the

OEHHA guidelines (2015). A 25-year exposure duration for workers is assumed based on the OEHHA recommended exposure duration period and an exposure frequency of 250 days in a year is used in the analysis.

Ramboll evaluated the Point of Maximum Impact (PMI) as the highest impact value for each health metric, but maximum impacts do not all occur in the same location. Locations of both long-term and acute PMIs are presented.

Calculation of Intake: The dose estimated for each exposure pathway is a function of the concentration of a chemical and the intake of that chemical. The intake factor for inhalation, IF_{inh}, can be calculated as follows:

$$IF_{inh} = \frac{DBR * FAH * EF * ED * CF}{AT}$$

Where:

IF_{inh}	=	Intake Factor for Inhalation (m^3/kg-day)
DBR	=	Daily Breathing Rate (L/kg-day)
FAH	=	Fraction of Time at Home (unitless)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
AT	=	Averaging Time (days)
CF	=	Conversion Factor, 0.001 (m^3/L)

The chemical intake or dose is estimated by multiplying the inhalation intake factor, IF_{inh}, by the chemical concentration in air, C_i. When coupled with the chemical concentration, this calculation is mathematically equivalent to the dose algorithm given in the OEHHA Hot Spots guidance (2015).

4.3 Toxicity Assessment

The toxicity assessment characterizes the relationship between the magnitude of exposure and the nature and magnitude of adverse health effects that may result from such exposure. For purposes of calculating exposure criteria to be used in risk assessments, adverse health effects are classified into two broad categories – cancer and non-cancer endpoints. Toxicity values used to estimate the likelihood of adverse effects occurring in humans at different exposure levels are identified as part of the toxicity assessment component of a risk assessment.

Excess lifetime cancer risk and chronic HI calculations for project operation utilized the toxicity values for DPM from diesel generators. Acute HI calculations utilized the toxicity values for TACs from speciated diesel TOG for diesel generators. The speciation profiles used are presented in **Table 8**. The toxicities of each chemical are shown in **Table 9**. The TACs of concern have inhalation health effects only.

4.4 Age Sensitivity Factors

The estimated excess lifetime cancer risks for a resident child was adjusted using the age sensitivity factors (ASFs) recommended by OEHHA (2015). This approach accounts for an "anticipated special sensitivity to carcinogens" of infants and children. Cancer risk estimates are weighted by a factor of 10 for exposures that occur from the third trimester of pregnancy to two years of age and by a factor of three for exposures that occur from two years through 15 years of age. No weighting factor (i.e., an ASF of one, which is equivalent to no adjustment) is applied to ages 16 to 30 years. **Table 10** shows the ASFs used.

4.5 Risk Characterization

4.5.1 Estimation of Cancer Risks

Excess lifetime cancer risks are estimated as the upper-bound incremental probability that an individual will develop cancer over a lifetime as a direct result of exposure to potential carcinogens. The estimated risk is expressed as a unitless probability. The cancer risk attributed to a chemical is calculated by multiplying the chemical intake or dose at the human exchange boundaries (e.g., lungs) by the chemical-specific cancer potency factor (CPF).

The equation used to calculate the potential excess lifetime cancer risk for the inhalation pathway is as follows:

$$Risk_{inh} = C_i \times CF \times IF_{inh} \times CPF \times ASF$$

Where:

$Risk_{inh}$	=	Cancer risk; the incremental probability of an individual developing cancer as a result of inhalation exposure to a particular potential carcinogen (unitless)
C_i	=	Annual average air concentration for chemical during activities$_i$ ($\mu g/m^3$)
CF	=	Conversion factor (mg/µg)
IF_{inh}	=	Intake factor for inhalation (m^3/kg-day)
CPF_i	=	Cancer potency factor for chemical$_i$ (mg chemical/kg body weight-day)$^{-1}$
ASF	=	Age sensitivity factor (unitless)

4.5.2 Estimation of Chronic and Acute Noncancer Hazard Quotients/Indices

Chronic HQ

The potential for exposure to result in adverse chronic noncancer effects is evaluated by comparing the estimated annual average air concentration (which is equivalent to the average daily air concentration) to the noncancer chronic reference exposure level (cREL) for each chemical. When calculated for a single chemical, the comparison yields a ratio termed a hazard quotient (HQ). To evaluate the potential for adverse chronic noncancer health effects from simultaneous exposure to multiple chemicals, the chronic HQs for all chemicals are summed, yielding a chronic HI.

$$HQi = Ci / cREL$$

Where:

HQi = Chronic hazard quotient for chemical i

HI = Hazard index

Ci = Annual average concentration of chemical i (µg/m3)

cRELi = Chronic noncancer reference exposure level for chemical i (µg/m³)

Acute HI

The potential for exposure to result in adverse acute effects is evaluated by comparing the estimated one-hour maximum air concentration of chemical to the acute reference exposure level (aREL) for each chemical evaluated in this analysis. When calculated for a single chemical, the comparison yields an HQ. To evaluate the potential for adverse acute health effects from simultaneous exposure to multiple chemicals, the acute HQs for all chemicals are summed, yielding an acute HI.

$$HQi = Ci / aREL$$

Where:

HQi = Acute hazard quotient for chemical i

HI = Hazard index

Ci = One-hour maximum concentration of chemical i (µg/m3)

aRELi = Acute reference exposure level for chemical i (µg/m³)

5. PROJECT HEALTH RISK ASSESSMENT

In this section, the Project HRA results are presented for each of the BAAQMD CEQA thresholds.

As discussed in Section 1.3, the single source significance thresholds for health risks and hazards from Project operation are:

- An excess lifetime cancer risk level of more than 10 in one million;
- A chronic noncancer HI greater than 1.0;
- A noncancer acute HI greater than 1.0; and
- An incremental increase in the annual average $PM_{2.5}$ of greater than 0.3 µg/m^3.

5.1 Operational HRA

Table 13 shows the excess lifetime cancer risk, chronic noncancer HI, acute noncancer HI and annual $PM_{2.5}$ concentration at the maximally exposed individual resident (MEI~~S~~R), maximally exposed individual worker (MEIW), the maximally exposed soccer child receptor (MESCR), and the point of maximum impact (PMI) during backup generator operation. The incremental increase in cancer risk due to Project operation is 0.69 in one million at the MEI~~S~~R. The MEIR chronic and acute noncancer HIs, which are not at the same receptor location, are 0.00018 and 0.34 respectively. The MEIR annual $PM_{2.5}$ concentration due to Project operation is 0.00091 µg/m^3. The incremental increase in cancer risk due to Project operation is 2.3 in one million at the MEIW and PMI, which occur at the same location. The MEIW/PMI chronic and acute noncancer HIs are 0.0074 and 0.84, respectively. The MEIW/PMI annual $PM_{2.5}$ concentration due to Project operation is 0.037 µg/m^3. The incremental increase in cancer risk due to Project operation is 0.080 in one million at the MESCR. The MESCR chronic and acute noncancer HIs are 0.0022 and 0.60, respectively. The MESCR annual $PM_{2.5}$ concentration due to Project operation is 0.011 µg/m^3. **Table 14** presents the health risk impacts for the maximally exposed sensitive receptor (MESIR) which includes only residents and soccer child receptors for cancer risk, chronic HI and annual $PM_{2.5}$ concentration and includes any offsite receptor for the acute analysis.

As noted in Section 3.4, l~~L~~ocal CO concentrations over both 1-hour and 8-hour averaging times are shown in **Table 11**. Pollutant 1-hour and annual concentrations at the MEISR for Project operation are listed in **Table 12**.

5.2 Cumulative HRA

The BAAQMD CEQA Guidelines establish numerical criteria for determining when an emissions increase is considered cumulatively considerable and thus triggers the need for a quantitative cumulative impacts assessment.

In developing thresholds of significance for air pollutants, BAAQMD considered the emission levels for which a project's individual emissions would be cumulatively considerable. If a project does not exceed the identified significance thresholds, its emissions would not be cumulatively considerable, resulting in less-than-significant air quality impacts to the region's existing air quality conditions. Therefore, additional analysis to assess cumulative impacts is unnecessary, but an analysis of cumulative sources is performed here for completeness. Ramboll~~ Environ~~ used the BAAQMD Stationary Source Screening Tool for Santa Clara County (BAAQMD 2012b) to identify existing permitted stationary sources within 1,000 feet of the

MEI~~S~~R. Ramboll ~~Environ~~ submitted a stationary source inquiry form to the BAAQMD to request updates and received the response in **Appendix B**. **Table 1~~5~~4** summarizes the risks and hazards at the MEISR from existing stationary sources. Some existing stationary source addresses do not match the location shown in the tool's Google Earth interface. Any source identified as being within 1,000 feet of the MEISR in the Google Earth interface is included in this analysis. When the BAAQMD provided updated HRSA results, as for Facility #19686, the updated HRSA results are used in **Table 1~~5~~4**.

BAAQMD on-road traffic tools were used along with existing trip count data to estimate health-risk impacts and $PM_{2.5}$ concentrations from on-road traffic. Traffic count data for Lafayette Street, the largest roadway in the vicinity of the Project, were taken from the Kimley Horn traffic study for the intersection of Lafayette Street and Walsh Avenue. The BAAQMD Roadway Screening Analysis Calculator (BAAQMD 2015) provides screening risk estimates for traffic for north-south roadways and east-west roadways in Santa Clara County. The peak hour traffic volume of 1,515 vehicles was conservatively used as the average daily traffic value input into the BAAQMD tool. Lafayette Street was treated as a north-south roadway with the MEISR to the west at a distance of 10 feet. As shown in **Table 1~~5~~4** the cancer risk from on-road traffic is 1.60 in one million and the $PM_{2.5}$ concentration is 0.033 μg/m^3. Caltrain was not considered in this cumulative assessment as the trains will be electric by Project operation in 2020,[4] so there will be no exhaust emissions impacts.

For TACs, the project would have a cumulatively considerable impact if project emissions would result in:

- Non-compliance with a qualified risk reduction plan; or
- An excess lifetime cancer risk level of more than 100 in one million;
- A chronic noncancer HI greater than 10; and
- An incremental increase in the annual average $PM_{2.5}$ of greater than 0.8 μg/m^3.

Based on the project-level analysis included above, the project would not have a cumulatively considerable impact based on these BAAQMD criteria:

- There is no qualified risk reduction plan in effect for the City of Santa Clara.
- The Project would not exceed the BAAQMD cumulatively considerable thresholds relative to the region's existing air quality conditions per the BAAQMD criteria.

Because the project would not meet the BAAQMD CEQA Guidelines criteria for a contribution to any potential adverse cumulative air health risk impacts from either construction or operation, it would not contribute to any potential adverse cumulative air impact on sensitive receptors.

As shown in **Table 1~~5~~4**, existing stationary sources contribute levels of $PM_{2.5}$ above the BAAQMD CEQA threshold of significance for $PM_{2.5}$ concentrations, although the Project contribution is less than significant.

4 www.caltrain.com/projectsplans/CaltrainModernization/Modernization/PeninsulaCorridorElectrificationProject.html

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TABLES

Table 1a
Emergency Generator Emission Factors
McLaren Project
Santa Clara, California

Generator Information

Make	Caterpillar
Model	3516E
USEPA Tier	2
USEPA Engine Family	HCPXL78.1NZS
Generator Output at 100% Load (kilowatt)	2,750
Engine Output at 100% Load (horsepower)	4,043

Control Efficiency (DPF) Information

Make	Johnson Matthey
Model	CRT® (+) Particulate Filter System

Pollutant	Uncontrolled Emission Factors[1] (g/hp-hr)	Control Efficiency at 100% Load	Controlled Emission Factors[2] (g/hp-hr)
NOx	3.78	0%	3.8
ROG	0.21	70%	0.06
CO	0.67	80%	0.13
PM	0.09	85%	0.013
$PM_{2.5}$	0.09	85%	0.013
CO_2[3]	522	0%	522
CH_4[4]	0.021	0%	0.021
N_2O[4]	0.0042	0%	0.0042
CO_2e[5]	523	0%	523

Notes:

1. Uncontrolled emission factors are from EPA D2 Cycle Certification from the spec sheet provided by Project sponsor.
2. Controlled Emission Factors are the USEPA Engine Family Certification emission factors with reductions assuming a Johnson Matthey CRT® Particulate Filter System on each engine.
3. Emissions factor from AP-42, Vol. I, Section 3.3, Table 3.3-1 for Uncontrolled Gasoline and Diesel Industrial Engines.
4. Emissions factors from 40 CFR 98, Subpart C, Table C-2. Petroleum emissions listed as 3 g CH_4/mmBtu and 0.6 g N_2O/mmBtu. Assumed conversion factor of 7000 Btu/hp-hr per AP-42 Vol I, Table 3.3-1.
5. Global warming potential values of 1 for CO_2, 25 for CH_4, and 298 for N_2O from US EPA's Federal Register (FR) final rule published on November 29, 2013 [78 FR 71904] and effective on January 1, 2014, were used to convert emissions to metric tones of carbon dioxide equivalents.

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Table 1a
Emergency Generator Emission Factors
McLaren Project
Santa Clara, California

Abbreviations:

CH_4 - methane	hp - horsepower
CO - carbon monoxide	hr - hour
CO_2 - carbon dioxide	N_2O - nitrous oxide
CO_2e - carbon dioxide equivalents	PM - Particulate Matter
DPF - Diesel Particulate Filter	ROG - reactive organic gases
g - gram	USEPA - United States Environmental Protection Agency

References:

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Table 1b
Life Safety Generator Emission Factors
McLaren Project
Santa Clara, California

Generator Information

Make	Caterpillar
Model	C18
USEPA Tier	2
USEPA Engine Family	JCPXL18.1NYS
Generator Output at 100% Load (kilowatt)	600
Engine Output at 100% Load (horsepower)	900

Control Efficiency (DPF) Information

Make	N/A
Model	N/A

Pollutant	Uncontrolled Emission Factors[1] (g/hp-hr)
NOx	3.8
ROG	0.088
CO	0.6
PM	0.05
$PM_{2.5}$	0.05
CO_2[2]	522
CH_4[3]	0.021
N_2O[3]	0.0042
CO_2e[4]	523

Notes:

1. Uncontrolled emission factors are from EPA D2 Cycle Certification from the spec sheet provided by Project sponsor.
2. Emissions factor from AP-42, Vol. I, Section 3.3, Table 3.3-1 for Uncontrolled Gasoline and Diesel Industrial Engines.
3. Emissions factors from 40 CFR 98, Subpart C, Table C-2. Petroleum emissions listed as 3 g CH_4/mmBtu and 0.6 g N_2O/mmBtu. Assumed conversion factor of 7000 Btu/hp-hr per AP-42 Vol I, Table 3.3-1.
4. Global warming potential values of 1 for CO_2, 25 for CH_4, and 298 for N_2O from US EPA's Federal Register (FR) final rule published on November 29, 2013 [78 FR 71904] and effective on January 1, 2014, were used to convert emissions to metric tones of carbon dioxide equivalents.

Table 1b
Life Safety Generator Emission Factors
McLaren Project
Santa Clara, California

Abbreviations:

CH_4 - methane
CO - carbon monoxide
CO_2 - carbon dioxide
CO_2e - carbon dioxide equivalents
DPF - Diesel Particulate Filter
g - gram
hp - horsepower
hr - hour
N_2O - nitrous oxide
PM - Particulate Matter
ROG - reactive organic gases
USEPA - United States Environmental Protection Agency

References:

USEPA. 2015. Large Engine Certification Data for Model Year 2015. Available at: https://www3.epa.gov/otaq/documents/eng-cert/nrci-cert-ghg-2015.xls.

Table 2
Engine Emissions, Daily
McLaren Project
Santa Clara, California

Engine Model	Engine Horsepower	Emissions by Pollutant[3]				
		Quantity of Engines	Operational Hours per Engine per Year	Pollutant	Average Daily Emissions (lb/day)	CEQA Threshold (lb/day)
3516E	4,043	47	50	NOx	217	54
				ROG[1]	3.6	54
				CO[1]	8	-
				PM_{10}[2]	0.77	82
				$PM_{2.5}$[2]	0.77	54
C18	900	3	50	NOx	3.08	54
				ROG	0.07	54
				CO	0.486	-
				PM_{10}[2]	0.0426	82
				$PM_{2.5}$[2]	0.0426	54

Notes:

1. Emission factors for ROG and CO are multiplied by (100% - 70%) and (100% - 80%), respectively, to account for the proposed DPF, which has a minimum abatement efficiency of 70% for ROG and 80% for CO for the emergency generators (Model 3516E).
2. Emission factors for PM_{10} and $PM_{2.5}$ are conservatively assumed to be equal to the PM emission factor. PM emissions for the emergency generators (Model 3516E) are multiplied by (100% - 85%) to account for the proposed DPF, which has a minimum PM abatement efficiency of 85%. Life safety generators (Model C18) do not include a DPF.
3. Emission factors for the emergency generators are the 100% Load emission factors from the USEPA Engine Family Certification with reductions assuming a Johnson Matthey CRT® (+) Particulate Filter System on each emergency generator engine (Model 3516 E). Life safety generators (Model C18) do not include a DPF.

Abbreviations:

CO - carbon monoxide
DPF - Diesel Particulate Filter
lb - pounds
NOx - oxides of nitrogen
PM - Particulate Matter
ROG - reactive organic gases
USEPA - United States Environmental Protection Agency

References:

Peterson Power Systems. 2017. Manufacturer's Performance Data for Model 3516E.

Johnson Matthey Proposal No. GR-394 to Peterson

USEPA. 2015. Large Engine Certification Data for Model Year 2015. Available at: https://www3.epa.gov/otaq/documents/eng-cert/nrci-cert-ghg-2015.xls.

RAMBOLL

Table 3
Engine Emissions, Annual
McLaren Project
Santa Clara, California

Engine Model	Engine Horsepower	Emissions by Pollutant[3]				
		Quantity of Engines	Operational Hours per Engine per Year	Pollutant	Average Annual Emissions (ton/year)	CEQA Threshold (ton/year)
3516E	4,043	47	50	NOx	40	10
				ROG[1]	0.65	10
				CO[1]	1.4	-
				PM_{10}[2]	0.14	15
				$PM_{2.5}$[2]	0.14	10
				GHG[4]	4973	10,000
C18	900	3	50	NOx	0.56	10
				ROG	1.3E-02	10
				CO	0.089	-
				PM_{10}[2]	7.8E-03	15
				$PM_{2.5}$[2]	7.8E-03	10
				GHG[4]	7.1E+01	10,000

Notes:

1. Emission factors for ROG and CO are multiplied by (100% - 70%) and (100% - 80%), respectively, to account for the proposed DPF, which has a minimum abatement efficiency of 70% for ROG and 80% for CO for the emergency generators (Model 3516E)
2. Emission factors for PM_{10} and $PM_{2.5}$ are conservatively assumed to be equal to the PM emission factor. PM emissions for the emergency generators (Model 3516E) are multiplied by (100% - 85%) to account for the proposed DPF, which has a minimum PM abatement efficiency of 85%. Life safety generators (Model C18) do not include a DPF.
3. Emission factors for the emergency generators are the 100% Load emission factors from the USEPA Engine Family Certification with reductions assuming a Johnson Matthey CRT® (+) Particulate Filter System on each emergency generator engine (Model 3516 E). Life safety generators (Model C18) do not include a DPF.
4. Annual greenhouse gas emissions are calculated in units of MT CO_2e/year. GHG emission factors for the generators are based on the AP-42 GHG factors as described in Tables 1 and 2.

Abbreviations:

CO - carbon monoxide
DPF - Diesel Particulate Filter
lb - pounds
GHG - greenhouse gases
NOx - oxides of nitrogen
PM - Particulate Matter
ROG - reactive organic gases
USEPA - United States Environmental Protection Agency

Table 3
Engine Emissions, Annual
McLaren Project
Santa Clara, California

References:

Peterson Power Systems. 2017. Manufacturer's Performance Data for Model 3516E.

Johnson Matthey Proposal No. GR-394 to Peterson

USEPA. 2015. Large Engine Certification Data for Model Year 2015. Available at: https://www3.epa.gov/otaq/documents/eng-cert/nrci-cert-ghg-2015.xls.

Table 4
Operational Mass Emissions of Criteria Air Pollutants
McLaren Project
Santa Clara, California

Emissions Source	**CAP Emissions [ton/year]**				**CAP Emissions [lb/day]**			
	ROG	**NO_x**	**PM_{10} Total**	**$PM_{2.5}$ Total**	**ROG**	**NO_x**	**PM_{10} Total**	**$PM_{2.5}$ Total**
Emergency Generators	0.66	40	0.15	0.15	3.6	220	0.81	0.81
BAAQMD Stationary Source Offsets	-	-40	-	-	-	-220	-	-
Total Project Emissions	**0.66**	**0**	**0.15**	**0.15**	**3.6**	**0**	**0.81**	**0.81**
BAAQMD Significance Threshold	10	10	15	10	54	54	82	54

Abbreviations:

BAAQMD - Bay Area Air Quality Management District
CAP - Criteria Air Pollutant
lb - pounds
NOx - nitrogen oxides
ROG - reactive organic gases
PM_{10} - particulate matter less than 10 microns
$PM_{2.5}$ - particulate matter less than 2.5 microns

Table 5
Operational Mass Emissions of Greenhouse Gases
McLaren Project
Santa Clara, California

Emissions Source	GHG Emissions	Units
Emergency Generators	5,044	MT CO_2e/yr
BAAQMD Stationary Source Threshold	**10,000**	

Abbreviations:

BAAQMD - Bay Area Air Quality Management District
CO_2e - carbon dioxide equivalents
GHG - greenhouse gas
MT - metric ton
yr - year

Table 6
Modeling Parameters
McLaren Project
Santa Clara, California

Emergency Generator Model

Source	Source Type	Number of Sources[1]	Release Height (m)	Exit Temperature (K)	Exit Velocity (m/s)	Exit Diameter (m)
Back-Up Generators	Point	47	14.55 meters, double stacked	753.71	29.932	0.66

Life Safety Generator Model

Source	Source Type	Number of Sources[1]	Release Height (m)	Exit Temperature (K)	Exit Velocity (m/s)	Exit Diameter (m)
Life-Safety Generator	Point	3	14.55 meters, double stacked	807.76	22.7356	0.36

[1] Forty-seven identical generators and three life safety generators will be installed at the Project site.

Abbreviations:

K - Kelvin
m - meter
s - second

Table 7
Exposure Parameters, 2015 OEHHA Methodology
McLaren Project
Santa Clara, California

Period	Receptor Type	Receptor Age Group	Exposure Parameters						
			Daily Breathing Rate (DBR)[1] (Resident: L/kg-day, Soccer Child L/kg-hr)	Exposure Duration (ED)[2] (years)	Fraction of Time at Home (FAH)[3] (unitless)	Exposure Frequency (EF)[4] (days/year)	Averaging Time (AT) (days)	Modeling Adjustment Factor (MAF) (unitless)	Intake Factor, Inhalation (IF_{inh}) (m^3/kg-day)
Operation	Offsite Resident	3rd Trimester	361	0.25	1	350	25,550	1	0.0012
		Age 0-<2 Years	1,090	2	1	350	25,550	1	0.030
		Age 2-<16 Years	572	14	1	350	25,550	1	0.11
		Age 16-30 Years	261	14	1	350	25,550	1	0.050
	Soccer Child	Age 2-<16 Years	65	14	N/A	52	25,550	1	0.0019
		Age 16-30 Years[5]	30	16	N/A	52	25,550	1	9.8E-04
	Worker[6]	Age 16-70 Years	230	25	1	250	25,550	1	0.056

Notes:

1. Daily breathing rates reflect default breathing rates from OEHHA 2015 as follows: Resident: 95th percentile for 3rd trimester and age 0-<2 years; 80th percentile for ages 2-<9 years, 2-<16 years, and 16-30 years. Soccer Child: 95th percentile moderate intensity for all ages.
2. The total exposure duration for operation reflects the default residential exposure duration from Cal/EPA 2015.
3. Fraction of time at home (FAH) was conservatively assumed to be 1 for all age groups for residential exposure. FAH is not applicable to recreational soccer receptors.
4. Exposure frequency reflects default exposure frequency for residents from Cal/EPA 2015. For Soccer Child receptors, it was assumed that children would attend the soccer facility once a week for 52 weeks.
5. Exposure for children using the soccer facility was assumed to start at age 2 since children younger than 2 cannot participate in the activities at this facility. For operational exposures, 30-year exposure was evaluated starting at age 2 and the 16-30 year breathing rate was assumed for ages 16-32.
6. Daily breathing rates reflect default breathing rates from OEHHA 2015 for a worker: 95th percentile 8-hour breathing rate for ages 16-<70 years. A 25-year exposure duration for workers was assumed based on the OEHHA's recommended exposure duration period. Exposure frequency for workers is assumed to be 250 days in a year.

Calculation:

Resident:

IF_{inh} = DBR * ED * FAH * EF * CF / AT

CF = 0.001 (m^3/L)

Table 7
Exposure Parameters, 2015 OEHHA Methodology
McLaren Project
Santa Clara, California

Abbreviations:

Cal/EPA - California Environmental Protection Agency

L - liter

kg - kilogram

m^3 - cubic meter

Reference:

Cal/EPA. 2015. Air Toxics Hot Spots Program. Risk Assessment Guidelines. Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment (OEHHA). February.

Available online at: http://oehha.ca.gov/air/hot_spots/hotspots2015.html.

Table 8
Speciation Values
McLaren Project
Santa Clara, California

Source	Emission Type	Fraction	Chemical[1]
Diesel Offroad Equipment (Generators)	**Exhaust PM**	1.0	Diesel PM
	Exhaust TOG	0.0019	1,3-Butadiene
		0.074	Acetaldehyde
		0.020	Benzene
		0.0031	Ethylbenzene
		0.15	Formaldehyde
		0.0016	n-Hexane
		3.0E-04	Methanol
		0.015	Methyl Ethyl Ketone
		9.0E-04	Naphthalene
		0.026	Propylene
		6.0E-04	Styrene
		0.015	Toluene
		0.0061	m-Xylene
		0.0034	o-Xylene
		0.0010	p-Xylene

Notes:

1. Compounds presented in this table are only those air toxic contaminants with toxicity values from Cal/EPA (2015) evaluated in the health risk assessment. Speciation profiles presented in this table are from the following sources:

   Diesel offroad exhaust, TOG: ARB 818 / EPA 3161

Abbreviations:

ARB - Air Resources Board
BAAQMD - Bay Area Air Quality Management District
Cal/EPA - California Environmental Protection Agency
PM - particulate matter
TOG - total organic gas
USEPA - United States Environmental Protection Agency

References:

ARB. Speciation Profiles Used in ARB Modeling. Available online at: http://www.arb.ca.gov/ei/speciate/speciate.htm#specprof

BAAQMD. 2011. Recommended Methods for Screening and Modeling Local Risks and Hazards. May.

Cal/EPA. 2015. OEHHA/ARB Consolidated Table of Approved Risk Assessment Health Values. May 13.

USEPA. SPECIATE 4.3. Available online at: http://cfpub.epa.gov/si/speciate/

Table 9
Toxicity Values
McLaren Project
Santa Clara, California

Chemical[1]	Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Chronic REL ($\mu g/m^3$)	Acute REL ($\mu g/m^3$)
Diesel PM	1.1	5.0	-
Acetaldehyde	0.010	140	470
Benzene	0.10	3.0	27
1,3-Butadiene	0.60	2.0	660
Chlorine	-	0.20	210
Copper	-	-	100
Ethylbenzene	0.0087	2,000	-
Formaldehyde	0.021	9.0	55
n-Hexane	-	7,000	-
Manganese	-	0.090	-
Methanol	-	4,000	28,000
Methyl Ethyl Ketone	-	-	13,000
Naphthalene	0.12	9.0	-
Propylene	-	3,000	-
Styrene	-	900	21,000
Toluene	-	300	37,000
Xylenes	-	700	22,000

Notes:

1. Chemicals presented in this table reflect air toxic contaminants in the proposed fuel types that are expected from off-road equipment, on-road truck trips, automobile traffic, and propane generators.

Abbreviations:

- - not available or not applicable
$\mu g/m^3$ - micrograms per cubic meter
ARB - Air Resources Board
Cal/EPA - California Environmental Protection Agency
$(mg/kg\text{-}day)^{-1}$ - per milligram per kilogram-day
OEHHA - Office of Environmental Health Hazard Assessment
PM - particulate matter
REL - reference exposure level

Reference:

Cal/EPA. 2015. OEHHA/ARB Consolidated Table of Approved Risk Assessment Health Values. May 13.

Table 10
Age Sensitivity Factors
McLaren Project
Santa Clara, California

Receptor Age Group	Age Sensitivity Factor[1] (ASF)
3rd Trimester	10
Age 0-<2 Years	10
Age 2-<16 Years	3
Age 16-30 Years	1

Notes:

1. Based on Cal/EPA 2015.

Abbreviation:

Cal/EPA: California Environmental Protection Agency

References:

Cal/EPA. 2015. Air Toxics Hot Spots Program. Risk Assessment Guidelines. Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment (OEHHA). February.

Available online at: http://oehha.ca.gov/air/hot_spots/hotspots2015.html.

Table 11
Carbon Monoxide Analysis
McLaren Project
Santa Clara, California

Averaging Period	Generator Type	Dispersion Factor at Maximum CO Concentration Location[1]	CO Emission Rate	Concentration
		$\mu g/m^3$ / g/s	lb/hr / gen	ppm
1-hr	Emergency Generators	2,195	1.2	0.33
	Life Safety Generator	285	1.18	
8-hr	Emergency Generators	1,405	1.2	0.23
	Life Safety Generator	299	1.18	

Notes:

1. This concentration reflects the highest modeled concentration for the respective averageing periods.

Abbreviations:

CO - carbon monoxide
gen - generator
$\mu g/m^3$ - microgram per meter cubed
g/s - gram per second
lb - pound
hr - hour
ppm - parts per million

Table 12
Concentrations at the Operational MEISR
McLaren Project
Santa Clara, California

Pollutant	Generators[4]
Annual Concentration (µg/m³)[1,2]	
Diesel PM	9.1E-04
$PM_{2.5}$[2]	9.1E-04
1-hr Concentration (µg/m³)[2]	
1,3-butadiene	0.45
acetaldehyde	17
Acrolein	--
benzene	4.7
ethylbenzene	0.73
formaldehyde	35
n-hexane	0.38
methanol	0.071
methyl ethyl ketone (mek) (2-butanone)	3.5
naphthalene	0.21
o-xylene	0.80
propene	6.1
styrene	0.14
toluene	3.5
Xylenes[5]	2.5

Notes:

1. Maximum annual emissions were reported for the scenario receptors with the highest cancer risk, chronic HI, and $PM_{2.5}$ concentration (Annual MEISRs).
2. Note that the presented $PM_{2.5}$ concentration includes estimated fugitive dust emissions.
3. Maximum one hour emissions were reported for the scenario receptors with the highest Acute HI (Acute MEISRs).
4. The table below lists the 2 MEISR locations:

Generators	UTMx	UTMy
Annual	593075	4135550
1-hr	593187.08	4135857.44

5. Xylene 1-hr concentrations include o-xylene concentrations shown above.

Table 12
Concentrations at the Operational MEISR
McLaren Project
Santa Clara, California

Abbreviations:

HI - health index
MEISR - Maximally Exposed Individual Sensitive Receptor
$PM_{2.5}$ - fine particulate matter less than 2.5 microns
UTM - Universal Transverse Mercator coordinate system
$\mu g/m^3$ - micrograms per cubic meter
hr - hour
m - meter

Table 13
Project-Related Operational Health Risk Impacts Summary
McLaren Project
Santa Clara, California

Receptor Type	MEIR	MEIW[1]	MESCR	PMI
Cancer Risk Impact (in one million)	0.69	2.29	0.08	2.29
Chronic Non-Cancer Hazard Index	0.00018	0.00739	0.00215	0.00739
Annual $PM_{2.5}$ Concentration ($\mu g/m^3$)	0.00091	0.03696	0.01076	0.03696
UTMx	593075	593357.83	593275	593357.83
UTMy	4135550	4135714.99	4135650	4135714.99
Acute Non-Cancer Hazard Index	0.34	0.84	0.60	0.84
UTMx for Acute HI	593050	593187.08	593250	593187.08
UTMy for Acute HI	4135575	4135857.44	4135650	4135857.44

Notes:

1 Worker exposure is assumed at any non-resident and non-soccer child receptor, including fenceline and sidewalk receptors adjacent to the Project Site. Given this assumption, the PMI and MEIW are in the same location.

Abbreviations:

MEIR - Maximally Exposed Individual Resident
MEIW - Maximally Exposed Individual Worker
MESCR -Maximally Exposed Soccer Child Receptor
PMI - Point of Maximum Impact
HI - Hazard Index
$PM_{2.5}$ - fine particulate matter less than 2.5 microns
UTM - Universal Transverse Mercator coordinate system
$\mu g/m^3$ - micrograms per cubic meter

Table 14
Project-Related Operational Health Risk Impacts to the MEISR
McLaren Project
Santa Clara, California

Emission Source	Cancer Risk Impact[1] (in one million)	Chronic Non-Cancer Hazard Index[1]	Acute Non-Cancer Hazard Index[2]	Annual $PM_{2.5}$ Concentration[1] ($\mu g/m^3$)
Emergency Generators	0.69	1.8E-04	0.84	9.1E-04
Project Operational Total	0.69	1.8E-04	0.84	9.1E-04
BAAQMD Significance Threshold	10	1	1	0.3

Notes:

1. The cancer risk, Chronic HI, and annual PM2.5 concentration MEISR is located at UTM coordinates: UTMx = 593075, UTMy = 4135550. Only residents and soccer child receptors were included in the MEISR analysis for cancer risk, chronic HI and annual PM2.5 concentration.

2. The acute HI MEISR is located at UTM coordinates: UTMx = 593187.08, UTMy = 4135857.44. All receptors, including workers, were considered for the acute MEISR analysis.

Abbreviations:

BAAQMD - Bay Area Air Quality Management District
HI - health index
MEISR - Maximally Exposed Individual Sensitive Receptor
$PM_{2.5}$ - fine particulate matter less than 2.5 microns
UTM - Universal Transverse Mercator coordinate system
$\mu g/m^3$ - micrograms per cubic meter

Table 15
Summary of Cumulative Health Risk Impacts to the MEISR
McLaren Project
Santa Clara, California

Emission Source	Cancer Risk Impact (in one million)	Chronic Non-Cancer Hazard Index	Acute Non-Cancer Hazard Index	Annual $PM_{2.5}$ Concentration (ug/m^3)
Project Operational Generators	0.69	1.8E-04	0.84	9.1E-04
Subtotal, Project Impacts	0.69	1.8E-04	0.84	9.1E-04
Existing Stationary Sources				
M's Refinishing (Facility #5269)	1.63	0.06	N/A	0
Bay Area Surgical Group (Facility #16964)	2.72	0.001	N/A	0.001
Microsoft Corporation (Facility #19686)	11	0.008	N/A	0.033
FMG Enterprises Inc (Facility #4400)	0.03	0	N/A	0
Memorex Dirve LLC (Facility #10299)	2.43	0.006	N/A	0
Mission Trail Waste Systems (Facility #8313)	0.43	0.003	N/A	29.5
Process Stainless Lab, Inc (Facility #17041)	0	0	N/A	0
Vivid Inc (Facility #11467)	0	0	N/A	0.037
Byington Steel Treating, Inc (Facility #4712)	0	0	N/A	0
West Coast Vanities (Facility #15355)	0	0	N/A	0
AMCO Auto Body & Painting (Facility #16494)	0	0	N/A	0
HGM (Facility #14667)	0	0	N/A	0
Choice Auto Body (Facility #17000)	0	0	N/A	0
Lafayette Street	1.60	NA	NA	0.033
Subtotal, Background Sources	19.4	0.08	0.00	29.6
Total Cumulative Impact	**20**	**0.078**	**0.84**	**30**
BAAQMD Significance Threshold	100	10	10	0.8

Table 15
Summary of Cumulative Health Risk Impacts to the MEISR
McLaren Project
Santa Clara, California

Notes:

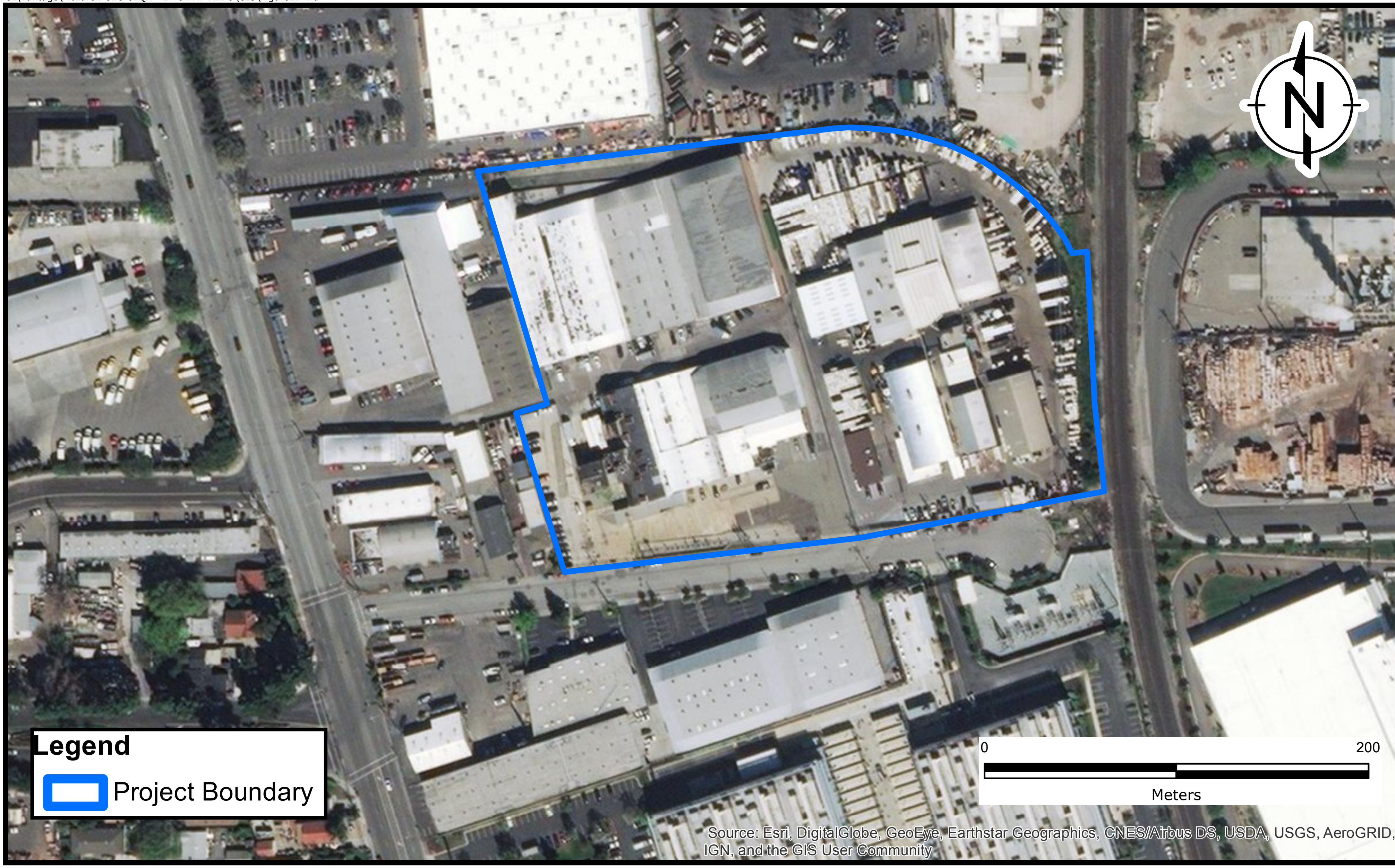
1. The existing receptor locations experiencing maximum project impacts are presented in the previous two tables.

Abbreviations:

BAAQMD - Bay Area Air Quality Management District
HI - health index
MEISR - Maximally Exposed Individual Sensitive Receptor
$PM_{2.5}$ - fine particulate matter
ug/m^3 - micrograms per cubic meter
UTM - Universal Transverse Mercator coordinate system

FIGURES

U:\Vantage\McLaren CEC CEQA - 2.75 MW REDO\GIS\Figure1.mxd



RAMBOLL

DRAFTED BY: | DATE: 5/2/2018

Project Boundary
McLaren Project
Vantage Data Centers
Santa Clara, California

FIGURE
1

PROJECT: 1690006450

U:\Vantage\McLaren CEC CEQA - 2.75 MW REDO\GIS\Figure2.mxd

RAMBOLL

DRAFTED BY:

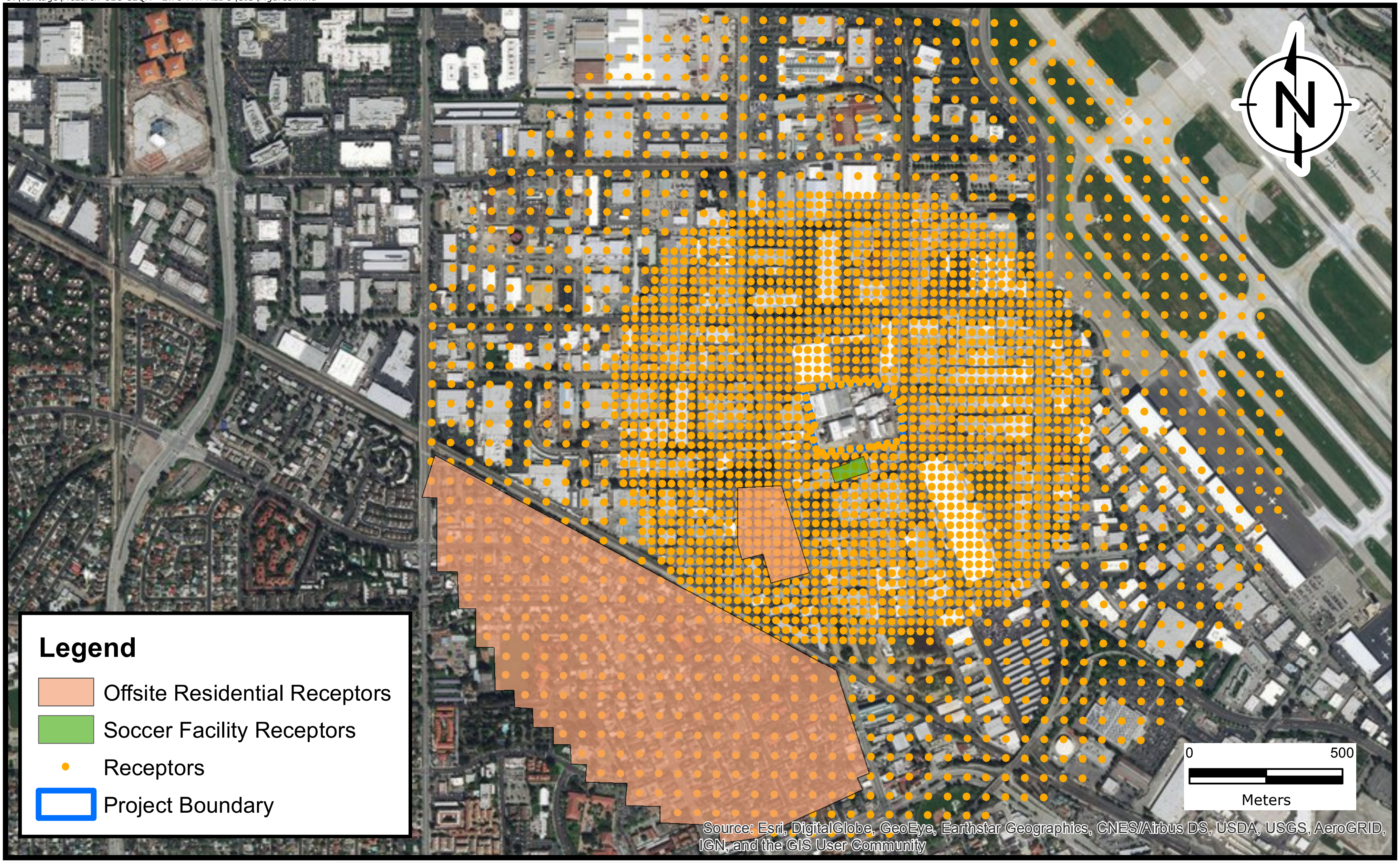
DATE: 5/2/2018

Generator Locations
McLaren Project
Vantage Data Centers
Santa Clara, California

FIGURE
2

PROJECT: 1690006450

U:\Vantage\McLaren CEC CEQA - 2.75 MW REDO\GIS\Figure3.mxd



RAMBOLL

DRAFTED BY:

DATE: 5/2/2018

Receptor Grid
McLaren Project
Vantage Data Centers
Santa Clara, California

FIGURE
3

PROJECT: 1690006450

Bay Area Air Quality Management District

Risk & Hazard Stationary Source Inquiry Form

This form is required when users request stationary source data from BAAQMD. This form is to be used with the BAAQMD's Google Earth stationary source screening tables.

For guidance on conducting a risk & hazard screening, including for roadways & freeways, refer to the District's Risk & Hazard Analysis flow chart.

Also see the District's Recommended Methods for Screening and Modeling Local Risks and Hazards document.

Table A: Requestor Contact Information	
Contact Name:	Julia Luongo
Affiliation:	Ramboll Environ
Phone:	415-426-5025
Email:	jluongo@ramboll.com
Date of Request	8/18/2016
Project Name:	-
Address:	North of Mathew St between Lafayette St and the railroad
City:	Santa Clara
County:	Santa Clara
Type (residential, commercial, mixed use, industrial, etc.):	Industrial
Project size (# of units, or building square feet):	
Comments:	

For Air District assistance, the following steps must be completed:

1. Complete all the contact and project information requested in Table A. Incomplete forms will not be processed. Please include a project site map.
2. Download and install the free program Google Earth, http://www.google.com/earth/download/ge/, and then download the county specific Google Earth stationary source application files from the District's website, http://www.baaqmd.gov/Divisions/Planning-and-Research/CEQA-GUIDELINES/Tools-and-Methodology.aspx. The small points on the map represent stationary sources permitted by the District (Map A on right). These permitted sources include diesel back-up generators, gas stations, dry cleaners, boilers, printers, auto spray booths, etc. Click on a point to view the source's Information Table, including the name, location, and preliminary estimated cancer risk, hazard index, and PM2.5 concentration.
3. Find the project site in Google Earth by inputting the site's address in the Google Earth search box.
4. Identify stationary sources near the project. Verify that the location of the source on the map matches with the source's address in the Information Table, by using the Google Earth address search box to confirm the source's address location. Please report any mapping errors to the District.
5. List the stationary source information in Table B Section 1 below.
6. Note that a small percentage of the stationary sources have Health Risk Screening Assessment (HRSA) data INSTEAD of screening level data. These sources will be noted by an asterisk next to the Plant Name (Map B on right). If HRSA values are presented, these values have already been modeled and cannot be adjusted further.
7. Email this completed form to District staff. District staff will provide the most recent risk, hazard, and PM2.5 data that are available for the source(s). If this information or data are not available, source emissions data will be provided. Staff will respond to inquiries within three weeks.

Note that a public records request received for the same stationary source information will cancel the processing of your SSIF request.

Submit forms, maps, and questions to Alison Kirk at 415-749-5169, or akirk@baaqmd.gov .

Map B: Snapshot of Google Earth with Plant G8736 Information Table Selected Showing HRSA Values

Note the asterisk next to the plant name. This means that the values that appear below are from the HRSA. These values cannot be further adjusted using our screening tools, such as the diesel multiplier sheet. These values are based on modeling. If the Information Table says "Contact District Staff" include in Table B below.

Table B: Stationary Sources

Table B Section 1: Requestor fills out these columns based on Google Earth data											Table B Section 2: BAAQMD returns form with additional information in these columns as needed								
Distance from Receptor (feet)	**Plant # or Gas Dispensary #**	**Facility Name**	**Street Address**	**Screening Level Cancer Risk (1)**	**Screening Level Hazard Index (1)**	**Screening Level PM2.5 (1)**	**Permit #s (2)**	**Source #s (2)**	**Fuel Code (3)**	**Type of Source(s) (4)**	**HRSA Ap # (5)**	**HRSA Date (6)**	**HRSA Engineer (7)**	**HRSA Cancer Risk in a million**	**Age Sensitivity Factor (8)**	**HRSA Adjusted Cancer Risk**	**HRSA Chronic Health (9)**	**HRSA PM2.5 Risk**	**Status/Comments**
220	9200	US Foam Inc	630 Martin Ave	0.05	0	22.6												0	emissions attached; consider site-specific modeling.
220	11324	Los Altos Garbage Company	650 Martin Ave	0	0	0												0	no risk/concentration, no further study needed.
520	G8575	Vargas Gardening Service	495 Robert Ave	1.9*	0.009*	na*												0	*Note that I added screening values for 2014 (not on web yet). Consider using provided screening values.
550	11223	88 Auto Body	518 Roberts Ave	0	0	0												0	no risk/concentration, no further study needed.
600	621	City of Snata Clara, Silicon Valley Power	560 Robert Ave	421	4.27	55												0	emissions attached; consider site-specific modeling.
0	16972	Magnessen's Car West Autobody	631 Martin Ave	0	0	0												0	no risk/concentration, no further study needed.
850	11013	Castro Body Shop	970 Martin Avenue	0	0	0												0	no risk/concentration, no further study needed.
600	5269	M's Refinishing	965 Richard Ave	1.63	0.06	0												0	low risk/concentration, no further study needed.
450	17885	K Auto Body & Repair	2555 Lafayette Street, #117	0.05	0	0												0	no risk/concentration, no further study needed.
0	11179	A Tool Shed, Inc	2556 lafayette Street	0	0	0												0	no risk/concentration, no further study needed.
100	17352	Align Technology	881 Martin Ave	24.62	0.009	0.044					13527	11/1/2005	DYC	1.600	1.7	2.72	0.001	0.008526646	consider using adjusted HRSA values.
400	19663	ACE Fuel Systems Inc	975 Richard Ave	0	0	0												0	no risk/concentration, no further study needed.
400	16472	R G Fine Finishes Inc	965 Richard Ave, Unit A	0	0	0												0	no risk/concentration, no further study needed.
950	5600	Frontier Auto Body	1050 Martin Ave	0	0.012	0.003												0	no risk/concentration, no further study needed.
650	16964	Bay Area Surgical Group	2222 Lafayette St, STE 101	2.72	0.001	0.001												0	low risk/concentration, no further study needed.

900	19686	Microsoft Corporation	2045 Lafayette Street	9478.87	3.353	16.8				diesel engines	24737	10/25/2012	JHL	10.600	1	10.6	0.008	0.03322884	Consider using HRSA values, which cover all 26 engines. See attached for emissions info.
950	4400	FMG Enterprises Inc	1125 Memorex Drive	0.03	0	0												0	no risk/concentration, no further study needed.
500	16950	Hand Crafted Cabinets	1001 Martin Ave	0	0	0												0	no risk/concentration, no further study needed.
600	16754	AT&T Mobility	1051 Martin Avenue	0	0	0												0	no risk/concentration, no further study needed.
850	10299	Memorex Dirve LLC	1200 Memorex Dirve	2.43	0.006	0												0	low risk/concentration, no further study needed.
750	8313	Mission Trail Waste Systems	1060 Richard Avenue	0.43	0.003	29.5												0	emissions attached. Consider site-specific study.
650	17041	Process Stainless Lab, Inc	1280 Memorex Drive	0	0	0												0	no risk/concentration, no further study needed.
500	12987	Economy Auto Body	2555 Lafayette St., Suite 110	0	0	0												0	no risk/concentration, no further study needed.
850	11467	Vivid Inc	1250 Memorex Drive	0	0	0.037												0	low risk/concentration, no further study needed.
850	4712	Byington Steel Treating, Inc	1225 Memorex Drive	0	0	0												0	no risk/concentration, no further study needed.

Footnotes:

1. These Cancer Risk, Hazard Index, and PM2.5 columns represent the values in the Google Earth Plant Information Table.

2. Each plant may have multiple permits and sources.
3. Fuel codes: 98 = diesel, 189 = Natural Gas.
4. Permitted sources include diesel back-up generators, gas stations, dry cleaners, boilers, printers, auto spray booths, etc.
5. If a Health Risk Screening Assessment (HRSA) was completed for the source, the application number will be listed here.
6. The date that the HRSA was completed.
7. Engineer who completed the HRSA. For District purposes only.
8. All HRSA completed before 1/5/2010 need to be multiplied by an age sensitivity factor of 1.7.
9. The HRSA "Chronic Health" number represents the Hazard Index.
10. Further information about common sources:
    a. Sources that only include diesel internal combustion engines can be adjusted using the BAAQMD's Diesel Multiplier worksheet.
    b. The risk from natural gas boilers used for space heating when <25 MM BTU/hr would have an estimated cancer risk of one in a million or less, and a chronic hazard index of 0.003 or less. To be conservative, requestor should assume the cancer risk is 1 in a million and the hazard index is 0.003 for these sources.
    c. BAAQMD Reg 11 Rule 16 required that all co-residential (sharing a wall, floor, ceiling or is in the same building as a residential unit) dry cleaners cease use of perc on July 1, 2010. Therefore, there is no cancer risk, hazard or PM2.5 concentrations from co-residential dry cleaning businesses in the BAAQMD.
    d. Non co-residential dry cleaners must phase out use of perc by Jan. 1, 2023. Therefore, the risk from these dry cleaners does not need to be factored in over a 70-year period, but instead should reflect the number of years perc use will continue after the project's residents or other sensitive receptors (such as students, patients, etc) take occupancy.
    e. Gas stations can be adjusted using BAAQMD's Gas Station Distance Mulitplier worksheet.
    f. Unless otherwise noted, exempt sources are considered insignificant. See BAAQMD Reg 2 Rule 1 for a list of exempt sources.
    g. This spray booth is considered to be insignificant.

Date last updated:
5/30/12

Plant# 9200 U S Foam Inc
630 Martin Avenue
Santa Clara, CA 95050

[C]urrent, [A]rchive, or [F]uture? c
[P]lant, [S]ource, [A]bate. device, or [E]mis. Point? p

CURRENT Sources:

1 Expandable Polystyrene Foam Molding Presses - Three
MISC> Molding/curing, plastics, Plastic, polyproducts, general
G7111225 /,S4,

2 Storage Area - Prepuff Bins
MISC> Molding/curing, plastics, Plastic, polyproducts, general
G7111225 /,S4,

3 Pre-Expander
MISC> Molding/curing, plastics, Plastic, polyproducts, general
G7111225 /,S4,

4 Boiler [registered]
Industrial Boiler - Other, 4200K BTU/hr max, Natural gas, 5 days/wk
C1150189 no train

BAY AREA AIR QUALITY MANAGEMENT DISTRICT Printed: AUG 23, 2016
DETAIL POLLUTANTS - ABATED
MOST RECENT P/O APPROVED (2012)

U S Foam Inc (P# 9200)

S# SOURCE NAME
MATERIAL SOURCE CODE
THROUGHPUT DATE POLLUTANT CODE LBS/DAY
----
1 Expandable Polystyrene Foam Molding Presses - Three
G7111225
Organics (other, including 990 9.64E+00
2 Storage Area - Prepuff Bins
G7111225
Organics (other, including 990 9.64E+00
3 Pre-Expander
G7111225
Organics (other, including 990 2.47E-04
Particulates (part not spe 1990 9.64E+00
4 Boiler
C1150189
Benzene 41 4.55E-05
Formaldehyde 124 1.62E-03
Toluene 293 7.36E-05
Organics (other, including 990 8.49E-02
Particulates (part not spe 1990 6.50E-02
Nitrous Oxide (N2O) 2030 5.00E-03
Nitrogen Oxides (part not 2990 2.81E+00
Sulfur Dioxide (SO2) 3990 1.23E-02
Carbon Monoxide (CO) pollu 4990 6.50E-01
Carbon Dioxide, non-biogen 6960 2.65E+03
Methane (CH4) 6970 4.11E-02

PLANT TOTAL:
lbs/day Pollutant

4.55E-05 Benzene (41)
2.65E+03 Carbon Dioxide, non-biogenic CO2 (6960)
6.50E-01 Carbon Monoxide (CO) pollutant (4990)
1.62E-03 Formaldehyde (124)
4.11E-02 Methane (CH4) (6970)
2.81E+00 Nitrogen Oxides (part not spec elsewhere) (2990)
5.00E-03 Nitrous Oxide (N2O) (2030)
1.94E+01 Organics (other, including CH4) (990)
9.70E+00 Particulates (part not spec elsewhere) (1990)
1.23E-02 Sulfur Dioxide (SO2) (3990)
7.36E-05 Toluene (293)

Plant# 621 City of Santa Clara
560 Robert Avenue
Santa Clara, CA 95050

[C]urrent, [A]rchive, or [F]uture? C
[P]lant, [S]ource, [A]bate. device, or [E]mis. Point? p

CURRENT Sources:

1 Gas Turbine with water injection
Turbine, Cogeneration, 55MM BTU/hr max, Natural gas, 7 days/wk
C7140189 /,P1,

2 Gas Turbine with water injection
Turbine, Cogeneration, 55MM BTU/hr max, Natural gas, 7 days/wk
C7140189 /,P2,

3 Supplemental Duct Burner for S-1
Direct Flame Afterburner, 20000K BTU/hr max, Natural gas, 7 days/wk
C8340189 no train

4 Supplementa Duct Burner for S-2
Direct Flame Afterburner, 20000K BTU/hr max, Natural gas, 7 days/wk
C8340189 no train

BAY AREA AIR QUALITY MANAGEMENT DISTRICT Printed: AUG 23, 2016
DETAIL POLLUTANTS - ABATED
MOST RECENT P/O APPROVED (2016)

City of Santa Clara (P# 621)

S# SOURCE NAME
MATERIAL SOURCE CODE
THROUGHPUT DATE POLLUTANT CODE LBS/DAY
----
1 Gas Turbine with water injection
C7140189
Benzene 41 5.10E-02
Formaldehyde 124 1.08E+01
Organics (other, including 990 3.55E+01
Particulates (part not spe 1990 1.54E+01
Nitrous Oxide (N2O) 2030 2.55E-01
Nitrogen Oxides (part not 2990 1.66E+02
Sulfur Dioxide (SO2) 3990 6.27E-01
Carbon Monoxide (CO) pollu 4990 1.27E+02
Carbon Dioxide, non-biogen 6960 1.35E+05
Methane (CH4) 6970 9.96E+00
2 Gas Turbine with water injection
C7140189
Benzene 41 4.86E-02
Formaldehyde 124 1.03E+01
Organics (other, including 990 3.39E+01
Particulates (part not spe 1990 1.47E+01
Nitrous Oxide (N2O) 2030 2.43E-01
Nitrogen Oxides (part not 2990 1.58E+02
Sulfur Dioxide (SO2) 3990 5.98E-01
Carbon Monoxide (CO) pollu 4990 1.21E+02
Carbon Dioxide, non-biogen 6960 1.29E+05
Methane (CH4) 6970 9.51E+00
3 Supplemental Duct Burner for S-1
C8340189
0 0.00E+00
4 Supplementa Duct Burner for S-2
C8340189
0 0.00E+00

PLANT TOTAL:
lbs/day Pollutant

9.96E-02 Benzene (41)
2.64E+05 Carbon Dioxide, non-biogenic CO2 (6960)
2.48E+02 Carbon Monoxide (CO) pollutant (4990)
2.10E+01 Formaldehyde (124)
1.95E+01 Methane (CH4) (6970)
3.23E+02 Nitrogen Oxides (part not spec elsewhere) (2990)
4.98E-01 Nitrous Oxide (N2O) (2030)
6.94E+01 Organics (other, including CH4) (990)
3.02E+01 Particulates (part not spec elsewhere) (1990)
1.23E+00 Sulfur Dioxide (SO2) (3990)

BAY AREA AIR QUALITY MANAGEMENT DISTRICT Printed: AUG 23, 2016
DETAIL POLLUTANTS - ABATED
MOST RECENT P/O APPROVED (2010)

Align Technology (P# 17352)

S# SOURCE NAME
MATERIAL SOURCE CODE
THROUGHPUT DATE POLLUTANT CODE LBS/DAY

----

1 Emergency Standby Diesel Generator Set
C22AG098

POLLUTANT	CODE	LBS/DAY
Benzene	41	3.45E-03
Formaldehyde	124	2.16E-02
Organics (other, including	990	1.86E-02
Arsenic (all)	1030	3.01E-06
Beryllium (all) pollutant	1040	1.76E-06
Cadmium	1070	7.52E-06
Chromium (hexavalent)	1095	1.56E-07
Lead (all) pollutant	1140	6.38E-06
Manganese	1160	1.00E-05
Nickel pollutant	1180	1.22E-04
Mercury (all) pollutant	1190	2.13E-06
Diesel Engine Exhaust Part	1350	2.31E-02
PAH's (non-speciated)	1840	1.59E-05
Nitrous Oxide (N2O)	2030	9.25E-04
Nitrogen Oxides (part not	2990	8.30E-01
Sulfur Dioxide (SO2)	3990	1.13E-03
Carbon Monoxide (CO) pollu	4990	1.65E-01
Carbon Dioxide, non-biogen	6960	1.16E+02
Methane (CH4)	6970	4.62E-03

Plant# 19686 Microsoft Corporation
2045 Lafayette Street
Santa Clara, CA 95050

[C]urrent, [A]rchive, or [F]uture? c
[P]lant, [S]ource, [A]bate. device, or [E]mis. Point? p

CURRENT Sources:

1 Emergency Genset, Diesel, 2935 hp, BY1 Hitec R11
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

2 Emergency Genset, Diesel, 2935 hp, BY1 Hitec R12
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

3 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P1
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

4 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P2
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

5 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P3
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

6 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P4
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

7 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P5
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

8 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P6
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

9 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P7
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

10 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P8
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

11 Emergency Genset, Diesel, 2935 hp, BY1 Hitec R21
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

12 Emergency Genset, Diesel, 2935 hp, BY1 Hitec R22
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

13 Emergency Genset, Diesel, 2935 hp, BY2 Hitec R11
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

14 Emergency Genset, Diesel, 2935 hp, BY2 Hitec R12
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

15 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P1
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

16 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P2
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

17 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P3
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

18 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P4
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

19 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P5
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

20 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P6

emissions

Benzene 41 3.90E-04
Formaldehyde 124 3.23E-05
Organics (other, including 990 1.95E-02
Arsenic (all) 1030 3.40E-07
Beryllium (all) pollutant 1040 1.99E-07
Cadmium 1070 8.50E-07
Chromium (hexavalent) 1095 1.76E-08
Lead (all) pollutant 1140 7.21E-07
Manganese 1160 1.13E-06
Nickel pollutant 1180 1.38E-05
Mercury (all) pollutant 1190 2.40E-07
Diesel Engine Exhaust Part 1350 3.64E-03
PAH's (non-speciated) 1840 1.79E-06
Nitrous Oxide (N2O) 2030 1.05E-04
Nitrogen Oxides (part not 2990 1.55E-01
Sulfur Dioxide (SO2) 3990 1.28E-04
Carbon Monoxide (CO) pollu 4990 2.42E-02
Carbon Dioxide, non-biogen 6960 1.31E+01
Methane (CH4) 6970 5.23E-04

5 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P3
C2240098
Benzene 41 4.11E-04
Formaldehyde 124 3.40E-05
Organics (other, including 990 2.05E-02
Arsenic (all) 1030 3.58E-07
Beryllium (all) pollutant 1040 2.10E-07
Cadmium 1070 8.94E-07
Chromium (hexavalent) 1095 1.85E-08
Lead (all) pollutant 1140 7.58E-07
Manganese 1160 1.19E-06
Nickel pollutant 1180 1.45E-05
Mercury (all) pollutant 1190 2.53E-07
Diesel Engine Exhaust Part 1350 3.82E-03
PAH's (non-speciated) 1840 1.89E-06
Nitrous Oxide (N2O) 2030 1.10E-04
Nitrogen Oxides (part not 2990 1.63E-01
Sulfur Dioxide (SO2) 3990 1.34E-04
Carbon Monoxide (CO) pollu 4990 2.55E-02
Carbon Dioxide, non-biogen 6960 1.38E+01
Methane (CH4) 6970 5.50E-04

6 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P4
C2240098
Benzene 41 5.07E-04
Formaldehyde 124 4.20E-05
Organics (other, including 990 2.53E-02
Arsenic (all) 1030 4.42E-07
Beryllium (all) pollutant 1040 2.59E-07
Cadmium 1070 1.10E-06
Chromium (hexavalent) 1095 2.28E-08
Lead (all) pollutant 1140 9.37E-07
Manganese 1160 1.47E-06
Nickel pollutant 1180 1.79E-05
Mercury (all) pollutant 1190 3.12E-07
Diesel Engine Exhaust Part 1350 4.72E-03
PAH's (non-speciated) 1840 2.33E-06
Nitrous Oxide (N2O) 2030 1.36E-04
Nitrogen Oxides (part not 2990 2.02E-01
Sulfur Dioxide (SO2) 3990 1.66E-04
Carbon Monoxide (CO) pollu 4990 3.15E-02
Carbon Dioxide, non-biogen 6960 1.70E+01
Methane (CH4) 6970 6.79E-04

7 Emergency Genset, Diesel, 2935 hp, BY1 Hitec P5
C2240098
Benzene 41 3.52E-04
Formaldehyde 124 2.91E-05
Organics (other, including 990 1.76E-02
Arsenic (all) 1030 3.07E-07
Beryllium (all) pollutant 1040 1.80E-07
Cadmium 1070 7.67E-07
Chromium (hexavalent) 1095 1.59E-08
Lead (all) pollutant 1140 6.50E-07
Manganese 1160 1.02E-06
Nickel pollutant 1180 1.24E-05
Mercury (all) pollutant 1190 2.17E-07
Diesel Engine Exhaust Part 1350 3.28E-03
PAH's (non-speciated) 1840 1.62E-06
Nitrous Oxide (N2O) 2030 9.43E-05
Nitrogen Oxides (part not 2990 1.40E-01

Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

21 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P7
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

22 Emergency Genset, Diesel, 2935 hp, BY2 Hitec P8
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

23 Emergency Genset, Diesel, 2935 hp, BY2 Hitec R21
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

24 Emergency Genset, Diesel, 2935 hp, BY2 Hitec R22
Standby Diesel engine, 2935 hp, Detroit Diesel, 3966 cu in
C2240098 no train

25 Stationary Standby Generator Set
Standby Diesel engine, 3058 hp, EPA# AMDDL95.4XTR, MTU Detroit
C22BG098 /,A25,

26 Stationary Standby Generator Set
Standby Diesel engine, 3058 hp, EPA# AMDDL95.4XTR, MTU Detroit
C22BG098 /,A26,

CURRENT Abatement Devices:

25 ****abate. dev. name not found****
Catalyzed Diesel Particulate Filter
train: ,S25,/,P1,

26 ****abate. dev. name not found****
Catalyzed Diesel Particulate Filter
train: ,S26,/,P1,

Plant# 8313 Mission Trail Waste Systems
1060 Richard Avenue
Santa Clara, CA 95050

[C]urrent, [A]rchive, or [F]uture? c
[P]lant, [S]ource, [A]bate. device, or [E]mis. Point? p

CURRENT Sources:

1 Spray Booth
Spray booth, Airless, 144.9 gal/yr solvent, Enamel, general, 54% solids
SG22A294 /,P1,

2 Waste Oil Tank [exempt]
Fixed roof tank, 1K gal, White, Waste oil, 7.5 ft diam
T42??549 no train

4 Solid Waste Transfer Station
MISC-HDLG> Material handling, Solid waste - other/not spec
G7013466 no train

No CURRENT Abatement Devices

CURRENT Emission Points:

BAY AREA AIR QUALITY MANAGEMENT DISTRICT Printed: AUG 31, 2016
DETAIL POLLUTANTS - ABATED
MOST RECENT P/O APPROVED (2016)

Mission Trail Waste Systems (P# 8313)

S# SOURCE NAME
MATERIAL SOURCE CODE
THROUGHPUT DATE POLLUTANT CODE LBS/DAY
----
1 Spray Booth
SG22A294
Organic liquid - other/not 201 2.38E+00
Xylene 307 7.93E-01
1,4-dioxane 359 1.98E-02
1,1,1-Trichloroethane 565 7.74E-01
2 Waste Oil Tank
T42??549
Waste oil 549 5.52E-03
4 Solid Waste Transfer Station
G7013466
Organics (other, including 990 5.20E+00
Particulates (part not spe 1990 1.21E+01
PLANT TOTAL:
lbs/day Pollutant

7.74E-01 1,1,1-Trichloroethane (565)
1.98E-02 1,4-dioxane (359)
2.38E+00 Organic liquid - other/not spec (201)
5.20E+00 Organics (other, including CH4) (990)
1.21E+01 Particulates (part not spec elsewhere) (1990)
5.52E-03 Waste oil (549)
7.93E-01 Xylene (307)

Intended for
California Energy Commission

Date
~~November 2017~~May~~April~~ 2018

MCLAREN DATA CENTER: AIR DISPERSION MODELING REPORT FOR ONE-HOUR NO2 CAAQS AND NAAQS

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ATTACHMENT

Attachment A
Figures

Attachment B
Tables

Attachment C
Manufactuer Performance Data Sheets

Attachment D
CD-ROM of Electronic Modeling Files

1. INTRODUCTION

Vantage Data Centers (the applicant) has proposed to develop a data center in Santa Clara, California. The data center will install up to fifty (50) generators (forty ~~eight~~ seven (~~48~~47) 2.75 MW backup emergency diesel generators and three (3) ~~1.0 MW~~600 kW safety generators) over the course of 10 years.

The applicant is submitting this air dispersion modeling report to the California Energy Commission (CEC) in support of its application for a Small Power Plant Exemption (SPPE). The SPPE application provides a detailed facility description, the quantification of emissions from facility sources, a review of applicability of federal and state air regulations, and the manufacturer's specification sheets for the proposed emergency generators. There are no stationary combustion sources at the facility other than the emergency standby generators.

A list of generator models at the facility and the generator ID numbers for the proposed generators at the applicant's facility are included in **Attachment B, Table B-1**.

2. AIR QUALITY ANALYSIS APPROACH

An air dispersion modeling analysis was completed to reflect the normal operating conditions of the facility and analyze potential air quality impacts in relation to the 1-hour nitrogen dioxide (NO_2) National Ambient Air Quality Standard (NAAQS) and the California Ambient Air Quality Standard (CAAQS). The analyses were conducted consistent with the following federal and state guidance documents:

- U.S. EPA's Guideline on Air Quality Models 40 CFR 51, Appendix W (Revised, January 17, 2017), herein referred to as Appendix W;
- U.S. EPA's AERMOD Implementation Guide (Revised, August 3, 2015);
- California Air Pollution Control Officers Association (CAPCOA) Guidance Document "Modeling Compliance of the Federal 1-Hour NO2 NAAQS" (Dated October 27, 2011)

The applicable values for the NO_2 NAAQS and CAAQS for the 1-hour averaging period are provided in **Table 1**.

Table 1. Applicable NAAQS and CAAQS

Pollutant	Averaging Period	NAAQS (µg/m³)	CAAQS (µg/m³)
NO_2	1-Hour	188 [(a)]	339 [(b)]

Notes:
(a) Standard of 100 ppb converted to µg/m3. 98th percentile of 1-hour daily maximum concentrations, averaged over three years.
(c) Standard of 180 ~~ppm~~ ppb(?) converted to µg/m3. Maximum 1-hour.

2.1 NAAQS and CAAQS Analysis

The NAAQS and CAAQS modeling evaluation incorporates all proposed sources at the project site (all ~~48~~ 50 ~~backup~~ generators). A~~n~~ seasonal-by-hour representative background concentration from concurrent historical NO_2 monitoring data near the site ~~is~~ was then added to the modeled concentrations on an hour-by-hour basis for comparison against the applicable NAAQS concentration to represent the contribution of sources not explicitly modeled. For the CAAQS analysis, the concurrent 1-hour NO_2 concentrations from the 5 years of monitoring data were added to the modelled concentration and compared to the standard. The model outputs that were used for assessing compliance with the NAAQS and CAAQS are summarized in **Table 2**.

Table 2. Modeling Output for NAAQS & CAAQS Compliance Demonstration

Pollutant and Averaging Period	Model Output
1-Hour NAAQS NO_2	Daily maximum 1-hour average of the 8^{th} high across 5 years, on a receptor-by-receptor basis
1-Hour CAAQS NO_2	Single maximum 1-hour concentration across 5 years on a receptor-by-receptor basis

2.1.1 Background Concentrations

NO_2 background data for the 1-hour NO_2 NAAQS and CAAQS analyses were obtained from the AQS Monitoring Station in San Jose (Jackson, 06-085-0005), the nearest station to the facility. These data, spanning the period from January 2013 through December 2017, ranged in value from 0.0 to 67.5 ppb. Missing values for one or two consecutive hours were replaced by the larger value of the preceding or following hour. When 3 or more consecutive hours were missing, the monthly-by-hour maximum for the 5-year period was used to substitute for the missing hours. For the NAAQS analysis, these data were then used to calculate the seasonal-by-hour background using the five year average of the 3rd highest value of the available monitoring data, determined by accounting for both season and hour-of-day. The 3rd, 2nd, or 1st highest season by hour-of-day value for each year was used to average over the five years depending on the completeness of the seasonal data for that year (3rd highest with more than 60 valid days per season, 2nd highest with between 30 and 60 days, and 1st highest with more than 15 days). For the CAAQS model, the 5-year dataset was used to generate hourly files concurrent with the meteorological data, which were added to the concentration on an hour-by-hour basis.

3. MODELING METHODOLOGY, SETTINGS, AND INPUTS

This section outlines the technical approach used in the NO_2 modeling evaluations. Figures and tables supporting this modeling evaluation and outlining the model inputs are provided in **Attachment A** and **Attachment B**, respectively. Manufacturer performance data sheets are included in **Attachment C**. A CD-ROM with the electronic modeling files is included in **Attachment D~~C~~**, and files will also be shared with Staff via direct upload.

3.1 Model Selection and Settings

To estimate off-property ambient concentrations of NO_2, the applicant used the latest version (16216r) of the AERMOD modeling system. AERMOD is U.S. EPA's recommended air dispersion model for near-field (within 50 kilometers [km]) modeling analyses. AERMOD is appropriate for use in estimating ground-level, short-term ambient air concentrations resulting from non-reactive buoyant emissions from sources located in simple and complex terrain. This analysis was conducted using AERMOD's regulatory default settings, except for the NO_2/NO_X in stack ratio (discussed in Section 3.1.1).

Ambient concentrations were estimated using AERMOD in conjunction with information about the site, the locations of the NO_X-emitting stacks, representative meteorological data, and nearby receptors. The North American Datum of 1983 (NAD83) of the Universal Transverse Mercator (UTM) Coordinate System (Zone 10) was used, which provides a constant distance relationship anywhere on the map or domain. The units of the coordinates are in meters.

3.1.1 NO_2 Modeling Approach

The applicant used the Tier 3 Plume Volume Molar Ratio Method (PVMRM) for the NO_2 Significance Analyses and to demonstrate compliance with the NO_2 NAAQS and PSD Increment standards. As part of the recent Appendix W updates, U.S. EPA incorporated the PVMRM as a regulatory default method for NO_2 modeling.

The applicant used a NO_2/NO_X in stack ratio of 0.10 for the facility's proposed backup emergency generators. This value was selected based on data from onsite generators of the same make and model as the proposed generators, and from U.S. EPA's In-Stack Ratio Database for diesel/kerosene-fired reciprocating internal combustion engines (RICE).[1] The U.S. EPA database has data for 57 diesel-fired RICE that indicate a median, mean, and even a second-high value, that are less than a 0.10 NO_2/NO_X ratio. Further, stack testing results from two of the facility's existing emergency generators showed a NO_2/NO_X ratio of less than 0.10.

Hourly ozone data from the San Jose AQS Monitoring Station were used (Jackson, 06-085-0005) with missing data substituted in two stages. If one or two consecutive hours were missing, the values were replaced by the larger value of the preceding or following hour~~with the 98th percentile value of 50 ppb~~. If three or more consecutive hours were missing, those values were replaced by the maximum values of the month-by-hour data set (i.e., the highest monitored value of the five years of data categorized by month of year and hour of day).

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

3.2 Modeled Sources and Release Parameters

The NAAQS and CAAQS analyses included cumulative assessments of the NO_2 impacts from the applicant's facility sources and the impacts from nearby NO_2-emitting sources (background). The following sections describe the release parameters that were used in the model.

3.2.1 Proposed Facility Sources

This ~~assessment~~ included an assessment of 1-hour NO_2 impacts from the facility's proposed sources (**Attachment A, Figure 1**). The emissions from the generators at the site exhaust through vertical stacks with barometric rain covers. The generator stacks have flapper-style rain caps that open with the exhaust flow such that they do not obstruct the exhaust from the release point. The site's emission sources were modeled as point sources using manufacturer-provided stack parameters (**Attachment B, Table B-2**).

For the 1-hour NO_2 NAAQS and CAAQS analyses for the 2.75 MW emergency back-up generators, a typical operating scenario was modeled that includes one 4-hour load banking test that is conducted for one generator at a time, once annually, for maintenance and readiness testing.[2] During this 4-hour test, the generator is ramped up in load. The first hour of testing is at 50% load, the second hour is at 75% load, and the last two hours are at 100% load. Generators are also ~~testing~~ tested monthly for 5 minutes at 0% load, but this scenario was not modeled since the annual 4-hour test is the more conservative scenario. For comparison with the NAAQS and CAAQS, the most conservative hourly emission rate was used in both models, assuming one hour of testing at 100% load.

The typical operating scenario for the ~~1.0 MW~~ 600 kW life safety generators includes a 90 minute testing period with the generators operating during the first 30 minutes at a 50% load, followed by an hour of testing at a 75% load. The most conservative hourly emission rate in this scenario corresponds to an hour of operation at 75% load. The emission rate corresponding to the hour of testing at 75% was used in the model and compared to the NAAQS and CAAQS standards for the safety generators.

Though not utilized in this analysis, an example of another representative emission rate would be an average hourly emission rate from the 4-hour test. The average hourly emission rate would calculated by taking the average emission rate over the 4-hour test using load-specific emission rates from the manufacturer's specification sheet in **Attachment C~~C~~**.

A detailed derivation of the modeled hourly NO_X emission rates used in the models is provided in **Attachment B, Table B-3**.

3.3 Building Downwash

The AERMOD model incorporates Plume Rise Modeling Enhancements (PRIME) to account for downwash. The direction-specific building downwash dimensions used as inputs were determined by the latest version (04274) of the Building Profile Input Program, PRIME (BPIP PRIME). BPIP PRIME uses building downwash algorithms incorporated into AERMOD to account for the plume dispersion effects of the aerodynamic wakes and eddies produced by buildings and structures.

The applicant evaluated onsite buildings at the facility for downwash effects on each modeled point source, as well as nearby offsite buildings. Each generator is located inside its own

[2] Emergency operation is not included.

weather-proof enclosure, with the generator stack extending from the top of the enclosure. Each generator enclosure was included as a building in the model. Three onsite buildings were included and 16 offsite buildings were included. The modeled parameters for the buildings and the weather-proof enclosures for the generators are provided in **Attachment B, Table B-4**.

3.4 Good Engineering Practice Stack Height Analysis

U.S. EPA has promulgated regulations that limit the maximum stack height one may use in a modeling analysis to no more than the Good Engineering Practice (GEP) stack height. The purpose of this requirement is to prevent the use of excessively tall stacks to reduce the modeled concentrations of a pollutant. GEP stack height is impacted by the heights of nearby structures. In general, the ~~minimum~~ maximum value for GEP stack height is 65 meters. The stack heights for the facility's generator stacks do not exceed the GEP stack height.

3.5 Terrain Data and Land Use

Per U.S. EPA guidance, terrain elevations were incorporated into the model using the most recent version (11103) of AERMAP, AERMOD's terrain preprocessor. Terrain elevation data for the entire modeling domain was extracted from 1/3 arc-second National Elevation Data (NED) files with a resolution of approximately 10 meters. The NED files were obtained from the United States Geological Survey (USGS) Multi-Resolution Land Characteristics Consortium (MRLC).[3] AERMAP was configured to assign elevations for the sources, buildings, property line receptors, and discrete gridded receptors in the modeling domain.

Land use classification determines the type of area to be modeled. The different classifications, urban or rural, incorporate distinct pollutant dispersion characteristics and affect the estimation of downwind concentrations when used in the model. Based on the land use around the facility, the urban boundary layer option in the model was selected. The population for the urban mode was based on the population of the ~~city of Santa Clara~~San Jose Urban Area (1,664,496~~126,251~~).

3.6 Meteorological Data

AERMOD requires a meteorological input file to characterize the transport and dispersion of pollutants in the atmosphere. Surface and upper air meteorological data inputs, as well as surface parameter data describing the land use and surface characteristics near the site, are processed using AERMET, the meteorological preprocessor to AERMOD. The output file generated by AERMET is the meteorological input file required by AERMOD.

A representative meteorological data set was developed using a combination of surface data from the National Weather Service (NWS) station at the San Jose Airport (KSJC, located approximately 2 km west of the facility) and NWS upper air data from the Oakland Airport (KOAK, located approximately 50 km northwest of the facility).

Per Appendix W, five years of representative meteorological data are considered adequate for dispersion modeling applications. Hourly and 1-minute wind speed and wind direction data from January ~~2009~~ 2013 through December ~~2013~~ 2017 were processed using the latest version of AERMINUTE (15272) and AERMET (16216). The meteorological data was processed using the ADJ_U* option that reduces overprediction of modeled concentrations

[3] http://www.mrlc.gov

that occur in stable conditions with low wind speeds due to underprediction of the surface friction velocity (u*). Underprediction of u* results in an underestimation of the mechanical mixing height and thus overprediction of ambient concentrations. The ADJ_U* option is now considered a regulatory default option with the recent update to Appendix W.

Additional meteorological variables and geophysical parameters are required for use in the AERMOD dispersion modeling analysis to estimate the surface energy fluxes and construct boundary layer profiles. Surface characteristics including albedo, Bowen ratio, and surface roughness length were determined for the area surrounding the San Jose Airport meteorological station using the AERMET surface characteristic preprocessor, AERSURFACE (13016), and the USGS 1992 National Land Cover (NLCD92) land use data set. The NLCD92 data set used in the analysis has a 30 meter resolution and 21 land use categories. Monthly surface parameters were determined using AERSURFACE according to U.S. EPA's guidance.

Monthly albedo and Bowen ratio values were based on averaging over a 10-km by 10-km region centered on the San Jose Airport meteorological site. Monthly surface roughness values were calculated for twelve 30 degree sectors within 1 km of the San Jose Airport meteorological station.

3.7 Receptor Grid

Ground-level concentrations were calculated at receptors placed along the facility fence line and on a circular, Cartesian grid. For this analysis, receptors extending up to 1 km from the fence line, as needed, were modeled using the following resolutions (**Attachment A, Figure 2**):

- 25 meter resolution for fence line receptors;
- 25 meter resolution extending from the fence line to 500 meters;
- 50 meter resolution extending from 500 meters to 1 km.

4. SUMMARY OF MODELING RESULTS

The following sections summarize the results of the NO_2 dispersion modeling analyses and demonstrate that the proposed project will not will not cause or contribute to a violation of the NAAQS or CAAQS.

4.1 NAAQS and CAAQS Analyses

Modeling was conducted to demonstrate compliance with the 1-hour and NO_2 NAAQS and CAAQS. The results of these analyses are presented in **Table 3** and demonstrate that there are no predicted violations of the NO_2 NAAQS or CAAQS.

Table 3. NO_2 NAAQS and CAAQS Results

Standard	Year	UTM East (m)	UTM North (m)	Total Ambient Conc.[a,b] (µg/m³)	Threshold (µg/m³)	Above Threshold?
1-Hour NAAQS	5Y AVG	~~593375~~593350.00	~~4135725~~4135700.00	158.61	188	No
1-Hour CAAQS	H1H	593162.89~~593325.00~~	4135854.26~~4135700.00~~	211.41	339	No

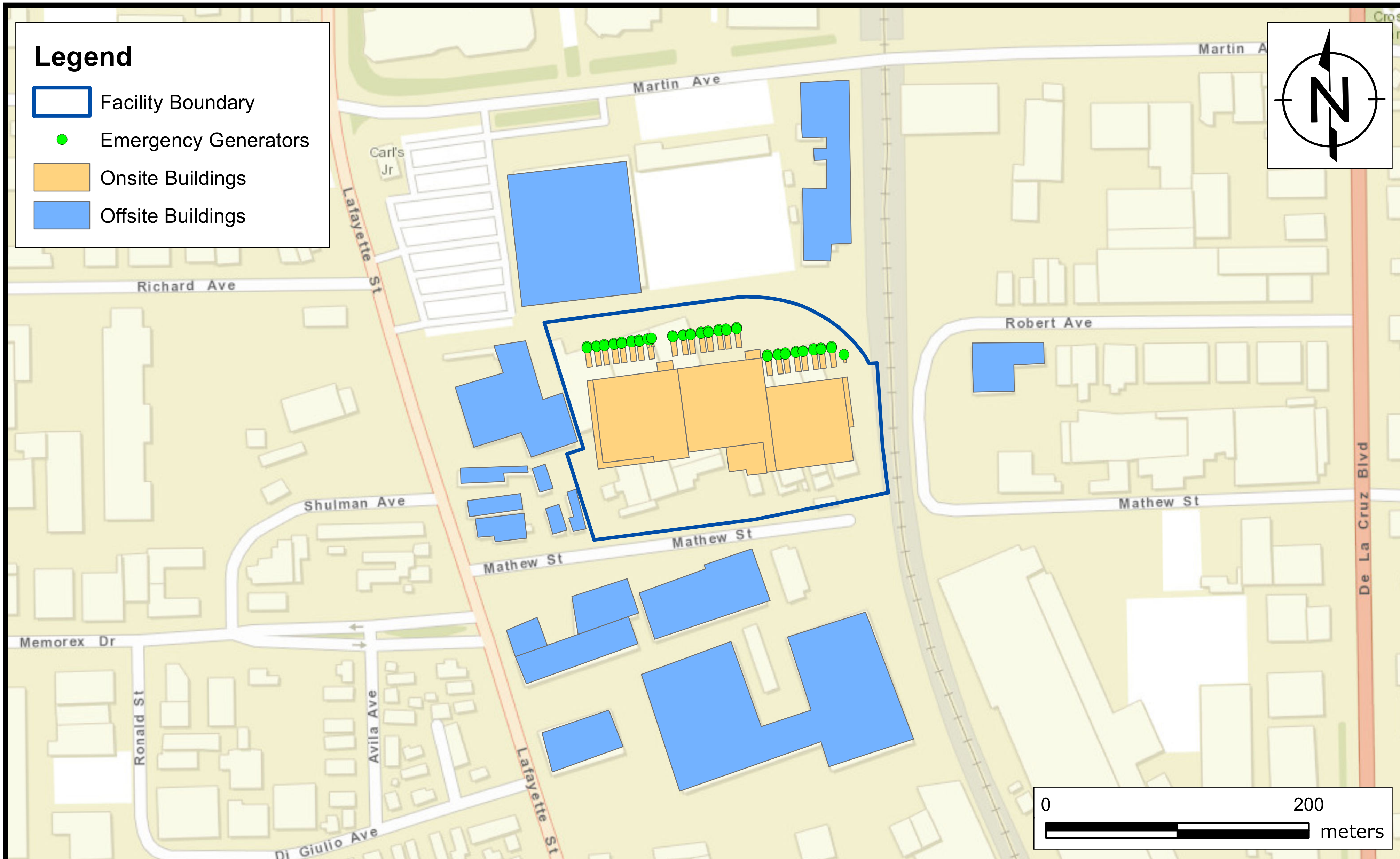
Notes:

(a) The value shown is the maximum from any of the emergency generators being tested for 1-hour at 100% load. The safety generators were tested at 75% load according to NFPA110 recommendations. ~~... guidance~~.

(b) Total ambient concentration represents the modeled concentration plus the background concentration. An hour-by-hour background file, concurrent with the meteorological data, was included in the C~~N~~AAQS model so the model output represents the total ambient concentration at each receptor. Season-by-hour background were used for the NAAQS model, so this model output also represents the total ambient concentration at each receptor~~The maximum single hourly NO2 concentration was used as background for the CAAQS model~~.

The maximum ambient concentration for the 1-hour NO_2 NAAQS analysis and the contributing generator are presented in **Attachment A, Figure 3**. The maximum ambient concentration for the 1-hour NO_2 CAAQS analysis and the contributing generator are presented in **Attachment A, Figure 4**. The modeled 1-hour NO_2 concentrations shown in **Table 3** are representative of the maximum value from all of the modeled generators. A full summary of the model results for the 1-hour NO_2 NAAQS and CAAQS analyses are provided in **Attachment B, Table B-5 and B-6,** respectively.

ATTACHMENT A
FIGURES



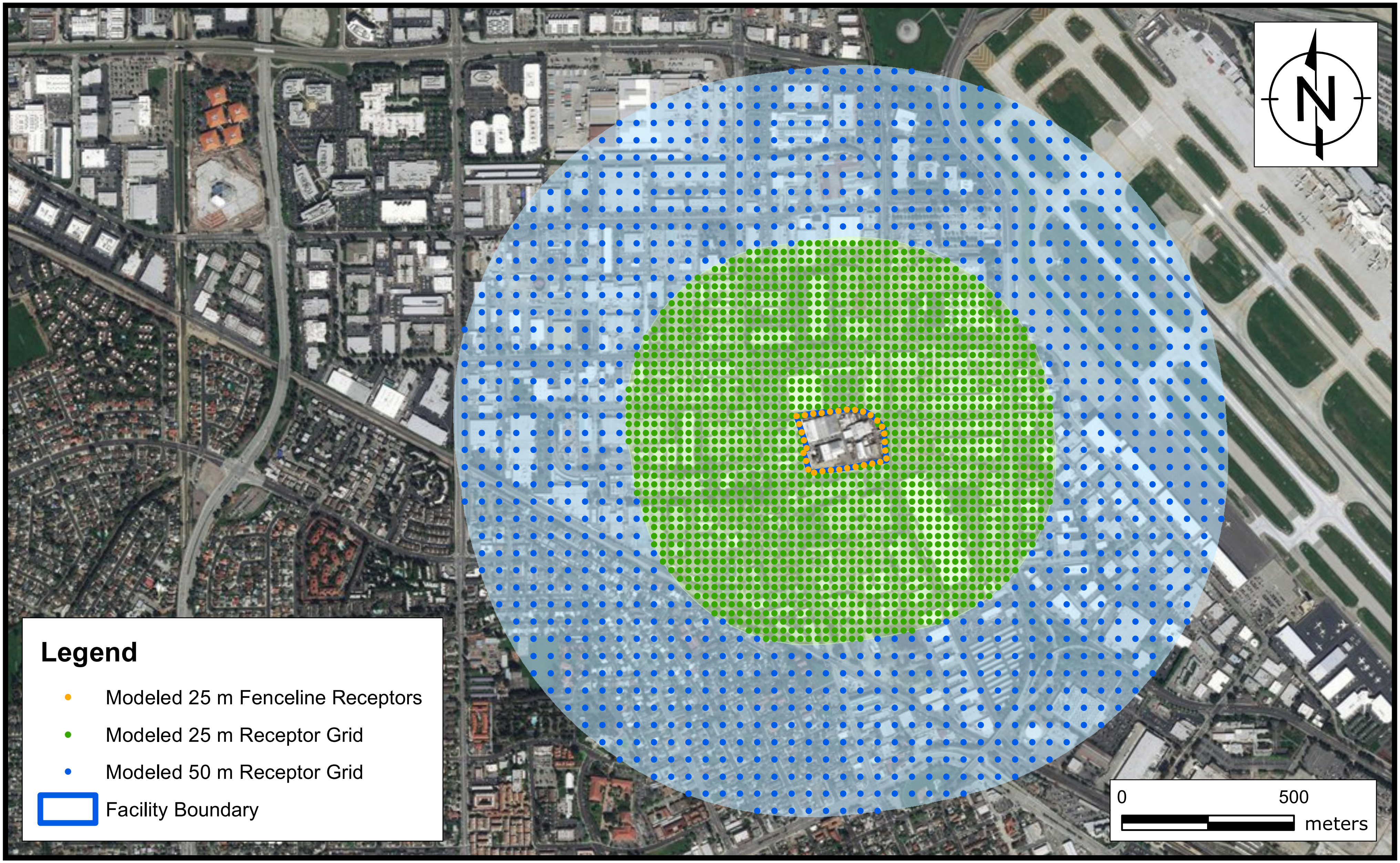
RAMBOLL ENVIRON

Project Location and Facility Layout
Vantage McLaren Campus
Santa Clara, California

FIGURE
1

DRAFTED BY: DCW | DATE: 4/25/2018

1690007689



RAMBOLL ENVIRON

DRAFTED BY: DCW | DATE: 4/25/2018

Modelled Receptor Location
Vantage McLaren Campus
Santa Clara, California

FIGURE
2

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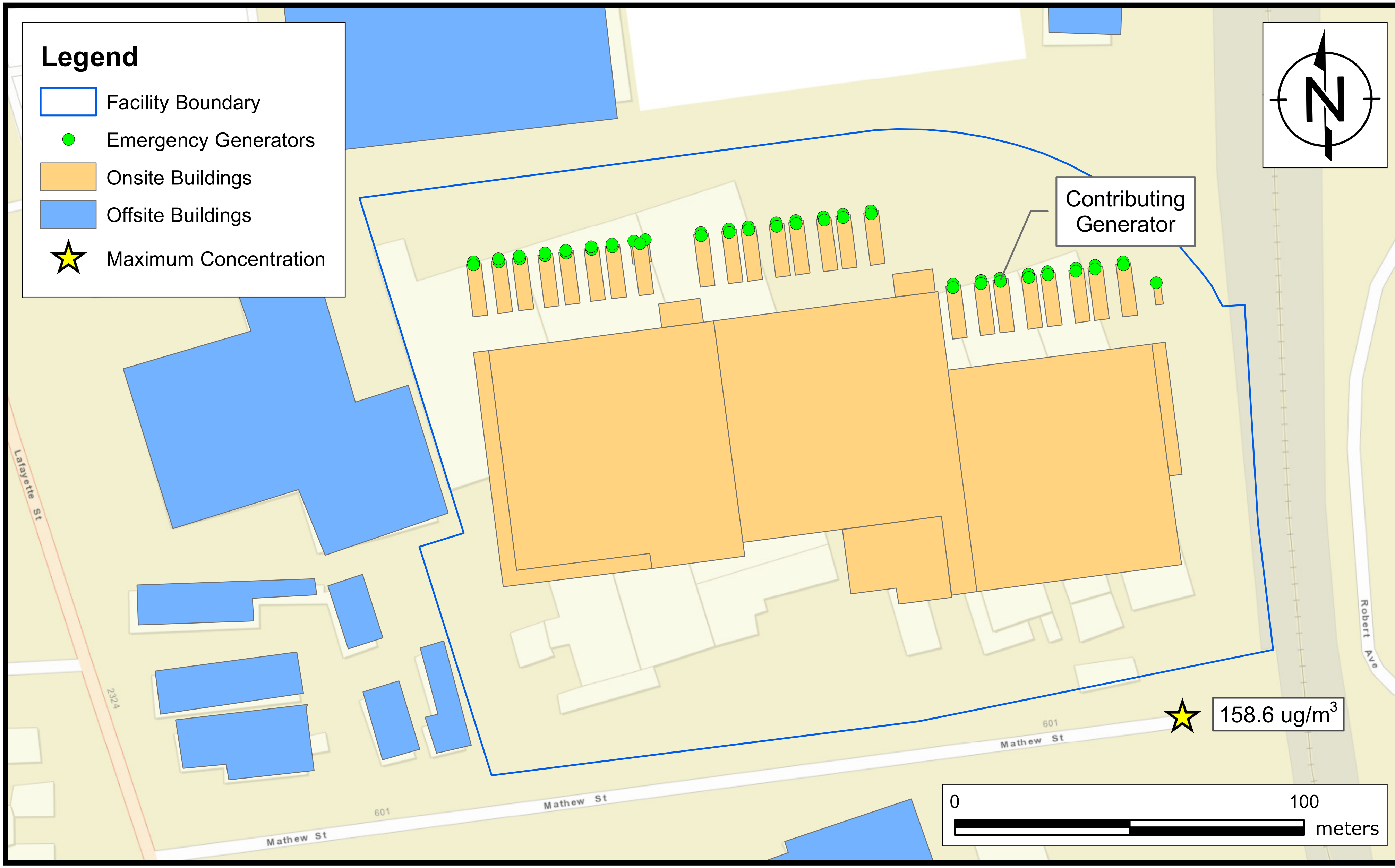

RAMBOLL ENVIRON

Maximum 1-Hour NO2 Concentration (NAAQS) and Contributing Generator
Vantage McLaren Campus
Santa Clara, California

FIGURE
3

DRAFTED BY: DCW | DATE: 4/25/2018

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RAMBOLL ENVIRON

Maximum 1-Hour NO2 Concentration (CAAQS) and Contributing Generator
Vantage McLaren Campus
Santa Clara, California

FIGURE
4

DRAFTED BY: DCW | DATE: 5/1/2018 | 1690001414

ATTACHMENT B
TABLES

Table B-1. Source Descriptions for the Mclaren Facility Sources

Model ID	Description	Specifications				
		Make	Model	USEPA Tier	Rated Power Output (kW)	Rated Power Output (HP)
EGEN_11A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_11B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_12A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_12B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_13A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_13B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_14A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_14B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_15A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_15B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_16A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_16B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_17A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_17B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_18A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_21A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_21B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_22A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_22B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_23A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_23B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_24A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_24B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_25A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_25B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_26A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_26B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043

Table B-1. Source Descriptions for the Mclaren Facility Sources

Model ID	Description	Specifications				
		Make	Model	USEPA Tier	Rated Power Output (kW)	Rated Power Output (HP)
EGEN_27A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_27B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_28A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_28B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_31A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_31B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_32A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_32B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_33A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_33B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_34A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_34B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_35A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_35B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_36A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_36B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_37A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_37B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_38A	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_38B	2.75 MW CAT 3516E Generator	Caterpillar	3516E	2	2,750	4,043
EGEN_ST1	600 kW CAT C18 Generator	Caterpillar	C18	2	600	900
EGEN_ST2	600 kW CAT C18 Generator	Caterpillar	C18	2	600	900
EGEN_ST3	600 kW CAT C18 Generator	Caterpillar	C18	2	600	900

Table B-2. Point Source Parameters for the Mclaren Facility Sources

Model ID	Description	UTM Zone 10 Coordinates (m)		Elevation (m)	NO_X Emission Rate (1-Hour Max.) (g/s)	Stack Height (m)	Stack Temp. (K)	Stack Velocity (m/s)	Stack Diameter (m)
		X	Y						
EGEN_11A	2.75 MW CAT 3516E Generator	593,147.09	4,135,829.61	14.88	5.703	14.55	753.71	29.932	0.66
EGEN_11B	2.75 MW CAT 3516E Generator	593,147.20	4,135,828.78	14.88	5.703	14.55	753.71	29.932	0.66
EGEN_12A	2.75 MW CAT 3516E Generator	593,154.26	4,135,830.52	14.92	5.703	14.55	753.71	29.932	0.66
EGEN_12B	2.75 MW CAT 3516E Generator	593,154.38	4,135,829.69	14.92	5.703	14.55	753.71	29.932	0.66
EGEN_13A	2.75 MW CAT 3516E Generator	593,160.24	4,135,831.33	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_13B	2.75 MW CAT 3516E Generator	593,160.36	4,135,830.50	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_14A	2.75 MW CAT 3516E Generator	593,167.53	4,135,832.25	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_14B	2.75 MW CAT 3516E Generator	593,167.64	4,135,831.42	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_15A	2.75 MW CAT 3516E Generator	593,173.51	4,135,833.02	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_15B	2.75 MW CAT 3516E Generator	593,173.62	4,135,832.19	14.94	5.703	14.55	753.71	29.932	0.66
EGEN_16A	2.75 MW CAT 3516E Generator	593,180.79	4,135,834.01	14.92	5.703	14.55	753.71	29.932	0.66
EGEN_16B	2.75 MW CAT 3516E Generator	593,180.90	4,135,833.18	14.92	5.703	14.55	753.71	29.932	0.66
EGEN_17A	2.75 MW CAT 3516E Generator	593,186.79	4,135,834.78	14.90	5.703	14.55	753.71	29.932	0.66
EGEN_17B	2.75 MW CAT 3516E Generator	593,186.90	4,135,833.95	14.90	5.703	14.55	753.71	29.932	0.66
EGEN_18A	2.75 MW CAT 3516E Generator	593,194.71	4,135,834.92	14.86	5.703	14.55	753.71	29.932	0.66
EGEN_21A	2.75 MW CAT 3516E Generator	593,212.19	4,135,838.04	14.80	5.703	14.55	753.71	29.932	0.66
EGEN_21B	2.75 MW CAT 3516E Generator	593,212.34	4,135,837.12	14.80	5.703	14.55	753.71	29.932	0.66
EGEN_22A	2.75 MW CAT 3516E Generator	593,220.18	4,135,839.03	14.77	5.703	14.55	753.71	29.932	0.66
EGEN_22B	2.75 MW CAT 3516E Generator	593,220.32	4,135,838.10	14.77	5.703	14.55	753.71	29.932	0.66
EGEN_23A	2.75 MW CAT 3516E Generator	593,225.70	4,135,839.73	14.74	5.703	14.55	753.71	29.932	0.66
EGEN_23B	2.75 MW CAT 3516E Generator	593,225.85	4,135,838.81	14.74	5.703	14.55	753.71	29.932	0.66
EGEN_24A	2.75 MW CAT 3516E Generator	593,233.72	4,135,840.79	14.64	5.703	14.55	753.71	29.932	0.66
EGEN_24B	2.75 MW CAT 3516E Generator	593,233.87	4,135,839.86	14.64	5.703	14.55	753.71	29.932	0.66
EGEN_25A	2.75 MW CAT 3516E Generator	593,239.35	4,135,841.53	14.56	5.703	14.55	753.71	29.932	0.66
EGEN_25B	2.75 MW CAT 3516E Generator	593,239.50	4,135,840.60	14.56	5.703	14.55	753.71	29.932	0.66
EGEN_26A	2.75 MW CAT 3516E Generator	593,247.27	4,135,842.51	14.42	5.703	14.55	753.71	29.932	0.66
EGEN_26B	2.75 MW CAT 3516E Generator	593,247.41	4,135,841.59	14.42	5.703	14.55	753.71	29.932	0.66
EGEN_27A	2.75 MW CAT 3516E Generator	593,252.79	4,135,843.25	14.30	5.703	14.55	753.71	29.932	0.66
EGEN_27B	2.75 MW CAT 3516E Generator	593,252.94	4,135,842.32	14.30	5.703	14.55	753.71	29.932	0.66
EGEN_28A	2.75 MW CAT 3516E Generator	593,260.81	4,135,844.31	14.23	5.703	14.55	753.71	29.932	0.66

RAMBOLL

Table B-2. Point Source Parameters for the Mclaren Facility Sources

Model ID	Description	UTM Zone 10 Coordinates (m)		Elevation (m)	NO_X Emission Rate (1-Hour Max.) (g/s)	Stack Height (m)	Stack Temp. (K)	Stack Velocity (m/s)	Stack Diameter (m)
		X	Y						
EGEN_28B	2.75 MW CAT 3516E Generator	593,260.96	4,135,843.38	14.23	5.703	14.55	753.71	29.932	0.66
EGEN_31A	2.75 MW CAT 3516E Generator	593,284.27	4,135,823.26	14.24	5.703	14.55	753.71	29.932	0.66
EGEN_31B	2.75 MW CAT 3516E Generator	593,284.36	4,135,822.34	14.24	5.703	14.55	753.71	29.932	0.66
EGEN_32A	2.75 MW CAT 3516E Generator	593,292.26	4,135,824.31	14.29	5.703	14.55	753.71	29.932	0.66
EGEN_32B	2.75 MW CAT 3516E Generator	593,292.34	4,135,823.40	14.29	5.703	14.55	753.71	29.932	0.66
EGEN_33A	2.75 MW CAT 3516E Generator	593,297.75	4,135,824.96	14.32	5.703	14.55	753.71	29.932	0.66
EGEN_33B	2.75 MW CAT 3516E Generator	593,297.83	4,135,824.05	14.32	5.703	14.55	753.71	29.932	0.66
EGEN_34A	2.75 MW CAT 3516E Generator	593,305.88	4,135,826.11	14.37	5.703	14.55	753.71	29.932	0.66
EGEN_34B	2.75 MW CAT 3516E Generator	593,305.96	4,135,825.19	14.37	5.703	14.55	753.71	29.932	0.66
EGEN_35A	2.75 MW CAT 3516E Generator	593,311.37	4,135,826.85	14.40	5.703	14.55	753.71	29.932	0.66
EGEN_35B	2.75 MW CAT 3516E Generator	593,311.45	4,135,825.93	14.40	5.703	14.55	753.71	29.932	0.66
EGEN_36A	2.75 MW CAT 3516E Generator	593,319.42	4,135,827.90	14.47	5.703	14.55	753.71	29.932	0.66
EGEN_36B	2.75 MW CAT 3516E Generator	593,319.50	4,135,826.99	14.47	5.703	14.55	753.71	29.932	0.66
EGEN_37A	2.75 MW CAT 3516E Generator	593,324.88	4,135,828.60	14.51	5.703	14.55	753.71	29.932	0.66
EGEN_37B	2.75 MW CAT 3516E Generator	593,324.96	4,135,827.69	14.51	5.703	14.55	753.71	29.932	0.66
EGEN_38A	2.75 MW CAT 3516E Generator	593,332.93	4,135,829.66	14.38	5.703	14.55	753.71	29.932	0.66
EGEN_38B	2.75 MW CAT 3516E Generator	593,333.01	4,135,828.75	14.38	5.703	14.55	753.71	29.932	0.66
EGEN_ST1	600 kW CAT C18 Generator	593,192.97	4,135,835.59	14.86	0.627	14.55	764.82	20.125	0.36
EGEN_ST2	600 kW CAT C18 Generator	593,196.32	4,135,836.04	14.86	0.627	14.55	764.82	20.125	0.36
EGEN_ST3	600 kW CAT C18 Generator	593,342.50	4,135,823.75	14.17	0.627	14.55	764.82	20.125	0.36

Table B-3. Modeled NO_X Emission Rates for Mclaren Facility Sources

Generator Model	Number of Generators	Load-Specific Emission Rates (g/s/gen)			NAAQS	CAAQS
		50%	75%	100%	Hourly NO_X Emissions per Generator[1] (g/s/gen)	Hourly NO_X Emissions per Generator[2] (g/s/gen)
2.75 MW CAT 3516E Generator	47	1.793	3.553	5.7025	5.7025	5.7025
600 kW CAT C18 Generator	3	0.3519	0.6269	1.424	0.6269	0.6269

Notes:

1. Hourly NOx emission rates for the NAAQS analysis for the 2.75 MW CAT gens assumed the worst case scenario of operating at 100% load for the full hour. Hourly NOx emissions rate for the 600 kW CAT gen assumed the worst case scenario of operating at 75% load for the full hour.
2. Hourly NOx emission rates for the CAAQS analysis for the 2.75 MW CAT gens assumed the worst case scenario of operating at 100% load for the full hour. Hourly NOx emissions rate for the 600 kW CAT gen assumed the worst case scenario of operating at 75% load for the full hour.
3. Generators are tested one at a time.

Table B-4. Modeled Buildings for the Vantage McLaren Facility

Model ID	Description	UTM Zone 10 Coordinates (m)		Elevation (m)	Height (m)
		X	Y		
ADMIN	Onsite Building	593268.98	4135744.47	14.90	6.35
BLDG01A	Onsite Data Center Building	593188.40	4135776.17	14.93	30.65
BLDG01B	Onsite Building	593162.78	4135759.95	14.93	6.35
BLDG01C	Onsite Building	593206.46	4135815.04	14.85	6.35
BLDG02A	Onsite Data Center Building	593253.38	4135783.78	14.70	30.65
BLDG02B	Onsite Building	593273.11	4135823.59	14.25	6.35
BLDG03A	Onsite Data Center Building	593316.19	4135770.79	14.72	30.65
BLDG03B	Onsite Building	593345.56	4135787.63	14.72	6.35
GENSET11	Generator Enclosure	593148.12	4135821.71	14.88	12.70
GENSET12	Generator Enclosure	593155.30	4135822.62	14.92	12.70
GENSET13	Generator Enclosure	593161.28	4135823.43	14.94	12.70
GENSET14	Generator Enclosure	593168.57	4135824.35	14.94	12.70
GENSET15	Generator Enclosure	593174.55	4135825.12	14.94	12.70
GENSET16	Generator Enclosure	593181.83	4135826.11	14.92	12.70
GENSET17	Generator Enclosure	593187.83	4135826.88	14.90	12.70
GENSET18	Generator Enclosure	593195.60	4135827.75	14.86	12.70
GENSET21	Generator Enclosure	593213.21	4135830.19	14.80	12.70
GENSET22	Generator Enclosure	593221.20	4135831.17	14.77	12.70
GENSET23	Generator Enclosure	593226.72	4135831.88	14.74	12.70
GENSET24	Generator Enclosure	593234.74	4135832.93	14.64	12.70
GENSET25	Generator Enclosure	593240.37	4135833.67	14.56	12.70
GENSET26	Generator Enclosure	593248.29	4135834.66	14.42	12.70
GENSET27	Generator Enclosure	593253.81	4135835.39	14.30	12.70
GENSET28	Generator Enclosure	593261.84	4135836.45	14.23	12.70
GENSET31	Generator Enclosure	593285.34	4135815.30	14.24	12.70
GENSET32	Generator Enclosure	593293.32	4135816.36	14.29	12.70
GENSET33	Generator Enclosure	593298.85	4135817.05	14.32	12.70
GENSET34	Generator Enclosure	593306.94	4135818.15	14.37	12.70
GENSET35	Generator Enclosure	593312.43	4135818.89	14.40	12.70

Table B-4. Modeled Buildings for the Vantage McLaren Facility

Model ID	Description	UTM Zone 10 Coordinates (m)		Elevation (m)	Height (m)
		X	Y		
GENSET36	Generator Enclosure	593320.49	4135819.95	14.47	12.70
GENSET37	Generator Enclosure	593325.94	4135820.65	14.51	12.70
GENSET38	Generator Enclosure	593334.00	4135821.71	14.38	12.70
GENSETS1	Safety Generator Enclosure	593193.42	4135832.13	14.86	3.18
GENSETS2	Safety Generator Enclosure	593196.67	4135832.56	14.86	3.18
GENSETS3	Safety Generator Enclosure	593343.01	4135820.37	14.17	3.18
HOMEDEPOT	Offsite Building	593137.34	4135915.47	14.71	9.70
B01	Offsite Building	593092.76	4135784.80	14.83	6.44
B02	Offsite Building	593138.79	4135703.82	15.36	2.70
B03	Offsite Building	593123.58	4135698.42	15.18	4.00
B04	Offsite Building	593113.36	4135729.54	15.04	3.90
B05	Offsite Building	593072.28	4135732.90	15.18	3.90
B06	Offsite Building	593077.07	4135709.25	15.25	4.90
B07	Offsite Building	593082.90	4135692.22	15.30	4.40
B08	Offsite Building	593329.84	4135965.42	13.29	6.40
B09	Offsite Building	593462.44	4135816.68	14.24	3.50
B10	Offsite Building	593237.02	4135640.99	15.57	6.40
B11	Offsite Building	593139.22	4135598.86	15.91	7.00
B12	Offsite Building	593101.20	4135608.64	15.71	4.90
B13	Offsite Building	593291.96	4135556.92	16.37	15.60
B14	Offsite Building	593142.83	4135530.12	16.75	7.40
B15	Offsite Building	593159.86	4135632.55	15.89	5.00

Table B-5. 1-hour NO_2 NAAQS Results

Averaging Period	Source ID	UTM Zone 10 Coordinates (m)		5Y Average H8H Modeled Conc. (µg/m³)	NAAQS (µg/m³)	Above NAAQS?
		X	Y			
1-Hour	EGEN_11A	593237.80	4135693.59	148.74	188	No
	EGEN_11B	593237.80	4135693.59	149.87		No
	EGEN_12A	593237.80	4135693.59	152.75		No
	EGEN_12B	593237.80	4135693.59	153.04		No
	EGEN_13A	593237.80	4135693.59	153.91		No
	EGEN_13B	593237.80	4135693.59	153.89		No
	EGEN_14A	593237.80	4135693.59	152.72		No
	EGEN_14B	593237.80	4135693.59	152.73		No
	EGEN_15A	593237.80	4135693.59	151.62		No
	EGEN_15B	593237.80	4135693.59	151.94		No
	EGEN_16A	593237.80	4135693.59	147.95		No
	EGEN_16B	593237.80	4135693.59	148.07		No
	EGEN_17A	593213.60	4135690.53	145.06		No
	EGEN_17B	593213.60	4135690.53	145.50		No
	EGEN_18A	593138.70	4135851.08	144.29		No
	EGEN_21A	593262.01	4135696.66	141.34		No
	EGEN_21B	593262.01	4135696.66	141.48		No
	EGEN_22A	593325.00	4135675.00	145.05		No
	EGEN_22B	593325.00	4135675.00	145.14		No
	EGEN_23A	593325.00	4135675.00	145.54		No
	EGEN_23B	593325.00	4135675.00	145.59		No
	EGEN_24A	593325.00	4135675.00	143.73		No
	EGEN_24B	593325.00	4135675.00	143.47		No
	EGEN_25A	593325.00	4135675.00	141.46		No
	EGEN_25B	593325.00	4135675.00	141.33		No
	EGEN_26A	593325.00	4135675.00	137.88		No
	EGEN_26B	593325.00	4135675.00	137.42		No
	EGEN_27A	593325.00	4135675.00	134.88		No
	EGEN_27B	593325.00	4135675.00	134.60		No
	EGEN_28A	593211.27	4135860.63	137.25		No
	EGEN_28B	593211.27	4135860.63	135.65		No
	EGEN_31A	592300.00	4135500.00	131.85		No
	EGEN_31B	592300.00	4135500.00	131.89		No
	EGEN_32A	593325.00	4135675.00	135.50		No
	EGEN_32B	593325.00	4135675.00	134.16		No
	EGEN_33A	593357.83	4135714.99	157.32		No
	EGEN_33B	593350.00	4135700.00	158.61		No
	EGEN_34A	593350.00	4135700.00	155.44		No
	EGEN_34B	593350.00	4135700.00	156.17		No
	EGEN_35A	593350.00	4135700.00	152.68		No

Table B-5. 1-hour NO_2 NAAQS Results

Averaging Period	Source ID	UTM Zone 10 Coordinates (m)		5Y Average H8H Modeled Conc. (µg/m³)	NAAQS (µg/m³)	Above NAAQS?
		X	Y			
	EGEN_35B	593333.91	4135710.18	153.42		No
	EGEN_36A	593375.00	4135800.00	157.51		No
	EGEN_36B	593375.00	4135800.00	156.43		No
	EGEN_37A	593375.00	4135800.00	155.42		No
	EGEN_37B	593375.00	4135800.00	153.96		No
	EGEN_38A	593400.00	4135775.00	151.76		No
	EGEN_38B	593400.00	4135775.00	151.32		No
	EGEN_ST1	593162.89	4135854.26	142.99		No
	EGEN_ST2	593162.89	4135854.26	144.09		No
	EGEN_ST3	593400.00	4135775.00	136.79		No
	Maximum NAAQS	593350.00	4135700.00	158.61		No

Table B-6. 1-hour NO_2 CAAQS Results

Averaging Period	Source ID	UTM Zone 10 Coordinates (m)		5Y Single Maximum H1H Modeled Conc. (µg/m³)	CAAQS (µg/m³)	Above CAAQS?
		X	Y			
1-Hour	EGEN_11A	593162.89	4135854.26	206.72	339	No
	EGEN_11B	593162.89	4135854.26	201.47		No
	EGEN_12A	593162.89	4135854.26	211.41		No
	EGEN_12B	593162.89	4135854.26	208.72		No
	EGEN_13A	593162.89	4135854.26	210.84		No
	EGEN_13B	593162.89	4135854.26	208.22		No
	EGEN_14A	593162.89	4135854.26	209.39		No
	EGEN_14B	593162.89	4135854.26	207.37		No
	EGEN_15A	593162.89	4135854.26	208.74		No
	EGEN_15B	593162.89	4135854.26	206.69		No
	EGEN_16A	593162.89	4135854.26	208.14		No
	EGEN_16B	593162.89	4135854.26	206.01		No
	EGEN_17A	593162.89	4135854.26	207.49		No
	EGEN_17B	593162.89	4135854.26	204.67		No
	EGEN_18A	593162.89	4135854.26	203.72		No
	EGEN_21A	593187.08	4135857.44	180.55		No
	EGEN_21B	593187.08	4135857.44	178.14		No
	EGEN_22A	593187.08	4135857.44	182.53		No
	EGEN_22B	593187.08	4135857.44	180.38		No
	EGEN_23A	593121.77	4135824.61	114.00		No
	EGEN_23B	593200.00	4135875.00	110.95		No
	EGEN_24A	593225.00	4135875.00	121.26		No
	EGEN_24B	593225.00	4135875.00	119.28		No
	EGEN_25A	593225.00	4135875.00	120.71		No
	EGEN_25B	593225.00	4135875.00	118.73		No
	EGEN_26A	593225.00	4135875.00	119.79		No
	EGEN_26B	593225.00	4135875.00	117.82		No
	EGEN_27A	593225.00	4135875.00	119.25		No
	EGEN_27B	593225.00	4135875.00	117.19		No
	EGEN_28A	593348.19	4135835.04	134.00		No
	EGEN_28B	593363.24	4135817.05	126.54		No
	EGEN_31A	592300.00	4135250.00	91.57		No
	EGEN_31B	592300.00	4135250.00	91.23		No
	EGEN_32A	593357.83	4135714.99	100.69		No
	EGEN_32B	593357.83	4135714.99	100.72		No
	EGEN_33A	593307.75	4135861.50	198.69		No
	EGEN_33B	593307.75	4135861.50	196.64		No
	EGEN_34A	593307.75	4135861.50	194.28		No
	EGEN_34B	593307.75	4135861.50	192.22		No
	EGEN_35A	593307.75	4135861.50	191.16		No

Table B-6. 1-hour NO_2 CAAQS Results

Averaging Period	Source ID	UTM Zone 10 Coordinates (m)		5Y Single Maximum H1H Modeled Conc. (µg/m³)	CAAQS (µg/m³)	Above CAAQS?
		X	Y			
	EGEN_35B	593307.75	4135861.50	189.12		No
	EGEN_36A	593307.75	4135861.50	187.63		No
	EGEN_36B	593307.75	4135861.50	183.74		No
	EGEN_37A	593307.75	4135861.50	184.29		No
	EGEN_37B	593307.75	4135861.50	180.37		No
	EGEN_38A	593307.75	4135861.50	179.06		No
	EGEN_38B	593307.75	4135861.50	175.34		No
	EGEN_ST1	593162.89	4135854.26	103.69		No
	EGEN_ST2	593162.89	4135854.26	103.36		No
	EGEN_ST3	593307.75	4135861.50	90.17		No
	Maximum CAAQS	593162.89	4135854.26	211.41		No

ATTACHMENT C
MANUFACTUER PERFORMANCE DATA SHEETS

Cat® 3516E

Diesel Generator Sets

Image shown may not reflect actual configuration

Bore – mm (in)	170 (6.69)
Stroke – mm (in)	215 (8.47)
Displacement – L (in^3)	78.1 (4766)
Compression Ratio	14.7:1
Aspiration	TA
Fuel System	EUI
Governor Type	ADEM™ A5

Standby 60 Hz ekW (kVA)	Mission Critical 60 Hz ekW (kVA)	Performance Strategy
2750 (3437)	2750 (3437)	U.S. EPA Certified for Emergency Stationary Applications (Tier 2)

Standard Features

Cat® Diesel Engine
- Meets U.S. EPA Stationary Emergency Use Only (Tier 2) emission standards
- Reliable performance proven in thousands of applications worldwide

Generator Set Package
- Accepts 100% block load in one step and meets other NFPA 110 loading requirements
- Conforms to ISO 8528-5 G3 load acceptance requirements
- Reliability verified through torsional vibration, fuel consumption, oil consumption, transient performance, and endurance testing

Alternators
- Superior motor starting capability minimizes need for oversizing generator
- Designed to match performance and output characteristics of Cat diesel engines

Cooling System
- Cooling systems available to operate in ambient temperatures up to 50°C (122°F)
- Tested to ensure proper generator set cooling

EMCP 4 Control Panels
- User-friendly interface and navigation
- Scalable system to meet a wide range of installation requirements
- Expansion modules and site specific programming for specific customer requirements

Warranty
- 24 months/1000-hour warranty for standby and mission critical ratings
- 12 months/unlimited hour warranty for prime and continuous ratings
- Extended service protection is available to provide extended coverage options

Worldwide Product Support
- Cat dealers have over 1,800 dealer branch stores operating in 200 countries
- Your local Cat dealer provides extensive post-sale support, including maintenance and repair agreements

Financing
- Caterpillar offers an array of financial products to help you succeed through financial service excellence
- Options include loans, finance lease, operating lease, working capital, and revolving line of credit
- Contact your local Cat dealer for availability in your region

Optional Equipment

Engine

Air Cleaner
- ❑ Single element

Muffler
- ❑ Industrial grade (15 dB)
- ❑ Critical grade (25 dB)
- ❑ Hospital grade (35 dB)

Starting
- ❑ Standard batteries
- ❑ Oversized batteries
- ❑ Heavy duty electric starter(s)
- ❑ Air starter(s)
- ❑ Jacket water heater

Alternator

Output voltage
- ❑ 416V ❑ 12470V
- ❑ 480V ❑ 13200V
- ❑ 600V ❑ 13800V
- ❑ 4160V

Temperature Rise (over 40°C ambient)
- ❑ 150°C
- ❑ 125°C/130°C
- ❑ 105°C
- ❑ 80°C

Winding type
- ❑ Form wound

Excitation
- ❑ Permanent magnet (PM)

Attachments
- ❑ Anti-condensation heater
- ❑ Stator and bearing temperature monitoring and protection

Power Termination

Type
- ❑ Bus bar
- ❑ Circuit breaker
- ❑ 1600A ❑ 2000A
- ❑ 2500A ❑ 3000A
- ❑ 3200A ❑ 4000A
- ❑ 5000A
- ❑ IEC ❑ UL
- ❑ 3-pole ❑ 4-pole
- ❑ Manually operated
- ❑ Electrically operated

Trip Unit
- ❑ LSI ❑ LSI-G
- ❑ LSI-P ❑ LSIG-P

Control System

Controller
- ❑ EMCP 4.2B
- ❑ EMCP 4.3
- ❑ EMCP 4.4

Attachments
- ❑ Local annunciator module
- ❑ Remote annunciator module
- ❑ Expansion I/O module
- ❑ Remote monitoring software

Charging
- ❑ Battery charger – 10A
- ❑ Battery charger – 20A
- ❑ Battery charger – 35A

Vibration Isolators
- ❑ Spring
- ❑ Seismic rated

Cat Connect

Connectivity
- ❑ Ethernet
- ❑ Cellular
- ❑ Satellite

Extended Service Options

Terms
- ❑ 2 year (prime)
- ❑ 3 year
- ❑ 5 year
- ❑ 10 year

Coverage
- ❑ Silver
- ❑ Gold
- ❑ Platinum
- ❑ Platinum Plus

Ancillary Equipment
- ❑ Automatic transfer switch (ATS)
- ❑ Uninterruptible power supply (UPS)
- ❑ Paralleling switchgear
- ❑ Paralleling controls

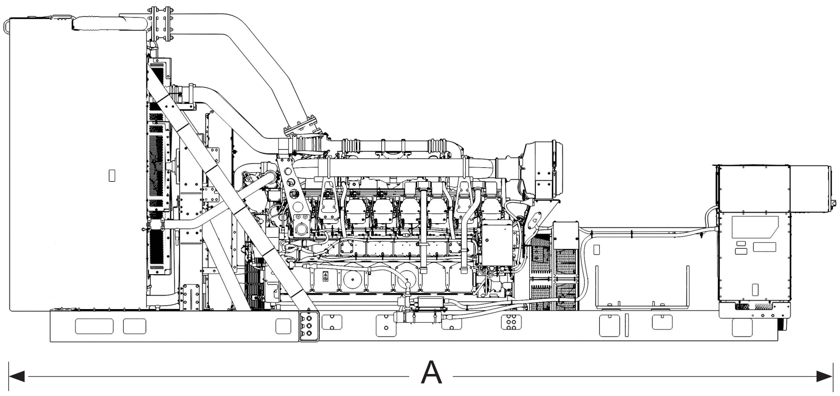
Certifications
- ❑ UL2200
- ❑ CSA
- ❑ IBC seismic certification
- ❑ OSHPD pre-approval
- ❑ EEC Declaration of Conformity
- ❑ EU Declaraton of Incorporation
- ❑ Eurasian Conformity (EAC) Mark

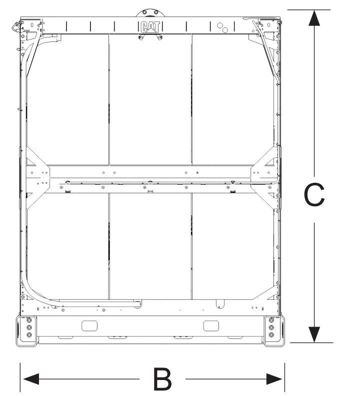
Note: *Some options may not be available on all models. Certifications may not be available with all model configurations. Consult factory for availability.*

Package Performance

Performance	Standby		Mission Critical	
Frequency	60 Hz		60 Hz	
Genset Power rating with fan	2750 ekW		2750 ekW	
Genset Power rating with fan @ 0.8 Power Factor	3437 kVA		3437 kVA	
Emissions	EPA ESE (Tier 2)		EPA ESE (Tier 2)	
Performance Number	EM2026-00		EM2116-00	
Fuel Consumption				
100% load with fan - L/hr (gal/hr)	735.6	(194.3)	735.6	(194.3)
75% load with fan - L/hr (gal/hr)	559.9	(147.9)	559.9	(147.9)
50% load with fan - L/hr (gal/hr)	406.7	(107.4)	406.7	(107.4)
25% load with fan - L/hr (gal/hr)	236.8	(62.6)	236.8	(62.6)
Cooling System				
Radiator Air flow restriction (system) - kPa (in. water)	0.12	(0.5)	0.12	(0.5)
kPa (in. water) Radiator airflow - m3/min (cfm)	3026	(106862)	3026	(106862)
Engine coolant capacity - L (gal)	233	(61.6)	233	(61.6)
Radiator coolant capacity - L (gal)	202	(53.3)	202	(53.3)
Total coolant capacity; L (gal)	435	(114.9)	435	(114.9)
Inlet Air				
Combustion air inlet flow rate; m^3/min (cfm)	235.4	(8313.0)	235.4	(8313.0)
Exhaust System				
Exhaust stack gas temperature - °C (°F)	480.6	(897)	480.6	(897)
Exhaust gas flow rate - m^3/min (cfm)	615.2	(21724.6)	615.2	(21724.6)
Exhaust system backpressure (maximum allowable) -	6.7	(27.0)	6.7	(27.0)
Heat Rejection				
Heat rejection to jacket water - kW (Btu/min)	898	(51083)	898	(51083)
Heat rejection to exhaust (total) - kW (Btu/min)	2867	(163046)	2867	(163046)
Heat rejection to aftercooler - kW (Btu/min)	874	(49686)	874	(49686)
Heat rejection to atmosphere from engine - kW (Btu/min)	160	(9085)	160	(9085)
Heat rejection from alternator - kW (Btu/min)	126	(7172)	126	(7172)

Weights and Dimensions





Dim "A" mm (in)	Dim "B" mm (in)	Dim "C" mm (in)	Dry Weight kg (lb)
8238 (324)	2640 (104)	3342 (132)	18 480 (40,750)

Note: *For reference only. Do not use for installation design. Contact your local Cat dealer for precise weights and dimensions.*

Ratings Definitions

Standby
Output available with varying load for the duration of the interruption of the normal source power. Average power output is 70% of the standby power rating. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year.

Mission Critical
Output available with varying load for the duration of the interruption of the normal source power. Average power output is 85% of the mission critical power rating. Typical peak demand up to 100% of rated power for up to 5% of the operating time. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year.

Applicable Codes and Standards
AS1359, CSA C22.2 No100-04, UL142, UL489, UL869, UL2200, NFPA37, NFPA70, NFPA99, NFPA110, IBC, IEC60034-1, ISO3046, ISO8528, NEMA MG1-22, NEMA MG1-33, 2014/35/EU, 2006/42/EC, 2014/30/EU.

Note: Codes may not be available in all model configurations. Please consult your local Cat dealer for availability.

Data Center Applications
Tier III/Tier IV compliant per Uptime Institute requirements. ANSI/TIA-942 compliant for Rated-1 through Rated-4 data centers.

Fuel Rates
Fuel rates are based on fuel oil of 35º API [16°C (60ºF)] gravity having an LHV of 42,780 kJ/kg (18,390 Btu/lb) when used at 29ºC (85ºF) and weighing 838.9 g/liter (7.001 lbs/U.S. gal.)

MANUFACTURER'S EMISSIONS DATA

CERTIFICATION YEAR: 2017   CERT AGENCY: EPA
EPA ENGINE FAMILY NAME: HCPXL78.1NZS

MODEL: 3516E
GENSET RATING (W/ FAN): 2750.0 EKW STANDBY 60 HERTZ @ 1800 RPM
ENGINE DISCPLACEMENT: 4766 CU IN
EMISSIONS POWER CATEGORY: >560 BKW
ENGINE TYPE: 4 Stroke Compression Ignition (Diesel)

GENERAL PERFORMANCE DATA

GEN W/F	ENG PWR	FUEL RATE	FUEL RATE	EXHAUST STACK TEMP	EXHAUST GAS FLOW
EKW	BHP	LB/BHP-HR	GPH	°F	CFM
2750.0	4043	0.337	194.3	897.0	21724.6

DATA REF NO.: EM2116-00

EPA D2 CYCLE CERTIFICATION

	UNITS	CO	HC	NOX	NOX + HC	PM
CERTIFICATION TEST LEVELS	GM/BHP-HR	0.67	0.19	3.78	3.95	0.09
	GM/BKW-HR	.9	0.26	5.07	5.3	0.12
EPA Tier 2 Max limits*	GM/BHP-HR	2.6	-	-	4.7	0.15
	GM/BKW-HR	3.5	-	-	6.4	0.2

DATA REF: https://www3.epa.gov/otaq/documents/eng-cert/nrci-cert-ghg-2017.xls
REF DATE: 01/20/2017

Gaseous emissions data measurements are consistent with those described in EPA 40 CFR PART 89 SUBPART D and ISO 8178 for measuring HC, CO, PM, and NOx.

***Gaseous emissions values are WEIGHTED CYCLE AVERAGES and are in compliance with the EPA non-road regulations.**

DESIGN PARAMETERS

The following conditions were used to design the CRT® Particulate Filter System:

Table 1. Design parameters at 100% load

Engine	**Caterpillar**
Model Number	**3516C-E**
Application	Generator
kW Rating	2750
Operating Hours per Year	TBD
Number of Systems	36
Type of Fuel	ULSD
Design Exhaust Flow Rate, ACFM	21724
Design Exhaust Temperature, °F	897
Recommended Size Load Bank/kW for Regeneration using CRTdM™	1250
Maximum Allowable Engine Back Pressure	26.9 “ H_2O
Typical (full load) Clean Back Pressure*	16.7 “ H_2O
Typical (full load) Operational Back Pressure*	23 ” H_2O
*Across the JM Product (Scope of Supply)	

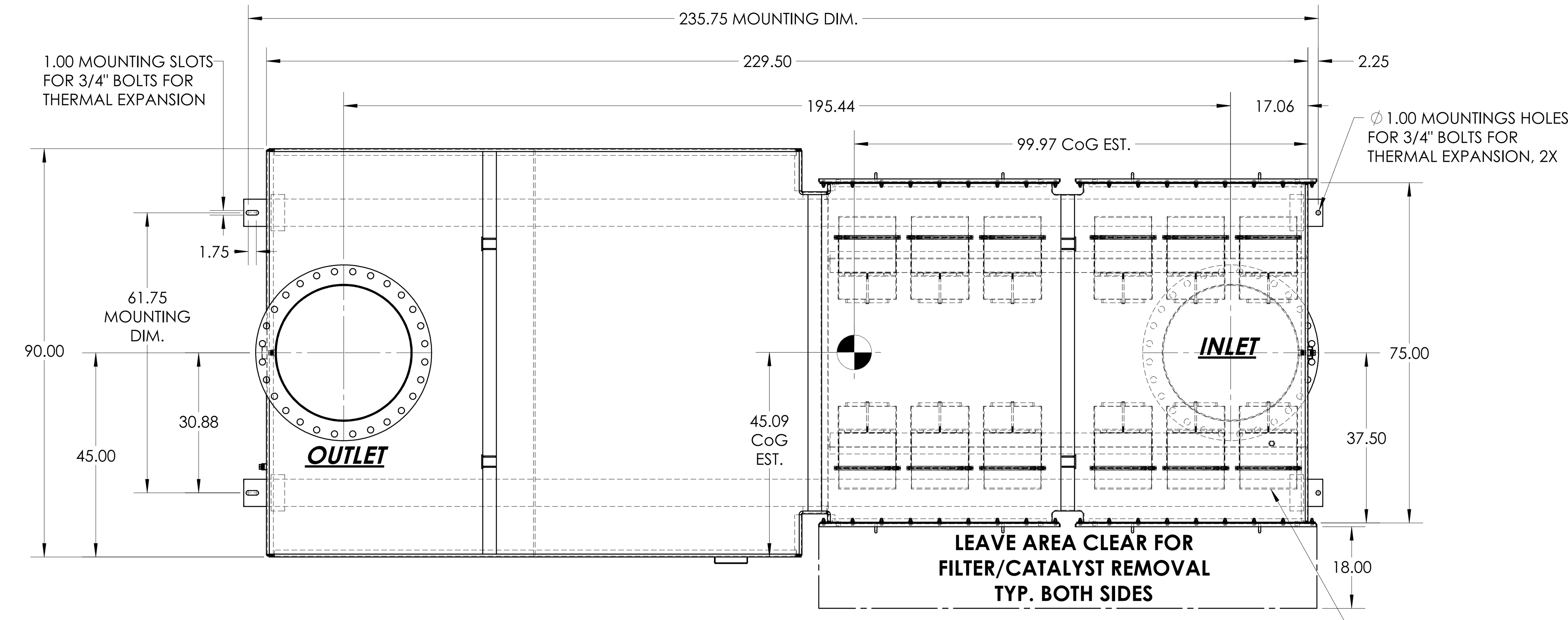
Table 2. Emissions Data (all values in gms/Bhp-hr at 100% load)

Pollutant	**Inlet Level**	**Outlet Level**	**% Reduction**
CO	1.16	80% Reduction	80
PM	.09	85% reduction	85
NO_x	6.14	NA	NA
HC	.14	70% Reduction	70

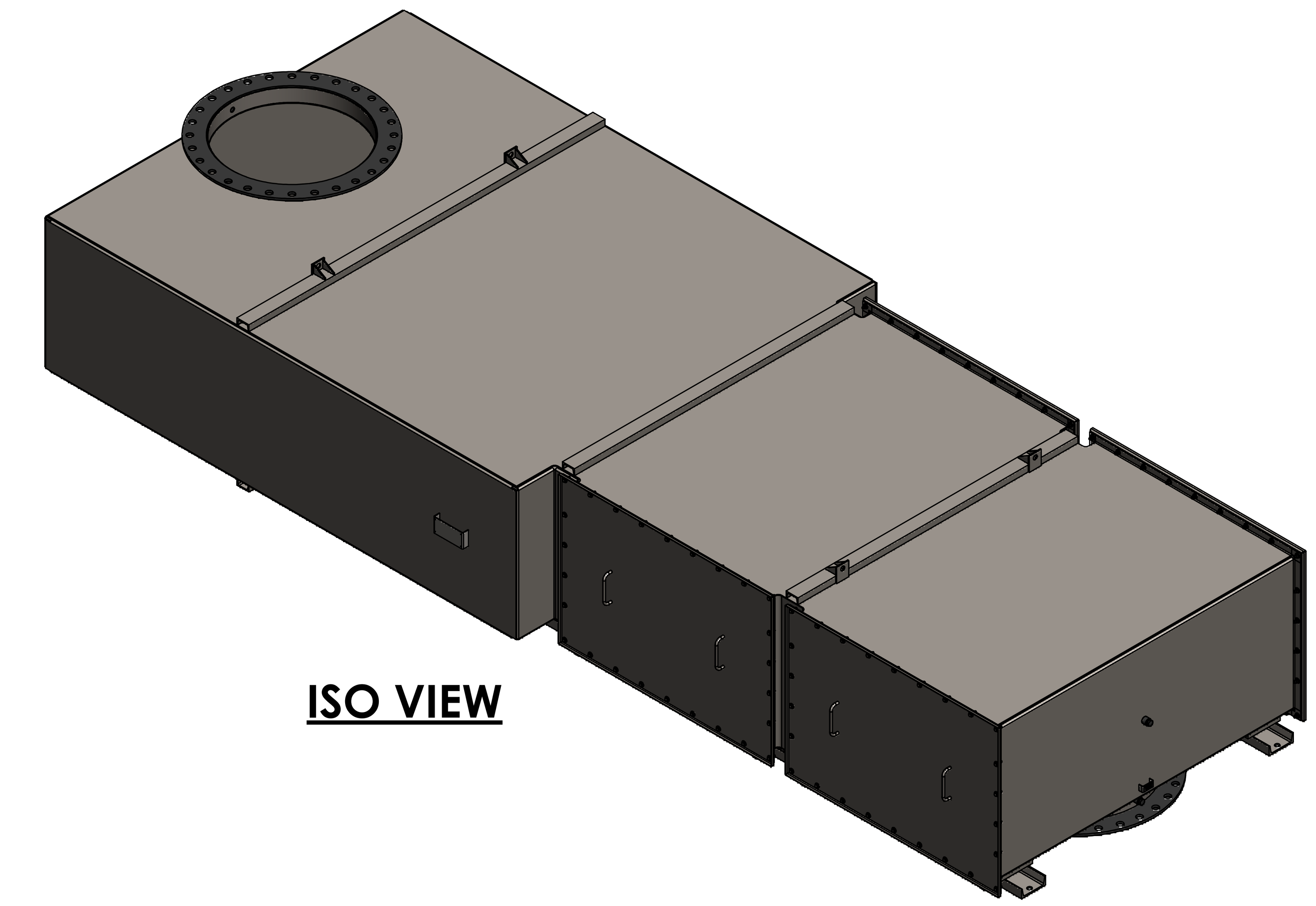
Johnson Matthey has calculated the appropriate catalyst volume and equipment required based on the above design parameters supplied. If actual operating conditions vary from above conditions, then more catalyst or filters may be required for the system to achieve desired destruction efficiencies. For this reason, all operating conditions must be closely reviewed, as different conditions will void the warranty.

In addition, CRTdM alarms must be responded to in the recommended manner, and sufficient engine load must be used to regenerate the CRT(+) unit, when necessary.

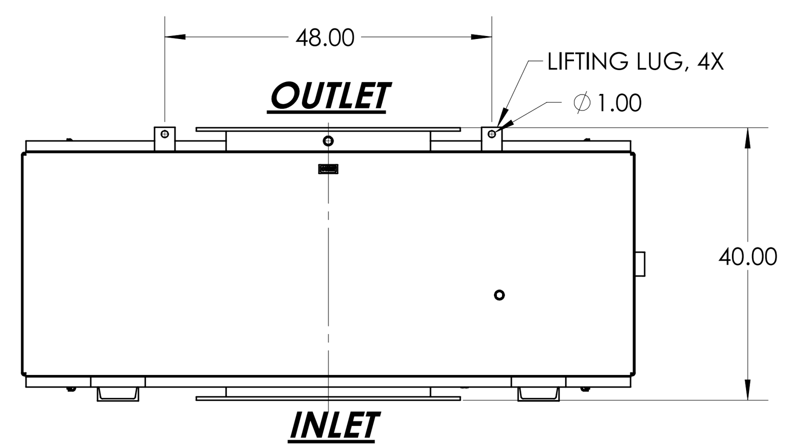
REVISIONS					
REV.	DATE	DESCRIPTION	BY	ENG	APPROVED
0	10/18/16	INITIAL RELEASE	M.D.C.		EJB 8/28/17



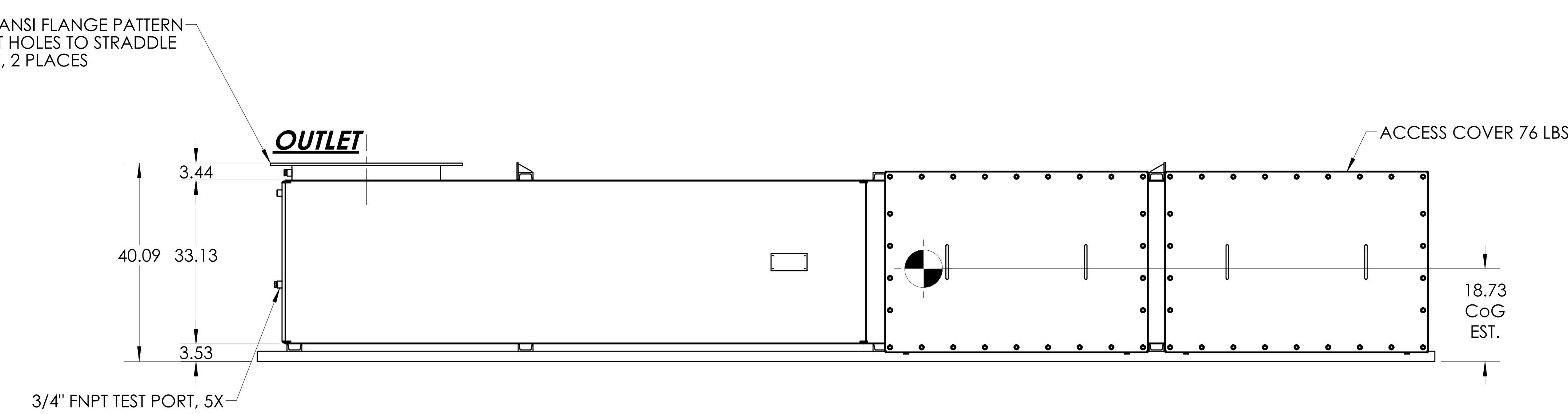
PLAN VIEW



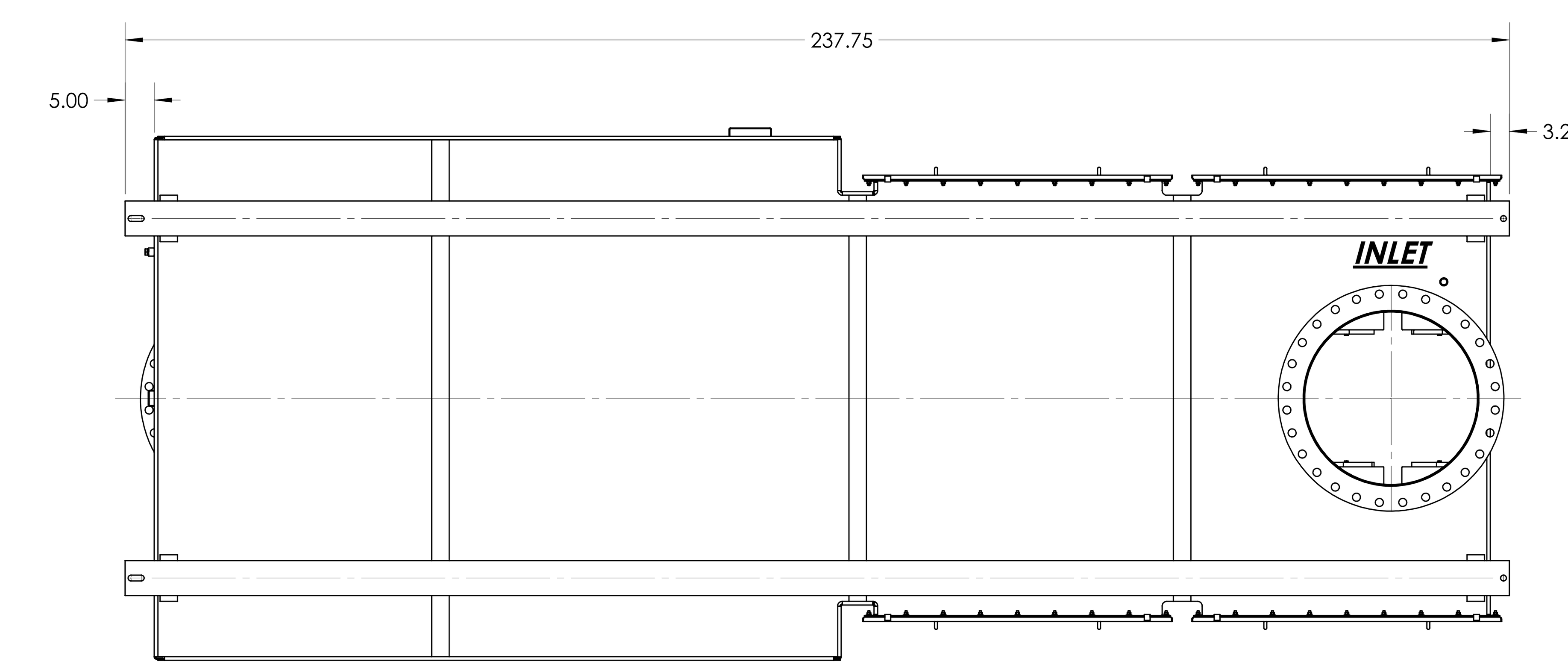
ISO VIEW



SIDE VIEW



ELEVATION VIEW



BOTTOM VIEW

NOTES:

1. WEIGHT IS ESTIMATED AND IS BASED UPON THE SHOWN CONFIGURATION.
2. SILENCER: HOSPITAL GRADE 30-35 dBA.
3. ALL WELDING TO BE IN ACCORDANCE WITH WELDING GUIDELINES, SEE DRAWING 609826.
4. MATERIAL (MS): 7 GA. ASTM A36 CARBON STEEL or 304 STAINLESS STEEL.
5. FINISH: HIGH TEMPERATURE BLACK PAINT TO HOUSING AND FLANGES (CARBON STEEL ONLY). PER JM PAINT SPEC SEC-EN-P-026.
6. PIPE DIAMETER OF CUSTOMER'S EXHAUST LINE(S) SHALL BE NO LESS THAN THE FLOW AREA OF THE INLET CONNECTION(S) PROVIDED BY JOHNSON MATTHEY.
7. JM BACKPRESSURE GUARANTEE EXTENDS FROM THE CRT INLET CONNECTION TO THE CRT OUTLET CONNECTION ONLY. CUSTOMER IS RESPONSIBLE FOR BACKPRESSURE OR PRESSURE DROP OF ALL OTHER COMPONENTS IN THE ENGINE EXHAUST SYSTEM.

FLANGE CONFIGURATION AND PART NUMBER		
FLANGE SIZE "A"	CS PART NO.	SS PART NO.
26	190157	190831
28	190158	190832
30	190159	190833

* BOLD FLANGE SIZE SHOWN

STANDARD TOLERANCES UNLESS SPECIFIED OTHERWISE [ ] ALTERNATE DIMENSION UNITS ARE FOR REFERENCE ONLY.					
MACHINING				GENERAL FABRICATION	
0.0	±0.0300"	FRACTIONS	±1/32"	< 36"	±1/32"
0.00	±0.0100	ANGLES	±0.2°	> 36"	±1/16"
0.000	±0.0050	SURFACE FINISH	125 μ"AA	ANGLES	±0.5°

FILLETS SHOWN SHARP = .03"R MAX.
BREAK CORNERS .03" X 45° CHAMFER
TAPPED HOLES - MIN. DEPTH FOR FULL THREADS = 1.8 X DIAMETER
CHAMFER ALL TAPPED HOLES TO ROOT OF FIRST THREAD
ALL DIMENSIONS ARE INCHES UNLESS SPECIFIED OTHERWISE

Shipping Dims		
Length L"	Width W"	Height H"
Material		
Finish		
Weight (lbs) 6104	Model Rev.	

Johnson Matthey
STATIONARY EMISSION CONTROL LLC
900 FORGE AVE
AUDUBON, PA 19403-2305

CRT(+) 24-H-MS-BITO-A/A-RT
GENERAL ARRANGEMENT

DRAWN BY	CHECKED	DATE	WHERE USED		DISCIP.	PROJECTION: THIRD ANGLE	SHEET NO.	SIZE
MDC	EJB	10-18-16					1 OF 7	D
ENGINEER	APPROVED	SCALE	EWR NO.	SO NO.	DRAWING NO.		SHT.	REV.
	BAT	1:24			609893		-1-	0

PERFORMANCE DATA [EM2026]

MAY 17, 2017

For Help Desk Phone Numbers Click here

Help

Perf No: EM2026 **Change Level:** 00

General Heat Rejection Emissions Regulatory Altitude Derate Cross Reference Perf Param Ref

View PDF

SALES MODEL:	3516E	**COMBUSTION:**	DI
BRAND:	CAT	**ENGINE SPEED (RPM):**	1,800
ENGINE POWER (BHP):	4,043	**HERTZ:**	60
GEN POWER WITH FAN (EKW):	2,750.0	**FAN POWER (HP):**	160.9
COMPRESSION RATIO:	14.7	**ASPIRATION:**	TA
RATING LEVEL:	STANDBY	**AFTERCOOLER TYPE:**	ATAAC
PUMP QUANTITY:	1	**AFTERCOOLER CIRCUIT TYPE:**	JW+OC, ATAAC
FUEL TYPE:	DIESEL	**INLET MANIFOLD AIR TEMP (F):**	122
MANIFOLD TYPE:	DRY	**JACKET WATER TEMP (F):**	219.2
GOVERNOR TYPE:	ADEM5	**TURBO CONFIGURATION:**	PARALLEL
ELECTRONICS TYPE:	ADEM5	**TURBO QUANTITY:**	4
IGNITION TYPE:	CI	**TURBOCHARGER MODEL:**	GTB6051N-44T-1.25
INJECTOR TYPE:	EUI	**CERTIFICATION YEAR:**	2017
FUEL INJECTOR:	3920221	**CRANKCASE BLOWBY RATE (FT3/HR):**	4,039.5
UNIT INJECTOR TIMING (IN):	64.34	**FUEL RATE (RATED RPM) NO LOAD (GAL/HR):**	15.8
REF EXH STACK DIAMETER (IN):	12	**PISTON SPD @ RATED ENG SPD (FT/MIN):**	2,539.4

INDUSTRY	SUB INDUSTRY	APPLICATION
ELECTRIC POWER	STANDARD	PACKAGED GENSET

General Performance Data Top

Note(s)
THIS STANDBY RATING IS FOR A STANDBY ONLY ENGINE ARRANGEMENT. RERATING THE ENGINE TO A PRIME OR CONTINUOUS RATING IS NOT PERMITTED.

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
2,750.0	100	4,043	373	0.337	194.3	89.0	124.7	1,248.7	69.3	897.0
2,475.0	90	3,655	337	0.332	173.2	78.5	119.6	1,200.8	60.2	874.3
2,200.0	80	3,266	302	0.334	156.1	70.3	115.1	1,168.4	53.8	862.1
2,062.5	75	3,072	284	0.337	147.9	66.2	114.4	1,156.4	50.7	859.3
1,925.0	70	2,878	266	0.340	139.8	62.1	113.3	1,144.6	47.6	857.1
1,650.0	60	2,490	230	0.348	123.7	53.9	110.5	1,119.4	41.4	852.3
1,375.0	50	2,102	194	0.358	107.4	45.7	107.2	1,088.4	35.3	844.3
1,100.0	40	1,714	158	0.367	89.7	35.3	105.0	1,053.2	28.0	836.6
825.0	30	1,325	122	0.378	71.5	24.5	103.4	1,002.0	20.9	816.3
687.5	25	1,131	104	0.387	62.6	19.7	102.8	959.8	17.9	788.1

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
550.0	20	937	87	0.399	53.5	15.3	102.0	900.5	15.0	745.1
275.0	10	549	51	0.444	34.8	7.5	100.0	707.7	9.6	600.4

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
2,750.0	100	4,043	95	459.3	8,311.0	21,724.6	36,043.6	37,404.6	7,873.2	7,173.7
2,475.0	90	3,655	84	424.9	7,644.3	19,597.8	33,105.4	34,316.5	7,223.3	6,600.5
2,200.0	80	3,266	76	398.7	7,134.8	18,059.1	30,814.3	31,907.0	6,717.5	6,163.1
2,062.5	75	3,072	71	386.6	6,868.3	17,312.6	29,600.4	30,637.2	6,453.6	5,928.8
1,925.0	70	2,878	67	373.5	6,592.5	16,561.5	28,375.0	29,355.4	6,184.0	5,685.4
1,650.0	60	2,490	58	345.0	6,037.4	15,050.4	25,928.9	26,795.9	5,640.3	5,194.1
1,375.0	50	2,102	50	312.1	5,508.7	13,534.6	23,489.4	24,242.0	5,103.3	4,718.9
1,100.0	40	1,714	39	272.3	4,755.3	11,552.1	20,219.6	20,847.9	4,381.7	4,062.9
825.0	30	1,325	27	228.1	3,957.2	9,452.4	16,797.6	17,298.4	3,642.2	3,388.1
687.5	25	1,131	22	205.3	3,608.1	8,401.7	15,278.6	15,716.4	3,310.6	3,087.4
550.0	20	937	18	182.7	3,284.0	7,356.2	13,863.7	14,238.0	3,002.1	2,810.0
275.0	10	549	9	139.5	2,714.7	5,306.2	11,377.1	11,621.0	2,461.2	2,333.0

Heat Rejection Data Top

GENSET POWER WITH FAN	PERCENT LOAD	ENGINE POWER	REJECTION TO JACKET WATER	REJECTION TO ATMOSPHERE	REJECTION TO EXH	EXHAUST RECOVERY TO 350F	FROM OIL COOLER	FROM AFTERCOOLER	WORK ENERGY	LOW HEAT VALUE ENERGY	HI HE VA EN
EKW	%	BHP	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BT
2,750.0	100	4,043	51,083	9,085	163,046	86,850	22,219	49,686	171,445	417,162	44
2,475.0	90	3,655	46,867	8,504	143,853	76,167	19,796	41,719	154,983	371,670	39
2,200.0	80	3,266	43,337	8,132	130,635	69,029	17,838	36,156	138,521	334,904	35
2,062.5	75	3,072	41,619	8,001	124,853	65,872	16,904	33,326	130,290	317,372	33

Emissions Data Top

Units Filter All Units

RATED SPEED POTENTIAL SITE VARIATION: 1800 RPM

GENSET POWER WITH FAN ENGINE POWER		EKW BHP	2,750.0 4,043	2,062.5 3,072	1,375.0 2,102	687.5 1,131	275.0 549
PERCENT LOAD		%	100	75	50	25	10
TOTAL NOX (AS NO2)		G/HR	24,635	15,352	7,747	3,924	4,756
TOTAL CO		G/HR	4,653	2,391	1,447	2,444	2,051
TOTAL HC		G/HR	557	539	539	433	309
PART MATTER		G/HR	379.2	181.2	175.4	284.9	130.0
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	2,634.2	2,198.0	1,531.8	1,354.4	3,405.8
TOTAL CO	(CORR 5% O2)	MG/NM3	510.1	343.8	279.0	818.5	1,221.9
TOTAL HC	(CORR 5% O2)	MG/NM3	52.9	66.7	91.4	126.1	158.1
PART MATTER	(CORR 5% O2)	MG/NM3	34.5	21.9	30.3	82.5	57.9
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,283	1,071	746	660	1,659
TOTAL CO	(CORR 5% O2)	PPM	408	275	223	655	978
TOTAL HC	(CORR 5% O2)	PPM	99	125	171	235	295
TOTAL NOX (AS NO2)		G/HP-HR	6.14	5.03	3.70	3.48	8.68
TOTAL CO		G/HP-HR	1.16	0.78	0.69	2.17	3.74
TOTAL HC		G/HP-HR	0.14	0.18	0.26	0.38	0.56

GENSET POWER WITH FAN ENGINE POWER		EKW BHP	2,750.0 4,043	2,062.5 3,072	1,375.0 2,102	687.5 1,131	275.0 549
PERCENT LOAD		**%**	**100**	**75**	**50**	**25**	**10**
PART MATTER		G/HP-HR	0.09	0.06	0.08	0.25	0.24
TOTAL NOX (AS NO2)		LB/HR	54.31	33.85	17.08	8.65	10.49
TOTAL CO		LB/HR	10.26	5.27	3.19	5.39	4.52
TOTAL HC		LB/HR	1.23	1.19	1.19	0.95	0.68
PART MATTER		LB/HR	0.84	0.40	0.39	0.63	0.29

RATED SPEED NOMINAL DATA: 1800 RPM

GENSET POWER WITH FAN ENGINE POWER		EKW BHP	2,750.0 4,043	2,062.5 3,072	1,375.0 2,102	687.5 1,131	275.0 549
PERCENT LOAD		**%**	**100**	**75**	**50**	**25**	**10**
TOTAL NOX (AS NO2)		G/HR	20,529	12,794	6,456	3,270	3,964
TOTAL CO		G/HR	2,585	1,328	804	1,358	1,140
TOTAL HC		G/HR	419	406	405	325	232
TOTAL CO2		KG/HR	1,950	1,485	1,076	623	345
PART MATTER		G/HR	270.9	129.4	125.3	203.5	92.9
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	2,195.2	1,831.7	1,276.5	1,128.7	2,838.2
TOTAL CO	(CORR 5% O2)	MG/NM3	283.4	191.0	155.0	454.7	678.9
TOTAL HC	(CORR 5% O2)	MG/NM3	39.8	50.2	68.8	94.8	118.9
PART MATTER	(CORR 5% O2)	MG/NM3	24.7	15.7	21.6	59.0	41.4
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,069	892	622	550	1,382
TOTAL CO	(CORR 5% O2)	PPM	227	153	124	364	543
TOTAL HC	(CORR 5% O2)	PPM	74	94	128	177	222
TOTAL NOX (AS NO2)		G/HP-HR	5.12	4.19	3.08	2.90	7.23
TOTAL CO		G/HP-HR	0.64	0.43	0.38	1.20	2.08
TOTAL HC		G/HP-HR	0.10	0.13	0.19	0.29	0.42
PART MATTER		G/HP-HR	0.07	0.04	0.06	0.18	0.17
TOTAL NOX (AS NO2)		LB/HR	45.26	28.20	14.23	7.21	8.74
TOTAL CO		LB/HR	5.70	2.93	1.77	2.99	2.51
TOTAL HC		LB/HR	0.92	0.89	0.89	0.72	0.51
TOTAL CO2		LB/HR	4,299	3,274	2,372	1,373	761
PART MATTER		LB/HR	0.60	0.29	0.28	0.45	0.20
OXYGEN IN EXH		%	8.8	9.7	10.6	11.7	14.1
DRY SMOKE OPACITY		%	2.5	1.7	2.0	4.3	2.4
BOSCH SMOKE NUMBER			0.91	0.57	0.67	1.35	0.84

Regulatory Information Top

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 Top

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	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043
1,000	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	3,969	4,043
2,000	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,043	4,030	3,996	3,824	4,043
3,000	4,043	4,043	4,043	4,043	4,042	4,031	4,009	4,006	4,003	3,964	3,864	3,678	4,043
4,000	4,043	4,043	4,026	3,990	3,958	3,926	3,908	3,913	3,904	3,870	3,747	3,510	3,976
5,000	3,988	3,959	3,925	3,892	3,859	3,827	3,809	3,814	3,798	3,759	3,628	3,331	3,889
6,000	3,926	3,890	3,854	3,818	3,784	3,750	3,723	3,706	3,676	3,634	3,483	3,173	3,828
7,000	3,862	3,824	3,781	3,741	3,699	3,661	3,623	3,584	3,544	3,502	3,325	3,040	3,767

AMBIENT OPERATING TEMP (F)	30	40	50	60	70	80	90	100	110	120	130	140	NORMAL
8,000	3,763	3,724	3,679	3,629	3,579	3,533	3,488	3,440	3,395	3,353	3,177	2,941	3,679
9,000	3,630	3,582	3,530	3,480	3,431	3,383	3,336	3,291	3,250	3,211	3,051	2,825	3,549
10,000	3,490	3,433	3,380	3,330	3,282	3,238	3,196	3,156	3,117	3,085	2,945	2,686	3,418
11,000	3,336	3,285	3,235	3,191	3,147	3,108	3,078	3,049	3,020	2,988	2,831	2,518	3,289
12,000	3,197	3,150	3,110	3,078	3,047	3,017	2,985	2,952	2,918	2,870	2,680	2,346	3,171
13,000	3,087	3,051	3,017	2,983	2,953	2,920	2,881	2,842	2,802	2,735	2,512	2,205	3,080
14,000	3,000	2,958	2,920	2,877	2,840	2,799	2,758	2,713	2,671	2,577	2,348	2,088	3,005
15,000	2,891	2,844	2,803	2,761	2,715	2,668	2,625	2,581	2,537	2,418	2,213	2,024	2,914

Cross Reference Top

Test Spec	Setting	Engine Arrangement	Engineering Model	Engineering Model Version	Start Effective Serial Number	End Effective Serial Number
4577276	LL1866	4558023	PG266	-	JD700001	

Performance Parameter Reference Top

Parameters Reference: DM9600 - 08

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
<u>FOR 3500 ENGINES AND SMALLER</u>
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.

<u>FOR 3600 ENGINES</u>
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.

Customer's may have special emission site requirements that need
to be verified by the Caterpillar Product Group engineer.

EMISSIONS DEFINITIONS:
Emissions : DM1176

HEAT REJECTION DEFINITIONS:
Diesel Circuit Type and HHV Balance : DM9500

HIGH DISPLACEMENT (HD) DEFINITIONS:
3500: EM1500

RATING DEFINITIONS:
Agriculture : TM6008

Fire Pump : TM6009

Generator Set : TM6035

Generator (Gas) : TM6041

Industrial Diesel : TM6010

Industrial (Gas) : TM6040

Irrigation : TM5749

Locomotive : TM6037

Marine Auxiliary : TM6036

Marine Prop (Except 3600) : TM5747

Marine Prop (3600 only) : TM5748

MSHA : TM6042

Oil Field (Petroleum) : TM6011

Off-Highway Truck : TM6039

On-Highway Truck : TM6038

SOUND DEFINITIONS:

Sound Power : DM8702

Sound Pressure : TM7080

Date Released : 7/7/15

State of California
AIR RESOURCES BOARD

EXECUTIVE ORDER DE-08-009-09

Pursuant to the authority vested in the California Air Resources Board (CARB) by Health and Safety Code, Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code section 39515 and 39516 and Executive Order G-14-012;

This action relates to Verification under sections 2700 through 2711 of title 13 of the California Code of Regulations

Johnson Matthey Inc.
CRT(+) Diesel Particulate Filter

CARB has reviewed the request by Johnson Matthey Inc. for verification of the CRT(+) diesel particulate filter (DPF). Based on an evaluation of the data provided, and pursuant to the terms and conditions specified below, the Executive Officer of the CARB hereby finds that the CRT(+) DPF reduces emissions of diesel particulate matter (PM) consistent with a Level 3 device (greater than or equal to 85 percent reductions) (California Code of Regulations (CCR), title 13, sections 2702 (f) and section 2708) and complies with the CARB January 1, 2009, nitrogen dioxide (NO_2) limit (CCR, title 13, section 2702 (f) and section 2706 (a)). Accordingly, the Executive Officer determines that the system merits verification and, subject to the terms and conditions specified below, classifies the CRT(+) DPF as a Level 3 Plus system, for use with stationary emergency standby and prime generators using engine families listed in Attachment 1.

This verification is subject to the following terms and conditions:

- The engine must be used in a stationary application associated with emergency standby or prime generators.
- The engines are model years 1996 or newer having the engine family names listed in Attachment 1.
- The engine must be a Tier 1, Tier 2, Tier 3, Tier 4i with a rated horse power between 50 and 75 or over 750, or Tier 4 Alt 20% NOx and PM certified off-road engine meeting 0.2 grams per brake horsepower hour (g/bhp-hr) diesel particulate matter (PM) or less based on certification or in-use emissions testing (as tested on an appropriate steady-state certification cycle outlined in the CARB off-road regulations – similar to ISO 8178 D2).
- The engine must be in its original certified configuration.
- The engine must not employ exhaust gas recirculation.
- The engine must not have a pre-existing selective catalytic reduction system.
- The engine must not have a pre-existing oxidation catalyst.
- The engine must not have a pre-existing diesel particulate filter.
- The engine must be four-stroke.
- The engine can be turbocharged or naturally-aspirated.
- The engine must be certified in California.

- Johnson Matthey Inc. must review actual operating conditions (duty cycle, baseline emissions, exhaust temperature profiles, and engine backpressure) prior to retrofitting an engine with the CRT(+) DPF to ensure compatibility.
- The engine should be well maintained and not consume lubricating oil at a rate greater than that specified by the engine manufacturer.
- The engine must not be operated with fuel additives, as defined in section 2701 of title 13, of the CCR, unless explicitly verified for use with fuel additive(s).
- The other terms and conditions specified in Table 1.

Table 1: Conditions for the CRT(+) DPF

Parameter	Value
Application	Stationary Emergency Standby and Prime Power Generation
Engine Type	Diesel, with or without turbocharger, without exhaust gas recirculation (EGR), mechanically or electronically controlled, Tier 1, Tier 2, Tier 3, Tier 4i with a rated horse power between 50 and 75 or over 750, or Tier 4 Alt 20% NOx and PM certified off-road engines meeting 0.2 g/bhp-hr diesel PM or less based on certification or in-use emissions testing.
Minimum Exhaust Temperature for Filter Regeneration	The engine must operate at the load level required to achieve 240 degrees Celsius (ºC) for a minimum of 40 percent of the engine's operating time and an oxides of nitrogen (NOx)/PM ratio of 15 @ ≥ 300°C and 20 @ ≤ 300°C. Operation at lower temperatures is allowed, but only for a limited duration as specified below.
Maximum Consecutive Minutes Operating Below Passive Regeneration Temperature	720 Minutes
NOx/PM Ratio Requirements	NOx/PM ratio of at least 8 with a preference for 20 or higher.
Number of Consecutive Cold Starts and 30 Minute Idle Sessions before Regeneration Required	24
Number of Months of Operation Before Cleaning of Filter Required	Filter cleaning is not required till after 150 half-hour cold starts with associated regenerations or 1000 hours of emergency/standby use or 6 to 12 months of prime operation depending on hours of operation, maintenance practice, and oil used. The CRTdm, which monitors engine exhaust back pressure and temperature will determine the actual cleaning interval and provide an alert when filter cleaning is required.
Fuel	California diesel fuel with less than or equal to 15 ppm sulfur or a biodiesel blend provided that the biodiesel portion of the blend complies with ASTM D6751, the diesel portion of the blend complies with title 13 (CCR), sections 2281 and 2282, and the blend contains no more than 20 percent biodiesel by volume. Other alternative diesel fuels such as, but not limited to, ethanol diesel blends and water emulsified diesel fuel are excluded from this Executive Order.
Verification Level	Level 3 Plus Verification: • PM - at least 85% reduction • NO_2 - meets January 2009 limit

The CRT(+) DPF consists of an oxidation catalyst and diesel particulate filter, referred to as a catalyzed passive continuously regenerated diesel particulate filter, and a backpressure monitor and data logger combination, CRTdm. A schematic of the approved label is shown in Attachment 2. Labels attached to the DPF and the engine must be identical.

This Executive Order is valid provided that installation instructions for the CRT(+) DPF do not recommend tuning the engine to specifications different from those of the engine manufacturer. The product must not be used with any other systems or engine modifications without CARB and manufacturer written approval.

Changes made to the design or operating conditions of the CRT(+) DPF, as exempted by CARB, which adversely affect the performance of the engine's pollution control system, shall invalidate this Executive Order. As such, no changes are permitted to the device.

If Johnson Matthey Inc. plans to make changes to the design of CRT(+) DPF, the CARB must be notified in writing of any changes to any part of the CRT(+) DPF. Any changes to the device must be evaluated and approved in writing by CARB. Failure to do so shall invalidate this Executive Order.

Marketing of the CRT(+) DPF using identification other than that shown in this Executive Order or for an application other than that listed in this Executive Order shall be prohibited unless prior approval is obtained from CARB.

As specified in the Diesel Emission Control Strategy Verification Procedure (title 13 CCR section 2706 (g)), the CARB assigns each Diesel Emission Control Strategy a family name. The designated family name for the verification as outlined above is:

CA/JMI/2008/PM3+/N00/ST/DPF01

Additionally, as stated in the Diesel Emission Control Strategy Verification Procedure, Johnson Matthey Inc. is responsible for record keeping requirements (section 2702), honoring the required warranty (section 2707), and conducting in-use compliance testing (section 2709).

Johnson Matthey Inc. must ensure that the installation of the CRT(+) DPF system conforms to all applicable industrial safety requirements.

A copy of this Executive Order must be provided to the ultimate purchaser at the time of sale.

Proper engine maintenance is critical for the proper functioning of the diesel emission control strategy. The owner and/or operator of the engine on which the diesel emission control strategy is installed, is strongly advised to adhere to all good engine maintenance practices. Failure to document proper engine maintenance, including keeping records of the engine's oil consumption, may be grounds for denial of a warranty claim.

In addition, CARB reserves the right in the future to review this Executive Order and verification provided herein to assure that the verified add-on or modified part continues to meet the standards and procedures of CCR, title 13, section 2222, et seq. and CCR, title 13, sections 2700 through 2711.

Systems verified under this Executive Order shall conform to all applicable California emissions regulations.

This Executive Order does not release Johnson Matthey Inc. from complying with all other applicable regulations.

Violation of any of the above conditions shall be grounds for revocation of this Executive Order.

Executive Order DE-08-009-08 is hereby superseded and is of no further force and effect.

Executed at Sacramento, California, this 5th day of December, 2017.

Richard W. Corey
Executive Officer
by

Cynthia Marvin, Chief
Transportation and Toxics Division

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter Off-Road Certified Engine Family List (0<=0.2 g/hp-hr PM)
Attachment 2: Diesel Emission Control System Label

ELECTRIC POWER - Technical Spec Sheet
STANDARD

C18

600 ekW/ 750 kVA/ 60 Hz/ 1800 rpm/ 480 V/ 0.8 Power Factor

Rating Type: STANDBY

Emissions: U.S. EPA Certified for Stationary Emergency Use Only (Tier 2 Nonroad Equivalent Emission Standards)

Image shown may not reflect actual configuration

C18

600 ekW/ 750 kVA
60 Hz/ 1800 rpm/ 480 V

	Metric	English
Package Performance		
Genset Power Rating with Fan @ 0.8 Power Factor	600 ekW	
Genset Power Rating	750 kVA	
Aftercooler (Separate Circuit)	N/A	N/A

	Metric	English
Fuel Consumption		
100% Load with Fan	161.6 L/hr	42.7 gal/hr
75% Load with Fan	129.6 L/hr	34.2 gal/hr
50% Load with Fan	91.7 L/hr	24.2 gal/hr
25% Load with Fan	46.8 L/hr	12.4 gal/hr

	Metric	English
Cooling System[1]		
Engine Coolant Capacity	20.8 L	5.5 gal

	Metric	English
Inlet Air		
Combustion Air Inlet Flow Rate	47.8 m³/min	1687.8 cfm
Max. Allowable Combustion Air Inlet Temp	49 ° C	120 ° F

	Metric	English
Exhaust System		
Exhaust Stack Gas Temperature	534.6 ° C	994.3 ° F
Exhaust Gas Flow Rate	135.5 m³/min	4784.4 cfm
Exhaust System Backpressure (Maximum Allowable)	10.0 kPa	40.0 in. water

Rating Type: STANDBY

Emissions: U.S. EPA Certified for Stationary Emergency Use Only (Tier 2 Nonroad Equivalent Emission Standards)

Heat Rejection		
Heat Rejection to Jacket Water	189 kW	10747 Btu/min
Heat Rejection to Exhaust (Total)	634 kW	36053 Btu/min
Heat Rejection to Aftercooler	153 kW	8700 Btu/min
Heat Rejection to Atmosphere from Engine	86 kW	4902 Btu/min
Heat Rejection to Atmosphere from Generator	41 kW	2332 Btu/min

Alternator[2]	
Motor Starting Capability @ 30% Voltage Dip	1633 skVA
Current	902 amps
Frame Size	LC7024F
Excitation	AR
Temperature Rise	150 ° C

DEFINITIONS AND CONDITIONS

1. For ambient and altitude capabilities consult your Cat dealer. Air flow restriction (system) is added to existing restriction from factory.

2. UL 2200 Listed packages may have oversized generators with a different temperature rise and motor starting characteristics. Generator temperature rise is based on a 40° C ambient per NEMA MG1-32.

3. Emissions data measurement procedures are consistent with those described in EPA CFR 40 Part 89, Subpart D & E and ISO8178-1 for measuring HC, CO, PM, NOx. Data shown is based on steady state operating conditions of 77° F, 28.42 in HG and number 2 diesel fuel with 35° API and LHV of 18,390 btu/lb. The nominal emissions data shown is subject to instrumentation, measurement, facility and engine to engine variations. Emissions data is based on 100% load and thus cannot be used to compare to EPA regulations which use values based on a weighted cycle.

Rating Type: STANDBY

Emissions: U.S. EPA Certified for Stationary Emergency Use Only (Tier 2 Nonroad Equivalent Emission Standards)

Applicable Codes and Standards:
AS1359, CSA C22.2 No100-04, UL142,UL489, UL869, UL2200,
NFPA37, NFPA70, NFPA99, NFPA110, IBC, IEC60034-1, ISO3046, ISO8528,
NEMA MG1-22,NEMA MG1-33, 2006/95/EC, 2006/42/EC, 2004/108/EC.

Note: Codes may not be available in all model configurations. Please consult your local Cat Dealer representative for availability.

STANDBY: Output available with varying load for the duration of the interruption of the normal source power. Average power output is 70% of the standby power rating. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year.

Ratings are based on SAE J1349 standard conditions. These ratings also apply at ISO3046 standard conditions

Fuel Rates are based on fuel oil of 35º API [16º C (60º F)] gravity having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 29º C (85º F) and weighing 838.9 g/liter (7.001 lbs/U.S. gal.). Additional ratings may be available for specific customer requirements, contact your Cat representative for details. For information regarding Low Sulfur fuel and Biodiesel capability, please consult your Cat dealer.

www.Cat-ElectricPower.com

Performance No.: DM8518-04

Feature Code: C18DE6E

Generator Arrangement: 4183897

Date: 07/26/2017

Source Country: U.S.

MANUFACTURER'S EMISSIONS DATA

CERTIFICATION YEAR: 2018   CERT AGENCY: EPA
EPA ENGINE FAMILY NAME: JCPXL18.1NYS

MODEL: C18
GENSET RATING (W/ FAN): 600.0 EKW STANDBY 60 HERTZ @ 1800 RPM
ENGINE DISCPLACEMENT: 1106.36 CU IN
EMISSIONS POWER CATEGORY: 560<=KW<2237
ENGINE TYPE: 4 Stroke Compression Ignition (Diesel)

GENERAL PERFORMANCE DATA

GEN W/F	ENG PWR	FUEL RATE	FUEL RATE	EXHAUST STACK TEMP	EXHAUST GAS FLOW
EKW	BHP	LB/BHP-HR	GPH	°F	CFM
600.0	900.0	0.332	42.7	994.3	4784.4

DATA REF NO.: DM8518-04

EPA D2 CYCLE CERTIFICATION

	UNITS	CO	HC	NOX	NOX + HC	PM
CERTIFICATION TEST LEVELS	GM/BHP-HR	0.6	0.08	3.80	3.9	0.05
	GM/BKW-HR	0.8	0.11	5.06	5.2	0.07
EPA Tier 2 Max limits*	GM/BHP-HR	2.6	-	-	4.8	0.15
	GM/BKW-HR	3.5	-	-	6.4	0.20

DATA REF: https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment
REF DATE: 02/2018

Gaseous emissions data measurements are consistent with those described in EPA 40 CFR PART 89 SUBPART D and ISO 8178 for measuring HC, CO, PM, and NOx.

*Gaseous emissions values are WEIGHTED CYCLE AVERAGES and are in compliance with the EPA non-road regulations.

PERFORMANCE DATA[DM8518]

April 17, 2018

Performance Number: DM8518 **Change Level: 04**

SALES MODEL:	C18	**COMBUSTION:**	DI
BRAND:	CAT	**ENGINE SPEED (RPM):**	1,800
ENGINE POWER (BHP):	900	**HERTZ:**	60
GEN POWER W/O FAN (EKW):	621.0	**FAN POWER (HP):**	24.1
GEN POWER WITH FAN (EKW):	600.0	**ASPIRATION:**	TA
COMPRESSION RATIO:	14.5	**AFTERCOOLER TYPE:**	ATAAC
RATING LEVEL:	STANDBY	**AFTERCOOLER CIRCUIT TYPE:**	JW+OC, ATAAC
PUMP QUANTITY:	1	**INLET MANIFOLD AIR TEMP (F):**	120
FUEL TYPE:	DIESEL	**JACKET WATER TEMP (F):**	192.2
MANIFOLD TYPE:	DRY	**TURBO CONFIGURATION:**	PARALLEL
GOVERNOR TYPE:	ELEC	**TURBO QUANTITY:**	2
CAMSHAFT TYPE:	STANDARD	**TURBOCHARGER MODEL:**	S310S089 1.10A/R
IGNITION TYPE:	CI	**CERTIFICATION YEAR:**	2006
INJECTOR TYPE:	EUI	**PISTON SPD @ RATED ENG SPD (FT/MIN):**	2,161.4
REF EXH STACK DIAMETER (IN):	6		
MAX OPERATING ALTITUDE (FT):	2,953		

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	ENGINE OUTLET TEMP
EKW	%	BHP	PSI	LB/BHP-HR	GAL/HR	IN-HG	DEG F	DEG F	DEG F
600.0	100	900	358	0.332	42.7	69.4	120.2	1,296.3	994.3
540.0	90	808	321	0.339	39.1	66.3	118.8	1,245.6	957.8
480.0	80	718	286	0.350	35.9	63.5	114.4	1,207.1	930.8
450.0	75	674	268	0.356	34.2	61.8	112.9	1,186.7	917.0
420.0	70	629	250	0.361	32.4	59.7	111.6	1,165.0	902.7
360.0	60	541	215	0.369	28.5	53.8	109.2	1,112.0	870.5
300.0	50	454	181	0.373	24.2	45.7	106.7	1,046.3	833.0
240.0	40	370	147	0.368	19.5	33.5	100.1	946.3	779.4
180.0	30	286	114	0.358	14.6	20.4	94.1	835.3	712.8
150.0	25	244	97	0.355	12.4	14.8	92.9	777.5	675.5
120.0	20	201	80	0.354	10.2	9.7	93.2	718.0	635.0
60.0	10	114	45	0.412	6.7	5.3	110.2	594.2	543.7

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
600.0	100	900	75	412.3	1,687.8	4,784.4	7,408.0	7,706.8	1,617.9	1,451.6
540.0	90	808	72	394.7	1,642.0	4,527.0	6,835.4	7,109.2	1,570.3	1,408.9
480.0	80	718	69	382.3	1,610.2	4,346.8	6,444.6	6,696.2	1,537.1	1,379.1
450.0	75	674	67	375.0	1,585.8	4,235.0	6,219.7	6,459.3	1,512.6	1,357.1
420.0	70	629	65	366.6	1,553.7	4,103.3	5,966.3	6,193.4	1,480.9	1,328.7
360.0	60	541	59	343.2	1,458.4	3,757.4	5,337.4	5,537.1	1,388.9	1,246.1
300.0	50	454	50	310.5	1,320.6	3,305.0	4,563.8	4,733.3	1,257.1	1,127.9
240.0	40	370	37	257.4	1,111.5	2,682.3	3,553.5	3,689.7	1,064.4	955.0
180.0	30	286	23	199.4	884.9	2,022.7	2,525.0	2,627.5	848.2	761.0
150.0	25	244	18	174.4	785.6	1,730.6	2,088.7	2,175.3	749.5	672.5
120.0	20	201	12	151.3	693.2	1,458.1	1,697.2	1,768.4	654.9	587.6
60.0	10	114	7	126.8	597.1	1,145.6	1,226.4	1,273.3	561.4	503.7

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

PERFORMANCE DATA[DM8518]

EKW	%	BHP	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN	BTU/MIN
600.0	100	900	10,747	4,902	36,053	25,532	4,927	8,700	38,156	92,511	98,547
540.0	90	808	9,782	4,629	33,384	23,204	4,501	8,019	34,283	84,515	90,030
480.0	80	718	8,986	4,214	31,336	21,497	4,132	7,621	30,466	77,572	82,634
450.0	75	674	8,588	3,960	30,201	20,572	3,935	7,343	28,577	73,883	78,704
420.0	70	629	8,190	3,714	28,948	19,564	3,728	6,995	26,691	69,994	74,562
360.0	60	541	7,280	3,361	25,878	17,120	3,276	6,029	22,961	61,507	65,520
300.0	50	454	6,312	3,082	22,121	14,274	2,778	4,777	19,272	52,156	55,559
240.0	40	370	5,495	2,832	17,303	10,690	2,231	3,160	15,694	41,880	44,613
180.0	30	286	4,715	2,598	12,425	7,201	1,677	1,641	12,128	31,482	33,537
150.0	25	244	4,301	2,088	10,360	5,720	1,416	1,113	10,337	26,580	28,314
120.0	20	201	3,873	1,654	8,496	4,395	1,163	687	8,525	21,841	23,266
60.0	10	114	2,853	1,533	5,930	2,515	768	173	4,826	14,415	15,355

Emissions Data

RATED SPEED POTENTIAL SITE VARIATION: 1800 RPM

GENSET POWER WITH FAN		EKW	600.0	450.0	300.0	150.0	60.0
PERCENT LOAD		**%**	**100**	**75**	**50**	**25**	**10**
ENGINE POWER		**BHP**	**900**	**674**	**454**	**244**	**114**
TOTAL NOX (AS NO2)		G/HR	5,538	2,437	1,369	1,803	1,161
TOTAL CO		G/HR	774	577	211	226	358
TOTAL HC		G/HR	15	29	65	37	37
PART MATTER		G/HR	58.3	81.9	46.9	19.9	16.8
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	3,022.6	1,643.1	1,364.2	3,552.7	4,023.2
TOTAL CO	(CORR 5% O2)	MG/NM3	421.1	389.9	203.1	444.4	1,292.1
TOTAL HC	(CORR 5% O2)	MG/NM3	7.1	17.6	54.2	59.2	114.4
PART MATTER	(CORR 5% O2)	MG/NM3	26.0	47.3	39.3	33.4	54.7
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,472	800	664	1,730	1,960
TOTAL CO	(CORR 5% O2)	PPM	337	312	162	356	1,034
TOTAL HC	(CORR 5% O2)	PPM	13	33	101	111	214
TOTAL NOX (AS NO2)		G/HP-HR	6.21	3.64	3.02	7.41	10.21
TOTAL CO		G/HP-HR	0.87	0.86	0.47	0.93	3.15
TOTAL HC		G/HP-HR	0.02	0.04	0.14	0.15	0.32
PART MATTER		G/HP-HR	0.07	0.12	0.10	0.08	0.15
TOTAL NOX (AS NO2)		LB/HR	12.21	5.37	3.02	3.97	2.56
TOTAL CO		LB/HR	1.71	1.27	0.46	0.50	0.79
TOTAL HC		LB/HR	0.03	0.06	0.14	0.08	0.08
PART MATTER		LB/HR	0.13	0.18	0.10	0.04	0.04

RATED SPEED NOMINAL DATA: 1800 RPM

GENSET POWER WITH FAN		EKW	600.0	450.0	300.0	150.0	60.0
PERCENT LOAD		**%**	**100**	**75**	**50**	**25**	**10**
ENGINE POWER		**BHP**	**900**	**674**	**454**	**244**	**114**
TOTAL NOX (AS NO2)		G/HR	5,128	2,257	1,267	1,669	1,075
TOTAL CO		G/HR	414	308	113	121	192
TOTAL HC		G/HR	8	15	35	19	19
TOTAL CO2		KG/HR	422	338	239	122	67
PART MATTER		G/HR	29.9	42.0	24.0	10.2	8.6
TOTAL NOX (AS NO2)	(CORR 5% O2)	MG/NM3	2,798.7	1,521.4	1,263.2	3,289.5	3,725.1
TOTAL CO	(CORR 5% O2)	MG/NM3	225.2	208.5	108.6	237.7	691.0
TOTAL HC	(CORR 5% O2)	MG/NM3	3.8	9.3	28.7	31.3	60.5
PART MATTER	(CORR 5% O2)	MG/NM3	13.3	24.3	20.2	17.2	28.1
TOTAL NOX (AS NO2)	(CORR 5% O2)	PPM	1,363	741	615	1,602	1,814
TOTAL CO	(CORR 5% O2)	PPM	180	167	87	190	553
TOTAL HC	(CORR 5% O2)	PPM	7	17	54	59	113
TOTAL NOX (AS NO2)		G/HP-HR	5.75	3.37	2.80	6.86	9.46
TOTAL CO		G/HP-HR	0.46	0.46	0.25	0.50	1.68
TOTAL HC		G/HP-HR	0.01	0.02	0.08	0.08	0.17
PART MATTER		G/HP-HR	0.03	0.06	0.05	0.04	0.08
TOTAL NOX (AS NO2)		LB/HR	11.30	4.98	2.79	3.68	2.37
TOTAL CO		LB/HR	0.91	0.68	0.25	0.27	0.42
TOTAL HC		LB/HR	0.02	0.03	0.08	0.04	0.04
TOTAL CO2		LB/HR	930	746	528	269	149
PART MATTER		LB/HR	0.07	0.09	0.05	0.02	0.02
OXYGEN IN EXH		%	9.0	10.9	12.5	13.6	15.9
DRY SMOKE OPACITY		%	0.8	1.1	0.9	0.6	0.5
BOSCH SMOKE NUMBER			0.46	0.74	0.54	0.30	0.22

Regulatory Information

EPA TIER 2		2006 - 2010		
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 - ----		
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	900	900	900	900	900	900	900	900	900	900	900	900	900
1,000	900	900	900	900	900	900	900	900	900	898	882	868	900
2,000	900	900	900	900	900	900	900	895	879	864	850	835	900
3,000	900	900	900	900	900	893	877	861	846	832	818	804	900
4,000	900	900	900	893	876	859	844	829	814	800	787	773	885
5,000	900	893	875	858	842	827	812	797	783	770	757	744	857
6,000	876	858	842	825	810	795	780	766	753	740	727	715	830
7,000	842	825	809	793	778	764	750	736	724	711	699	687	803
8,000	809	793	777	762	748	734	720	708	695	683	672	660	777
9,000	777	761	746	732	718	705	692	680	668	656	645	634	751
10,000	746	731	716	703	689	677	664	652	641	630	619	609	726
11,000	716	701	687	674	661	649	637	626	615	604	594	584	702
12,000	686	673	659	647	635	623	611	601	590	580	570	560	678
13,000	658	645	632	620	608	597	586	576	566	556	546	537	655
14,000	631	618	606	594	583	572	562	552	542	533	524	515	632
15,000	604	592	581	569	559	548	538	529	519	510	502	493	610

Cross Reference

Test Spec	Setting	Engine Arrangement	Engineering Model	Engineering Model Version	Start Effective Serial Number	End Effective Serial Number
0K7257	PP5703	2726915	GS338	-	EST00001	

Performance Parameter Reference

Parameters Reference:DM9600-10

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 deg C (84.2 deg F), 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.

Customer's may have special emission site requirements that need to be verified by the Caterpillar Product Group engineer.

EMISSIONS DEFINITIONS:

Emissions : DM1176

HEAT REJECTION DEFINITIONS:

Diesel Circuit Type and HHV Balance : DM9500

HIGH DISPLACEMENT (HD) DEFINITIONS:

3500: EM1500

RATING DEFINITIONS:

Agriculture : TM6008
Fire Pump : TM6009
Generator Set : TM6035
Generator (Gas) : TM6041
Industrial Diesel : TM6010
Industrial (Gas) : TM6040
Irrigation : TM5749
Locomotive : TM6037
Marine Auxiliary : TM6036
Marine Prop (Except 3600) : TM5747
Marine Prop (3600 only) : TM5748
MSHA : TM6042
Oil Field (Petroleum) : TM6011
Off-Highway Truck : TM6039
On-Highway Truck : TM6038

SOUND DEFINITIONS:

Sound Power : DM8702
Sound Pressure : TM7080

Date Released : 7/7/15

ATTACHMENT D
CD-ROM OF ELECTRONIC MODELING FILES

Table 1
Construction Related Emissions From Generator Placement
McLaren Project
Santa Clara, California

	ROG	NO_x	PM[3,4]
	Total tons		
Structure[1]	0.0022	0.018	7.4E-04
Generator[2]	7.2E-05	9.3E-04	4.0E-05
17 Generators with 1 Structure[3]	0.0034	0.033	0.0014
50 Generators with 3 Structures[4]	0.010	0.10	0.0042
Total Construction Emissions in 2016 CEQA MND (tons)	4.3	20	1.0
Percentage of Total Construction Emissions from 2016 CEQA MND	**0.23%**	**0.50%**	**0.43%**

Notes:

1 Emissions estimated using CalEEMod 2016.3.2 and EMFAC 2014 for Santa Clara county.

2 Emissions estimated using CalEEMod 2016.3.2.

3 PM emissions from construction is applicable only for exhaust emissions based on BAAQMD CEQA Guidance. Buildlings 1 and 3 have 17 generators with 1 structure and Building 2 has 16 generators with 1 structure. Construction emissions for Building 2 were assumed to be the same as other buildilngs, to be

4 Including only PM_{10} emissions to be conservative. For this analysis, DPM is assumed to equal PM_{10}.

Abbreviations:

CalEEMod - California Emissions Estimator Model
lb - pounds
NOx - nitrogen oxides
ROG - reactive organic gases
PM_{10} - particulate matter < 10 µm
BAAQMD - Bay Area Air Quality District

MEMO

Date: **May 3, 2018**

Prepared for: **Vantage Data Centers**

Prepared by: **Ramboll US Corporation**

Subject: **Update to Additional Analyses from CEC Data Request**

CONSTRUCTION EMISSIONS FOR THE MBGF

This serves as an update to the response to the previous data request item concerning construction emissions for the MBGF. Emissions estimates are updated to reflect the changes to the project description. The only construction activities associated with the MBGF are placement of the generators and the construction of the structure that hold the second stack of generators. The following characteristics were used to estimate emissions from construction activities: For placement of one generator, a crane would be operating for 2 hours and a heavy-heavy duty truck would be idling for 2 hours. For the construction of the structure, it was assumed to take one loader and one welder operating for 8 hours/day for 5 days to build the structure for 1 building. This means that the three structures needed for the 3 buildings would take 15 days total to construct. Attachment 1 (provided to Commission Staff via upload) summarizes calculated total emissions estimates. CalEEMod was used to estimate emissions from construction equipment and EMFAC2014 was used to estimate idling emissions from the heavy-heavy duty truck. Calculated emissions from placement of all 50 generators and construction of the 3 structures was compared to the total construction emissions from the 2016 CEQA MND analysis submitted to the City of Santa Clara for the impacts analysis. For comparison, the calculated emissions from placement of the generators and structures ranged from 0.23-0.50%of total emissions from the 2016 analysis, depending on the pollutant. The cancer risk from the 2016 CEQA MND construction HRA was 3.54 in one million. Since all pollutants, including DPM (which is the surrogate for health risk) were well below the totals from the less-than-significant 2016 CEQA MND construction HRA emission totals, the estimated construction emissions from placement of the generators and structures are deemed de minimis.

SCREENING ANALYSIS

This serves as an update to the screening analysis provided in the previous data request. This analysis accounts for the new generators of 2.75-MW capacity, a change from the previously presented 3-MW capacity. Ramboll performed a screening analysis using SCREEN3 to determine the worst-case operating scenario for each pollutant (Attachment 2, provided to the Commission via upload). 100% load conditions were found to be the worst case for short and long term effects of NO_2 and SO_2. Low load conditions (10% load in this analysis, which is the closest data we have to 0% load) were found to be worst case for 1-hour of emissions of CO and ROG, but were no longer worst case when the duration of the low load test, 5-minutes, was accounted for. When excluding the 10% load case due to short duration of testing, 25% load was worst case for CO, PM, and ROG for both short and long term effects. PM concentration at 25% load was 65% greater than the concentration at 100% load, CO concentration at 25% load was 12% greater than the concentration at 100% load, and ROG concentration at 25% load was 66% greater than the concentration at 100% load. Even if long-term health risks were doubled, they would still result in levels below BAAQMD CEQA thresholds. However, Ramboll justifies not requiring a refined analysis at the 25% load condition because generators will spend a much larger portion (more than double of the time) of the year's permitted testing hours at 100% load versus 25% load, so assuming all testing hours at the worst case load of 25% would not be representative of operations. The same argument can be made for CO and ROG. Even if currently modelled CO concentrations were doubled, concentrations would be well below BAAQMD CEQA thresholds, and in practice the generators will spend more than double of the year's permitted testing hours at 100% load versus 25% load, so the modelled impacts are representative of the operating scenario and the worst-case impacts based on those operating scenarios.

SCREEN3 modeling was conducted to predict which operating scenario is the worst-case for each of the following pollutants: NO2, CO, PM, ROG, and SO2. This is a screening analysis using worst-case uniform met data and full NOx and SOx conversion, and does not represent actual modelled concentrations, it is merely an exersize to find worst-case dispersion. Table 1 to Table 3 show the input parameters used to run each load scenario.

SCREEN3 results are presented in Table 4. It can be seen that 100% load is not the most conservative scenario for all species, the most conservative scenario is highlighted in yellow. For example, the maximum annual and 1-hour concentrations of CO and ROG are predicted to occur at 10% engine load. However, engines are only tested at low loads for 5-minute periods, once monthly. 25% load was found to be worst-case for PM.

The model was also used to estimate the distance between the source (generator) and the location at with imaximum concentration is predicted, showing that 100% load parameters have a maximum furthest from the source.

The modeled maximum 1-hour concentrations were used to estimate annual average concentrations for each pollutant and load scenario using SCREEN3 scaling ratio of 0.08, as per USEPA guidance.

Table 1. Engine Specfications and Stack Exhaust Parameters

	Case 1 10% Load	Case 2 25% Load	Case 3 50% Load	Case 4 75% Load	Case 5 100% Load
Temperature (K)	588.90	693.20	724.40	732.80	753.70
Flow (m3/s)	2.5	4.0	6.4	8.2	10.3
Velocity (m/s)	7.31	11.58	18.65	23.85	29.93
Stack height (m)	14.55	14.55	14.55	14.55	14.55
Stack Diamater (m)	0.66	0.66	0.66	0.66	0.66
Stack Area (m2)	0.34	0.34	0.34	0.34	0.34
Enigin Power (bhp)	549	1131	2102	3072	4043
Fuel Consumption (gallons/hour)	34.8	62.6	107.4	147.9	194.3
Diesel Density (lb/US gallons)	6.943				
Fuel Consumption (g/s)	30.44	54.76	93.96	129.39	169.98

Table 2. Emission Rates

Emission rate (g/s)	Case 1 10% Load	Case 2 25% Load	Case 3 50% Load	Case 4 75% Load	Case 5 100% Load
NOx	1.101	0.908	1.793	3.554	5.70
CO	0.317	0.377	0.223	0.369	0.718
PM	0.026	0.057	0.035	0.036	0.075
ROG[a]	0.064	0.090	0.113	0.113	0.116
SO2[b]	0.0009	0.0016	0.0028	0.0039	0.0051

Table 3. SCREEN3 Input Parameters

Ambient Air Temperature (K)	293
Receptor Heaight (m)	1.8
Urban/Rural Land Use (U/R)	U
Building Downwash? (Y/N)	N
Building Height (m)	-
Minimum Horizontal Building Dimension (m)	-
Maximum Horizontal Building Dimension(m)	-
Complex terrain screen? (Y/N)	N
Simple terrain screen? (Y/N)	N
Meteorology Option	Full Met
Automated Distance Array	Y
Mininum Distance (m)	0
Maximum Distance (m)	300

Table 4. SCREEN3 Results

1-hour HR Max Concentration	Case 1 10% Load	Case 2 25% Load	Case 3 50% Load	Case 4 75% Load	Case 5 100% Load
NOx (ug/m3)	69.160	36.180	48.840	80.430	106.000
CO (ug/m3)	19.910	15.020	6.074	8.351	13.360
PM (ug/m3)	1.633	2.271	0.953	0.815	1.395
ROG (ug/m3)	4.020	3.586	3.078	2.557	2.158
SO2 (ug/m3)	0.057	0.064	0.076	0.088	0.095
Distance from source (m)	99	111	96	105	116

Table 5. Annual Max Concentration[c] of Each Emission Compound

Annual Max Concentration	Case 1 10% Load	Case 2 25% Load	Case 3 50% Load	Case 4 75% Load	Case 5 100% Load
NOx (ug/m3)	5.533	2.894	3.907	6.434	8.480
CO (ug/m3)	1.593	1.202	0.486	0.668	1.069
PM (ug/m3)	0.131	0.182	0.076	0.065	0.112
ROG (ug/m3)	0.322	0.287	0.246	0.205	0.173
SO2 (ug/m3)	0.005	0.005	0.006	0.007	0.008

[a] ROG(g/s)=0.1498(g/(bhp-hr)*engine power(BHP)/3600, EPA Tier 4 nonroad diesel burn model

[b] SO2 (g/s)= 0.01998* fuel consumption (g/s)* %sulfur in fuel, in this case % sulfur is given as 0.0015

[c] Annual Conversion factor = 0.08*1-hr Concentration

Appendix F

Revised Thermal Plume Technical Report

RAMBOLL

Prepared for
Vantage Data Centers
Santa Clara, California

Prepared by
Ramboll US Corporation
San Francisco, CA

Project Number
1690006450~~0341184B~~

Date
~~December, 2017~~May, 2018

PLUME ASSESSMENT
MCLAREN DATA CENTER
SANTA CLARA, CALIFORNIA

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FIGURES

Figure 1: Stack Locations

ACRONYMS AND ABBREVIATIONS

ACFM	Actual cubic feet per minute
CASA	Civil Aviation Safety Authority
CEC	California Energy Commission
F	Fahrenheit
ft	feet
ft/s	feet per second
K	Kelvin
m	meter
m/s	meters per second
s	second

1. INTRODUCTION

1.1 Background

Vantage Data Centers has proposed to develop a data center in Santa Clara, California, in a location near the San Jose airport. The data center will involve fifty~~forty eight~~ (50~~48~~) backup emergency diesel generators and seventy two (72) roof-mounted air chillers.

The California Energy Commission (CEC) has required Vantage Data Centers to evaluate the potential implications of the thermal plumes from the proposed stacks on aviation safety. Ramboll has been engaged by Vantage to undertake this assessment and has completed a screening assessment. The assessment of vertical plume velocity was conducted in accordance with CEC methodology, invoking the Spillane methodology to analytically solve for plume height. The effect of merged plumes are taken into account.

The acceptable plume vertical velocity threshold is specified in recent supplemental testimony of James Adams and Appendix TT-2 of a CEC project titled “Palmdale Energy Project” (PEP) docketed on December 29, 2016. This project defines the significance level of 5.3 m/s at all heights above 1,500 feet AGL (above ground level). The threshold of 5.3 m/s average velocity is used in this assessment.

The vertical velocity of the emissions from the emergency standby generators and the air-cooled chillers will be greater than 5.3 m/s at the point of discharge and therefore an assessment of the vertical velocity is required to be undertaken.

2. SCREENING ASSESSMENT

2.1 Vertical plume velocity guidelines

The assessment will conservatively determine the potential for turbulence generated by the plume-averaged vertical velocity of the emergency standby generator and chiller exhaust plumes. The method uses worst-case assumptions of calm winds and neutral atmospheric conditions for the entire vertical extent of the plume to determine the worst-case impacts.

Since the development of a simple-cycle gas turbine power station at the end of a runway in Australia in the mid-1990s,[1] the Australian Civil Aviation Safety Authority (CASA) has taken an active role in the review of the siting of facilities with the potential to affect aviation activities.

Potential hazards that could affect the safety of aircraft include tall visible or invisible obstructions. Visible obstructions include structures such as tall stacks or communication towers. Invisible obstructions include industrial exhausts that generate significant turbulence due to high velocity and buoyancy. CASA has issued an Advisory Circular, (CASA 2004) that specifies the requirements and methodologies to be used to assess whether a new industrial plume is likely to have adverse implications for aviation safety.

The general CASA requirement is to determine the height at which the plume (or plumes) could generate atmospheric turbulence and to determine the dimensions of the plume in these circumstances. The frequency of in-plume vertical velocities at the lowest height an aircraft may travel over the site, and at other heights are also required. For large plumes that are remote from airports, CASA requires an assessment that determines the size of a hazard zone to alert pilots to the potential hazard. Normally this analysis uses a sophisticated air dispersion model that determines plume vertical velocities and lateral/vertical extents based on wind fields generated from actual meteorological data. Rather than use such a refined technique, a conservative screening analysis based on calm wind field assumptions was used for this project.

For this assessment, the plume-averaged vertical velocities were calculated as a function of height under calm conditions. The established CEC significance criteria is for an averaged plume velocity to equal or exceed 5.3 m/s at altitudes where aircraft can operate. This significance criteria was adopted in the CEC Palmdale Energy Project.

[1] Note that this project consists of internal combustion engines (ICEs) and air-cooled chillers that have plume exhausts with much smaller volumetric flows and buoyancy fluxes than the turbine projects that elicited the initial interest of CASA.

3. MODEL INPUT DATA

3.1 Emissions information

The proposed data center will have a number of atmospheric emission sources including:

1. Emergency standby diesel generators; and
2. Air-cooled “free cooling” chillers;

The highest exit velocity and emissions volume is associated with the emergency generators and therefore the screening assessment has primarily focused on these sources. An additional scenario associated with the cooling towers was also included. The emission parameters used within the screening assessment for the three scenarios considered for emergency generators and one scenario considered for the chillers are presented in Table 1.

Table 1. Stack Parameters

	Emergency generators		
	Scenario 1 - Worst-case	**Scenario 2**	**Scenario 3**
Ambient Potential Temp (F)	30	59	76
Stack Height (feet)	47.75~~5.2~~	4~~5.2~~7.75	4~~5.2~~7.75
Stack Diameter (feet)	2.2~~1.7~~	2.2~~1.7~~	2.2~~1.7~~
Stack Velocity at exit (m/s)	29.93~~59.2~~	29.93~~59.2~~	29.93~~59.2~~
Stack Potential Temp (F)	897~~1.9~~	897~~1.9~~	897~~1.9~~
	Air-cooled chillers		
	Scenario 1 - Worst-case		
Ambient Potential Temp (F)	30		
Stack Height (feet)	120		
Stack Diameter (feet)	2.3		
Stack Velocity at exit (m/s)	9.4		
Stack Potential Temp (F)	101.5		

The 50~~48~~ generator stacks and 72 chiller stacks are arranged in the configuration displayed in Figure 1. Although the project consists of 47 2.75~~3~~-MW generators and three (3)~~one~~ 6~~5~~00-kW generators, the 6~~5~~00-kW generators were~~as~~ conservatively assumed to have the same stack parameters as a 2.75~~3~~-MW generator for ease of calculation. The chillers are located on the roofs of the buildings. Buildings are approximately 101~~6~~ feet in height. The chiller is placed on a dunnage platform on the roof and the height of the chiller is 8 feet from the top of the dunnage platform. The top of the chiller would be 120 feet above ground level (including the 5’ for the dunnage platform), so that was the height assumed for the chiller stack height.

3.2 Methodology

This assessment analyses vertical plume rise using the Spillane methodology, developed by Dr. Kevin Spillane, to analytically solve for plume heights above the jet phase in calm conditions. Three methods were evaluated: Method 1 assumes conservation of buoyancy and a Gaussian distribution of the vertical velocities, Method 2 is based on the Best et al., 2003 paper's analytical solution, and Method 3 considers the enhancement of vertical velocities that may occur if the plumes from multiple stacks merge and form a higher buoyancy combined/merged plume. Method 3, developed by the CEC, is based on the single stack plume velocity multiplied by the number of stacks raised to the 0.25 power.

Table 2. Model Results

Assumptions							Maximum Height Above Ground with Vertical Velocity above Threshold (5.3 m/s)		
Source (Number of Units)	**Ambient Temperature**	**Stack Height (h_s)**	**Stack Diameter (D)**	**Stack Velocity (V_{exit})**	**Volumetric Flow**	**Stack Potential Temperature (θ_S)**	**Method 1**	**Method 2**	**Merged Plumes**
Emergency Diesel Generators (50~~48~~)	272 K (30°F)	14.55~~3.77~~ m (4~~5.2~~7.75 ft)	0.66~~51~~ m (2.2~~1.7~~ ft)	29.93~~59.22~~ m/s (98.2~~194.3~~ ft/s)	21,725~~5,620~~ ACFM	754~~1~~ K (897~~1.9~~°F)	27.74~~32.92~~ m (91~~108~~ ft)	24.38~~7.74~~ m (80~~91~~ ft)	24.38~~7.74~~ m (80~~91~~ ft)
Chillers (72)	272 K (30°F)	36.58 m (120 ft)	0.71 m (2.3 ft)	9.40 m/s (30.8 ft/s)	8,476 ACFM	312 K (101.5°F)	40.84 m (134 ft)	40.54 m (133 ft)	42.37 m (139 ft)

4. MODEL RESULTS

4.1 Worst-case calm wind scenario

Plumes that may have a vertical velocity of greater than 5.3 m/s are of primary interest to the airport safety authorities. While the vertical velocity of the plumes at the point of discharge are in excess of 5.3 m/s, the vertical velocity is quickly dissipated following discharge as the plume mixes with ambient air.

An assessment assuming calm winds for the entire height of the plume and an ambient temperature of 30 F is presented here to represent the worst-case. Results of the plume vertical velocities at various heights are presented in Appendix A and summarized in Table 2 based both the Spillane methodology and the CEC methodology (merged plumes).

For this conservative analysis, both single plume and merged plume velocities were evaluated. Using the Spillane methodology Method 1, the plume-averaged vertical velocity drops below the CEC screening threshold of 5.3 m/s at 91~~108~~ feet above ground level for one emergency generator and at 134 feet above ground level for one chiller. Method 2 yielded slightly lower heights than Method 1. Using the CEC methodology of merged plumes, the vertical velocity drops below 5.3 m/s for the 50~~48~~ generators at 80~~91~~ feet above ground level and for the 72 chillers at 139 feet above ground level.

5. SUMMARY AND CONCLUSION

Modelling of the characteristics of the plumes from the diesel emergency generators and roof-mounted air chillers at the Vantage McLaren data center has been completed and indicates:

1. Under worst-case ambient conditions and calculation methodology, predicted vertical velocities are below 5.3 m/s for emergency generators at a height of 91~~108~~ feet above ground; and
2. Under worst-case ambient conditions and calculation methodology, predicted vertical velocities are below 5.3 m/s for roof-mounted air chillers at a height of 139 feet above ground.

6. REFERENCES

Best, P., Jackson, L., Killip, C., Kanowski, M., Spillane, K. (2003) "Aviation Safety and Buoyant Plumes." Clean Air Conference, Newcastle, New South Wale, Australia.

FIGURES

RAMBOLL

DRAFTED BY: DCW | DATE: 5/2/2018

Stack Locations
McLaren Project
Vantage Data Centers
Santa Clara, California

FIGURE
1

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	Assumptions						Maximum Height Above Ground with Vertical Velocity above Threshold (5.3 m/s)		
Source (Number of Units)	Ambient Temperature	Stack Height (h_s)	Stack Diameter (D)	Stack Velocity (V_{exit})	Volumetric Flow	Stack Potential Temperature (θ_s)	Method 1	Method 2	Merged Plumes
Emergencey Diesel Generators (48)	272 K (30°F)	14.55 m (47.75 ft)	0.66 m (2.2 ft)	29.93 m/s (98.2 ft/s)	21,725 ACFM	754 K (897°F)	27.74 m (91 ft)	24.38 m (80 ft)	24.38 m (80 ft)
Chillers (72)	272 K (30°F)	36.58 m (120 ft)	0.71 m (2.3 ft)	9.40 m/s (30.8 ft/s)	8,476 ACFM	312 K (101.5°F)	40.84 m (134 ft)	40.54 m (133 ft)	42.37 m (139 ft)

Stack Parameters			
Emergency generators			
	Scenario 1 - Worst-case	Scenario 2	Scenario 3
Ambient Potential Temp (F)	30	59	76
Stack Height (feet)	47.75	47.75	47.75
Stack Diameter (feet)	2.2	2.2	2.2
Stack Velocity at exit (m/s)	29.933	29.933	29.933
Stack Potential Temp (F)	897.0	897.0	897.0
Air-cooled chillers			
	Scenario 1 - Worst-case		
Ambient Potential Temp (F)	30		
Stack Height (feet)	120		
Stack Diameter (feet)	2.3		
Stack Velocity at exit (m/s)	9.4		
Stack Potential Temp (F)	101.5		

PETER BEST PAPER ILLUSTRATIVE EXAMPLE - SINGLE TURBINE - Assumes Heights in Table 2 are meters above ground

Plume Averaged Vertical Velocities: **"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.**

Ambient Conditions:					Constants:		
Ambient Potential Temp θ_a	272	Kelvins	30	°F	Assume neutral conditions ($d\theta/dz=0$)		
Plume Exit Conditions:					Gravity g	9.81 m/s^2	
Stack Height h_s	14.55	meters	47.8	feet	λ	1.11	
Stack Diameter D	0.66	meters	2.2	feet		0.3048 meters/feet	
Stack Velocity V_{exit}	29.93	m/s	98.2	ft/sec			
Volumetric Flow	10	cu.m/sec	21,725	ACFM	$\pi V_{exit} D^2/4$		Sect.2/¶1
Stack Potential Temp θ_s	754	Kelvins	897.0	°F	Back-Calc'd from Buoyancy Flux		
Initial Stack Buoyancy Flux F_o	20	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$		Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (not used here)		

Conditions at End (Top) of Jet Phase:

Height above Stack z	4.128	meters*	13.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	18.682	meters	61.3	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	14.967	m/s	49.10	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.321	meters	4.3	feet	2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	1.648	meters*	5.4	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	16.202	meters	53.2	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.600778854

Method(1): Simplified Plume-averaged Vertical Velocity V' - Assumes Product Va constant above jet phase such that $V_{plume}(2a) = V_{exit}D$

Vertical Velocity V'	**Solutions in Table Below**	$V_{exit}D/2a'$ (conservation of buoyancy)	Sect.3&4

Method(2): Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Vertical Velocity V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	5.938 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

Table of plume Top-Hat Diameters (2a) and Plume-averaged Vertical Velocities for both Method(1) (assuming conservation of buoyancy & gaussian distribution of vertical velocities) and Method (2) (based on Peter Best's paper's Analytical Solution) starting at end of jet phase:

from 100 meters above ground in increments of 50.0 meters

				Vert.Vel (m/s)	
				Method(1)	**Method(2)**
	Ht above Ground =	$h_{plume}+h_s$	D_{plume}=2a=	V_{plume}=	$\{(Va)_o^3+0.12F_o[(z-z_v)^2$
Height above stack top, meters*	meters	feet	2*0.16(z-z_v)	V_{exit}*D/2a	$-(6.25D-z_v)^2]\}^{1/3}$ / a
End of jet phase at 6.25D = 4.128 meters*	***18.682***	***61.3***	***1.321***		***14.97***
85.446 meters*	**100.000**	328.1	26.815	0.74	**1.93**
135.446 meters*	150.000	492.1	42.815	0.46	1.65
185.446 meters*	**200.000**	656.2	58.815	0.34	**1.48**
235.446 meters*	250.000	820.2	74.815	0.26	1.37
285.446 meters*	**300.000**	984.3	90.815	0.22	**1.28**
335.446 meters*	350.000	1148.3	106.815	0.19	1.22
385.446 meters*	400.000	1312.3	122.815	0.16	1.16
435.446 meters*	450.000	1476.4	138.815	0.14	1.11
485.446 meters*	**500.000**	1640.4	154.815	0.13	**1.07**
535.446 meters*	550.000	1804.5	170.815	0.12	1.04
585.446 meters*	600.000	1968.5	186.815	0.11	1.01
635.446 meters*	650.000	2132.5	202.815	0.10	0.98
685.446 meters*	**700.000**	2296.6	218.815	0.09	**0.96**
735.446 meters*	750.000	2460.6	234.815	0.08	0.93
785.446 meters*	800.000	2624.7	250.815	0.08	0.91
835.446 meters*	850.000	2788.7	266.815	0.07	0.90
885.446 meters*	900.000	2952.8	282.815	0.07	0.88
935.446 meters*	950.000	3116.8	298.815	0.07	0.86
985.446 meters*	**1000.000**	3280.8	314.815	0.06	**0.85**
1035.446 meters*	1050.000	3444.9	330.815	0.06	0.83
1085.446 meters*	1100.000	3608.9	346.815	0.06	0.82
1135.446 meters*	1150.000	3773.0	362.815	0.05	0.81
1185.446 meters*	1200.000	3937.0	378.815	0.05	0.80
1235.446 meters*	1250.000	4101.0	394.815	0.05	0.79

3.734 meters*	18.288	60.0	0.668	29.61	17.66
6.782 meters*	21.336	70.0	1.643	12.03	7.76
7.087 meters*	21.641	71.0	1.740	11.36	7.40
7.391 meters*	21.946	72.0	1.838	10.76	7.08
7.696 meters*	22.251	73.0	1.936	10.21	6.79
8.001 meters*	22.555	74.0	2.033	9.72	6.54
8.306 meters*	22.860	75.0	2.131	9.28	6.31
8.611 meters*	23.165	76.0	2.228	8.87	6.10
8.916 meters*	23.470	77.0	2.326	8.50	5.91
9.220 meters*	23.775	78.0	2.423	8.16	5.73
9.525 meters*	24.079	79.0	2.521	7.84	5.57
9.830 meters*	24.384	80.0	2.618	7.55	5.43
10.135 meters*	24.689	81.0	2.716	7.28	5.29
10.440 meters*	24.994	82.0	2.813	7.03	5.17
10.744 meters*	25.299	83.0	2.911	6.79	5.05
11.049 meters*	25.604	84.0	3.008	6.57	4.94
11.354 meters*	25.908	85.0	3.106	6.36	4.84
11.659 meters*	26.213	86.0	3.203	6.17	4.75
11.964 meters*	26.518	87.0	3.301	5.99	4.66
12.268 meters*	26.823	88.0	3.399	5.82	4.58
12.573 meters*	27.128	89.0	3.496	5.65	4.50
12.878 meters*	27.432	90.0	3.594	5.50	4.43
13.183 meters*	27.737	91.0	3.691	5.36	4.36
13.488 meters*	28.042	92.0	3.789	5.22	4.29
13.792 meters*	28.347	93.0	3.886	5.09	4.23
14.097 meters*	28.652	94.0	3.984	4.96	4.17
14.402 meters*	28.956	95.0	4.081	4.84	4.12
14.707 meters*	29.261	96.0	4.179	4.73	4.07
15.012 meters*	29.566	97.0	4.276	4.62	4.02
15.316 meters*	29.871	98.0	4.374	4.52	3.97
15.621 meters*	30.176	99.0	4.471	4.42	3.92
15.926 meters*	30.480	100.0	4.569	4.33	3.88
16.231 meters*	30.785	101.0	4.667	4.24	3.83
16.536 meters*	31.090	102.0	4.764	4.15	3.79

Stack Distances (ft)	Number of Stacks
21	50

ft	m/s	merged cells	Plume Diamter Feet
60	17.66	1.00	2.19
70	7.76	1.00	5.39
71	7.40	1.00	5.71
72	7.08	1.00	6.03
73	6.79	1.00	6.35
74	6.54	1.00	6.67
75	6.31	1.00	6.99
76	6.10	1.00	7.31
77	5.91	1.00	7.63
78	5.73	1.00	7.95
79	5.57	1.00	8.27
80	5.43	1.00	8.59
81	5.29	1.00	8.91
82	5.17	1.00	9.23
83	5.05	1.00	9.55
84	4.94	1.00	9.87
85	4.84	1.00	10.19
86	4.75	1.00	10.51
87	4.66	1.00	10.83
88	4.58	1.00	11.15
89	4.50	1.00	11.47
90	4.43	1.00	11.79
91	4.36	1.00	12.11
92	4.29	1.00	12.43
93	4.23	1.00	12.75
94	4.17	1.00	13.07
95	4.12	1.00	13.39
96	4.07	1.00	13.71
97	4.02	1.00	14.03
98	3.97	1.00	14.35
99	3.92	1.00	14.67
100	3.88	1.00	14.99
101	3.83	1.00	15.31
102	3.79	1.00	15.63

16.840 meters*	31.395	103.0	4.862	4.07	3.76
17.145 meters*	31.700	104.0	4.959	3.99	3.72
17.450 meters*	32.004	105.0	5.057	3.91	3.68
17.755 meters*	32.309	106.0	5.154	3.84	3.65
18.060 meters*	32.614	107.0	5.252	3.76	3.62
18.364 meters*	32.919	108.0	5.349	3.70	3.58
18.669 meters*	33.224	109.0	5.447	3.63	3.55
18.974 meters*	33.528	110.0	5.544	3.57	3.52
22.022 meters*	36.576	120.0	6.520	3.03	3.27
22.327 meters*	36.881	121.0	6.617	2.99	3.25
22.632 meters*	37.186	122.0	6.715	2.94	3.23
22.936 meters*	37.491	123.0	6.812	2.90	3.21
23.241 meters*	37.796	124.0	6.910	2.86	3.19
23.546 meters*	38.100	125.0	7.007	2.82	3.17
23.851 meters*	38.405	126.0	7.105	2.78	3.15
24.156 meters*	38.710	127.0	7.203	2.74	3.13
24.460 meters*	39.015	128.0	7.300	2.71	3.12
24.765 meters*	39.320	129.0	7.398	2.67	3.10
25.070 meters*	39.624	130.0	7.495	2.64	3.08
28.118 meters*	42.673	140.0	8.471	2.33	2.93
31.166 meters*	45.721	150.0	9.446	2.09	2.81
34.214 meters*	48.769	160.0	10.421	1.90	2.70
37.262 meters*	51.817	170.0	11.397	1.73	2.61
40.310 meters*	54.865	180.0	12.372	1.60	2.54
43.358 meters*	57.913	190.0	13.347	1.48	2.47
46.406 meters*	60.961	200.0	14.323	1.38	2.41
76.887 meters*	91.441	300.0	24.076	0.82	2.01
107.367 meters*	121.921	400.0	33.830	0.58	1.79
137.847 meters*	152.402	500.0	43.584	0.45	1.64
168.328 meters*	182.882	600.0	53.338	0.37	1.53
198.808 meters*	213.363	700.0	63.091	0.31	1.45
229.289 meters*	243.843	800.0	72.845	0.27	1.38
259.769 meters*	274.323	900.0	82.599	0.24	1.32
290.249 meters*	304.804	1000.0	92.352	0.21	1.28
320.730 meters*	335.284	1100.0	102.106	0.19	1.23
351.210 meters*	365.764	1200.0	111.860	0.18	1.20
381.690 meters*	396.245	1300.0	121.614	0.16	1.16
412.171 meters*	426.725	1400.0	131.367	0.15	1.13
442.651 meters*	457.206	1500.0	141.121	0.14	1.11
473.132 meters*	487.686	1600.0	150.875	0.13	1.08
503.612 meters*	518.166	1700.0	160.629	0.12	1.06
534.092 meters*	548.647	1800.0	170.382	0.12	1.04
564.573 meters*	579.127	1900.0	180.136	0.11	1.02
595.053 meters*	609.607	2000.0	189.890	0.10	1.00
625.533 meters*	640.088	2100.0	199.643	0.10	0.99
656.014 meters*	670.568	2200.0	209.397	0.09	0.97
686.494 meters*	701.049	2300.0	219.151	0.09	0.96
716.975 meters*	731.529	2400.0	228.905	0.09	0.94
747.455 meters*	762.009	2500.0	238.658	0.08	0.93
777.935 meters*	792.490	2600.0	248.412	0.08	0.92
808.416 meters*	822.970	2700.0	258.166	0.08	0.91
838.896 meters*	853.450	2800.0	267.919	0.07	0.89
869.376 meters*	883.931	2900.0	277.673	0.07	0.88
899.857 meters*	914.411	3000.0	287.427	0.07	0.87
930.337 meters*	944.891	3100.0	297.181	0.07	0.86
960.817 meters*	975.372	3200.0	306.934	0.06	0.85
991.298 meters*	1005.852	3300.0	316.688	0.06	0.85
1021.778 meters*	1036.333	3400.0	326.442	0.06	0.84
1052.259 meters*	1066.813	3500.0	336.195	0.06	0.83
1082.739 meters*	1097.293	3600.0	345.949	0.06	0.82
1113.219 meters*	1127.774	3700.0	355.703	0.06	0.81
1143.700 meters*	1158.254	3800.0	365.457	0.05	0.81
1174.180 meters*	1188.734	3900.0	375.210	0.05	0.80
1204.660 meters*	1219.215	4000.0	384.964	0.05	0.79

103	3.76	1.00	15.95
104	3.72	1.00	16.27
105	3.68	1.00	16.59
106	3.65	1.00	16.91
107	3.62	1.00	17.23
108	3.58	1.00	17.55
109	3.55	1.00	17.87
110	3.52	1.00	18.19
120	3.37	1.12	21.39
121	3.36	1.14	21.71
122	3.35	1.15	22.03
123	3.34	1.17	22.35
124	3.33	1.18	22.67
125	3.32	1.20	22.99
126	3.31	1.21	23.31
127	3.30	1.23	23.63
128	3.29	1.24	23.95
129	3.28	1.26	24.27
130	3.27	1.27	24.59
140	3.20	1.43	27.79
150	3.15	1.58	30.99
160	3.10	1.73	34.19
170	3.06	1.88	37.39
180	3.03	2.04	40.59
190	3.00	2.19	43.79
200	2.98	2.34	46.99
300	2.81	3.86	78.99
400	2.72	5.39	110.99
500	2.66	6.91	142.99
600	2.61	8.44	174.99
700	2.58	9.96	206.99
800	2.54	11.48	238.99
900	2.52	13.01	270.99
1,000	2.49	14.53	302.99
1,100	2.47	16.06	334.99
1,200	2.45	17.58	366.99
1,300	2.43	19.10	398.99
1,400	2.42	20.63	431.00
1,500	2.40	22.15	463.00
1,600	2.39	23.67	495.00
1,700	2.38	25.20	527.00
1,800	2.37	26.72	559.00
1,900	2.35	28.25	591.00
2,000	2.34	29.77	623.00
2,100	2.33	31.29	655.00
2,200	2.32	32.82	687.00
2,300	2.32	34.34	719.00
2,400	2.31	35.86	751.00
2,500	2.30	37.39	783.00
2,600	2.29	38.91	815.00
2,700	2.28	40.44	847.00
2,800	2.28	41.96	879.00
2,900	2.27	43.48	911.00
3,000	2.26	45.01	943.00
3,100	2.26	46.53	975.00
3,200	2.25	48.06	1007.00
3,300	2.25	49.58	1039.00
3,400	2.23	50.00	1071.00
3,500	2.21	50.00	1103.00
3,600	2.18	50.00	1135.00
3,700	2.16	50.00	1167.00
3,800	2.15	50.00	1199.00
3,900	2.13	50.00	1231.01
4,000	2.11	50.00	1263.01

PETER BEST PAPER ILLUSTRATIVE EXAMPLE - SINGLE TURBINE - Assumes Heights in Table 2 are meters above ground

Plume Averaged Vertical Velocities: **"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.**

Ambient Conditions:					Constants:	
Ambient Potential Temp θ_a	288	Kelvins	59	°F	Assume neutral conditions ($d\theta/dz=0$)	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Stack Height h_s	14.55	meters	47.8	feet	λ 1.11	
Stack Diameter D	0.66	meters	2.2	feet	0.3048 meters/feet	
Stack Velocity V_{exit}	29.93	m/s	98.2	ft/sec		
Volumetric Flow	10	cu.m/sec	21,725	ACFM	$\pi V_{exit} D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	754	Kelvins	897.0	°F	Back-Calc'd from Buoyancy Flux	
Initial Stack Buoyancy Flux F_o	20	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (not used here)	

Conditions at End (Top) of Jet Phase:

Height above Stack z	4.128	meters*	13.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z+h_s$	18.682	meters	61.3	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	14.967	m/s	49.10	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.321	meters	4.3	feet	2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	1.575	meters*	5.2	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	16.130	meters	52.9	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}=$	0.618313108

Method(1): Simplified Plume-averaged Vertical Velocity V' - Assumes Product Va constant above jet phase such that $V_{plume}(2a) = V_{exit}D$

Vertical Velocity V'	**Solutions in Table Below**	$V_{exit}D/2a'$ (conservation of buoyancy)	Sect.3&4

Method(2): Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Vertical Velocity V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	6.111 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

Table of plume Top-Hat Diameters (2a) and Plume-averaged Vertical Velocities for both Method(1) (assuming conservation of buoyancy & gaussian distribution of vertical velocities) and Method (2) (based on Peter Best's paper's Analytical Solution) starting at end of jet phase:

from 100 meters above ground in increments of 50.0 meters

				Vert.Vel (m/s)	
				Method(1)	**Method(2)**
	Ht above Ground =	$h_{plume}+h_s$	$D_{plume}=2a=$	$V_{plume}=$	$\{(Va)_o^3+0.12F_o[(z-z_v)^2$
Height above stack top, meters*	meters	feet	$2*0.16(z-z_v)$	$V_{exit}*D/2a$	$-(6.25D-z_v)^2]\}^{1/3} / a$
End of jet phase at 6.25D = 4.128 meters*	***18.682***	***61.3***	***1.321***		***14.97***
85.446 meters*	**100.000**	328.1	26.838	0.74	**1.91**
135.446 meters*	150.000	492.1	42.838	0.46	1.63
185.446 meters*	**200.000**	656.2	58.838	0.34	**1.47**
235.446 meters*	250.000	820.2	74.838	0.26	1.35
285.446 meters*	**300.000**	984.3	90.838	0.22	**1.27**
335.446 meters*	350.000	1148.3	106.838	0.19	1.20
385.446 meters*	400.000	1312.3	122.838	0.16	1.15
435.446 meters*	450.000	1476.4	138.838	0.14	1.10
485.446 meters*	**500.000**	1640.4	154.838	0.13	**1.06**
535.446 meters*	550.000	1804.5	170.838	0.12	1.03
585.446 meters*	600.000	1968.5	186.838	0.11	1.00
635.446 meters*	650.000	2132.5	202.838	0.10	0.97
685.446 meters*	**700.000**	2296.6	218.838	0.09	**0.95**
735.446 meters*	750.000	2460.6	234.838	0.08	0.92
785.446 meters*	800.000	2624.7	250.838	0.08	0.90
835.446 meters*	850.000	2788.7	266.838	0.07	0.89
885.446 meters*	900.000	2952.8	282.838	0.07	0.87
935.446 meters*	950.000	3116.8	298.838	0.07	0.85
985.446 meters*	**1000.000**	3280.8	314.838	0.06	**0.84**
1035.446 meters*	1050.000	3444.9	330.838	0.06	0.82
1085.446 meters*	1100.000	3608.9	346.838	0.06	0.81
1135.446 meters*	1150.000	3773.0	362.838	0.05	0.80
1185.446 meters*	1200.000	3937.0	378.838	0.05	0.79
1235.446 meters*	1250.000	4101.0	394.838	0.05	0.78

Stack Distances (ft)	Number of Stacks
21	50
6.4008	

3.734 meters*	18.288	60.0	0.691	28.62	17.58
6.782 meters*	21.336	70.0	1.666	11.87	7.83
9.830 meters*	24.384	80.0	2.641	7.48	5.46
12.878 meters*	27.432	90.0	3.617	5.47	4.44
13.183 meters*	27.737	91.0	3.714	5.32	4.36
13.488 meters*	28.042	92.0	3.812	5.19	4.30
13.792 meters*	28.347	93.0	3.909	5.06	4.23
14.097 meters*	28.652	94.0	4.007	4.93	4.17
14.402 meters*	28.956	95.0	4.104	4.82	4.12
14.707 meters*	29.261	96.0	4.202	4.70	4.06
15.012 meters*	29.566	97.0	4.300	4.60	4.01
15.316 meters*	29.871	98.0	4.397	4.50	3.96
15.621 meters*	30.176	99.0	4.495	4.40	3.91
15.926 meters*	30.480	100.0	4.592	4.30	3.87
16.231 meters*	30.785	101.0	4.690	4.22	3.83
16.536 meters*	31.090	102.0	4.787	4.13	3.79
16.840 meters*	31.395	103.0	4.885	4.05	3.75
17.145 meters*	31.700	104.0	4.982	3.97	3.71
17.450 meters*	32.004	105.0	5.080	3.89	3.67
17.755 meters*	32.309	106.0	5.177	3.82	3.64
18.060 meters*	32.614	107.0	5.275	3.75	3.60
18.364 meters*	32.919	108.0	5.372	3.68	3.57
18.669 meters*	33.224	109.0	5.470	3.61	3.54
18.974 meters*	33.528	110.0	5.568	3.55	3.51
22.022 meters*	36.576	120.0	6.543	3.02	3.25
22.327 meters*	36.881	121.0	6.640	2.98	3.23
22.632 meters*	37.186	122.0	6.738	2.93	3.21
22.936 meters*	37.491	123.0	6.836	2.89	3.19

ft	m/s	merged cells
60	17.58	1.00
70	7.83	1.00
80	5.46	1.00
90	4.44	1.00
91	4.36	1.00
92	4.30	1.00
93	4.23	1.00
94	4.17	1.00
95	4.12	1.00
96	4.06	1.00
97	4.01	1.00
98	3.96	1.00
99	3.91	1.00
100	3.87	1.00
101	3.83	1.00
102	3.79	1.00
103	3.75	1.00
104	3.71	1.00
105	3.67	1.00
106	3.64	1.00
107	3.60	1.00
108	3.57	1.00
109	3.54	1.00
110	3.51	1.00
120	3.35	1.13
121	3.34	1.14
122	3.33	1.16
123	3.32	1.17

23.241 meters*	37.796	124.0	6.933	2.85	3.17
23.546 meters*	38.100	125.0	7.031	2.81	3.15
25.070 meters*	39.624	130.0	7.518	2.63	3.06
28.118 meters*	42.673	140.0	8.494	2.33	2.91
31.166 meters*	45.721	150.0	9.469	2.09	2.78
46.406 meters*	60.961	200.0	14.346	1.38	2.38
76.887 meters*	91.441	300.0	24.100	0.82	1.98
107.367 meters*	121.921	400.0	33.853	0.58	1.77
137.847 meters*	152.402	500.0	43.607	0.45	1.62
168.328 meters*	182.882	600.0	53.361	0.37	1.52
198.808 meters*	213.363	700.0	63.114	0.31	1.43
229.289 meters*	243.843	800.0	72.868	0.27	1.37
259.769 meters*	274.323	900.0	82.622	0.24	1.31
290.249 meters*	304.804	1000.0	92.376	0.21	1.26
320.730 meters*	335.284	1100.0	102.129	0.19	1.22
351.210 meters*	365.764	1200.0	111.883	0.18	1.18
381.690 meters*	396.245	1300.0	121.637	0.16	1.15
412.171 meters*	426.725	1400.0	131.391	0.15	1.12
442.651 meters*	457.206	1500.0	141.144	0.14	1.10
473.132 meters*	487.686	1600.0	150.898	0.13	1.07
503.612 meters*	518.166	1700.0	160.652	0.12	1.05
534.092 meters*	548.647	1800.0	170.405	0.12	1.03
564.573 meters*	579.127	1900.0	180.159	0.11	1.01
595.053 meters*	609.607	2000.0	189.913	0.10	0.99
625.533 meters*	640.088	2100.0	199.667	0.10	0.98
656.014 meters*	670.568	2200.0	209.420	0.09	0.96
686.494 meters*	701.049	2300.0	219.174	0.09	0.95
716.975 meters*	731.529	2400.0	228.928	0.09	0.93
747.455 meters*	762.009	2500.0	238.681	0.08	0.92
777.935 meters*	792.490	2600.0	248.435	0.08	0.91
808.416 meters*	822.970	2700.0	258.189	0.08	0.90
838.896 meters*	853.450	2800.0	267.943	0.07	0.88
869.376 meters*	883.931	2900.0	277.696	0.07	0.87
899.857 meters*	914.411	3000.0	287.450	0.07	0.86
930.337 meters*	944.891	3100.0	297.204	0.07	0.85
960.817 meters*	975.372	3200.0	306.957	0.06	0.85
991.298 meters*	1005.852	3300.0	316.711	0.06	0.84
1021.778 meters*	1036.333	3400.0	326.465	0.06	0.83
1052.259 meters*	1066.813	3500.0	336.219	0.06	0.82
1082.739 meters*	1097.293	3600.0	345.972	0.06	0.81
1113.219 meters*	1127.774	3700.0	355.726	0.06	0.80
1143.700 meters*	1158.254	3800.0	365.480	0.05	0.80
1174.180 meters*	1188.734	3900.0	375.233	0.05	0.79
1204.660 meters*	1219.215	4000.0	384.987	0.05	0.78

124	3.31	1.19
125	3.30	1.20
130	3.25	1.28
140	3.18	1.43
150	3.12	1.58
200	2.95	2.34
300	2.78	3.87
400	2.69	5.39
500	2.63	6.92
600	2.58	8.44
700	2.55	9.96
800	2.51	11.49
900	2.49	13.01
1,000	2.46	14.53
1,100	2.44	16.06
1,200	2.42	17.58
1,300	2.41	19.11
1,400	2.39	20.63
1,500	2.38	22.15
1,600	2.36	23.68
1,700	2.35	25.20
1,800	2.34	26.73
1,900	2.33	28.25
2,000	2.32	29.77
2,100	2.31	31.30
2,200	2.30	32.82
2,300	2.29	34.34
2,400	2.28	35.87
2,500	2.27	37.39
2,600	2.27	38.92
2,700	2.26	40.44
2,800	2.25	41.96
2,900	2.24	43.49
3,000	2.24	45.01
3,100	2.23	46.53
3,200	2.23	48.06
3,300	2.22	49.58
3,400	2.20	50.00
3,500	2.18	50.00
3,600	2.16	50.00
3,700	2.14	50.00
3,800	2.12	50.00
3,900	2.10	50.00
4,000	2.08	50.00

PETER BEST PAPER ILLUSTRATIVE EXAMPLE - SINGLE TURBINE - Assumes Heights in Table 2 are meters above ground

Plume Averaged Vertical Velocities: **"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.**

Ambient Conditions:					Constants:			
Ambient Potential Temp θ_a	298	Kelvins	76	°F	Assume neutral conditions ($d\theta/dz=0$)			
Plume Exit Conditions:					Gravity g	9.81	m/s^2	
Stack Height h_s	14.55	meters	47.8	feet	λ	1.11		
Stack Diameter D	0.66	meters	2.2	feet		0.3048	meters/feet	
Stack Velocity V_{exit}	29.93	m/s	98.2	ft/sec				
Volumetric Flow	10	cu.m/sec	21,725	ACFM	$\pi V_{exit} D^2/4$			Sect.2/¶1
Stack Potential Temp θ_s	754	Kelvins	897.0	°F	Back-Calc'd from Buoyancy Flux			
Initial Stack Buoyancy Flux F_o	19	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$			Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (not used here)			

Conditions at End (Top) of Jet Phase:

Height above Stack z	4.128	meters*	13.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z+h_s$	18.682	meters	61.3	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	14.967	m/s	49.10	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.321	meters	4.3	feet	2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	1.534	meters*	5.0	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	16.088	meters	52.8	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}=$	0.62836437

Method(1): Simplified Plume-averaged Vertical Velocity V' - Assumes Product Va constant above jet phase such that $V_{plume}(2a) = V_{exit}D$

Vertical Velocity V'	**Solutions in Table Below**	$V_{exit}D/2a'$ (conservation of buoyancy)	Sect.3&4

Method(2): Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Vertical Velocity V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	6.211 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

Table of plume Top-Hat Diameters (2a) and Plume-averaged Vertical Velocities for both Method(1) (assuming conservation of buoyancy & gaussian distribution of vertical velocities) and Method (2) (based on Peter Best's paper's Analytical Solution) starting at end of jet phase:

from 100 meters above ground in increments of 50.0 meters

				Vert.Vel (m/s)	
				Method(1)	**Method(2)**
	Ht above Ground =	$h_{plume}+h_s$	D_{plume}=2a=	V_{plume}=	$\{(Va)_o^3+0.12F_o[(z-z_v)^2$
Height above stack top, meters*	meters	feet	$2*0.16(z-z_v)$	V_{exit}*D/2a	$-(6.25D-z_v)^2]\}^{1/3}$ / a
End of jet phase at 6.25D = 4.128 meters*	***18.682***	***61.3***	***1.321***		***14.97***
85.446 meters*	**100.000**	328.1	26.852	0.74	**1.90**
135.446 meters*	150.000	492.1	42.852	0.46	1.62
185.446 meters*	**200.000**	656.2	58.852	0.34	**1.46**
235.446 meters*	250.000	820.2	74.852	0.26	1.34
285.446 meters*	**300.000**	984.3	90.852	0.22	**1.26**
335.446 meters*	350.000	1148.3	106.852	0.19	1.19
385.446 meters*	400.000	1312.3	122.852	0.16	1.14
435.446 meters*	450.000	1476.4	138.852	0.14	1.09
485.446 meters*	**500.000**	1640.4	154.852	0.13	**1.05**
535.446 meters*	550.000	1804.5	170.852	0.12	1.02
585.446 meters*	600.000	1968.5	186.852	0.11	0.99
635.446 meters*	650.000	2132.5	202.852	0.10	0.96
685.446 meters*	**700.000**	2296.6	218.852	0.09	**0.94**
735.446 meters*	750.000	2460.6	234.852	0.08	0.92
785.446 meters*	800.000	2624.7	250.852	0.08	0.90
835.446 meters*	850.000	2788.7	266.852	0.07	0.88
885.446 meters*	900.000	2952.8	282.852	0.07	0.86
935.446 meters*	950.000	3116.8	298.852	0.07	0.85
985.446 meters*	**1000.000**	3280.8	314.852	0.06	**0.83**
1035.446 meters*	1050.000	3444.9	330.852	0.06	0.82
1085.446 meters*	1100.000	3608.9	346.852	0.06	0.81
1135.446 meters*	1150.000	3773.0	362.852	0.05	0.79
1185.446 meters*	1200.000	3937.0	378.852	0.05	0.78
1235.446 meters*	1250.000	4101.0	394.852	0.05	0.77

Stack Distances (ft)	Number of Stacks
21	50

3.734 meters*	18.288	60.0	0.704	28.08	17.54
6.782 meters*	21.336	70.0	1.679	11.77	7.86
9.830 meters*	24.384	80.0	2.655	7.45	5.48
12.878 meters*	27.432	90.0	3.630	5.45	4.44
13.183 meters*	27.737	91.0	3.728	5.30	4.37
13.488 meters*	28.042	92.0	3.825	5.17	4.30
13.792 meters*	28.347	93.0	3.923	5.04	4.24
14.097 meters*	28.652	94.0	4.020	4.92	4.17
14.402 meters*	28.956	95.0	4.118	4.80	4.12
14.707 meters*	29.261	96.0	4.215	4.69	4.06
15.012 meters*	29.566	97.0	4.313	4.58	4.01
15.316 meters*	29.871	98.0	4.410	4.48	3.96
15.621 meters*	30.176	99.0	4.508	4.39	3.91
15.926 meters*	30.480	100.0	4.605	4.29	3.87
16.231 meters*	30.785	101.0	4.703	4.20	3.82
16.536 meters*	31.090	102.0	4.801	4.12	3.78
16.840 meters*	31.395	103.0	4.898	4.04	3.74
17.145 meters*	31.700	104.0	4.996	3.96	3.70
17.450 meters*	32.004	105.0	5.093	3.88	3.66
17.755 meters*	32.309	106.0	5.191	3.81	3.63
18.060 meters*	32.614	107.0	5.288	3.74	3.60
18.364 meters*	32.919	108.0	5.386	3.67	3.56
18.669 meters*	33.224	109.0	5.483	3.61	3.53
18.974 meters*	33.528	110.0	5.581	3.54	3.50
22.022 meters*	36.576	120.0	6.556	3.02	3.24
22.327 meters*	36.881	121.0	6.654	2.97	3.22
22.632 meters*	37.186	122.0	6.751	2.93	3.20
22.936 meters*	37.491	123.0	6.849	2.89	3.18

ft	m/s	merged cells
60	17.54	1.00
70	7.86	1.00
80	5.48	1.00
90	4.44	1.00
91	4.37	1.00
92	4.30	1.00
93	4.24	1.00
94	4.17	1.00
95	4.12	1.00
96	4.06	1.00
97	4.01	1.00
98	3.96	1.00
99	3.91	1.00
100	3.87	1.00
101	3.82	1.00
102	3.78	1.00
103	3.74	1.00
104	3.70	1.00
105	3.66	1.00
106	3.63	1.00
107	3.60	1.00
108	3.56	1.00
109	3.53	1.00
110	3.50	1.00
120	3.34	1.13
121	3.33	1.14
122	3.32	1.16
123	3.31	1.17

23.241 meters*	37.796	124.0	6.946	2.85	3.16
23.546 meters*	38.100	125.0	7.044	2.81	3.14
46.406 meters*	60.961	200.0	14.359	1.38	2.37
76.887 meters*	91.441	300.0	24.113	0.82	1.97
107.367 meters*	121.921	400.0	33.867	0.58	1.76
137.847 meters*	152.402	500.0	43.620	0.45	1.61
168.328 meters*	182.882	600.0	53.374	0.37	1.51
198.808 meters*	213.363	700.0	63.128	0.31	1.42
229.289 meters*	243.843	800.0	72.881	0.27	1.36
259.769 meters*	274.323	900.0	82.635	0.24	1.30
290.249 meters*	304.804	1000.0	92.389	0.21	1.25
320.730 meters*	335.284	1100.0	102.143	0.19	1.21
351.210 meters*	365.764	1200.0	111.896	0.18	1.18
381.690 meters*	396.245	1300.0	121.650	0.16	1.14
412.171 meters*	426.725	1400.0	131.404	0.15	1.11
442.651 meters*	457.206	1500.0	141.158	0.14	1.09
473.132 meters*	487.686	1600.0	150.911	0.13	1.06
503.612 meters*	518.166	1700.0	160.665	0.12	1.04
534.092 meters*	548.647	1800.0	170.419	0.12	1.02
564.573 meters*	579.127	1900.0	180.172	0.11	1.00
595.053 meters*	609.607	2000.0	189.926	0.10	0.99
625.533 meters*	640.088	2100.0	199.680	0.10	0.97
656.014 meters*	670.568	2200.0	209.434	0.09	0.95
686.494 meters*	701.049	2300.0	219.187	0.09	0.94
716.975 meters*	731.529	2400.0	228.941	0.09	0.93
747.455 meters*	762.009	2500.0	238.695	0.08	0.91
777.935 meters*	792.490	2600.0	248.448	0.08	0.90
808.416 meters*	822.970	2700.0	258.202	0.08	0.89
838.896 meters*	853.450	2800.0	267.956	0.07	0.88
869.376 meters*	883.931	2900.0	277.710	0.07	0.87
899.857 meters*	914.411	3000.0	287.463	0.07	0.86
930.337 meters*	944.891	3100.0	297.217	0.07	0.85
960.817 meters*	975.372	3200.0	306.971	0.06	0.84
991.298 meters*	1005.852	3300.0	316.724	0.06	0.83
1021.778 meters*	1036.333	3400.0	326.478	0.06	0.82
1052.259 meters*	1066.813	3500.0	336.232	0.06	0.81
1082.739 meters*	1097.293	3600.0	345.986	0.06	0.81
1113.219 meters*	1127.774	3700.0	355.739	0.06	0.80
1143.700 meters*	1158.254	3800.0	365.493	0.05	0.79
1174.180 meters*	1188.734	3900.0	375.247	0.05	0.79
1204.660 meters*	1219.215	4000.0	385.000	0.05	0.78

124	3.30	1.19
125	3.29	1.20
200	2.93	2.35
300	2.77	3.87
400	2.68	5.39
500	2.61	6.92
600	2.57	8.44
700	2.53	9.97
800	2.50	11.49
900	2.47	13.01
1,000	2.45	14.54
1,100	2.43	16.06
1,200	2.41	17.58
1,300	2.39	19.11
1,400	2.37	20.63
1,500	2.36	22.16
1,600	2.35	23.68
1,700	2.33	25.20
1,800	2.32	26.73
1,900	2.31	28.25
2,000	2.30	29.78
2,100	2.29	31.30
2,200	2.28	32.82
2,300	2.27	34.35
2,400	2.27	35.87
2,500	2.26	37.39
2,600	2.25	38.92
2,700	2.24	40.44
2,800	2.24	41.97
2,900	2.23	43.49
3,000	2.22	45.01
3,100	2.22	46.54
3,200	2.21	48.06
3,300	2.20	49.58
3,400	2.19	50.00
3,500	2.17	50.00
3,600	2.15	50.00
3,700	2.13	50.00
3,800	2.11	50.00
3,900	2.09	50.00
4,000	2.07	50.00

PETER BEST PAPER ILLUSTRATIVE EXAMPLE - SINGLE TURBINE - Assumes Heights in Table 2 are meters above ground

Plume Averaged Vertical Velocities: **"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.**

Ambient Conditions:					Constants:		
Ambient Potential Temp θ_a	309	Kelvins	96	°F	Assume neutral conditions ($d\theta/dz=0$)		
Plume Exit Conditions:					Gravity g	9.81 m/s^2	
Stack Height h_s	14.55	meters	47.8	feet	λ	1.11	
Stack Diameter D	0.66	meters	2.2	feet		0.3048 meters/feet	
Stack Velocity V_{exit}	29.93	m/s	98.2	ft/sec			
Volumetric Flow	10	cu.m/sec	21,725	ACFM	$\pi V_{exit}D^2/4$		Sect.2/¶1
Stack Potential Temp θ_s	754	Kelvins	897.0	°F	Back-Calc'd from Buoyancy Flux		
Initial Stack Buoyancy Flux F_o	19	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$		Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (not used here)		

Conditions at End (Top) of Jet Phase:							
Height above Stack z	4.128	meters*	13.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z+h_s$	18.682	meters	61.3	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	14.967	m/s	49.10	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.321	meters	4.3	feet	2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	1.486	meters*	4.9	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	16.040	meters	52.6	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.639987313

Method(1): Simplified Plume-averaged Vertical Velocity V' - Assumes Product Va constant above jet phase such that $V_{plume}(2a) = V_{exit}D$

Vertical Velocity V'	**Solutions in Table Below**	$V_{exit}D/2a'$ (conservation of buoyancy)	Sect.3&4

Method(2): Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Vertical Velocity V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	6.326 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

Table of plume Top-Hat Diameters (2a) and Plume-averaged Vertical Velocities for both Method(1) (assuming conservation of buoyancy & gaussian distribution of vertical velocities) and Method (2) (based on Peter Best's paper's Analytical Solution) starting at end of jet phase:

from 100 meters above ground in increments of 50.0 meters

				Vert.Vel (m/s)	
				Method(1)	**Method(2)**
	Ht above Ground =	$h_{plume}+h_s$	D_{plume}=2a=	V_{plume}=	$\{(Va)_o^3+0.12F_o[(z-z_v)^2$
Height above stack top, meters*	meters	feet	$2*0.16(z-z_v)$	V_{exit}*D/2a	$-(6.25D-z_v)^2]\}^{1/3}$ / a
End of jet phase at 6.25D = 4.128 meters*	***18.682***	***61.3***	***1.321***		***14.97***
85.446 meters*	**100.000**	328.1	26.867	0.74	**1.88**
135.446 meters*	150.000	492.1	42.867	0.46	1.61
185.446 meters*	**200.000**	656.2	58.867	0.34	**1.45**
235.446 meters*	250.000	820.2	74.867	0.26	1.33
285.446 meters*	**300.000**	984.3	90.867	0.22	**1.25**
335.446 meters*	350.000	1148.3	106.867	0.18	1.18
385.446 meters*	400.000	1312.3	122.867	0.16	1.13
435.446 meters*	450.000	1476.4	138.867	0.14	1.08
485.446 meters*	**500.000**	1640.4	154.867	0.13	**1.05**
535.446 meters*	550.000	1804.5	170.867	0.12	1.01
585.446 meters*	600.000	1968.5	186.867	0.11	0.98
635.446 meters*	650.000	2132.5	202.867	0.10	0.96
685.446 meters*	**700.000**	2296.6	218.867	0.09	**0.93**
735.446 meters*	750.000	2460.6	234.867	0.08	0.91
785.446 meters*	800.000	2624.7	250.867	0.08	0.89
835.446 meters*	850.000	2788.7	266.867	0.07	0.87
885.446 meters*	900.000	2952.8	282.867	0.07	0.86
935.446 meters*	950.000	3116.8	298.867	0.07	0.84
985.446 meters*	**1000.000**	3280.8	314.867	0.06	**0.83**
1035.446 meters*	1050.000	3444.9	330.867	0.06	0.81
1085.446 meters*	1100.000	3608.9	346.867	0.06	0.80
1135.446 meters*	1150.000	3773.0	362.867	0.05	0.79
1185.446 meters*	1200.000	3937.0	378.867	0.05	0.78
1235.446 meters*	1250.000	4101.0	394.867	0.05	0.77

Stack Distances (ft)	Number of Stacks
21	50

3.734 meters*	18.288	60.0	0.719	27.48	17.49
6.782 meters*	21.336	70.0	1.695	11.66	7.91
9.830 meters*	24.384	80.0	2.670	7.40	5.50
12.878 meters*	27.432	90.0	3.645	5.42	4.44
13.183 meters*	27.737	91.0	3.743	5.28	4.37
13.488 meters*	28.042	92.0	3.841	5.15	4.30
13.792 meters*	28.347	93.0	3.938	5.02	4.24
14.097 meters*	28.652	94.0	4.036	4.90	4.18
14.402 meters*	28.956	95.0	4.133	4.78	4.12
14.707 meters*	29.261	96.0	4.231	4.67	4.06
15.012 meters*	29.566	97.0	4.328	4.57	4.01
15.316 meters*	29.871	98.0	4.426	4.47	3.96
15.621 meters*	30.176	99.0	4.523	4.37	3.91
15.926 meters*	30.480	100.0	4.621	4.28	3.86
16.231 meters*	30.785	101.0	4.718	4.19	3.82
16.536 meters*	31.090	102.0	4.816	4.10	3.78
16.840 meters*	31.395	103.0	4.913	4.02	3.73
17.145 meters*	31.700	104.0	5.011	3.94	3.70
17.450 meters*	32.004	105.0	5.108	3.87	3.66
17.755 meters*	32.309	106.0	5.206	3.80	3.62
18.060 meters*	32.614	107.0	5.304	3.73	3.59
18.364 meters*	32.919	108.0	5.401	3.66	3.55
18.669 meters*	33.224	109.0	5.499	3.60	3.52
18.974 meters*	33.528	110.0	5.596	3.53	3.49
22.022 meters*	36.576	120.0	6.572	3.01	3.23
22.327 meters*	36.881	121.0	6.669	2.96	3.21
22.632 meters*	37.186	122.0	6.767	2.92	3.19
22.936 meters*	37.491	123.0	6.864	2.88	3.16

ft	m/s	merged cells
60	17.49	1.00
70	7.91	1.00
80	5.50	1.00
90	4.44	1.00
91	4.37	1.00
92	4.30	1.00
93	4.24	1.00
94	4.18	1.00
95	4.12	1.00
96	4.06	1.00
97	4.01	1.00
98	3.96	1.00
99	3.91	1.00
100	3.86	1.00
101	3.82	1.00
102	3.78	1.00
103	3.73	1.00
104	3.70	1.00
105	3.66	1.00
106	3.62	1.00
107	3.59	1.00
108	3.55	1.00
109	3.52	1.00
110	3.49	1.00
120	3.33	1.13
121	3.32	1.15
122	3.31	1.16
123	3.30	1.18

23.241 meters*	37.796	124.0	6.962	2.84	3.14
23.546 meters*	38.100	125.0	7.059	2.80	3.12
46.406 meters*	60.961	200.0	14.375	1.38	2.35
76.887 meters*	91.441	300.0	24.128	0.82	1.96
107.367 meters*	121.921	400.0	33.882	0.58	1.74
137.847 meters*	152.402	500.0	43.636	0.45	1.60
168.328 meters*	182.882	600.0	53.389	0.37	1.49
198.808 meters*	213.363	700.0	63.143	0.31	1.41
229.289 meters*	243.843	800.0	72.897	0.27	1.35
259.769 meters*	274.323	900.0	82.651	0.24	1.29
290.249 meters*	304.804	1000.0	92.404	0.21	1.24
320.730 meters*	335.284	1100.0	102.158	0.19	1.20
351.210 meters*	365.764	1200.0	111.912	0.18	1.17
381.690 meters*	396.245	1300.0	121.665	0.16	1.13
412.171 meters*	426.725	1400.0	131.419	0.15	1.11
442.651 meters*	457.206	1500.0	141.173	0.14	1.08
473.132 meters*	487.686	1600.0	150.927	0.13	1.06
503.612 meters*	518.166	1700.0	160.680	0.12	1.03
534.092 meters*	548.647	1800.0	170.434	0.12	1.01
564.573 meters*	579.127	1900.0	180.188	0.11	0.99
595.053 meters*	609.607	2000.0	189.941	0.10	0.98
625.533 meters*	640.088	2100.0	199.695	0.10	0.96
656.014 meters*	670.568	2200.0	209.449	0.09	0.95
686.494 meters*	701.049	2300.0	219.203	0.09	0.93
716.975 meters*	731.529	2400.0	228.956	0.09	0.92
747.455 meters*	762.009	2500.0	238.710	0.08	0.91
777.935 meters*	792.490	2600.0	248.464	0.08	0.89
808.416 meters*	822.970	2700.0	258.217	0.08	0.88
838.896 meters*	853.450	2800.0	267.971	0.07	0.87
869.376 meters*	883.931	2900.0	277.725	0.07	0.86
899.857 meters*	914.411	3000.0	287.479	0.07	0.85
930.337 meters*	944.891	3100.0	297.232	0.07	0.84
960.817 meters*	975.372	3200.0	306.986	0.06	0.83
991.298 meters*	1005.852	3300.0	316.740	0.06	0.82
1021.778 meters*	1036.333	3400.0	326.494	0.06	0.82
1052.259 meters*	1066.813	3500.0	336.247	0.06	0.81
1082.739 meters*	1097.293	3600.0	346.001	0.06	0.80
1113.219 meters*	1127.774	3700.0	355.755	0.06	0.79
1143.700 meters*	1158.254	3800.0	365.508	0.05	0.79
1174.180 meters*	1188.734	3900.0	375.262	0.05	0.78
1204.660 meters*	1219.215	4000.0	385.016	0.05	0.77

124	3.28	1.19
125	3.27	1.21
200	2.91	2.35
300	2.74	3.87
400	2.65	5.40
500	2.59	6.92
600	2.55	8.44
700	2.51	9.97
800	2.48	11.49
900	2.45	13.02
1,000	2.43	14.54
1,100	2.41	16.06
1,200	2.39	17.59
1,300	2.37	19.11
1,400	2.36	20.63
1,500	2.34	22.16
1,600	2.33	23.68
1,700	2.32	25.21
1,800	2.30	26.73
1,900	2.29	28.25
2,000	2.28	29.78
2,100	2.27	31.30
2,200	2.26	32.83
2,300	2.26	34.35
2,400	2.25	35.87
2,500	2.24	37.40
2,600	2.23	38.92
2,700	2.22	40.44
2,800	2.22	41.97
2,900	2.21	43.49
3,000	2.20	45.02
3,100	2.20	46.54
3,200	2.19	48.06
3,300	2.19	49.59
3,400	2.17	50.00
3,500	2.15	50.00
3,600	2.13	50.00
3,700	2.11	50.00
3,800	2.09	50.00
3,900	2.07	50.00
4,000	2.05	50.00

PETER BEST PAPER ILLUSTRATIVE EXAMPLE - SINGLE TURBINE - Assumes Heights in Table 2 are meters above ground

Plume Averaged Vertical Velocities: **"*Aviation Safety and Buoyant Plumes*," Peter Best, et. al.**

Ambient Conditions:					Constants:	
Ambient Potential Temp θ_a	272	Kelvins	30	°F	Assume neutral conditions ($d\theta/dz=0$)	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Stack Height h_s	36.58	meters	120.0	feet	λ 1.11	
Stack Diameter D	0.71	meters	2.3	feet	0.3048 meters/feet	
Stack Velocity V_{exit}	9.40	m/s	30.8	ft/sec		
Volumetric Flow	4	cu.m/sec	8,476	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	312	Kelvins	101.5	°F	Back-Calc'd from Buoyancy Flux	
Initial Stack Buoyancy Flux F_o	1	m^4/s^3			$gV_{exit}D^2(1-\theta_a/\theta_s)/4$ = Vol.Flow$(g/\pi)(1-\theta_a/\theta_s)$	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_p)$ for a,V,θ_p at plume height (not used here)	

Conditions at End (Top) of Jet Phase:

Height above Stack z	4.445	meters*	14.6	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	41.021	meters	134.6	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	4.699	m/s	15.42	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.422	meters	4.7	feet	2D	Conservation of momentum	"

Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet Phase

Plume Top-Hat Radius a	**Solutions in Table Below**				$0.16(z-z_v)$, or linear increase with height	Sect.2/Eq.6
Virtual Source Height z_v	0.293	meters*	1.0	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	36.869	meters	121.0	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$=	0.93412399

Method(1): Simplified Plume-averaged Vertical Velocity V' - Assumes Product Va constant above jet phase such that $V_{plume}(2a) = V_{exit}D$

Vertical Velocity V'	**Solutions in Table Below**	$V_{exit}D/2a'$ (conservation of buoyancy)	Sect.3&4

Method(2): Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below:

Vertical Velocity V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)} / a$	Sect.2.1(6)
Product $(Va)_o$	3.122 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

Table of plume Top-Hat Diameters (2a) and Plume-averaged Vertical Velocities for both Method(1) (assuming conservation of buoyancy & gaussian distribution of vertical velocities) and Method (2) (based on Peter Best's paper's Analytical Solution) starting at end of jet phase:

from 100 meters above ground in increments of 50.0 meters

				Vert.Vel (m/s)	
				Method(1)	**Method(2)**
	Ht above Ground =	$h_{plume}+h_s$	D_{plume}=2a=	V_{plume}=	$\{(Va)_o^3+0.12F_o[(z-z_v)^2$
Height above stack top, meters*	meters	feet	$2*0.16(z-z_v)$	V_{exit}*D/2a	$-(6.25D-z_v)^2]\}^{1/3}$ / a
End of jet phase at 6.25D = 4.445 meters*	***41.021***	***134.6***	***1.422***		***4.70***
63.424 meters*	**100.000**	328.1	20.202	0.33	**0.89**
113.424 meters*	150.000	492.1	36.202	0.18	0.73
163.424 meters*	**200.000**	656.2	52.202	0.13	**0.64**
213.424 meters*	250.000	820.2	68.202	0.10	0.59
263.424 meters*	**300.000**	984.3	84.202	0.08	**0.55**
313.424 meters*	350.000	1148.3	100.202	0.07	0.52
363.424 meters*	400.000	1312.3	116.202	0.06	0.49
413.424 meters*	450.000	1476.4	132.202	0.05	0.47
463.424 meters*	**500.000**	1640.4	148.202	0.05	**0.45**
513.424 meters*	550.000	1804.5	164.202	0.04	0.44
563.424 meters*	600.000	1968.5	180.202	0.04	0.43
613.424 meters*	650.000	2132.5	196.202	0.03	0.41
663.424 meters*	**700.000**	2296.6	212.202	0.03	**0.40**
713.424 meters*	750.000	2460.6	228.202	0.03	0.39
763.424 meters*	800.000	2624.7	244.202	0.03	0.38
813.424 meters*	850.000	2788.7	260.202	0.03	0.38
863.424 meters*	900.000	2952.8	276.202	0.02	0.37
913.424 meters*	950.000	3116.8	292.202	0.02	0.36
963.424 meters*	**1000.000**	3280.8	308.202	0.02	**0.36**
1013.424 meters*	1050.000	3444.9	324.202	0.02	0.35
1063.424 meters*	1100.000	3608.9	340.202	0.02	0.34
1113.424 meters*	1150.000	3773.0	356.202	0.02	0.34
1163.424 meters*	1200.000	3937.0	372.202	0.02	0.33
1213.424 meters*	1250.000	4101.0	388.202	0.02	0.33

0.000 meters*	36.576	120.0	-0.094	-71.33	-64.32
0.305 meters*	36.881	121.0	0.004	1743.32	1571.79
0.610 meters*	37.186	122.0	0.101	65.94	59.46
0.914 meters*	37.491	123.0	0.199	33.60	30.32
1.219 meters*	37.796	124.0	0.296	22.55	20.37
1.524 meters*	38.100	125.0	0.394	16.97	15.35
1.829 meters*	38.405	126.0	0.492	13.60	12.32
2.134 meters*	38.710	127.0	0.589	11.35	10.31
2.438 meters*	39.015	128.0	0.687	9.73	8.86
2.743 meters*	39.320	129.0	0.784	8.52	7.78
3.048 meters*	39.624	130.0	0.882	7.58	6.95
3.353 meters*	39.929	131.0	0.979	6.83	6.28
3.658 meters*	40.234	132.0	1.077	6.21	5.73
3.962 meters*	40.539	133.0	1.174	5.69	5.28
4.267 meters*	40.844	134.0	1.272	5.26	4.90
4.572 meters*	41.149	135.0	1.369	4.88	4.57
4.877 meters*	41.453	136.0	1.467	4.56	4.29
5.182 meters*	41.758	137.0	1.564	4.27	4.04
5.486 meters*	42.063	138.0	1.662	4.02	3.83
5.791 meters*	42.368	139.0	1.760	3.80	3.64
6.096 meters*	42.673	140.0	1.857	3.60	3.47
6.401 meters*	42.977	141.0	1.955	3.42	3.32
6.706 meters*	43.282	142.0	2.052	3.26	3.18
7.010 meters*	43.587	143.0	2.150	3.11	3.05
7.315 meters*	43.892	144.0	2.247	2.97	2.94
7.620 meters*	44.197	145.0	2.345	2.85	2.84
7.925 meters*	44.501	146.0	2.442	2.74	2.75
8.230 meters*	44.806	147.0	2.540	2.63	2.66
8.535 meters*	45.111	148.0	2.637	2.53	2.58
8.839 meters*	45.416	149.0	2.735	2.44	2.51
9.144 meters*	45.721	150.0	2.832	2.36	2.44
24.384 meters*	60.961	200.0	7.709	0.87	1.32
54.865 meters*	91.441	300.0	17.463	0.38	0.94
85.345 meters*	121.921	400.0	27.217	0.25	0.81

Stack Distances (ft)	Number of Stacks
2	72

ft	m/s	merged cells	Plume Diamter Feet
120	-64.53	1.01	-0.31
121	1635.75	1.17	0.01
122	63.89	1.33	0.33
123	33.52	1.49	0.65
124	23.09	1.65	0.97
125	17.81	1.81	1.29
126	14.60	1.97	1.61
127	12.45	2.13	1.93
128	10.91	2.29	2.25
129	9.74	2.45	2.57
130	8.83	2.61	2.89
131	8.10	2.77	3.21
132	7.50	2.93	3.53
133	7.00	3.09	3.85
134	6.57	3.25	4.17
135	6.21	3.41	4.49
136	5.90	3.57	4.81
137	5.62	3.73	5.13
138	5.38	3.89	5.45
139	5.16	4.05	5.77
140	4.97	4.21	6.09
141	4.79	4.37	6.41
142	4.64	4.53	6.73
143	4.50	4.69	7.05
144	4.37	4.85	7.37
145	4.25	5.01	7.69
146	4.14	5.17	8.01
147	4.04	5.33	8.33
148	3.95	5.49	8.65
149	3.87	5.65	8.97
150	3.79	5.81	9.29
200	2.54	13.81	25.29
300	2.20	29.81	57.29
400	2.10	45.81	89.29

115.825 meters*	152.402	500.0	36.970	0.18	0.72
146.306 meters*	182.882	600.0	46.724	0.14	0.67
176.786 meters*	213.363	700.0	56.478	0.12	0.63
207.267 meters*	243.843	800.0	66.232	0.10	0.60
237.747 meters*	274.323	900.0	75.985	0.09	0.57
268.227 meters*	304.804	1000.0	85.739	0.08	0.55
298.708 meters*	335.284	1100.0	95.493	0.07	0.53
329.188 meters*	365.764	1200.0	105.246	0.06	0.51
359.668 meters*	396.245	1300.0	115.000	0.06	0.49
390.149 meters*	426.725	1400.0	124.754	0.05	0.48
420.629 meters*	457.206	1500.0	134.508	0.05	0.47
451.109 meters*	487.686	1600.0	144.261	0.05	0.46
481.590 meters*	518.166	1700.0	154.015	0.04	0.45
512.070 meters*	548.647	1800.0	163.769	0.04	0.44
542.551 meters*	579.127	1900.0	173.522	0.04	0.43
573.031 meters*	609.607	2000.0	183.276	0.04	0.42
603.511 meters*	640.088	2100.0	193.030	0.03	0.42
633.992 meters*	670.568	2200.0	202.784	0.03	0.41
664.472 meters*	701.049	2300.0	212.537	0.03	0.40
694.952 meters*	731.529	2400.0	222.291	0.03	0.40
725.433 meters*	762.009	2500.0	232.045	0.03	0.39
755.913 meters*	792.490	2600.0	241.799	0.03	0.39
786.394 meters*	822.970	2700.0	251.552	0.03	0.38
816.874 meters*	853.450	2800.0	261.306	0.03	0.38
847.354 meters*	883.931	2900.0	271.060	0.02	0.37
877.835 meters*	914.411	3000.0	280.813	0.02	0.37
908.315 meters*	944.891	3100.0	290.567	0.02	0.36
938.795 meters*	975.372	3200.0	300.321	0.02	0.36
969.276 meters*	1005.852	3300.0	310.075	0.02	0.36
999.756 meters*	1036.333	3400.0	319.828	0.02	0.35
1030.237 meters*	1066.813	3500.0	329.582	0.02	0.35
1060.717 meters*	1097.293	3600.0	339.336	0.02	0.34
1091.197 meters*	1127.774	3700.0	349.089	0.02	0.34
1121.678 meters*	1158.254	3800.0	358.843	0.02	0.34
1152.158 meters*	1188.734	3900.0	368.597	0.02	0.34
1182.638 meters*	1219.215	4000.0	378.351	0.02	0.33
1182.638 meters*	1219.215	4000.0	378.351	0.02	0.33
1182.638 meters*	1219.215	4000.0	378.351	0.02	0.33

500	2.03	61.81	121.29
600	1.95	72.00	153.29
700	1.83	72.00	185.29
800	1.73	72.00	217.30
900	1.66	72.00	249.30
1,000	1.59	72.00	281.30
1,100	1.53	72.00	313.30
1,200	1.49	72.00	345.30
1,300	1.44	72.00	377.30
1,400	1.40	72.00	409.30
1,500	1.37	72.00	441.30
1,600	1.34	72.00	473.30
1,700	1.31	72.00	505.30
1,800	1.28	72.00	537.30
1,900	1.26	72.00	569.30
2,000	1.23	72.00	601.30
2,100	1.21	72.00	633.30
2,200	1.19	72.00	665.30
2,300	1.17	72.00	697.30
2,400	1.16	72.00	729.30
2,500	1.14	72.00	761.30
2,600	1.13	72.00	793.30
2,700	1.11	72.00	825.30
2,800	1.10	72.00	857.30
2,900	1.08	72.00	889.30
3,000	1.07	72.00	921.30
3,100	1.06	72.00	953.30
3,200	1.05	72.00	985.30
3,300	1.04	72.00	1017.30
3,400	1.02	72.00	1049.31
3,500	1.01	72.00	1081.31
3,600	1.00	72.00	1113.31
3,700	1.00	72.00	1145.31
3,800	0.99	72.00	1177.31
3,900	0.98	72.00	1209.31
4,000	0.97	72.00	1241.31
4,000	0.97	72.00	1241.31
4,000	0.97	72.00	1241.31