DOCKETED	
Docket Number:	19-SPPE-03
Project Title:	Sequoia Data Center
TN #:	229938-2
Document Title:	C1 Santa Clara, LLC's Response to CEC Staff Data Request - Set 1 - SBGF Appendices
Description:	N/A
Filer:	Scott Galati
Organization:	DayZenLLC
Submitter Role:	Applicant Representative
Submission Date:	10/2/2019 3:35:21 PM
Docketed Date:	10/2/2019

APPENDICES TO DATA REQUEST SET 1

APPENDIX AIR DR-7

Construction Emission Air Dispersion Modeling Tables

Table 1
Construction 1-hr, 3-hr and 8-hr Model Emission Rates
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

	Emission Rate[1] [lb/hr]					Emission Rate[1] [g/s]				
	NO_x	**CO**	**SO_2**	**Exhaust PM_{10}**	**Exhaust $PM_{2.5}$**	**NO_x**	**CO**	**SO_2**	**Exhaust PM_{10}**	**Exhaust $PM_{2.5}$**
Demolition	4.2	2.8	0.0050	0.21	0.19	0.52	0.35	6.3E-04	0.026	0.024
Site Preparation	5.3	2.7	0.0049	0.27	0.25	0.67	0.35	6.2E-04	0.03	0.03
Grading	6.3	4.1	0.0079	0.27	0.25	0.79	0.51	0.0010	0.03	0.03
Building Construction	4.3	3.6	0.010	0.15	0.14	0.54	0.46	0.0013	0.019	0.018
Paving	1.6	1.9	0.0030	0.085	0.08	0.20	0.24	3.8E-04	0.011	0.010
Architectural Coating	0.2	0.4	9.5E-04	0.012	0.01	0.026	0.052	1.2E-04	0.002	0.002
Max	**6.28**	**4.06**	**0.010**	**0.27**	**0.25**	**0.79**	**0.51**	**0.00**	**0.03**	**0.03**

Notes

1. Emission rates calculated using CalEEMod output rates in pounds/day, divided by 8 hours of assumed construction operation per day

Abbreviations:

lb - pound
g - gram
s - second
hr - hour
NO_x - Nitrous Oxides
CO - carbon monoxide
SO_2 - Sulfur Dioxide
PM - Particulate Matter

Table 2
Construction 24-hr Model Emission Rates
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

	Emission Rate[1] [lb/hr]			Emission Rate[1] [g/s]		
	SO_2	**Exhaust PM_{10}**	**Exhaust $PM_{2.5}$**	**SO_2**	**Exhaust PM_{10}**	**Exhaust $PM_{2.5}$**
Demolition	0.0036	0.15	0.14	4.6E-04	0.019	0.018
Site Preparation	0.0036	0.20	0.18	4.5E-04	0.025	0.023
Grading	0.0058	0.20	0.18	7.3E-04	0.025	0.023
Building Construction	0.0076	0.11	0.10	0.0010	0.014	0.013
Paving	0.0022	0.062	0.06	2.7E-04	0.0078	0.0071
Architectural Coating	6.9E-04	0.009	0.01	8.7E-05	0.0011	0.0011
Max	**0.0076**	**0.20**	**0.18**	**0.00**	**0.03**	**0.02**

Notes

1. Emission rates assume CalEEMod output rates in pounds/day, assuming a construction during of 11 hours per day.

Abbreviations:

lb - pound
g - gram
s - second
hr - hour
NO_x - Nitrous Oxides
CO - carbon monoxide
SO_2 - Sulfur Dioxide
PM - Particulate Matter

Table 3
Construction Annual Model Emission Rates
Sequoia Back-up Power Facility
Santa Clara, California

Project Construction	CAP Emissions [lb][1,2]				
	NO_x	CO	SO_2	Exhaust PM_{10}	Exhaust $PM_{2.5}$
Site Preparation	425	220	0.40	22.00	20
Grading	1,507	974	1.9	65.24	60
Building Construction	9,831	8,417	25	336.78	316.72
Paving	259	300	0.48	13.58	13
Architectural Coating	33	66	0.16	1.94	1.9
Total	**12,056**	**9,976**	**28**	**440**	**411**
Length of Construction (days)	531				
Average Daily Emissions (lb/hour)	**2.064**	**1.708**	**0.005**	**0.075**	**0.070**
Average Daily Emissions (g/s)	**0.260**	**0.215**	**0.001**	**0.009**	**0.009**

Notes:

1. Emissions estimated using CalEEMod version 2016.3.2.
2. Construction activities associated with the SBGF are negligible and are included in the estimates for SDC.

Abbreviations:

CalEEMod - California Emissions Estimator Model
lb - pounds
NOx - nitrogen oxides
ROG - reactive organic gases
$PM_{2.5}$ - particulate matter < 2.5 µm
PM_{10} - particulate matter < 10 µm
BAAQMD - Bay Area Air Quality District
CAP - Criteria Air Pollutants
SBGF - Sequoia Backup Generating Facility
SDC - Sequoia Data Center

References:

CalEEMod Version 2013.2.2 Available Online at: http://www.caleemod.com

Table 4
Modeled Construction Concentrations and NAAQS
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Pollutant	Averaging Period	UTM Zone 10 Coordinates (m)		Max. Dispersion Factor ($\mu g/m^3)(g/s)^{-1}$	Emission rate (g/s)	Modeled Concentration ($\mu g/m^3$)	3-Year Average Background Concentrations ($\mu g/m^3$)[2,3]	Total Concentrations	NAAQS (µg/m3)	Above NAAQS?
		X	Y							
NO_2[1]	5-year average of 1-Hour Yearly 98th%	593760	4136140	115	--	115	N/A	115	188	No
	Annual	593661	4136202	28	--	28	N/A	28	100	No
CO	1-Hour	593740	4136200	60	0.51	31	2,443	2,474	40,000	No
	8-Hour	593360	4136380	27	0.51	14	1,909	1,922	10,000	No
SO_2	5-year average of 1-Hour Yearly 99th%	593740	4136200	57	0.0013	0.076	6.1	6.2	196	No
	3-Hour	593740	4136200	47	0.0013	0.063	9.4	9.5	1,300	No
PM_{10}[4]	24-Hour 6th highest over 5 years	593360	4136400	13	0.025	0.32	56	56	150	No
$PM_{2.5}$[4]	5-year average of 24-Hour Yearly 98th%	593691.0	4136203.0	11	0.023	0.25	31	31	35	No
	5-year average of annual concentrations	593661.1	4136202.4	6.5	0.0089	0.058	10	10	12	No

Notes:

1. Direct emissions rate for NO_2 was used in the dispersion modeling to obtain NO_2 concentration using the Plume Volume Molar Ratio Method (PVMRM) to incorporate both dispersion and chemistry analyses. Since unit emissions rate was not used, there is no value for emissions rate in this table.
2. The 3-year average background concentrations were calculated using 2015-2017 data collected from Monitor Site ID 060850005 located at 158B Jackson Street in San Jose, California, as reported by EPA.
3. Seasonal NO_2 background values are computed using AERMOD and are already included in the modeled concentrations.
4. Modeled Particulate Matter concentrations are given for Exhaust PM only. Fugitive PM emissions addressed in a separate data response.

Table 5
Modeled Construction Concentrations and CAAQS
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Pollutant	Averaging Period	UTM Zone 10 Coordinates (m)		Max. Dispersion Factor ($\mu g/m^3)(g/s)^{-1}$	Emission rate (g/s)	Modeled Concentration ($\mu g/m^3$)	Maximum Background Concentrations ($\mu g/m^3$)[2,3]	Total Concentrations	CAAQS (µg/m3)	Above CAAQS?
		X	Y							
NO_2[1]	1-Hour Maximum	593,740	4,136,200	43	--	43	128	171	339	No
	Annual Maximum	593,661.1	4,136,202.4	28	--	28	N/A	28	57	No
CO	1-Hour Maximum	593740	4136200	60	0.51	31	2,748	2,779	23,000	No
	8-Hour Maximum	593360	4136380	27	0.51	14	2,061	2,075	10,000	No
SO_2	1-Hour Maximum	593740	4136200	60	0.0013	0.080	9.4	9.5	655	No
	24-Hour Maximum	593340	4136420	16	0.0010	0.015	2.9	2.90	105	No
PM_{10}[4]	24-Hour Maximum	593340.0	4136420.0	16	0.025	0.40	69.0	69.4	50	Yes
	Annual Maximum	593661.1	4136202.4	6.5	0.0095	0.062	21.9	22.0	20	Yes
$PM_{2.5}$[4]	Annual Maximum	593661.1	4136202.4	6.5	0.0089	0.058	11	10.7	12	No

Notes:

1. Direct emissions rate for NO_2 was used in the dispersion modeling to obtain NO_2 concentration using the Plume Volume Molar Ratio Method (PVMRM) to incorporate both dispersion and chemistry analyses. Since unit emissions rate was not used, there is no value for emissions rate in this table.

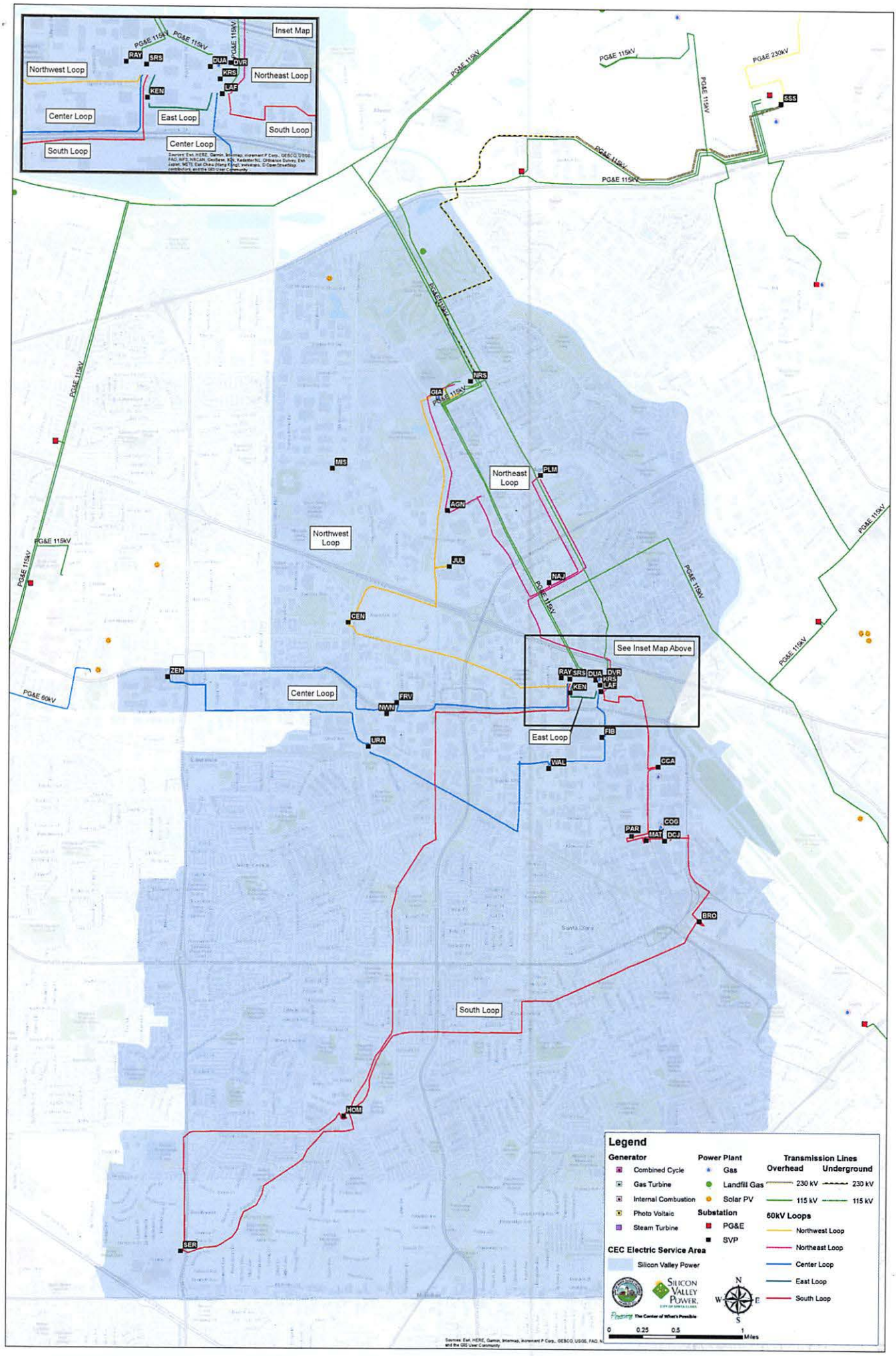
2 The maximum background concentrations from 2015 to 2017 data was used to show compliance with CAAQS.

3. Seasonal NO_2 background values are computed using AERMOD and are included in modeled annual concentrations. 1-hour NO_2 concentrations are modeled to give background-subtracted concentrations, and total 1-hour NO2 concentrations are calculated as the sum of the modeled value and the max background concentration from 2015 to 2017.

4. Modeled Particulate Matter concentrations are given for Exhaust PM only. Fugitive PM emissions addressed in a separate data response.

APPENDIX AIR DR-11

Silicon Valley Power Network Map


Inset Map
Northwest Loop
Northeast Loop
Center Loop
East Loop
South Loop
Center Loop
South Loop
PG&E 115kV
PG&E 230kV
PG&E 60kV
RAY
SRS
KEN
DUA
DVR
KRS
LAF
SSS
MRS
GIA
MIS
PLM
AGN
JUL
NAJ
CEN
ZEN
FRY
NWN
URA
FIB
WAL
CGA
PAR
MAT
COG
DCJ
BRO
HOM
SER
See Inset Map Above
Legend
Generator
Combined Cycle
Gas Turbine
Internal Combustion
Photo Voltaic
Steam Turbine
Power Plant
Gas
Landfill Gas
Solar PV
Substation
PG&E
SVP
CEC Electric Service Area
Silicon Valley Power
Transmission Lines
Overhead
Underground
230 kV
115 kV
60kV Loops
Northwest Loop
Northeast Loop
Center Loop
East Loop
South Loop
N
W
E
S
0
0.25
0.5
1
Miles

APPENDIX AIR DR-23

CARB Executive Order and Certificate DPM and Oxidation Catalyst

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 (°C) 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

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 1996 Engines

Manufacturer	Engine Families
Caterpillar	TCP14.RZDBRK
	TCP10.RZDBRD
Deutz AG	TDZ16.RGDARA
	TDZ16.RGDARB
	TDZ7.1R6DARA
	TDZ7.1R6DARB
Generac	TGN13.R6DARA
Komatsu	TKL11.RZDARB
Navistar	TNV466R6DARA
	TNV466R6DARB
	TNV466R6DASC
	TNV466R6DASD
	TNV530R6DARA
	TNV530R6DARB
	TNV530R6DASD
	TNV530R8DASC

Model Year 1997 Engines

Manufacturer	Engine Families
Caterpillar	VCP10.RZDARD
	VCP14.RZDARK
Deere	VJD10.RJDBRB
	VJD6.8R6DBRA
	VJD8.1R6DBRA
	VJD8.1RBDRB
Deutz AG	VDZ16.RGDARA
	VDZ16.RGDARB
	VDZ7.1R6DARA
	VDZ7.1R6DARB
Generac	VGN13.R6DARA
Navistar	VNV466R6DASC
	VNV466R6DASD
	VNV530R6DARB
	VNV530R6DASC
	VNV530R6DASD

Model Year 1998 Engines

Manufacturer	Engine Families
AB Volvo Penta	WVPXL09.6ACB
	WVPXL12.0ACB
Case	WX9XL0239ACA
	WX9XL0359ABA
	WX9XL0505ABA
	WX9XL0505ABB
	WX9XL0505ACA
Caterpillar	WCPXL07.0MRB
	WCPXL10.5MRD
	WCPXL10.5MRG
	WCPXL14.6ERK
	WCPXL14.6MRJ
Cummins	WCEXL019.AAA
	WCEXL0359ABA
	WCEXL0359ABB
	WCEXL0505ABA
	WCEXL0505ABB
	WCEXL0505ACA
	WCEXL0661AAA
	WCEXL0855AAA
	WCEXL0855AAB
Daewoo	WDWXL11.1BHT
	WDWXL11.1BIA
Detroit Diesel Corporation	VDDXL08.5TJD
	WDDXL09.0TFE
	WDDXL11.1THD
	WDDXL12.1TFE
	WDDXL12.1TFM
	WDDXL12.7TGD
	WDDXL15.9TRE
	WDDXL23.9TRE
Deere	WJDXL06.8012
	WJDXL08.1007
	WJDXL08.1008
	WJDXL08.1009
	WJDXL10.5003

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 1998 Engines Continued

Manufacturer	Engine Families
Deutz AG	WDZXL07.1003
	WDZXL07.1004
	WDZXL15.9001
	WDZXL15.9002
GMC	WGNXL13.3HTA
ISUZU	WSZXL06.4DTA
Komatsu	WKDXL0239AAA
	WKDXL0359ABA
	WKLXL11.0DB1
	WKLXL11.0DC1
	WKLXL15.2EB1
	WKLXL23.2FC1
	WKLXL7.15CB1
	WKLXL7.15CC1
MTU	WMUXL12.0G2V
Navistar	WNVXL0530BNB
	WNVXL0530BND

Model Year 1999 Engines

Manufacturer	Engine Families
AB Volvo Penta	XVPXL07.3ABB
	XVPXL07.3ACB
	XVPXL09.6ACB
	XVPXL12.0ACB
Case	XX9XL0239ACA
	XX9XL0359ABA
	XX9XL0505ABA
	XX9XL0505ABB
	XX9XL0505ACA
Caterpillar	XCPXL07.0MRB
	XCPXL10.5MRD
	XCPXL10.5MRG
	XCPXL14.6ERK
Cummins	XCEXL019.AAA
	XCEXL0359ABA
	XCEXL0505ABA
	XCEXL0505ABB
	XCEXL0505ACA
	XCEXL0661AAA
	XCEXL0855AAA
	XCEXL0855AAB

Model Year 1999 Engines Continued

Manufacturer	Engine Families
Daewoo	XDWXL03.3AMN
	XDWXL03.3BMN
	XDWXL03.3LMN
	XDWXL05.8AOA
	XDWXL05.8ARN
	XDWXL05.8ATT
	XDWXL08.1ACN
	XDWXL08.1ADT
	XDWXL11.1BIA
	XDWXL11.1BHT
	XDWXL11.1DJA
	XDWXL14.6AZA
	XDWXL14.6CVT
	XDWXL18.3ASA
Detroit Diesel Corporation	XDDXL08.5TJD
	XDDXL09.1TFE
	XDDXL11.1THD
	XDDXL12.1TFE
	XDDXL12.1TFM
	XDDXL12.7TGD
	XDDXL14.0TLD
	XDDXL15.9TRE
	XDDXL23.9TRE
Deere	XJDXL06.8012
	XJDXL08.1007
	XJDXL08.1008
	XJDXL10.5022
Deutz AG	XDZXL02.7014
	XDZXL07.1005
	XDZXL07.1004
	XDZXL15.9002
	XDZXL15.9003
Generac	XGNXL13.3HTA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 1999 Engines Continued

Manufacturer	Engine Families
Komatsu	XKLXL03.3JA1
	XKLXL11.0DB1
	XKLXL11.0DC1
	XKLXL15.2EC1
	XKLXL23.2FC1
	XKLXL7.15CB1
	XKLXL7.15CC1
	XKDXL0239ACA
	XKDXL0359ABA
	XKDXL0505ABB
	XKDXL0505ACA
KUBOTA	XKBXL03.3BAC
	XKBXL03.3BCC
Mitsubishi	XMTXL07.5D6C
	XMTXL11.9D6A
Navistar	XNVXL0466BNA
	XNVXL0530ANA
	XNVXL0530ANB
	XNVXL0530ANC
	XNVXL0530AND
	XNVXL0530BNA
	XNVXL0530BNB
	XNVXL0530BNC
	XNVXL0530BND
Yanmar	XYDXL2.00D4T
	XYDXL2.78D4N
	XYDXL4.41D4N
	XYDXL4.41D4T

Model Year 2000 Engines

Manufacturer	Engine Families
AB Volvo Penta	YVPXL07.3ABB
	YVPXL07.3ACB
	YVPXL09.6ACB
	YVPXL12.0ACB
Case	YX9XL0239ACA
	YX9XL0239ADA
	YX9XL0359ABA
	YX9XL0359ABB
	YX9XL0505ABA
	YX9XL0505ABB
	YX9XL0505ACA
Caterpillar	YCPXL07.0MRB
	YCPXL10.5MRD
	YCPXL10.5MRG
	YCPXL14.6ERK
	YCPXL27.0MRH
	YCPXL27.0MRS
	YCPXL34.5ERK
	YCPXL69.OERK
Cummins	YCEXL03.3AAA
	YCEXL03.3AAB
	YCEXL015.ABA
	YCEXL019.AAA
	YCEXL019.AAB
	YCEXL030.ABA
	YCEXL050.ABA
	YCEXL0239ACA
	YCEXL0239ADA
	YCEXL0359AAA
	YCEXL0359ABA
	YCEXL0359ABC
	YCEXL050.AAA
	YCEXL0505ABA
	YCEXL0505ABB
	YCEXL0505ACA
	YCEXL060.ABA
	YCEXL0661AAA
	YCEXL0855AAA
	YCEXL0855AAB

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2000 Engines Continued

Manufacturer	Engine Families
Deere	YJDXL06.8012
	YJDXL08.1007
	YJDXL08.1008
	YJDXL10.5022
Detroit Diesel Corporation	YDDXL08.5TJD
	YDDXL11.1THD
	YDDXL12.1TFE
	YDDXL12.1TFM
	YDDXL12.7TGD
	YDDXL14.0TLD
	YDDXL15.9TRE
	YDDXL23.9TRE
	YDDXL31.8VRE
	YDDXL65.0VTE
Deutz AG	YDZXL02.7014
	YDZXL07.1004
	YDZXL07.1005
	YDZXL15.9002
	YDZXL15.9003
	YDZXL17.5001
Genrac	YGNXL13.3HAA
	YGNXL13.3HTA
	YGNXL16.0MAA
Komatsu	YKLXL0505ACA
	YKLXL11.0DB1
	YKLXL11.0DC1
	YKLXL15.2EC1
	YKLXL23.2FC1
	YKLXL23.2FC2
	YKLXL30.5GC1
	YKLXL7.15CB1
	YKLXL7.15CC1
Navistar	YNVXL0466ANA
	YNVXL0530ANA
	YNVXL0530ANB
	YNVXL0530ANC
	YNVXL0530AND
VM Motori	YV5XI02.1R3V
	YV5XL02.8R2T

Model Year 2001 Engines

Manufacturer	Engine Families
AB Volvo Penta	1VPXL07.3ABB
	1VPXL07.3ACB
	1VPXL09.6ACB
	1VPXL12.1ACB
Case	1X9XL0239ACA
	1X9XL0239ADA
	1X9XL0359ABA
	1X9XL0359ABB
	1X9XL0505ABA
	1X9XL0505ABB
	1X9XL0505ACA
Caterpillar	1CPXL07.0MRB
	1CPXL10.5MRD
	1CPXL10.5MRG
	1CPXL12.0ESK
	1CPXL14.6ERK
	1CPXL14.6ESK
	1CPXL15.8ESK
	1CPXL18.0HRN
	1CPXL27.0HRK
	1CPXL27.0MRS
	1CPXL27.0MRT
	1CPXL34.5ERK
	1CPXL78.1ERK
Cummins	1CEXL03.3AAA
	1CEXL03.3AAB
	1CEXL015.AAA
	1CEXL015.ABA
	1CEXL019.AAB
	1CEXL0239ACA
	1CEXL0239ADA
	1CEXL030.ABA
	1CEXL0359ABA
	1CEXL0359ABB
	1CEXL0359ABC
	1CEXL0359ABD
	1CEXL050.AAA
	1CEXL050.ABA
	1CEXL0505ABA
	1CEXL0505ABB
	1CEXL0505ACA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2001 Engines Continued

Manufacturer	Engine Families
Cummins continued	1CEXL0505ACE
	1CEXL0661AAA
	1CEXL0661AAD
	1CEXL060.ABA
Daewoo	1DWXL2.37ANT
	1DWXL03.3AMN
	1DWXL03.3BMA
	1DWXL03.3LMN
	1DWXL05.8AOA
	1DWXL05.8ARN
	1DWXL08.1ACN
	1DWXL11.1BIA
	1DWXL14.6AZA
	1DWXL14.6CVT
	1DWXL18.3ASA
	1DWXL21.9AYA
Detroit Diesel Corporation	1DDXL08.5TJD
	1DDXL08.5YJD
	1DDXL12.7VGD
	1DDXL14.0VLD
	1DDXL14.0WLD
	1DDXL15.9WRE
	1DDXL23.9WRE
	1DDXL31.8XRE
	1DDXL65.0XTE
Deere	1JDXL06.8012
	1JDXL06.8038
	1JDXL06.8039
	1JDXL08.1007
	1JDXL08.1008
	1JDXL08.1036
	1JDXL08.1037
Deutz	1DZXL02.7014
	1DZXL02.7015
	1DZXL04.8006
	1DDXL08.5TJD
	1DDXL08.5YJD
	1DZXL07.1005
	1DZXL15.9002
	1DZXL15.9003

Model Year 2001 Engines Continued

Manufacturer	Engine Families
Generac	1GNXL04.0HAA
	1GNXL04.0HNA
	1GNXL05.0FAA
Isuzu	1SZXL06.5BTA
	1SZXL09.8EXA
	1SZXL15.7ETA
	1SZXL15.7EXA
International	1NVXL0530ANC
	1NVXL0530AND
	1NVXL0530ANF
Komatsu	1KLXL0239ACA
	1KLXL0239ADA
	1KLXL0359ABA
	1KLXL0359ABC
	1KLXL0505ABB
	1KLXL0505ACA
	1KLXL03.3JA1
	1KLXL03.3JB1
	1KLXL7.15CB1
	1KLXL7.15CC1
	1KLXL11.0DD3
	1KLXL15.2EC3
	1KLXL30.5GC1
	1KLXL30.5GD1
Mitsubishi	1MTXL07.5D6A
	1MTXL07.5D6C
	1MTXL11.9D6A

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2002 Engines

Manufacturer	Engine Families
Case	2X9XL0239ACA
	2X9XL0239ADA
	2X9XL0359ABA
	2X9XL0359ABB
	2X9XL0359ABE
	2X9XL0505ABA
	2X9XL0505ABB
	2X9XL0505ABD
	2X9XL0505ACA
Caterpillar	2CPXL07.0MRB
	2CPXL10.5MRD
	2CPXL10.5MRG
	2CPXL14.6ESK
	2CPXL27.0MRS
	2CPXL27.0MRT
	2CPXL34.5ERK
	2CPXL78.1ERK
Cummins	2CEXL03.3AAA
	2CEXL03.3AAB
	2CEXL015.AAA
	2CEXL015.AAB
	2CEXL015.ABA
	2CEXL019.AAB
	2CEXL0239ACA
	2CEXL0239ADA
	2CEXL0359ABA
	2CEXL0359ABB
	2CEXL0359ABC
	2CEXL0359ABE
	2CEXL0505ABA
	2CEXL0505ABB
	2CEXL0505ABD
	2CEXL0505ACA
	2CEXL0505ACB
	2CEXL0505ACE
	2CEXL060.ABA
	2CEXL0661AAA
	2CEXL0661AAD

Model Year 2002 Engines Continued

Manufacturer	Engine Families
Detroit Diesel	2DDXL08.5TJD
	2DDXL08.5YJD
	2DDXL12.7VGD
	2DDXL14.0VLD
	2DDXL31.8XRE
	2DDXL65.0XTE
Deere	2JDXL06.8012
	2JDXL06.8038
	2JDXL06.8039
	2JDXL06.8041
	2JDXL06.8044
	2JDXL06.8049
	2JDXL08.1007
	2JDXL08.1008
	2JDXL08.1036
	2JDXL08.1037
Deutz AG	2DZXL02.7014
	2DZXL02.7015
	2DZXL05.7033
	2DZXL07.1004
	2DZXL07.1005
	2DZXL07.1032
	2DZXL15.9002
	2DZXL15.9003
Daewoo	2DWXL2.37ANT
	2DWXL03.3AMN
	2DWXL03.3BMA
	2DWXL03.3LMN
	2DWXL05.8AOA
	2DWXL05.8ARN
	2DWXL08.1ACN
	2DWXL11.1BIA
	2DWXL14.6CVT
	2DWXL21.9AYA
Generac	2GNXL04.0HAA
	2GNXL04.0HNA
	2GNXL05.0FAA
Isuzu	2SZXL06.5BTA
	2SZXL09.8EXA
	2SZXL15.7ETA
	2SZXL15.7EXA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2002 Engines Continued

Manufacturer	Engine Families
International Truck	2NVXL0444ANA
	2NVXL0530ANC
	2NVXL0530AND
	2NVXL0530ANF
Komatsu	2KLXL0239ACA
	2KLXL0239ADA
	2KLXL0359ABA
	2KLXL0359ABC
	2KLXL0505ABB
	2KLXL0505ABD
	2KLXL0505ACA
	2KLXL03.3JA1
	2KLXL03.3JB1
	2KLXL11.0DB1
	2KLXL11.0DD3
	2KLXL15.2EC3
	2KLXL30.5GC1
	2KLXL30.5GD1
	2KLXL46.3HC1
	2KLXL7.15CB1
	2KLXL7.15CC1
Mitsubishi	2MTXL07.5D6A
	2MTXL07.5D6C
	2MTXL11.9D6A
	2MVXL24.5AAB
	2MVXL65.4ABA
	2MVXL65.4ABB
	2MVXL65.4ABC
AB Volvo Penta	2VPXL07.3ABB
	2VPXL07.3ACB
	2VPXL09.6ACB
	2VPXL12.1ABA
	2VPXL12.1ACA
	2VPXL12.1ACB
VM Motori	2V5XL02.8R2T

Model Year 2003 Engines

Manufacturer	Engine Families
Caterpillar	3CPXL12.0ESK
	3CPXL14.6ESK
	3CPXL15.8ERK
	3CPXL15.8ESK
	3CPXL18.0HRX
	3CPXL27.0HRK
	3CPXL27.0MRS
	3CPXL27.0MRT
	3CPXL34.5ERK
	3CPXL58.6ERK
	3CPXL78.1ERK
CNH Engine Corp	3X9XL0239AAA
	3X9XL0239ABA
	3X9XL0359AAC
	3X9XL0359ABE
	3X9XL0505AAB
	3X9XL0505ABD
Cummins	3CEXL015.AAB
	3CEXL015.ABA
	3CEXL023.AAA
	3CEXL0239AAD
	3CEXL0239AAF
	3CEXL0275AAA
	3CEXL0275AAB
	3CEXL030.ABA
	3CEXL0359AAB
	3CEXL0359AAC
	3CEXL0359ABC
	3CEXL0359ABE
	3CEXL050.ABA
	3CEXL0505ABD
	3CEXL0505ACB
	3CEXL060.ABA
	3CEXL0661AAD
	3CEXL078.AAB
Daewoo Motors	3DWXL05.8COA
	3DWXL11.1DJA
	3DWXL21.9AYA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2003 Engines Continued

Manufacturer	Engine Families
Detroit Diesel	3DDXL08.5YJD
	3DDXL12.7VGD
	3DDXL14.0VLD
	3DDXL15.9WRE
	3DDXL31.8XRE
	3DDXL35.8GRP
	3DDXL65.0GTP
	3DDXL65.0XTE
Deere	3JDXL06.8038
	3JDXL06.8039
	3JDXL06.8041
	3JDXL06.8044
	3JDXL06.8048
	3JDXL06.8049
	3JDXL08.1037
Deutz AG	3DZXL05.7033
	3DZXL06.1028
	3DZXL07.1032
	3DZXL15.9002
Daewoo Heavy Ind.	3DWXL08.1CPA
	3DWXL18.3ASC
	3DWXL2.37ANT
Isuzu	3SZXL09.8EXA
	3SZXL15.7ETA
	3SZXL15.7EXA
International Truck	3NVXL0530ANF
Komatsu	3KLXL0239AAD
	3KLXL0239AAF
	3KLXL0359AAB
	3KLXL0359ABC
	3KLXL0505ABD
	3KLXL11.0DD3
	3KLXL15.2EC3
	3KLXL23.2FD4
	3KLXL30.5GC1
	3KLXL30.5GD1

Model Year 2003 Engines Continued

Manufacturer	Engine Families
Lombardini Motori	3LBDL2.07CHT
Mack Trucks	3MKXL11.9P69
Mitsubishi Heavy Ind	3MVXL24.5AAB
	3MVXL24.5ABA
	3MVXL24.5ABB
	3MVXL24.5ABD
	3MVXL24.5ABE
	3MVXL33.9ABA
	3MVXL33.9ABB
	3MVXL33.9ABD
	3MVXL33.9ABE
	3MVXL37.1ABA
	3MVXL37.1ABB
	3MVXL37.1ABC
	3MVXL37.1ABD
	3MVXL49.0ABA
	3MVXL49.0ABB
	3MVXL49.0ABC
	3MVXL65.4ABA
	3MVXL65.4ABB
	3MVXL65.4ABC
	3MVXL65.4ABD
	3MVXL65.4ABE
	3MVXL65.4ABF
	3MVXL65.4ABG
AB Volvo Penta	3VPXL07.3ACB
	3VPXL09.6ACB
	3VPXL12.1ABA
	3VPXL12.1ACA
	3VPXL12.1ACB
	3VPXL16.0ACB

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2004 Engines

Manufacturer	Engine Families
Caterpillar	4CPXL12.0ESK
	4CPXL14.6ESK
	4CPXL15.8ERK
	4CPXL15.8ESK
	4CPXL18.0ESK
	4CPXL18.0HRX
	4CPXL27.0HRK
	4CPXL27.0MRS
	4CPXL27.0MRT
	4CPXL34.5ERK
	4CPXL58.6ERK
	4CPXL78.1ERK
CNH Engine Corp.	4X9XL0239AAC
	4X9XL0359AAK
	4X9XL0359ABE
	4X9XL0505AAB
	4X9XL0505ABD
Cummins	4CEXL015.AAB
	4CEXL015.ABA
	4CEXL023.AAA
	4CEXL0239AAD
	4CEXL0239AAF
	4CEXL0239AAG
	4CEXL0275AAB
	4CEXL0275AAC
	4CEXL0275AAF
	4CEXL03.3ABA
	4CEXL03.3ABB
	4CEXL030.ABA
	4CEXL0359AAB
	4CEXL0359AAC
	4CEXL0359AAD
	4CEXL0359AAE
	4CEXL0359AAF
	4CEXL0359AAH
	4CEXL0359ABC
	4CEXL0359ABE
	4CEXL050.ABA
	4CEXL0505ABD
	4CEXL0505ACB
	4CEXL060.ABA
	4CEXL0661AAD

Model Year 2004 Engines Continued

Manufacturer	Engine Families
Cummins (cont.)	4CEXL078.AAB
	4CEXL2.28A41
	4CEXL2.28A42
Detroit Diesel	4DDXL08.5YJD
	4DDXL12.7VGD
	4DDXL14.0VLD
	4DDXL23.9WRE
	4DDXL31.8XRE
	4DDXL35.8GRP
	4DDXL65.0GTP
	4DDXL65.0XTE
	4DDXL90.0XTP
Deere	4JDXL03.0064
	4JDXL06.8038
	4JDXL06.8041
	4JDXL06.8048
	4JDXL06.8049
	4JDXL08.1037
Deutz AG	4DZXL03.1039
	4DZXL03.1040
	4DZXL03.1041
	4DZXL05.7033
	4DZXL06.1038
	4DZXL06.5036
	4DZXL06.5037
	4DZXL06.5042
	4DZXL06.5043
	4DZXL07.1032
	4DZXL15.9002
	4DZXL71.0021
Daewoo	4DWXL05.8COA
	4DWXL05.8CRN
	4DWXL08.1CPA
	4DWXL11.1BIA
	4DWXL11.1DJA
	4DWXL18.3ASC
	4DWXL2.37ANT
	4DWXL21.9AYA
Isuzu	4SZXL03.1GTB
	4SZXL06.5FXG
	4SZXL15.7ETA
	4SZXL15.7EXA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2004 Engines Continued

Manufacturer	Engine Families
International Truck	4NVXL0530ANF
Iveco	4VEXL05.9DGS
	4VEXL12.9GEN
Kubota	4KBXL03.3ACD
	4KBXL03.3BAC
	4KBXL03.3BCC
	4KBXL03.8ACD
Komatsu	4KLXL0239AAD
	4KLXL0239AAF
	4KLXL0239ADA
	4KLXL0275AAC
	4KLXL03.3JA3
	4KLXL03.3JB3
	4KLXL03.3JD3
	4KLXL0359AAB
	4KLXL0359AAE
	4KLXL0359ABC
	4KLXL0505ABD
	4KLXL11.0DD3
	4KLXL15.2EC3
	4KLXL23.2FD4
	4KLXL30.5GC1
	4KLXL30.5GD1
MACK Trucks	4MKXL11.9P69
	4MKXL11.9P72
MOTORENFABRIK HATZ	4HZXL3.43C42
	4HZXL3.43V42
Mitsubishi Heavy Ind.	4MVXL05.0AAA
	4MVXL05.0AAD
	4MVXL24.5AAB
	4MVXL24.5ABA
	4MVXL24.5ABB
	4MVXL24.5ABD
	4MVXL24.5ABE
	4MVXL33.9ABB
	4MVXL33.9ABE
	4MVXL37.1ABB
	4MVXL37.1ABC
	4MVXL37.1ABD

Model Year 2004 Engines Continued

Manufacturer	Engine Families
Mitsubishi Heavy Ind (continued)	4MVXL49.0ABA
	4MVXL49.0ABB
	4MVXL49.0ABC
	4MVXL49.0ABD
	4MVXL49.0ABE
	4MVXL65.4ABA
	4MVXL65.4ABB
	4MVXL65.4ABC
	4MVXL65.4ABD
	4MVXL65.4ABE
	4MVXL65.4ABF
	4MVXL65.4ABG
	4MVXL65.4ABH
MTU	4MTUL21.9R2A
Nissan Diesel	4NDXL03.0FTA
AB Volvo Penta	4VPXL07.3ACB
	4VPXL09.4ACA
	4VPXL09.4ACB
	4VPXL09.4ACC
	4VPXL09.6ACB
	4VPXL09.6ACC
	4VPXL12.1ABA
	4VPXL12.1ACA
	4VPXL12.1ACB
Yanmar	4YDXL3.05M4N
	4YDXL3.32J4N
	4YDXL3.32J4T
	4YDXL3.32K4N
	4YDXL3.32K4T
	4YDXL4.41K4T
Perkins	4PKXL15.8H16
Scania AB	4Y9XL11.7BBG
	4Y9XL15.6BDA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2005 Engines

Manufacturer	Engine Families
Caterpillar	5CPXL15.2ESK
	5CPXL15.8ERK
	5CPXL18.0ESK
	5CPXL27.0MRS
	5CPXL27.0MRT
	5CPXL34.5ERK
	5CPXL58.6ERK
	5CPXL78.1ERK
CNH Engine Corp.	5X9XL0239AAC
	5X9XL0359AAK
	5X9XL0359ABE
	5X9XL0505AAB
	5X9XL0505ABD
	5X9XL0540AAB
Cummins	5CEXL015.AAB
	5CEXL015.ABA
	5CEXL019.AAB
	5CEXL023.AAA
	5CEXL0239AAD
	5CEXL0239AAF
	5CEXL0239AAG
	5CEXL0275AAB
	5CEXL0275AAC
	5CEXL0275AAF
	5CEXL03.3ABA
	5CEXL03.3ABB
	5CEXL030.ABA
	5CEXL0359AAB
	5CEXL0359AAC
	5CEXL0359AAD
	5CEXL0359AAE
	5CEXL0359AAF
	5CEXL0359AAH
	5CEXL0359ABC
	5CEXL0359ABE
	5CEXL0409AAB
	5CEXL0409AAC
	5CEXL050.ABA
	5CEXL0505AAE
	5CEXL0505ABD
	5CEXL0505ACB

Model Year 2005 Engines (Continued)

Manufacturer	Engine Families
Cummins	5CEXL0540AAB
	5CEXL060.ABA
	5CEXL078.AAB
	5CEXL2.28A41
	5CEXL2.28A42
Detroit Diesel Corporation	5DDXL08.5YJD
	5DDXL15.9WRE
	5DDXL31.8XRR
	5DDXL35.8GRP
	5DDXL65.0GTE
	5DDXL65.0GTP
	5DDXL65.0XTE
	5DDXL90.0XTP
Deere	5JDXL04.5083
	5JDXL06.8038
	5JDXL06.8041
	5JDXL06.8048
	5JDXL06.8049
	5JDXL06.8078
	5JDXL06.8101
	5JDXL08.1037
	5JDXL08.1059
	5JDXL09.0102
Deutz	5DZXL03.1039
	5DZXL03.1040
	5DZXL05.7033
	5DZXL06.1038
	5DZXL06.5036
	5DZXL06.5037
	5DZXL06.5042
	5DZXL06.5043
	5DZXL07.1032
	5DZXL15.9002
	5DZXL71.0021
Daewoo Heavy Ind.	5DWXL08.1CPA
	5DWXL18.3ASC
	5DWXL21.9AYA
MotorenFabrik HATZ GMBH	5HZXL3.43C42

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2005 Engines (Continued)

Manufacturer	Engine Families
Isuzu	5SZXL03.1GTB
	5SZXL04.3GTG
	5SZXL06.5FXG
	5SZXL09.8EXA
	5SZXL15.7ETA
	5SZXL15.7EXA
Iveco	5VEXL05.9DGS
	5VEXL06.7DGA
	5VEXL12.9GEN
Komatsu	5KLXL0239AAD
	5KLXL0239AAF
	5KLXL0239ADA
	5KLXL0275AAC
	5KLXL03.3JA3
	5KLXL03.3JB3
	5KLXL03.3JD3
	5KLXL0359AAB
	5KLXL0359AAE
	5KLXL0359AAL
	5KLXL0359ABC
	5KLXL0409AAB
	5KLXL0409AAC
	5KLXL0505ABD
Komatsu	5KLXL23.2FD4
	5KLXL30.5GC1
	5KLXL30.5GD1
Kuboto	5KBXL03.3BAC
	5KBXL03.3BCC
KUKJ	5KMCL2.28A41
	5KMCL2.28A42
Lombardini Motori	5LBDL2.19CHT
Mitsubishi Heavy Industries	5MVXL05.0AAA
	5MVXL05.0AAC
	5MVXL05.0AAD
	5MVXL24.5ABB
	5MVXL33.9ABB
	5MVXL37.1ABC
	5MVXL49.0ABD
	5MVXL65.4ABB
	5MVXL65.4ABH

Model Year 2005 Engines (Continued)

Manufacturer	Engine Families
MITF	5MFTL07.5D6A
MTU-Friedrichshafen	5MTUL21.9R2A
Nissan Diesel	5NDXL02.7TNA
	5NDXL03.0FTA
AB Volvo Penta	5VPXL07.3ACB
	5VPXL09.4ACA
	5VPXL09.4ACB
	5VPXL09.4ACC
	5VPXL09.6ACB
	5VPXL12.1ABA
	5VPXL12.1ACA
	5VPXL12.1ACB
	5VPXL16.1ACB
	5VPXL16.1ACC
	5VPXL16.1ACD
	5VPXL16.1ACE
	5VPXL16.1ACF
Yanmar	5YDXL3.05M4N
	5YDXL3.32J4N
	5YDXL3.32J4T
	5YDXL3.32K4N
	5YDXL3.32K4T
	5YDXL4.41K4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2006 Engines

Manufacturer	Engine Families
AB Volvo Penta	6VPXL12.1BAA
	6VPXL16.1ACB
	6VPXL9.4BAA
Caterpillar	6CPXL15.2ESK
	6CPXL18.0ESK
	6CPXL18.1ESK
	6CPXL18.1ESL
	6CPXL32.0ESK
	6CPXL34.5E2T
	6CPXL34.5T2E
	6CPXL58.6E2T
	6CPXL58.6T2E
	6CPXL78.1E2T
	6CPXL78.1T2E
CNH Engine Corp.	6X9XL0239AAC
	6X9XL0359AAM
	6X9XL0359ABE
	6X9XL0505ABD
	6X9XL0540AAB
Cummins	6CEXK0505AAE
	6CEXL015.AAB
	6CEXL019.AAB
	6CEXL019.AAC
	6CEXL023.AAA
	6CEXL0239AAD
	6CEXL0239AAF
	6CEXL0239AAG
	6CEXL0275AAB
	6CEXL0275AAC
	6CEXL0275AAG
	6CEXL0275AAH
	6CEXL030.AAB
	6CEXL030.AAD
	6CEXL030.ABA
	6CEXL03.3ABC
	6CEXL0359AAB
	6CEXL0359AAC
	6CEXL0359AAD
	6CEXL0359AAF
	6KLXL0359AAL
	6CEXL0359AAN
	6CEXL0359ABC
	6CEXL0359ABE

Model Year 2006 Engines (Continued)

Manufacturer	Engine Families
Cummins (cont.)	6CEXL0409AAB
	6CEXL0409AAC
	6CEXL050.AAD
	6CEXL050.ABA
	6CEXL0505ABD
	6CEXL0540AAB
	6CEXL060.AAD
	6CEXL078.AAB
DAIMLERCHRYSLER	6MBXL7.20RJA
	6MBXL12.8RJB
Deere	6JDXL03.0064
	6JDXL04.5057
	6JDXL04.5083
	6JDXL06.8001
	6JDXL06.8004
	6JDXL06.8006
	6JDXL06.8038
	6JDXL06.8041
	6JDXL06.8048
	6JDXL06.8049
	6JDXL06.8078
	6JDXL08.1037
	6JDXL09.0102
	6JDXL12.5035
	6JDXL12.5073
	6JDXL13.5103
Detroit Diesel Corporation	6DDXL14.0VLD
	6DDXL31.8XRR
Deutz	6DZXL06.1038
	6DZXL06.1028
	6DZXL05.7033
	6DZXL06.5036
	6DZXL06.5037
	6DZXL06.5042
	6DZXL03.1066
	6DZXL03.1039
	6DZXL03.1040

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2006 Engines (Continued)

Manufacturer	Engine Families
Isuzu	6SZXL04.3GTG
	6SZXL06.5FXG
	6SZXL05.2HXA
	6SZXL05.2IXA
	6SZXL07.8HXA
	6SZXL15.7HXA
IVECO	6VEXL04.5DGT
	6VEXL04.5DGN
	6VEXL06.7DGA
	6VEXL06.7DGB
	6VEXL06.7DGS
Komatsu	6KLXL0239AAD
	6KLXL0239AAF
	6KLXL0239ADA
	6KLXL0275AAC
	6KLXL0275AAG
	6KLXL0275AAH
	6KLXL03.3JD3
	6KLXL0359AAB
	6KLXL0359AAE
	6KLXL0359AAL
	6KLXL0359ABC
	6KLXL0409AAB
	6KLXL0409AAC
	6KLXL0505ABD
Kubota	6KBXL03.3CCD
Mitsubishi Fuso Truck & Bus Corp	6MFTL05.8D3A
Mitsubishi Heavy Industries	6MVXL05.0AAA
	6MVXL05.0AAD
	6MVXL05.0DDD
	6MVXL06.4DDD
	6MVXL06.4EEE
MotorenFabrik HATZ GMBH	6HZXL3.43C42
	6HZXL3.43V42
Nissan	6NDXL03.0FTA
VMMI	6V5XL04.2G5V
Yanmar	6YDXL3.32J4T
	6YDXL3.32K4T
	6YDXL4.41K4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2007 Engines

Manufacturer	Engine Families
AB Volvo Penta	7VPXL09.4BAA
	7VPXL12.1BAA
	7VPXL16.1ACB
Caterpillar	7CPXL07.2ESL
	7CPXL08.8ESK
	7CPXL11.1ESK
	7CPXL12.5ESK
	7CPXL15.2ESK
	7CPXL15.2ESL
	7CPXL18.1ESK
	7CPXL18.1ESL
	7CPXL27.0ESK
	7CPXL32.0ESK
	7CPXL51.8E2W
	7CPXL78.1ERK
	7CPXL34.5T2E
	7CPXL58.6T2E
	7CPXL78.1T2E
CNH Engine Corp.	7X9XL0505AAE
	7X9XL0540AAB
	7X9XL0239AAB
	7NHXL04.5DAA
	7NHXL04.5DCA
	7NHXL06.7DAA
	7NHXL06.7DCA
	7NHXL06.7DCB
	7NHXL06.7DTA
	7NHXL06.7DTC
Cummins	7CEXL015.AAA
	7CEXL015.AAB
	7CEXL015.AAE
	7CEXL019.AAD
	7CEXL023.AAA
	7CEXL0239AAG
	7CEXL0275AAC
	7CEXL0275AAG
	7CEXL0275AAH
	7CEXL03.3ABA
	7CEXL03.3ABB
	7CEXL03.3ACA
	7CEXL03.3ACB
	7CEXL030.AAB
	7CEXL030.AAD

Model Year 2007 Engines (Continued)

Manufacturer	Engine Families
Cummins (cont.)	7CEXL030.ABA
	7CEXL038.AAA
	7CEXL0409AAB
	7CEXL0409AAC
	7CEXL045.AAA
	7CEXL050.AAC
	7CEXL050.AAD
	7CEXL050.ABA
	7CEXL0505AAE
	7CEXL0540AAB
	7CEXL060.AAB
	7CEXL060.AAD
	7CEXL0661AAF
	7CEXL0661AAG
	7CEXL0661AAH
	7CEXL0661AAJ
	7CEXL078.AAA
	7CEXL078.AAB
DAIMLERCHRYSLER	7MBXL12.8RJB
	7MBXL15.9RJA
Deere	7JDXL03.0064
	7JDXL04.5075
	7JDXL04.5076
	7JDXL04.5081
	7JDXL04.5083
	7JDXL06.8038
	7JDXL06.8039
	7JDXL06.8041
	7JDXL06.8044
	7JDXL06.8048
	7JDXL06.8049
	7JDXL06.8078
	7JDXL06.8080
	7JDXL06.8084
	7JDXL06.8101
	7JDXL06.8104
	7JDXL06.8105
	7JDXL06.8106
	7JDXL08.1037
	7JDXL09.0102
	7JDXL12.5035
	7JDXL12.5073
	7JDXL13.5103

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2007 Engines (Continued)

Manufacturer	Engine Families
Detroit Diesel Corporation	7DDXL14.0VLD
	7DDXL14.0WLD
Deutz	7DZXL03.1039
	7DZXL03.1040
	7DZXL03.1066
	7DZXL06.1038
	7DZXL06.1059
	7DZXL06.1060
	7DZXL06.1061
	7DZXL06.1063
	7DZXL06.5042
	7DZXL06.5043
	7DZXL07.1051
	7DZXL07.1053
	7DZXL07.1055
	7DZXL15.9065
Doosan Infracore	7DWXL05.8CRN
	7DWXL05.8UTA
	7DWXL07.6UPA
	7DWXL11.0UJA
	7DWXL21.9UYA
GNH UK LTD	7NHXL06.7DCC
Hino Motors	7HMXL05.1JTA
	7HMXL07.7JTM
	7HMXL10.5PUN
Ishikawajima-Shibaura Machinery	7H3XL2.22N4L
Isuzu	7SZXL03.0IXA
	7SZXL03.1GNA
	7SZXL03.1GNB
	7SZXL03.1GTB
	7SZXL04.3GTG
	7SZXL04.3GXA
	7SZXL05.2HXA
	7SZXL05.2IXA
	7SZXL07.8HXA
	7SZXL07.8HXB
	7SZXL09.8HXA
	7SZXL15.7HXA

Model Year 2007 Engines (Continued)

Manufacturer	Engine Families
IVECO	7VEXL03.9B1Z
	7VEXL04.5DAA
	7VEXL04.5DGN
	7VEXL04.5DGT
	7VEXL06.7DAA
	7VEXL06.7DCA
	7VEXL06.7DCB
	7VEXL06.7DCC
	7VEXL06.7DGB
	7VEXL06.7DGS
	7VEXL06.7DTA
	7VEXL06.7DTC
	7VEXL08.7TR3
	7VEXL10.3MLR
	7VEXL12.9IGR
	7VEXL12.9MLR
	7VEXL12.9TR3
	7VEXL20.1DSL
Komatsu	7KLXL0239ADA
	7KLXL0275AAC
	7KLXL0275AAG
	7KLXL0275AAH
	7KLXL03.3JA3
	7KLXL03.3JB3
	7KLXL03.3JD3
	7KLXL03.3JD6
	7KLXL03.3JD7
	7KLXL0359AAE
	7KLXL038.AAA
	7KLXL0409AAB
	7KLXL0409AAC
	7KLXL045.AAA
	7KLXL050.AAC
	7KLXL0505AAE
	7KLXL060.AAB
	7KLXL078.AAA
	7klxl11.0DD6
	7KLXL11.0DD6
	7KLXL15.2ED6
	7klxl15.2ED6
	7KLXL15.2ED7
	7KLXL23.2FD6
	7KLXL30.5GD3

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2007 Engines (Continued)

Manufacturer	Engine Families
Kubota	7KBXL02.0FAD
	7KBXL02.4HCD
	7KBXL03.3BAC
	7KBXL03.3BAD
	7KBXL03.3BBD
	7KBXL03.3BCC
	7KBXL03.3BCD
	7KBXL03.3CCD
	7KBXL03.8AHD
Lombardini S.R.L.	7LBDL2.19CHT
MAHINDRA & MAHINDRA LTD.,	7MMLL03.1NEF
	7MMLL03.2NEF
	7MMLL03.2NET
	7MMLL03.4NEF
	7MMLL03.5NEF
Mitsubishi Fuso Truck & Bus Corp	7MFTL02.8M4A
	7MFTL04.9M5A
	7MFTL07.5M6A
	7MFTL12.9M7A
Mitsubishi Heavy Industries	7MVXL05.0AAA
	7MVXL05.0AAC
	7MVXL05.0AAD
	7MVXL06.4FFF
	7MVXL24.5BBA
	7MVXL33.9BBA
	7MVXL37.1BBA
	7MVXL49.0BBA
	7MVXL65.4BBA
MotorenFabrik HATZ GMBH	7HZXL2.57C41
	7HZXL3.43C42
	7HZXL3.43V42
MTU Detroit Diesel, Inc.	7MDDL31.8XRR
Nissan	7NDXL02.7TNA
	7NDXL03.0FTA
	7NDXL03.2TNA

Model Year 2007 Engines (Continued)

Manufacturer	Engine Families
Perkins Engines	7PKXL03.3DC1
	7PKXL03.3DD1
	7PKXL04.4NH1
	7PKXL04.4NJ1
	7PKXL04.4RE1
	7PKXL04.4RF1
	7PKXL06.6PJ1
	7PKXL06.6PJ2
	7PKXL15.2TA2
	7PKXL15.2TAG
	7PKXL18.1TAG
SCANIA CV AB	7Y9XL11.7BBA
	7Y9XL11.7BBB
	7Y9XL15.6BDE
Shandong Weichai Huafeng Power	7SDWL4.33BBB
	7SDWL7.52AAA
Sisu Diesel	7SIDL03.3G4A
	7SIDL04.4J2A
	7SIDL07.4G4D
	7SIDL07.4G4E
	7SIDL07.4G5B
	7SIDL07.4G5C
	7SIDL08.4H5B
Volvo Construction Equipment AB	7VSXL09.4CE3
	7VSXL12.1CE3
	7VSXL16.1CE3
Yanmar	7YDXL3.05M4N
	7YDXL3.05P4N
	7YDXL3.32J4N
	7YDXL3.32J4T
	7YDXL3.32K4T
	7YDXL3.32P4N
	7YDXL4.41K4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2008 Engines

Manufacturer	Engine Families
AB Volvo Penta	8VPXL09.4BAA
	8VPXL12.1BAA
	8VPXL12.8BCA
	8VPXL16.1ACB
	8VPXL16.1ACW
Caterpillar	8CPXL07.2ESL
	8CPXL08.8ESK
	8CPXL106.T2E
	8CPXL11.1ESK
	8CPXL12.5ESK
	8CPXL15.2ELW
	8CPXL15.2ESW
	8CPXL18.1ESK
	8CPXL18.1ESW
	8CPXL18.1ESX
	8CPXL27.0ESK
	8CPXL27.0ESW
	8CPXL27.0ESX
	8CPXL32.0ESW
	8CPXL32.0ESX
	8CPXL34.5E2W
	8CPXL34.5T2E
	8CPXL51.8E2W
	8CPXL58.6T2E
	8CPXL58.6T2X
	8CPXL78.1E2W
	8CPXL78.1T2E
CNH Engine	8X9XL0540AAB
CNH UK LTD	8NHXL04.5DAA
	8NHXL04.5DAB
	8NHXL04.5DCA
	8NHXL04.5DCB
	8NHXL06.7DAA
	8NHXL06.7DCA
	8NHXL06.7DCB
	8NHXL06.7DCC

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
Cummins	8CEXL015.AAA
	8CEXL015.AAB
	8CEXL015.AAE
	8CEXL015.AAH
	8CEXL015.AAJ
	8CEXL019.AAD
	8CEXL023.AAA
	8CEXL023.AAB
	8CEXL023.AAC
	8CEXL0275AAG
	8CEXL0275AAH
	8CEXL0275AAK
	8CEXL03.3ACA
	8CEXL03.3ACB
	8CEXL03.3ACD
	8CEXL03.3ACE
	8CEXL030.AAB
	8CEXL030.AAD
	8CEXL030.ABA
	8CEXL0409AAB
	8CEXL0409AAC
	8CEXL0409AAD
	8CEXL045.AAA
	8CEXL050.AAA
	8CEXL050.AAC
	8CEXL050.AAD
	8CEXL050.ABA
	8CEXL0505AAE
	8CEXL0540AAB
	8CEXL060.AAB
	8CEXL060.AAD
	8CEXL0661AAF
	8CEXL0661AAG
	8CEXL0661AAH
	8CEXL0661AAJ
	8CEXL078.AAA
	8CEXL078.AAB
	8CEXL2.28A41

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
DAIMLERCHRYSLER	8MBXL07.2RJA
	8MBXL12.8RJB
	8MBXL15.9RJA
Detroit Diesel	8DDXL14.0VLD
Deutz	8DZXL02.3099
	8DZXL02.7096
	8DZXL03.2088
	8DZXL03.6081
	8DZXL03.6082
	8DZXL03.6084
	8DZXL03.6086
	8DZXL03.6097
	8DZXL03.6098
	8DZXL04.1069
	8DZXL04.1070
	8DZXL04.1076
	8DZXL04.1078
	8DZXL04.1079
	8DZXL04.1080
	8DZXL04.8064
	8DZXL04.8068
	8DZXL04.8071
	8DZXL05.4087
	8DZXL06.1057
	8DZXL06.1059
	8DZXL06.1060
	8DZXL06.1061
	8DZXL06.1063
	8DZXL06.1067
	8DZXL06.1077
	8DZXL06.5074
	8DZXL06.5075
	8DZXL07.1051
	8DZXL07.1053
	8DZXL07.1055
	8DZXL07.1056
	8DZXL15.9065
DOOSAN INFRACORE	8DWXL05.8UTA
	8DWXL07.6UPA
	8DWXL11.0UJA
	8DWXL21.9UYA
HINO MOTORS	8HMXL05.1JTA

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
Ishikawajima	8H3XL2.00N4T
	8H3XL2.22N4L
	8H3XL2.22N4T
Isuzu	8SZXL02.2UTA
	8SZXL02.2UXA
	8SZXL03.0IXA
	8SZXL03.0JTA
	8SZXL03.0JXA
	8SZXL03.0JXB
	8SZXL03.0UTB
	8SZXL05.2HXA
	8SZXL05.2IXA
	8SZXL05.2IXB
	8SZXL07.8HXA
	8SZXL07.8HXB
	8SZXL09.8HXA
	8SZXL09.8HXB
	8SZXL15.7HXA
	8SZXL15.7HXB
IVECO	8VEXL03.2TAI
	8VEXL03.2TCE
	8VEXL03.2TCI
	8VEXL04.5DAA
	8VEXL04.5DAB
	8VEXL04.5DCA
	8VEXL04.5DCB
	8VEXL06.7DAA
	8VEXL06.7DCA
	8VEXL06.7DCB
	8VEXL06.7DCC
	8VEXL06.7DGB
	8VEXL06.7DGS
	8VEXL08.7TR3
	8VEXL10.3MLR
	8VEXL10.3TR3
	8VEXL12.9IGR
	8VEXL12.9MLR
	8VEXL12.9TCD
	8VEXL20.1DSL
JCB Power Systems	8JCBL04.4TA7
	8JCBL04.4TA8
	8JCBL04.4TAE
	8JCBL04.4TC6

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
John Deere Power	8JDXL03.0064
	8JDXL03.0208
	8JDXL04.5075
	8JDXL04.5083
	8JDXL04.5107
	8JDXL06.8038
	8JDXL06.8039
	8JDXL06.8041
	8JDXL06.8049
	8JDXL06.8078
	8JDXL06.8080
	8JDXL06.8101
	8JDXL06.8104
	8JDXL06.8105
	8JDXL06.8106
	8JDXL08.1037
	8JDXL09.0102
	8JDXL09.0114
	8JDXL12.5035
	8JDXL13.5103
Komatsu	8KLXL0275AAG
	8KLXL0275AAH
	8KLXL03.3JA6
	8KLXL03.3JB6
	8KLXL03.3JD6
	8KLXL03.3JD7
	8KLXL03.3JD9
	8KLXL0409AAB
	8KLXL0409AAC
	8KLXL050.AAA
	8KLXL050.AAC
	8KLXL0505AAE
	8KLXL060.AAA
	8KLXL060.AAB
	8KLXL078.AAA
	8KLXL11.0DD6
	8KLXL15.2ED6
	8KLXL15.2ED7
	8KLXL23.2FD5
	8KLXL23.2FD6
	8KLXL23.2FD7
	8KLXL30.5GD3

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
Kubota	8KBXL02.4FAD
	8KBXL02.4HAD
	8KBXL02.6EAD
	8KBXL03.3CAD
	8KBXL03.6BAC
	8KBXL03.6BAD
	8KBXL03.6BCD
	8KBXL03.6DAD
	8KBXL03.8AAC
	8KBXL03.8AGD
Kukje Machinery	8KMCL2.28A41
M/S. SIMPSON & C.	8SCLL02.7V50
Liebherr Machines	8LHAL10.5LPA
	8LHAL10.5LPE
	8LHAL12.0KPA
	8LHAL12.8RMC
	8LHAL24.2VCE
	8LHAL9.54SPA
Liebherr Werk	8LHAL21.9VMR
Mitsubishi	8MVXL02.5HHH
	8MVXL03.3AAC
	8MVXL04.2BBB
	8MVXL04.2CCC
	8MVXL05.0AAD
	8MVXL05.0AAG
	8MVXL06.4FFF
	8MVXL24.5BBA
	8MVXL33.9BBA
	8MVXL37.1BBA
	8MVXL49.0BBA
	8MVXL65.4BBA
MAHINDRA & MAHINDRA	8MMLL02.5N52
	8MMLL02.5N57
	8MMLL02.5N59
	8MMLL02.5N62
	8MMLL02.5N64
	8MMLL02.7M30
	8MMLL03.3N75
	8MMLL03.3N79

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2008 Engines (Continued)

Manufacturer	Engine Families
MOTORENFABRIK	8HZXL3.43C42
	8HZXL3.43V42
MTU DETROIT DIESEL,	8MDDL31.8XRR
	8MDDL35.8GRR
	8MDDL95.4XTR
NISSAN DIESEL	8NDXL03.2TNA
	8NDXL04.2TNA
Perkins Engines	8PKXL04.4NH1
	8PKXL04.4NJ1
	8PKXL04.4NJ2
	8PKXL04.4NM1
	8PKXL04.4RG3
	8PKXL06.6PJ1
	8PKXL06.6PJ2
	8PKXL15.2TA2
	8PKXL15.2TAG
	8PKXL18.1TAG
Scania	8Y9XL11.7BBA
	8Y9XL11.7BBB
	8Y9XL15.6BDE
Volvo	8VSXL09.4CE3
	8VSXL12.1CE3
	8VSXL16.1CE3
Yanmar	8YDXL2.00N4T
	8YDXL3.32C4N
	8YDXL3.32C4T
	8YDXL3.32R4N
	8YDXL3.32M4N
	8YDXL3.32M4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2009 Engines

Manufacturer	Engine Families
AB Volvo Penta	9VPXL09.4BAA
	9VPXL12.1BAA
	9VPXL12.8BCA
	9VPXL16.1ACB
	9VPXL16.1ACW
	9VPXL16.1BEA
	9VSXL09.4CE3
	9VSXL12.1CE3
	9VSXL16.1CE3
Caterpillar	9CPXL07.2ESL
	9CPXL08.8ESK
	9CPXL106.T2E
	9CPXL11.1ESK
	9CPXL12.5ESK
	9CPXL12.5ESX
	9CPXL14.2ELW
	9CPXL15.2ESW
	9CPXL18.1ESK
	9CPXL18.1ESW
	9CPXL18.1ESX
	9CPXL27.0ESK
	9CPXL27.0ESW
	9CPXL27.0ESX
	9CPXL27.0ESX
	9CPXL32.0ESP
	9CPXL32.0ESW
	9CPXL32.0ESX
	9CPXL34.5T2C
	9CPXL34.5T2E
	9CPXL58.6T2E
	9CPXL58.6T2X
	9CPXL58.6T2Y
	9CPXL78.1E2W
	9CPXL78.1T2E
CNH UK LTD	9NHXL04.5DAA
	9NHXL04.5DAB
	9NHXL04.5DCA
	9NHXL04.5DCB
	9NHXL06.7DAA
	9NHXL06.7DCA
	9NHXL06.7DCB
	9NHXL06.7DCC

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
Cummins	9CEXL015.AAA
	9CEXL015.AAE
	9CEXL015.AAH
	9CEXL015.AAJ
	9CEXL019.AAD
	9CEXL023.AAA
	9CEXL023.AAB
	9CEXL023.AAC
	9CEXL0275AAG
	9CEXL0275AAH
	9CEXL0275AAK
	9CEXL03.3ACA
	9CEXL03.3ACB
	9CEXL03.3ACD
	9CEXL03.ACE
	9CEXL030.AAB
	9CEXL030.AAD
	9CEXL030.ABA
	9CEXL0409AAB
	9CEXL0409AAC
	9CEXL0409AAD
	9CEXL045.AAA
	9CEXL050.AAA
	9CEXL050.AAC
	9CEXL050.AAD
	9CEXL050.AAF
	9CEXL050.ABA
	9CEXL0505AAE
	9CEXL0540AAB
	9CEXL0540AAD
	9CEXL060.AAB
	9CEXL060.AAD
	9CEXL0661AAF
	9CEXL0661AAG
	9CEXL0661AAH
	9CEXL0661AAJ
	9CEXL078.AAA
	9CEXL2.28A41

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
Detroit Diesel	9DDXL14.DVLD
Deutz	9DXZL04.8071
	9DZL04.8073
	9DZXL02.3048
	9DZXL02.3099
	9DZXL02.7096
	9DZXL03.2088
	9DZXL03.6081
	9DZXL03.6082
	9DZXL03.6084
	9DZXL03.6086
	9DZXL03.6097
	9DZXL03.6098
	9DZXL04.1069
	9DZXL04.1070
	9DZXL04.1072
	9DZXL04.1076
	9DZXL04.1078
	9DZXL04.1079
	9DZXL04.1080
	9DZXL04.8064
	9DZXL04.8068
	9DZXL06.1057
	9DZXL06.1059
	9DZXL06.1060
	9DZXL06.1061
	9DZXL06.1063
	9DZXL06.1067
	9DZXL06.1077
	9DZXL06.5074
	9DZXL07.1051
	9DZXL07.1053
	9DZXL07.1055
	9DZXL07.1056
	9DZXL15.9065
DOOSAN INFRACORE	9DICL05.8UTA
	9DICL07.6UPA
	9DICL11.0UJA

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
HINO MOTORS	9HMXL04.0NUA
	9HMXL05.1JTA
	9HMXL07.7JTM
	9HMXL10.5PUN
	9HMXL10.5PUP
	9HXML12.9EUV
Isuzu	9SZXL02.2UXA
	9SZXL03.0IXA
	9SZXL03.0JTA
	9SZXL03.0JXA
	9SZXL03.0JXB
	9SZXL03.0UTB
	9SZXL05.2HXA
	9SZXL05.2IXA
	9SZXL05.2IXB
	9SZXL07.8HXA
	9SZXL07.8HXB
	9SZXL09,8HXA
	9SZXL09.8HXB
	9SZXL15.7HXA
	9SZXL15.7HXB
IVECO	9VEXL03.2TCE
	9VEXL03.2TCI
	9VEXL04.4DCB
	9VEXL04.5DAA
	9VEXL04.5DAB
	9VEXL04.5DCA
	9VEXL06.7DAA
	9VEXL06.7DCA
	9VEXL06.7DCB
	9VEXL06.7DCC
	9VEXL06.7DGB
	9VEXL06.7DGS
	9VEXL08.7TR3
	9VEXL10.3MLR
	9VEXL10.3TR3
	9VEXL12.9IGR
	9VEXL12.9MLR
	9VEXL12.9TCD
	9VEXL20.1DSL

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
JCB Power Systems	9JCBL04.4TA7
	9JCBL04.4TA8
	9JCBL04.4TAE
	9JCBL04.4TC6
John Deere Power	9JDXL03.0064
	9JDXL03.0113
	9JDXL03.0203
	9JDXL03.0208
	9JDXL04.5083
	9JDXL04.5107
	9JDXL06.8049
	9JDXL06.8080
	9JDXL06.8104
	9JDXL06.8105
	9JDXL06.8106
	9JDXL08.1037
	9JDXL09.0102
	9JDXL09.0114
	9JDXL13.5103
Komatsu	9KLXL0275AAG
	9KLXL0275AAH
	9KLXL03.3JA6
	9KLXL03.3JB6
	9KLXL03.3JD6
	9KLXL03.3JD7
	9KLXL0409AAB
	9KLXL0409AAC
	9KLXL050.AAA
	9KLXL050.AAC
	9KLXL0505AAE
	9KLXL060.AAA
	9KLXL060.AAB
	9KLXL11.0DD6
	9KLXL15,2ED7
	9KLXL15.2ED6
	9KLXL23.2FD5
	9KLXL23.2FD6
	9KLXL23.2FD7
	9KLXL30.5GD3
	9XLXL03.3JD9

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
Kubota	9KBXL02.4FAD
	9KBXL02.4HAD
	9KBXL02.6EAD
	9KBXL03.3CAD
	9KBXL03.6BAC
	9KBXL03.6BAD
	9KBXL03.6BCD
	9KBXL03.6DAD
	9KBXL03.8AAC
	9KBXL03.8AGD
	9KBXL03.8AHD
	9KBXL06.1AHD
Kukje Machinery	9KMCL2.28A41
Liebherr Machines	9LHAL10.5LPA
	9LHAL10.5LPE
	9LHAL12.0KPA
	9LHAL12/8RMC
	9LHAL24.2VCE
	9LHAL24.2VCI
LOMBARDINI MOTORI	9LBDL2.19CH2
Mitsubishi	9MFTL02.8M4B
	9MFTL04.9M5A
	9MFTL07.5M6A
	9MFTL12.9M7A
	9MVXL03.3AAC
	9MVXL03.3AAH
	9MVXL04.2BBB
	9MVXL04.2CCC
	9MVXL05.0AAD
	9MVXL06.4FFF
	9MVXL24.5BBA
	9MVXL33.9BBA
	9MVXL37.1BBA
	9MVXL49.0BBA
	9MVXL65.4BBA

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2009 Engines (Continued)

Manufacturer	Engine Families
MOTORENFABRIK	9HZXL2.57C41
	9HZXL2.57V41
	9HZXL3.43C42
	9HZXL3.43V42
MTU DETROIT DIESEL	9MDDL31.8XRR
	9MDDL35.8GRR
NAVISTAR	9NVXL0466ANA
NISSAN DIESEL	9NDXL03.2TNA
	9NDXL04.2TNA
Perkins Engines	9PKXL04.4NJ1
	9PKXL04.4NJ2
	9PKXL04.4NM1
	9PKXL04.4NM2
	9PKXL04.4RG3
	9PKXL06.6PJ1
	9PKXL06.6PJ2
	9PKXL12.5TAG
	9PKXL15.2TAG
	9PKXL15.2TAG
	9PKXL18.1TAG
Scania	9Y9XL11.7BBA
	9Y9XL11.7BBB
	9Y9XL15.6BDE
TOYOTA INDUSTRIAL	9TALL02.51DZ
Yanmar	9YDXL2.00N4T
	9YDXL3.05K4N
	9YDXL3.32C4N
	9YDXL3.32C4T
	9YDXL3.32M4N
	9YDXL3.32M4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2010 Engines

Manufacturer	Engine Families
AB Volvo Penta	AVPXL16.1ACB
	AVPXL16.1ACG
	AVPXL16.1ACW
Caterpillar	ACPXL08.8ESX
	ACPXL12.5ESK
	ACPXL15.2ELW
	ACPXL15.2ESW
	ACPXL15.2ESX
	ACPXL18.1ESW
	ACPXL27.0ESW
	ACPXL27.0ESX
	ACPXL32.0ESW
	ACPXL32.0ESX
	ACPXL34.5T2C
	ACPXL34.5T2E
	ACPXL58.6T2E
	ACPXL58.6T2X
	ACPXL58.6T2Y
	ACPXL78.1T2E
	ACPXL78.1T2X
	ACPXL78.1T2Y
	ACPXL106.T2E
Cummins	ACEXL03.3ACD
	ACEXL03.3ACE
	ACEXL015.AAJ
	ACEXL023.AAA
	ACEXL023.AAB
	ACEXL030.AAD
	ACEXL050.AAD
	ACEXL050.ABA
	ACEXL060.AAD
	ACEXL060.AAE
	ACEXL0275AAG
	ACEXL0275AAK
	ACEXL0409AAB
	ACEXL0409AAC
	ACEXL0409AAD
	ACEXL0540AAB
	ACEXL0540AAC
	ACEXL0540AAD
	ACEXL0505AAE
	ACEXL0661AAG

Model Year 2010 Engines (continued)

Manufacturer	Engine Families
Detroit Diesel	ADDXL14.0WLD
Deutz	ADZXL07.1052
Doosan Infracore	ADICL21.9UYA
	ADICL18.3USA
IVECO	AVEXL06.7DGB
	AVEXL06.7DGS
	AVEXL08.7TR3
	AVEXL10.3MLR
	AVEXL10.3TR3
	AVEXL12.9IGR
	AVEXL12.9MLR
	AVEXL12.9TCD
	AVEXL20.1DSL
JCB Power	AJCBL04.4TA7
	AJCBL04.4TC6
John Deere	AJDXL06.8049
	AJDXL08.1037
	AJDXL03.0206
	AJDXL03.0064
	AJDXL03.0203
	AJDXL02.4207
	AJDXL04.5083
	AJDXL09.0114
	AJDXL04.5107
	AJDXL06.8078
	AJDXL06.8106
	AJDXL06.8104
	AJDXL03.0113
	AJDXL08.1037
Komatsu	AKLXL03.3JA6
	AKLXL03.3JB6
	AKLXL23.2FD5
	AKLXL30.5GD3
	AKLXL0275AAG
	AKLXL0409AAB
	AKLXL0409AAC
	AKLXL0505AAE
Kukje Machinery	AKMCL2.39A44

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2010 Engines (continued)

Manufacturer	Engine Families
Mitsubishi	AMVXL04.2CCC
	AMVXL24.5BBA
	AMVXL33.9BBA
	AMVXL37.1BBA
	AMVXL49.0BBA
	AMVXL65.4BBA
	AMVXL65.4BBB
MTU	AMDDL95.4XTR
	AMDDL31.8XRR
	AMDDL35.8GRR
	AMDDL21.0GWR
	AMDDL14.0GWK
Perkins Engines	APKXL04.4NJ1
	APKXL06.6PJ2
	APKXL12.5TAG
	APKXL15.2TA2
	APKXL15.2TAG
	APKXL18.1TAG
SCANIA	AY9XL11.7BBA
	AY9XL11.7BBB
	AY9XL15.6BDE
VM Motori	AV5XL04.5T60
Yanmar	AYDXL3.32R4N

Model Year 2011 Engines

Manufacturer	Engine Family
AGCO Sisu Power	BSIDL07.4G4E
	BSIDL07.4G5C
Caterpillar Inc.	BCPXL08.8NZS
	BCPXL11.1ESK
	BCPXL12.5ESK
	BCPXL15.2ESW
	BCPXL15.2NYS
	BCPXL15.2NZS
	BCPXL18.1ESK
	BCPXL18.1NYS
	BCPXL18.1NZS
	BCPXL27.0NZS
	BCPXL32.0NZS
CNH UK LTD.	BNHXL04.5DAA
	BNHXL04.5DAB
	BNHXL04.5DCA
	BNHXL06.7DAA
	BNHXL06.7DCA
	BNHXL06.7DCB
	BNHXL06.7DCC
Cummins Inc.	BCEXL03.3ACA
	BCEXL03.3ACB
	BCEXL03.3ACD
	BCEXL03.3ACE
	BCEXL015.AAJ
	BCEXL030.AAD
	BCEXL0409AAC
	BCEXL050.AAC
	BCEXL050.AAD
	BCEXL060.AAB
	BCEXL060.AAD
	BCEXL050.AAB
	BCEXL0275AAG
	BCEXL0275AAH
Hyundai Motor Co	BHYXL03.9TDI
Ishikawarajima Shibaura	BH3XL2.22N4L
IHI Shibaura Machinery Corporation	BH3XL2.00N4T

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2011 Engines (continued)

Manufacturer	Engine Family
Iveco	BVEXL03.2TAI
	BVEXL03.2 TCI
	BVEXL04.5DAA
	BVEXL04.5DAB
	BVEXL04.5DCA
	BVEXL06.7DAA
	BVEXL06.7DCA
	BVEXL06.7DCB
	BVEXL06.7DCC
	BVEXL08.7TR3
JCB Power Systems	BJCBL04.4TAE
	BJCBL04.4TA7
	BJCBL04.4TA8
	BJCBL04.4TC6
John Deere Power Systems	BJDXL02.9050
	BJDXL03.0064
	BJDXL03.0113
	BJDXL03.0203
	BJDXL03.0206
	BJDXL03.0208
	BJDXL04.5107
	BJDXL06.8078
	BJDXL06.8104
	BJDXL06.8105
	BJDXL06.8106
	BJDXL06.8117
Komatsu Ltd	BKLXL03.3JA6
	BKLXL03.3JB6
	BKLXL03.3JD6
	BKLXL03.3JD7
	BKLXL03.3JD9
	BKLXL050.AAC
	BKLXL0275AAG
	BKLXL0275AAH
	BKLXL0409AAC
Kubota	BKBXL02.4HAD
	BKBXL03.6BCD
Kukje	BKMCL2.28A41
	BKMCL2.39A44
Mitsubishi Fuso Truck	BMFTL02.8M4B

Model Year 2011 Engines (continued)

Manufacturer	Engine Family
Mitsubishi Heavy Industries	BMVXL022.5HHH
	BMVXL03.3AAC
	BMVXL03.3AAH
	BMVXL04.2BBB
	BMVXL04.2CCC
	BMVXL05.0AAD
	BMVXL05.0AAG
	BMVXL06.4FFF
MTU	BMDDL35.8GRR
	BMDDL14.0ZWK
	BMDDL21.0ZWR
	BMDDL31.8XRR
	BMDDL95.4XTR
Perkins	BPKXL04.4NJ1
	BPKXL04.4NJ2
	BPKXL04.4NM1
	BPKXL04.4NM2
	BPKXL04.4RG3
	BPKXL06.6PJ2
	BPKXL06.6PJ3
Toyota Industrial	BTALL02.51DZ
UD Trucks Corp	BNDXL03.2TNA
	BNDXL04.2TNA
VM Motori S.P.A.	BV5XL04.5T60

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2012 Engines

Manufacturer	Engine Family
Caterpillar Inc.	CCPXL11.1ESK
	CCPXL12.5ESK
	CCPXL15.2ESW
	CCPXL18.1ESK
	CCPXL08.8ESJ
	CCPXL07.2ESJ
	CCPXL11.1ESJ
	CCPXL12.5ESJ
	CCPXL15.2ESJ
	CCPXL18.1ESJ
	CCPXL27.0NZS
	CCPXL08.8NZS
	CCPXL15.2NYS
	CCPXL18.1NZS
	CCPXL32.0NZS
	CCPXL15.2NZS
	CCPXL18.1NYS
	CCPXL78.1NZS
	CCPXL106.NZS
Cummins	CCEXL0275AAK
	CCEXL0409AAD
	CCEXL0275AAG
	CCEXL0409AAB
	CCEXL0409AAC
	CCEXL030.AAD
	CCEXL0540AAB
	CCEXL050.AAD
	CCEXL015.AAH
	CCEXL0505AAE
	CCEXL015.AAJ
	CCEXL019.AAD
	CCEXL023.AAB
	CCEXL03.3ACE
	CCEXL15.0AAI
DETROIT DIESEL	CDDXL14.0WLD
DOOSAN	CDICL21.9UYA
	CDICL18.3USA

Model Year 2012 Engines (continued)

Manufacturer	Engine Family
FPT INDUSTRIAL S.P.	CFPXL06.7DGB
	CFPXL06.7DGS
	CFPXL08.7TR3
	CFPXL10.3TR3
	CFPXL03.2TAI
John Deere Power Systems	CJDXL03.0203
	CJDXL09.0140
	CJDXL09.0114
	CJDXL03.0113
	CJDXL13.5103
	CJDXL04.5119
	CJDXL04.5107
	CJDXL13.5132
Komatsu Ltd	CKLXL03.3JA6
	CKLXL23.2FD5
	CKLXL03.3JD9
Kubota	CKBXL03.6BCD
KUKJE MACHINERY	CKMCL3.41D43
Mitsubishi Fuso Truck	CMFTL02.8M4B
MTU DD	CMDDL57.2XTC
	CMDDL31.8XRR
	CMDDL35.8GRR
	CMDDL14.0ZWK
	CMDDL21.0ZW R
	CMDDL95.4XTR
PERKINS	CPKXL06.6PJ2
	CPKXL04.4NH1
	CPKXL04.4NJ1
	CPKXL12.5TAG
	CPKXL15.2TA2
	CPKXL18.1TAG
	CPKXL15.2TAG
	CPKXL06.6PJ3

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2012 Engines (continued)

Manufacturer	Engine Family
SIMPSON & CO LIMITED	CSCLL03.6V74
TIEM	CTIEL05.26CA
VPX	CVPXL16.1ACG
	CVPXL16.1ACB
	CVPXL16.1ACW

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2013 Engines

Manufacturer	Engine Family
Caterpillar Inc.	DCPXL07.2ESJ
	DCPXL08.8ESJ
	DCPXL08.8NZS
	DCPXL11.1ESJ
	DCPXL11.1ESK
	DCPXL12.5ESJ
	DCPXL12.5ESK
	DCPXL15.2ESJ
	DCPXL15.2ESW
	DCPXL15.2NYS
	DCPXL15.2NZS
	DCPXL18.1ESJ
	DCPXL18.1ESK
	DCPXL18.1NYS
	DCPXL18.1NZS
	DCPXL27.0NZS
	DCPXL32.0NZS
	DCPXL78.1NZS
	DCPXL106.NZS
Cummins	DCEXL015.AAH
	DCEXL015.AAJ
	DCEXL15.0AAI
	DCEXL019.AAD
	DCEXL023.AAB
	DCEXL0275AAG
	DCEXL0275AAK
	DCEXL03.3ACE
	DCEXL030.AAD
	DCEXL0409AAB
	DCEXL0409AAC
	DCEXL0409AAD
	DCEXL050.AAD
	DCEXL0505AAE
	DCEXL0540AAB
	DCEXL060.AAD
DETROIT DIESEL	DDDXL14.0WLD
Deutz	DDZXL07.1028
	DDZXL07.1031
	DDZXL07.1032
DOOSAN	DDICL18.3USA
	DDICL21.9UYA

Model Year 2013 Engines (continued)

Manufacturer	Engine Family
FPT INDUSTRIAL S.P.	DFPXL06.7DGB
	DFPXL06.7DGS
	DFPXL08.7TR3
	DFPXL10.3TR3
John Deere Power Systems	DJDXL04.5119
	DJDXL06.8104
	DJDXL06.8106
	DJDXL06.8115
	DJDXL06.8120
	DJDXL09.0114
	DJDXL13.5103
	DJDXL13.5132
Komatsu Ltd	DKLXL23.2FD5
Mitsubishi	DMVXL33.9BBA
	DMVXL37.1BBA
	DMVXL49.0BBA
	DMVXL65.4BBA
	DMVXL65.4BBB
MTU DD	DMDDL14.0ZWK
	DMDDL21.0ZWR
	DMDDL31.8XRR
	DMDDL35.7XNC
	DMDDL35.8GRR
	DMDDL57.2XTC
	DMDDL95.4XTR
PERKINS	DPKXL04.4NJ1
	DPKXL04.4NH1
	DPKXL06.6PJ1
	DPKXL06.6PJ2
	DPKXL06.6PJ3
	DPKXL12.5TAG
	DPKXL15.2TA2
	DPKXL15.2TAG
	DPKXL18.1TAG

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2014 Engines

Manufacturer	Engine Family
Caterpillar Inc.	ECPXL08.8NZS
	ECPXL106.NZS
	ECPXL12.5NYS
	ECPXL15.2NYS
	ECPXL15.2NZS
	ECPXL18.1NYS
	ECPXL18.1NZS
	ECPXL27.0NZS
	ECPXL32.0NZS
	ECPXL78.1NZS
Cummins	ECEXL015.AAH
	ECEXL015.AAJ
	ECEXL019.AAD
	ECEXL023.AAB
	ECEXL0275AAG
	ECEXL0275AAH
	ECEXL0275AAK
	ECEXL03.3ACF
	ECEXL03.3ACG
	ECEXL03.3ACH
	ECEXL03.3ACK
	ECEXL030.AAD
	ECEXL0409AAB
	ECEXL0409AAC
	ECEXL0409AAD
	ECEXL050.AAD
	ECEXL0505AAE
	ECEXL0540AAB
	ECEXL060.AAD
	ECEXL0661AAH
	ECEXL13.0AAA
DETROIT DIESEL	EDDXL14.0WLD
DOOSAN	EDICL18.3USA
	EDICL21.9UYA
FPT INDUSTRIAL S.P.	EFPXL06.7DGB
	EFPXL06.7DGS
	EFPXL08.7TR3
	EFPXL10.3TR3

Model Year 2014 Engines (continued)

Manufacturer	Engine Family
John Deere Power Systems	EJDXL04.5119
	EJDXL04.5141
	EJDXL06.8105
	EJDXL06.8120
	EJDXL09.0114
	EJDXL13.5132
	EJDXL13.5146
ISM	EH3XL2.22N4L
Komatsu Ltd	EKLXL060.AAE
	EKLXL23.2FD5
KUKJE MACHINERY	EKMCL3.41D43
Mitsubishi	EMVXL24.5BBA
	EMVXL33.9BBA
	EMVXL37.1BBA
	EMVXL49.0BBA
	EMVXL65.4BBA
	EMVXL65.4BBB
MTU DD	EMDDL14.0ZWK
	EMDDL21.0ZWR
	EMDDL31.8XRR
	EMDDL35.8GRR
	EMDDL95.4XTR
PERKINS	EPKXL04.4NH1
	EPKXL04.4NH3
	EPKXL04.4NJ2
	EPKXL04.4NJ3
	EPKXL04.4NM1
	EPKXL04.4NM2
	EPKXL06.6PJ1
	EPKXL06.6PJ2
	EPKXL07.0PW1
AB Volvo Penta	EVPXL16.1ACB
	EVPXL16.1ACG
	EVPXL16.1ACW

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2015 Engines

Manufacturer	Engine Family
Caterpillar Inc.	FCPXL08.8NZS
	FCPXL106.NZS
	FCPXL12.5NYS
	FCPXL15.2NYS
	FCPXL15.2NZS
	FCPXL18.1NYS
	FCPXL18.1NZS
	FCPXL27.0NZS
	FCPXL32.0NZS
	FCPXL78.1NZS
Cummins	FCEXL015.AAH
	FCEXL015.AAJ
	FCEXL019.AAD
	FCEXL023.AAB
	FCEXL0275AAG
	FCEXL0275AAH
	FCEXL0275AAK
	FCEXL030.AAD
	FCEXL0409AAB
	FCEXL0409AAC
	FCEXL0409AAD
	FCEXL050.AAD
	FCEXL0505AAE
	FCEXL0540AAB
	FCEXL060.AAD
	FCEXL0661AAH
	FCEXL13.0AAA
	FCEXL95.0AAA
John Deere Power Systems	FJDXL04.5119
	FJDXL04.5141
	FJDXL04.5212
	FJDXL06.8120
	FJDXL09.0114
	FJDXL13.5132
	FJDXL13.5146
DETROIT DIESEL	FDDXL14.0WLD

Model Year 2015 Engines (continued)

Manufacturer	Engine Family
FPT INDUSTRIAL S.P.	FFPXL03.2TCI
	FFPXL04.5DCB
	FFPXL06.7DGB
	FFPXL06.7DGS
	FFPXL08.7TR3
	FFPXL10.3TR3
ISM	FH3XL2.22N4L
Komatsu Ltd	FKLXL23.2FD5
KUKJE MACHINERY	FKMCL3.41D43
MERCEDES-BENZ	FMBXL07.2RJC
Mitsubishi	FMVXL24.5BBA
	FMVXL33.9BBA
	FMVXL37.1BBA
	FMVXL49.0BBA
	FMVXL65.4BBA
MTU DD	FMDDL14.0ZWK
	FMDDL21.0ZWR
	FMDDL31.8XRR
	FMDDL35.8GRR
	FMDDL40.1GNR
	FMDDL95.4XTR
PERKINS	FPKXL04.4NH1
	FPKXL04.4NJ1
	FPKXL04.4NM1
	FPKXL04.4NM2
	FPKXL06.6PJ1
	FPKXL06.6PJ2
	FPKXL07.0PW1
	FPKXL07.0PW2
AB Volvo Penta	FVPXL16.1ACB
	FVPXL16.1ACG
	FVPXL16.1ACW

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2016 Engines

Manufacturer	Engine Family
Caterpillar Inc.	GCPXL08.8NZS
	GCPXL106.NZS
	GCPXL12.5NYS
	GCPXL15.2NYS
	GCPXL15.2NZS
	GCPXL18.1NYS
	GCPXL18.1NZS
	GCPXL27.0NZS
	GCPXL32.0NZS
	GCPXL78.1NZS
Cummins	GCEXL015.AAH
	GCEXL015.AAJ
	GCEXL019.AAD
	GCEXL023.AAB
	GCEXL0275AAG
	GCEXL0275AAH
	GCEXL0275AAK
	GCEXL030.AAD
	GCEXL0409AAB
	GCEXL0409AAC
	GCEXL0409AAD
	GCEXL050.AAD
	GCEXL0505AAE
	GCEXL0540AAB
	GCEXL060.AAD
	GCEXL0661AAH
	GCEXL13.0AAA
	GCEXL95.0AAA
John Deere Power Systems	GJDXL04.5119
	GJDXL04.5141
	GJDXL06.8120
	GJDXL09.0114
	GJDXL13.5132
	GJDXL13.5146
	GJDXL04.5119
DETROIT DIESEL	GDDXL14.0WLD

Model Year 2016 Engines (continued)

Manufacturer	Engine Family
FPT INDUSTRIAL S.P.	GFPXL06.7DGB
	GFPXL06.7DGS
	GFPXL08.7TR3
	GFPXL10.3TR3
	GFPXL12.9IGR
Kubota	GKBXL03.6BAC
KUKJE MACHINERY	GKMCL3.41D43
MERCEDES-BENZ	GMBXL07.2RJC
Mitsubishi	GMVXL03.3CBA
	GMVXL24.5BBA
	GMVXL33.9BBA
	GMVXL37.1BBA
	GMVXL49.0BBA
	GMVXL65.4BBA
MTU DD	GMDDL14.0ZWK
	GMDDL21.0ZWR
	GMDDL31.8XRR
	GMDDL35.8GRR
	GMDDL40.1GNR
	GMDDL95.4GTR
PERKINS	GPKXL04.4NH1
	GPKXL04.4NJ1
	GPKXL04.4NM1
	GPKXL04.4NM2
	GPKXL04.4NP1
	GPKXL04.4NR1
	GPKXL07.0PW1
	GPKXL07.0PW2
AB Volvo Penta	GVPXL16.1ACB
	GVPXL16.1ACG
	GVPXL16.1ACW

Attachment 1: Johnson Matthey CRT(+) Diesel Particulate Filter
Off-Road Certified Engine Family List (0<=0.2 g/bhp-hr PM)

Model Year 2017 Engines

Manufacturer	Engine Family
Caterpillar Inc.	HCPXL08.8NZS
	HCPXL106.NZS
	HCPXL12.5NYS
	HCPXL15.2NYS
	HCPXL15.2NZS
	HCPXL18.1NYS
	HCPXL18.1NZS
	HCPXL27.0NZS
	HCPXL32.0NZS
	HCPXL78.1NZS
Cummins	HCEXL015.AAH
	HCEXL015.AAJ
	HCEXL019.AAD
	HCEXL023.AAB
	HCEXL0275AAG
	HCEXL0275AAK
	HCEXL030.AAD
	HCEXL0409AAB
	HCEXL0409AAC
	HCEXL0409AAD
	HCEXL050.AAD
	HCEXL0505AAE
	HCEXL0540AAB
	HCEXL060.AAD
	HCEXL0661AAH
	HCEXL13.0AAA
	HCEXL95.0AAA
John Deere Power Systems	HJDXL04.5119
	HJDXL06.8120
	HJDXL09.0114
	HJDXL13.5132
	HJDXL13.5146
DETROIT DIESEL	HDDXL14.0WLD
FPT INDUSTRIAL S.P.	HFPXL06.7DGB
	HFPXL06.7DGS
	HFPXL08.7TR3
	HFPXL10.3TR3
	HFPXL12.9IGR

Model Year 2017 Engines (continued)

Manufacturer	Engine Family
KUKJE MACHINERY	HKMCL3.41D43
LMB	HLHAL45.0ESP
MERCEDES-BENZ	HMBXL07.2RJC
Mitsubishi	HMVXL03.3CBA
	HMVXL24.5BBA
	HMVXL33.9BBA
	HMVXL37.1BBA
	HMVXL49.0BBA
	HMVXL65.4BBA
MTU DD	HMDDL21.0ZWR
	HMDDL35.8GRR
	HMDDL40.1GNR
	HMDDL95.4GTR
PERKINS	HPKXL04.4NP1
	HPKXL04.4NR1
	HPKXL07.0PW1
	HPKXL07.0PW2
AB Volvo Penta	HVPXL16.1ACB
	HVPXL16.1ACG
	HVPXL16.1ACW

APPENDIX AIR DR-27

Updated Air Quality Modeling Results

Table 1
Construction 1-hr, 3-hr and 8-hr Model Emission Rates
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

	Emission Rate[1] [lb/hr]						Emission Rate[1] [g/s]					
	NO_x	**CO**	**ROG**	**SO_2**	**Total PM_{10}**	**Total $PM_{2.5}$**	**NO_x**	**CO**	**ROG**	**SO_2**	**Total PM_{10}**	**Total $PM_{2.5}$**
Demolition	4.2	2.8	0.4	0.0	0.22	0.20	0.52	0.35	0.053	6.3E-04	0.028	0.025
Site Preparation	5.3	2.7	0.5	0.0	1.31	0.82	0.67	0.35	0.065	6.2E-04	0.16	0.10
Grading	6.3	4.1	0.6	0.0	0.78	0.46	0.79	0.51	0.071	0.0010	0.10	0.058
Building Construction	4.3	3.6	0.5	0.0	0.58	0.26	0.54	0.46	0.060	0.0013	0.073	0.033
Paving	1.6	1.9	0.2	0.0	0.10	0.08	0.20	0.24	0.023	3.8E-04	0.013	0.010
Architectural Coating	0.2	0.4	46.0	0.0	0.08	0.03	0.026	0.052	5.8	1.2E-04	0.010	0.0037
Max	**6.28**	**4.06**	**45.97**	**0.01**	**1.31**	**0.82**	**0.7914**	**0.5114**	**5.7915**	**0.0013**	**0.1650**	**0.1029**

Notes

1. Emission rates calculated using CalEEMod output rates in pounds/day, divided by 8 hours of assumed construction operation per day

Abbreviations:

lb - pound
g - gram
s - second
hr - hour
NO_x - Nitrous Oxides
CO - carbon monoxide
SO_2 - Sulfur Dioxide
PM - Particulate Matter

Table 2
Construction 24-hr Model Emission Rates
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

	Emission Rate[1] [lb/hr]							Emission Rate[1] [g/s]						
	SO_2	**Exhaust PM_{10}**	**Fugitive PM_{10}**	**Total PM_{10}**	**Exhaust $PM_{2.5}$**	**Fugitive $PM_{2.5}$**	**Total $PM_{2.5}$**	**SO_2**	**Exhaust PM_{10}**	**Fugitive PM_{10}**	**Total PM_{10}**	**Exhaust $PM_{2.5}$**	**Fugitive $PM_{2.5}$**	**Total $PM_{2.5}$**
Demolition	0.0	0.15	0.011	0.16	0.14	0.003	0.14	4.6E-04	0.019	0.0014	0.020	0.018	3.7E-04	0.018
Site Preparation	0.0	0.20	0.753	0.95	0.18	0.410	0.59	4.5E-04	0.025	0.09	0.12	0.023	0.05	0.075
Grading	0.0	0.20	0.370	0.57	0.18	0.151	0.33	7.3E-04	0.025	0.05	0.072	0.023	0.019	0.042
Building Construction	0.0	0.11	0.315	0.42	0.10	0.085	0.19	0.0010	0.014	0.040	0.053	0.013	0.011	0.024
Paving	0.0	0.062	0.011	0.07	0.06	0.003	0.06	2.7E-04	0.0078	0.0014	0.0092	0.0071	3.7E-04	0.0075
Architectural Coating	0.0	0.009	0.048	0.06	0.01	0.013	0.02	8.7E-05	0.0011	0.0060	0.0071	0.0011	0.0016	0.0027
Max	**0.01**	**0.20**	**0.75**	**0.95**	**0.18**	**0.41**	**0.59**	**0.00**	**0.03**	**0.09**	**0.12**	**0.02**	**0.05**	**0.07**

Notes

1. Emission rates assume CalEEMod output rates in pounds/day

Abbreviations:

lb - pound	g - gram
s - second	hr - hour
NO_x - Nitrous Oxides	CO - carbon monoxide
SO_2 - Sulfur Dioxide	PM - Particulate Matter

Table 3
Construction Annual Model Emission Rates
Sequoia Back-up Power Facility
Santa Clara, California

Project Construction	CAP Emissions [lb][1,2]								
	NO_x	CO	SO_2	Exhaust PM_{10}	Fugitive PM_{10}	Total PM_{10}	Exhaust $PM_{2.5}$	Fugitive $PM_{2.5}$	Total $PM_{2.5}$
Site Preparation	425	220	0.40	22.00	82.82	105	20	44.98	65
Grading	1,507	974	1.9	65.24	121.96	187	60	49.86	110
Building Construction	9,831	8,417	25	336.78	1003.80	1,341	316.72	272.60	589
Paving	259	300	0.48	13.58	2.38	16	13	0.64	13
Architectural Coating	33	66	0.16	1.94	10.16	12	1.9	2.7	4.6
Total	**12,056**	**9,976**	**28**	**440**	**1221**	**1,661**	**411**	**371**	**782**
Length of Construction (days)	531								
Average Daily Emissions (lb/hour)	**2.064**	**1.708**	**0.005**	**0.075**	**0.209**	**0.284**	**0.070**	**0.063**	**0.134**
Average Daily Emissions (g/s)	**0.260**	**0.215**	**0.001**	**0.009**	**0.026**	**0.036**	**0.009**	**0.008**	**0.017**

Notes:

1. Emissions estimated using CalEEMod version 2016.3.2.
2. Construction activities associated with the SBGF are negligible and are included in the estimates for SDC.

Abbreviations:

CalEEMod - California Emissions Estimator Model
lb - pounds
NOx - nitrogen oxides
ROG - reactive organic gases
$PM_{2.5}$ - particulate matter < 2.5 µm
PM_{10} - particulate matter < 10 µm
BAAQMD - Bay Area Air Quality District
CAP - Criteria Air Pollutants
SBGF - Sequoia Backup Generating Facility
SDC - Sequoia Data Center

References:

CalEEMod Version 2013.2.2 Available Online at: http://www.caleemod.com

Table 4
Modeled Construction Concentrations and NAAQS
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Pollutant	Averaging Period		UTM Zone 10 Coordinates (m)		Max. Dispersion Factor ($\mu g/m^3)(g/s)^{-1}$	Emission rate (g/s)	Modeled Concentration ($\mu g/m^3$)	3-Year Average Background Concentrations ($\mu g/m^3$)[1,2]	Total Concentrations	NAAQS (µg/m3)	Above NAAQS?
			X	Y							
NO_2	5-year average of 1-Hour Yearly 98th%		593760	4136140	115	--	115	N/A	115	188	No
	Annual		593661	4136202	28	--	28	N/A	28	100	No
CO	1-Hour		593740	4136200	60	0.51	31	2,443	2,474	40,000	No
	8-Hour		593360	4136380	27	0.51	14	1,909	1,922	10,000	No
SO_2	5-year average of 1-Hour Yearly 99th%		593740	4136200	57	0.0013	0.076	6.1	6.2	196	No
	3-Hour		593740	4136200	47	0.0013	0.063	9.4	9.5	1,300	No
PM_{10}[3]	24-Hour 6th highest over 5 years	Exhaust Contribution	593360	4136400	13	0.025	0.32	56	56	150	No
PM_{25}[3]	5-year average of 24-Hour Yearly 98th%	Exhaust Contribution	593691.0	4136203.0	11	0.023	0.25	31	31	35	No
	5-year average of annual concentrations	Exhaust Contribution	593661.1	4136202.4	6.5	0.0089	0.058	10	10	12	No

Notes:

1. The 3-year average background concentrations were calculated using 2015-2017 data collected from Monitor Site ID 060850005 located at 158B Jackson Street in San Jose, California, as reported by EPA.
2. Seasonal NO_2 background values are computed using AERMOD and are already included in the modeled concentrations.
3. Modeled Particulate Matter concentrations are given for Exhaust PM only. Fugitive PM concentrations to be provided in a further update to modeled values.

Table 5
Modeled Construction Concentrations and CAAQS
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Pollutant	Averaging Period		UTM Zone 10 Coordinates (m)		Max. Dispersion Factor ($\mu g/m^3)(g/s)^{-1}$	Emission rate (g/s)	Modeled Concentration ($\mu g/m^3$)	Maximum Background Concentrations ($\mu g/m^3$)[1,2]	Total Concentrations	CAAQS (µg/m3)	Above CAAQS?
			X	Y							
NO_2	1-Hour Maximum		593,740	4,136,200	43	--	43	128	171	339	No
	Annual Maximum		593,661.1	4,136,202.4	28	--	28	24	28	57	No
CO	1-Hour Maximum		593740	4136200	60	0.51	31	2,748	2,779	23,000	No
	8-Hour Maximum		593360	4136380	27	0.51	14	2,061	2,075	10,000	No
SO_2	1-Hour Maximum		593740	4136200	60	0.0013	0.080	9.4	9.5	655	No
	24-Hour Maximum		593340	4136420	16	0.0010	0.015	2.9	2.90	105	No
PM_{10}[3]	24-Hour Maximum	Exhaust Contribution	593340.0	4136420.0	16	0.025	0.40	69.0	69.4	50	Yes
	Annual Maximum	Exhaust Contribution	593661.1	4136202.4	6.5	0.0095	0.062	21.9	22.0	20	Yes
$PM_{2.5}$[3]	Annual Maximum	Exhaust Contribution	593661.1	4136202.4	6.5	0.0089	0.058	11	10.7	12	No

Notes:

1. The maximum background concentrations from 2015 to 2017 data was used to show compliance with CAAQS.

2 Seasonal NO_2 background values are computed using AERMOD and are included in modeled annual concentrations. 1-hour NO_2 concentrations are modeled to give background-subtracted concentrations, and total 1-hour NO2 concentrations are calculated as the sum of the modeled value and the max background concentration from 2015 to 2017

3. Modeled Particulate Matter concentrations are given for Exhaust PM only. Fugitive PM concentrations to be provided in a further update to modeled values.

Table 6
Comparison of Modeled Construction PM10 Results to the SIL
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Pollutant	Averaging Period	UTM Zone 10 Coordinates (m)		Modeled Concentrations ($\mu g/m^3$)	SIL ($\mu g/m^3$)[2]	Above SIL?
		X	Y			
PM_{10}	24-Hour Maximum	593,377.88	4,136,255.85	0.40	5.0	No

Notes:

1. Modeled concentration are the maximum high-first-high value of the 5 individual modeled years (2013-2017).
2. Significance Impact Level (SIL) value taken from the EPA's "Guidance on Significance Impact Levels for Ozone and Fine Particles in the Prevention of Significance Deterioration Permitting Program" Memorandum dated April 17, 2018.

APPENDIX AIR DR-29

Construction Health Risk Assessment

RAMBOLL

ENVIRONMENT
& HEALTH

MEMO

Date **September 26 ,2019**

To **Jeff Devine, Cyrus One (LLC)**
Sequoia Backup Generating Facility

From **Steven Branoff**
Sarah Manzano

subject **CONSTRUCTION HEALTH RISK ASSESSMENT FOR THE CYRUSONE SEQUOIA DATA CENTER IN SANTA CLARA, CALIFORNIA**

September 26, 2019

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Ramboll US Corporation (Ramboll) conducted a construction Health Risk Assessment (HRA) for CyrusOne LLC (CyrusOne)'s Project Sequoia at 2600 De La Cruz Boulevard, California ("the Project"). This memo details the methods and assumptions used in the HRA, including emissions estimation and dispersion modelling.

The Sequoia Data Center (SDC) and Sequoia Backup Generating Facility (SBGF) would be located on a 15-acre plot bounded by rail tracks and existing warehouse buildings to the West, De La Cruz Boulevard and the San Jose International Airport to the East, an Enterprise Rent a Car facility to the North, and One Work Place, a furniture warehouse to the South. The proposed plan for the SBGF includes fifty-four (54) 2.25-megawatts (MW) emergency diesel generators to provide back-up power for the data center which may draw up to 96.5 MW to support the maximum critical IT load and up to 96.5 MW total of power from the grid to support the total maximum SDC demand. The construction of the SDC and SBGF would take place in one phase from 2020 to 2021. The site has been demolished in accordance with a demolition permit issued by the City of Santa Clara.[1] Therefore, for environmental baseline purposes, the site is vacant and unpaved. Development of the site would include construction of an approximately 702,000 square feet SDC data center building and 141 parking spaces. Approximately 70,00 square feet of the SDC building would be dedicated for administrative and office uses. The proposed location and boundary are shown in **Figure 1**.

1. THRESHOLDS OF SIGNIFICANCE

Per the California Energy Commission (CEC) requirement, Ramboll evaluated the Project in accordance with the current Bay Area Air Quality Management District (BAAQMD) California Environmental Quality Act (CEQA) Guidelines, which were updated in May 2017.[2] These guidelines present methods for evaluating compliance

[1] All that is remaining on the site at the time of this report is miscellaneous piping and foundations associated with a demolished cogeneration facility.

[2] BAAQMD. 2017. California Environmental Quality Act (CEQA) Air Quality Guidelines. May. Available online at: http://www.baaqmd.gov/~/media/files/planning-and-research/ceqa/ceqa_guidelines_may2017-pdf.pdf?la=en

with CEQA as well as thresholds for determining significance. With respect to the construction HRA, the BAAQMD thresholds of significance are as follows:

- Increased cancer risk of >10.0 in a million
- Increased non-cancer risk of > 1.0 HI (chronic or acute)
- Ambient $PM_{2.5}$ increase: > 0.3 µg/m^3 annual average

Ramboll evaluated each of these thresholds for both worker and residential (including sensitive) receptors. Ramboll 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 Sequoia site. However, for completeness, Ramboll also included a nearby soccer facility (2,130 feet from project site) directly south of the Project Sequoia site as a potential sensitive receptor and a childcare receptor (about 4,000 feet from project site) located Southeast of the site.

2. CONSTRUCTION EMISSIONS

The following sections describe the input data and methodologies used in the construction HRA. Detailed information for each section can be found in the referenced tables and appendices.

Toxic Air Contaminant (TAC) Emissions

The TAC emissions associated with the Project construction were calculated with the following assumptions and exceptions:

1. Diesel Particulate Matter (DPM): DPM emissions were used to evaluate the cancer risk and non-cancer chronic HI from Project construction. In this analysis, only onsite (i.e., construction equipment) Particulate Matter less than 10 microns (PM_{10}) exhaust emissions[3] were calculated as DPM and modeled within the Project boundary (as discussed in the next section). All off-road construction equipment was assumed to be default Tiers as specified in California Emission Estimator Model version 2016.3.2 (CalEEMod®).
2. $PM_{2.5}$: Exhaust Particulate Matter less 2.5 microns ($PM_{2.5}$) emissions were used to evaluate the $PM_{2.5}$ concentration due to the Project construction. $PM_{2.5}$ emissions include exhaust emissions from construction equipment and fugitive emissions.
3. TOG: TOG emissions from gasoline vehicles (exhaust and evaporation) were used to evaluate non-cancer acute HI From Project construction. These includes gasoline emissions from truck trips as well as from construction equipment. TOG emitted from gasoline vehicle exhaust and evaporative losses are composed of a number of toxic components such as benzene, naphthalene and acetaldehyde. Unlike DPM, no surrogate method is currently approved to estimate health impacts from TOG as a whole. Thus, TOG impacts must be calculated using a component based method. Total TOG emissions from construction equipment are split into individual toxic components using CARB's Diesel offroad exhaust profile.[4]

[3] Local offsite (mobile source) emissions were calculated by including CalEEMod® on-road emissions for a one-way trip lengths of two miles, based on the modelled roadway from the Northern edge of the Project boundary to the freeway (See Figure 3).

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

Modeled emissions are presented in **Table 1** as exhaust PM_{10} emissions, exhaust TOG emissions and $PM_{2.5}$ emissions.

Ramboll utilized the California Emission Estimator Model version 2016.3.2 (CalEEMod®)[5] to quantify all construction emissions. CalEEMod® is a statewide program designed to calculate emissions for development projects in California.

CalEEMod® utilizes widely accepted models for emission estimates combined with appropriate default data that can be used if site-specific information is not available. CalEEMod® uses sources such as the US Environmental Protection Agency (USEPA) AP-42 emission factors,[6] California Air Resources Board's (CARB) on-road and off-road equipment emission models such as the EMission FACtor model (EMFAC) and the Emissions Inventory Program model (OFFROAD), and studies commissioned by California agencies such as the California Energy Commission (CEC) and CalRecycle.

Construction emissions from the Project are primarily from off-road heavy equipment. Where project-specific data were not available, Ramboll used CalEEMod® defaults for General Light Industry land use. The CalEEMod® output report is included as **Appendix B**.

Modeled Emission Rates

A default construction schedule provided by the Project Sponsor was used to estimate construction emissions since detailed construction activity is not known at this time. Sensitive and residential receptors were assumed to be exposed to emissions occurring during the entire construction period.

Emitting activities are modeled to reflect the actual hours of construction. Emissions are modeled using the x/Q ("chi over q") method, such that each phase has unit emission rates (i.e., 1 gram per second [g/s]), and the model estimates dispersion factors with units of [µg/m3]/[g/s].

For annual average ambient air concentrations, the estimated annual average dispersion factors are multiplied by the annual average emission rates. For acute impacts, the maximum 1-hour ambient air concentrations are multiplied by the maximum hourly emission rate for a given activity.

The model considered meteorological conditions between the hours of 7:00 AM to 6:00 PM, consistent with the restrictions on construction in the City of Santa Clara's noise ordinance[7]. This way, only representative meteorological data was considered in determining the dispersion factors. Emission rates are adjusted such that on average unit emission rates are modeled, i.e. 1 g/s for 24 hours a day, 7 days a week.

Air Dispersion Modelling

Ramboll analyzed Project construction-related risks by estimating ambient air concentrations of DPM, $PM_{2.5}$ and TOG. To estimate air concentrations, Ramboll used AERMOD, a steady-state Gaussian plume model developed by USEPA for regulatory applications. AERMOD requires emission source locations and release parameters, receptor locations, and processed meteorological data. The construction source parameters are shown in **Table 2**. 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 used surface meteorological data from the San Jose Airport for

[5] California Air Pollution Control Officers Association (CAPCOA). 2016. California Emissions Estimator Model. Available at: http://www.CalEEMod.com/.

[6] The USEPA maintains a compilation of Air pollutant Emission Factors and process information for several air pollution source categories. The data is based on source test data, material balance studies, and engineering estimates. Available at: http://epa.gov/ttnchie1/ap42/.

[7] City of Santa Clara. Control of Noise and Vibration. Available at: https://www.sccgov.org/sites/cpd/programs/NP/Documents/NP_Noise_Ordinance.pdf

years 2013 through 2017, with upper air data collected at the Oakland Airport for the same time period. Meteorological data processed using AERMINUTE (15272) and AERMET (18081) were provided by BAAQMD. 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.

The AERMOD input files are provided electronically within the operational model. The model sources setup is presented in **Figure 2**, and all receptors are shown in **Figure 3**.

Exposure Parameters and Cancer Risk Calculation

This analysis followed the recommended methodology from the 2015 Office of Environmental Health Hazard Assessment (OEHHA) Hot Spots Guidance[8] as adopted in the BAAQMD HRA Guidelines.[9] For offsite residential receptors, Ramboll selected conservative exposure parameters assuming that exposure would begin during the third trimester of a residential child's life. Ramboll used 95th percentile breathing rates up to age 2, and 80th percentile breathing rates above age 2, consistent with BAAQMD guidance. For offsite recreations soccer receptors and childcare receptors, Ramboll conservatively used residential exposure parameters.

For offsite receptors, including fenceline and adjacent sidewalk receptors, Ramboll adopted the Commission Staff-requested methodology of assigning worker exposure parameters to those locations for assessment of the point of maximum impact. Exposure for a worker receptor used the 95th percentile 8–hour breathing rate from the OEHHA guidelines. 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.

The exposure parameters used to estimate excess lifetime cancer risks for all populations are presented in **Table 3**.

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:

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

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)

[8] Air Toxics Hot Spot Program. Risk Assessment Guidelines. Guidance Manual for Preparation of Health Risk Assessment. February 2015. Available online at: https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf

[9] BAAQMD. 2016. Proposed Health Risk Assessment Guidelines. Air Toxics NSR program. January. Available at: http://www.baaqmd.gov/~/media/files/planning-and-research/rules-and-regs/workshops/2016/reg-2-5/hra-guidelines_clean_jan_2016-pdf.pdf?la=en

EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
CF	=	Conversion Factor, 0.001 (m^3/L)
ASF	=	Age Sensitivity Factor (unitless)
FY	=	Fraction of Year, to correct annualization of partial year emissions
AT	=	Averaging Time (days)

The chemical intake or dose is estimated by multiplying the inhalation intake factor, IF_{inh}, by the chemical concentration in air. When coupled with the chemical concentration, this calculation is mathematically equivalent to the dose algorithm given in the OEHHA Hot Spots guidance (Cal/EPA 2003).

Excess Lifetime Cancer Risk

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:

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

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 $activities_i$ (µg/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)$^{-1}$

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)

As discussed above in **Section 2**, annual and hourly emission rates from construction were calculated for each type of receptor.

Cancer risk and chronic HI were calculated from ambient annual concentrations using intake factors, cancer potency factors, and chronic reference exposure levels calculated consistent with the 2015 OEHHA Hot Spots Guidance.[10] Acute HI was calculating using hourly concentrations, the TOG speciation values and the acute reference exposure levels. Speciation values for DPM and TOG are provided in **Table 4**. Toxicity values including chronic and acute reference exposure levels are provided in **Table 5**.

3. RESULTS

As shown in **Table 6**, the maximum cancer risk from construction activities is seen in worker receptors and is calculated to be 0.22 in 1 million, compared to a threshold of 10 in 1 million. Construction activities would also result in a non-cancer acute hazard index of 0.012 and non-cancer chronic hazard index of 0.012 (thresholds of 1.0), and maximum $PM_{2.5}$ concentration of 0.06 micrograms per cubic meter (µg/m³) (threshold of 0.3 µg/m³). These results are all below the BAAQMD thresholds of significance; thus, health risk impacts associated with construction of the Project are less than significant.

[10] Cal/EPA. 2015. The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment. February. Available at: https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf

Attachments:

Tables

Figures

Appendix A: Sensitive Receptor Search Results

Appendix B: CalEEMod® Output Files

TABLES

Table 1
Construction Emissions Summary
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Project Construction Phase[1,2]	Exhaust TOG (hourly)	Exhaust PM_{10} (annualized)	Total $PM_{2.5}$ (annualized)
	(g/s)	(g/s)	(g/s)
Site Preparation	0.065	4.75E-04	4.36E-04
Grading	0.071	1.41E-03	1.29E-03
Building Construction	0.064	6.82E-03	6.41E-03
Paving	0.020	2.93E-04	2.69E-04
Architectural Coating	0.0	4.06E-05	4.06E-05
Max Emission Rate	**0.071**	**--**	**--**
Total Emissions	--	**0.009**	**0.008**
Length of Construction (days)	531		
Modeled Emission Rate	**0.071**	**0.009**	**0.008**

Notes:

1. Emissions estimated using CalEEMod version 2016.3.2.
2. The site has already been demolished in accordance with a demolition permit issued by the City of Santa Clara. Therefore, for emission purposes, the site is vacant and unpaved.

Abbreviations:

CalEEMod - California Emissions Estimator Model

lb - pounds

NOx - nitrogen oxides

ROG - reactive organic gases

$PM_{2.5}$ - particulate matter < 2.5 μm

PM_{10} - particulate matter < 10 μm

BAAQMD - Bay Area Air Quality District

CAP - Criteria Air Pollutants

SBGF - Sequoia Backup Generating Facility

SDC - Sequoia Data Center

References:

CalEEMod Version 2013.2.2 Available Online at: http://www.caleemod.com

Table 2
Modeling Parameters - Construction
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Source	Source Type[1]	Number of Sources[1]	Source Dimension (m)	Release Height[3] (m)	Stack Temperature (K)	Stack Diameter (m)	Stack Velocity (m/s)
Construction	Point	90	Project Area	3.05	750	0.15	64.68

Abbreviations:

K - Kelvin
m - meter
s - second

Table 3
Construction Exposure Parameters, 2015 OEHHA Methodology
Sequoia Back-up Power Facility
CyrusOne - Santa Clara, California

Period	Starting Age	Receptor Age Group	Exposure Parameters								
			Daily Breathing Rate (DBR)[2] (L/kg-day, Soccer Child: L/kg-hr)	Exposure Duration (ED)[3] (years)	Fraction of Time at Home (FAH)[4] (unitless)	Exposure Frequency (EF)[5] (days/year)	Conversion Factor (CF) (m^3/L)	Averaging Time (AT) (days)	Modeling Adjustment Factor (MAF)[6] (unitless)	Age Sensitivity Factor[7] (unitless)	Intake Factor, Inhalation (IF_{inh}) (m^3/kg-day)
Resident[1]	Age 0-<2 Years	Age 0-<2 Years	1,090	1.517	1	350	0.001	25,550	1	10	0.22653
Worker	16 years	Age 16-70 Years	230	1.517	--	250	0.001	25,550	4.2	1	0.003414

Notes:

1. Residential exposure parameters were conservatively used for child care and soccer facility receptors in addition to residential receptors.
2. Daily breathing rates reflect default breathing rates from OEHHA 2015 as follows: Resident: 95th percentile for age 0-<2 years, Worker: 95th percentile 8-hour breathing rate for ages 16-<70 years. For resident exposure, the starting age for exposure is 0 -< 2 years age since this is a conservative estimate for scenarios where construction duration is less than 2 years.
3. The total exposure duration for construction reflects the actual construction duration.
4. Fraction of time at home (FAH) was conservatively assumed to be 1 for all age groups for residential exposure. FAH is not applicable for worker exposure.
5. Exposure frequency reflects default exposure frequency for residents from Cal/EPA 2015. Exposure frequency for workers is assumed to be 250 days in a year.
6. Age Sensitivity Factors for different age bins are from Cal/EPA 2015.
7. 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. An MAF of 4.2 is applied to worker receptors.

Calculation:

Resident:

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

CF = 0.001 (m^3/L)

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 4
Speciation Values
Sequoia Back-up Power Facility
CyrusOne - 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
Cal/EPA. 2015. OEHHA/ARB Consolidated Table of Approved Risk Assessment Health
USEPA. SPECIATE 4.3. Available online at: http://cfpub.epa.gov/si/speciate/

Table 5
Toxicity Values
Sequoia Back-up Power Facility
CyrusOne - 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
Ethylbenzene	0.0087	2,000	-
Formaldehyde	0.021	9.0	55
n-Hexane	-	7,000	-
Methanol	-	4,000	28,000
Methyl Ethyl Ketone	-	-	13,000
Naphthalene	0.12	9.0	-
Nickel	0.91	0.014	0.20
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 emergency 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 6
Health Risk Analysis Summary - Construction
Cyrus One
Santa Clara, CA

Receptor Type	Cancer Risk (in a million)	Non-cancer Chronic Hazard Index (unitless)	Non-cancer Acute Hazard Index (unitless)	Max $PM_{2.5}$ Concentration (ug/m3)
Residential	0.1	9.08E-05	8.84E-05	4.2E-04
UTMx: 593040 UTMy: 4135660				
Soccer Child	0.1	1.19E-04	1.16E-04	5.6E-04
UTMx: 593260 UTMy: 4135660				
Childcare	0.1	4.66E-05	4.54E-05	2.2E-04
UTMx: 592740 UTMy: 4135340				
Worker and PMI[1]	0.2	1.18E-02	1.15E-02	0.06
UTMx: 593661.1 UTMy: 4136202				

Notes:

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

Abbreviations:

PM - Particulate matter

FIGURES

RAMBOLL

DRAFTED BY: LTK

DATE: 9/25/2019

Proposed Project Location

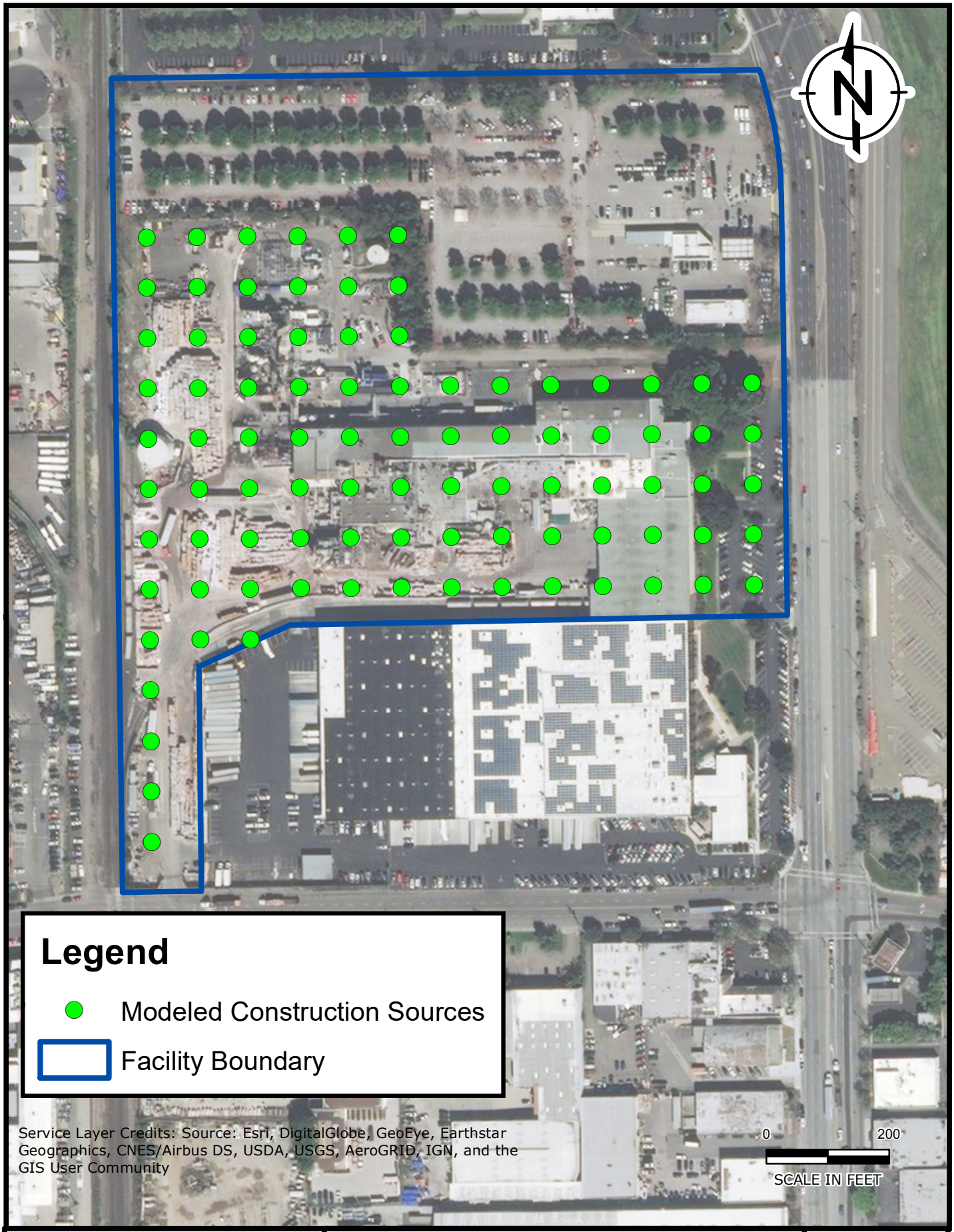
Cyrus One Data Center
Santa Clara, CA

FIGURE
1

Ramboll

PROJECT: 1690013366

C:\Users\lkunik\OneDrive - Ramboll\Documents\CyrusOne\GIS\CyrusOne.mxd



RAMBOLL

DRAFTED BY: LTK

DATE: 9/26/2019

Modeled Construction Sources

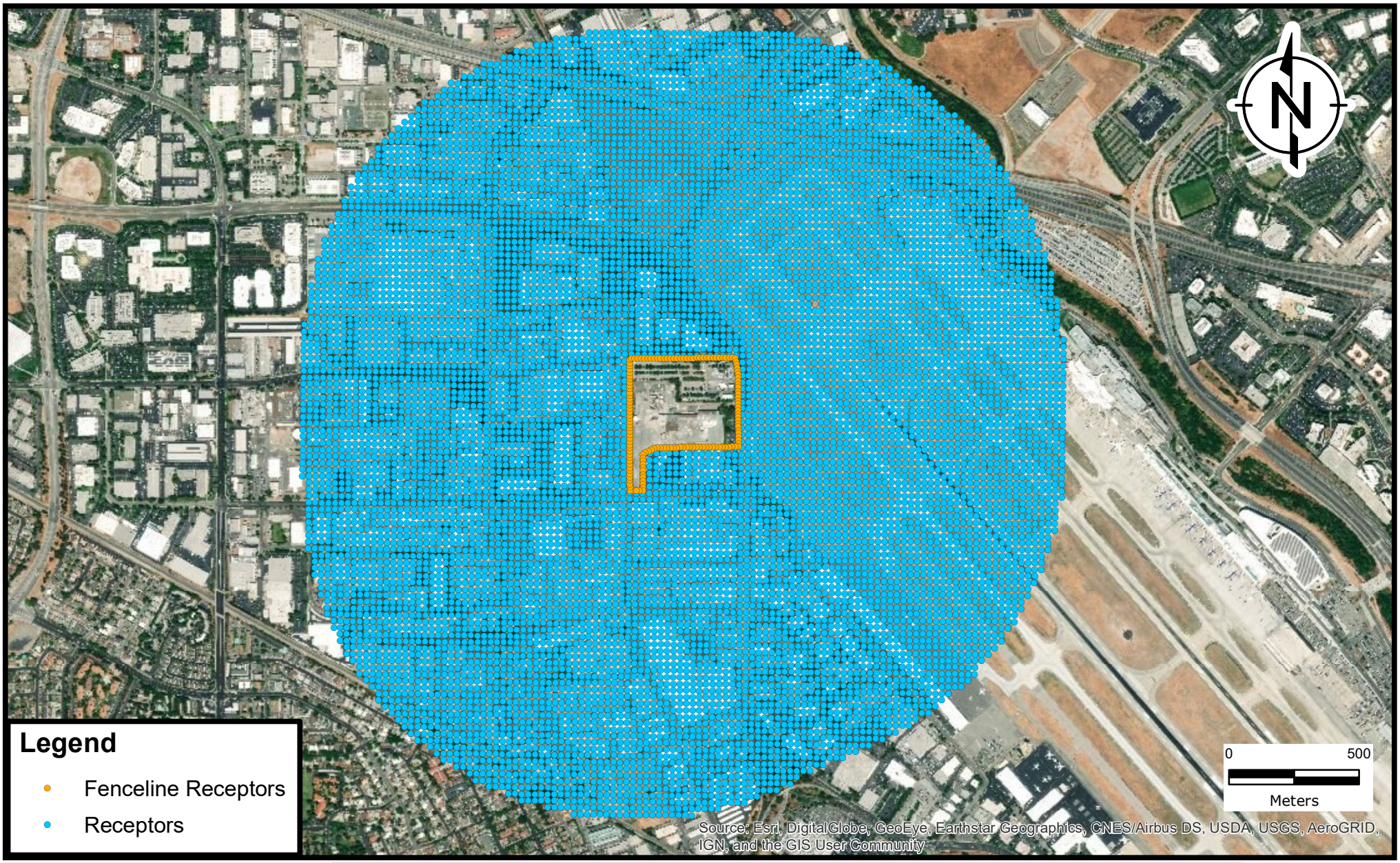
Cyrus One Data Center
Santa Clara, CA

FIGURE
2

Ramboll

PROJECT: 1690013366

C:\Users\lkunik\OneDrive - Ramboll\Documents\CyrusOne\GIS\CyrusOne.mxd



RAMBOLL

DRAFTED BY: SB | DATE: 7/29/2019

Modelled Receptor Locations
CyrusOne Project
CyrusOne Data Center
Santa Clara, California

FIGURE
3

Ramboll

PROJECT: 1690013366

APPENDIX A
SENSITIVE RECEPTOR SEARCH RESULTS

Cyrusone Data Center
2600 DE LA Cruz Blvd
Santa Clara, CA 95050

Inquiry Number: 5689568.1s
June 19, 2019

EDR Offsite Receptor Report

6 Armstrong Road, 4th floor
Shelton, CT 06484
Toll Free: 800.352.0050
www.edrnet.com

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Census Map	3
Census Findings	4
Receptor Map	5
Map Findings	6
Records Searched/Data Currency Tracking Addendum	16

Thank you for your business
Please contact EDR at 1-800-352-0050
with any questions or comments.

EXECUTIVE SUMMARY

A search of available records was conducted by Environmental Data Resources, Inc. (EDR). The EDR Offsite Receptor Report provides information which may be used to comply with the Clean Air Act Risk Management Program 112-R. *"The rule requires that you estimate in the RMP residential populations within the circle defined by the endpoint for your worst-case and alternative release scenarios (i.e., the center of the circle is the point of release and the radius is the distance to the endpoint). In addition, you must report in the RMP whether certain types of public receptors and environmental receptors are within the circles."*

The address of the subject property, for which the search was intended, is:

CYRUSONE DATA CENTER
2600 DE LA CRUZ BLVD
SANTA CLARA, CA 95050

Distance Searched: 1.000 miles from subject property

RECEPTOR SUMMARY
An X indicates the presence of the receptor within the search radius.

Residential Population
Estimated population within search radius: 5525 persons.

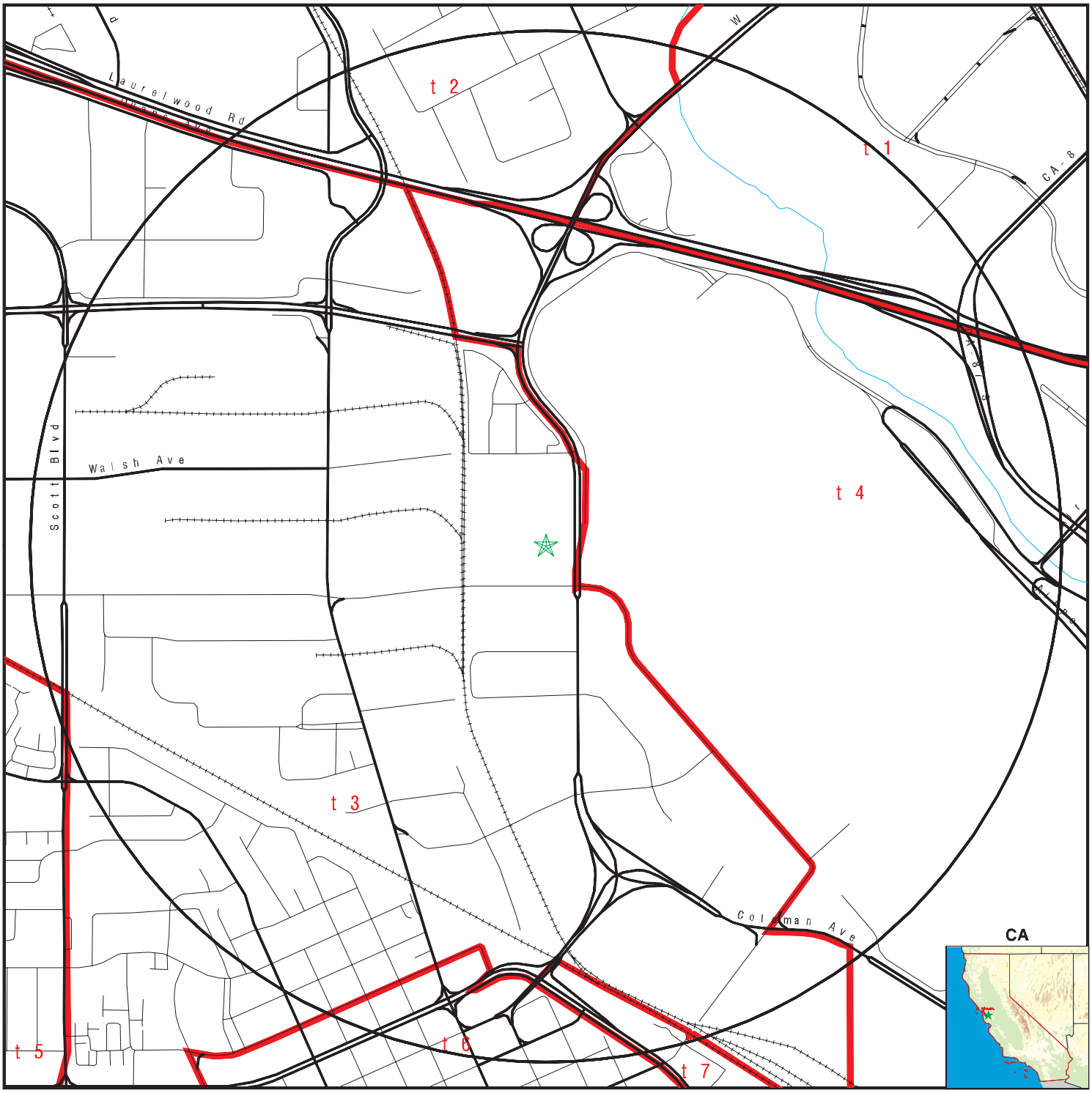
Other Public Receptors

Type	Within Search Radius	Sites Total
Day Care Centers:	X	5
Medical Centers:		
Nursing Homes:		
Schools:		
Hospitals:	X	8
Colleges:		
Arena:		
Prison:		

Environmental Receptors

Type	Within Search Radius	Sites Total
Federal Land:		

CENSUS MAP - 5689568.1s



Target Property
Roads
Waterways
Census Tracts

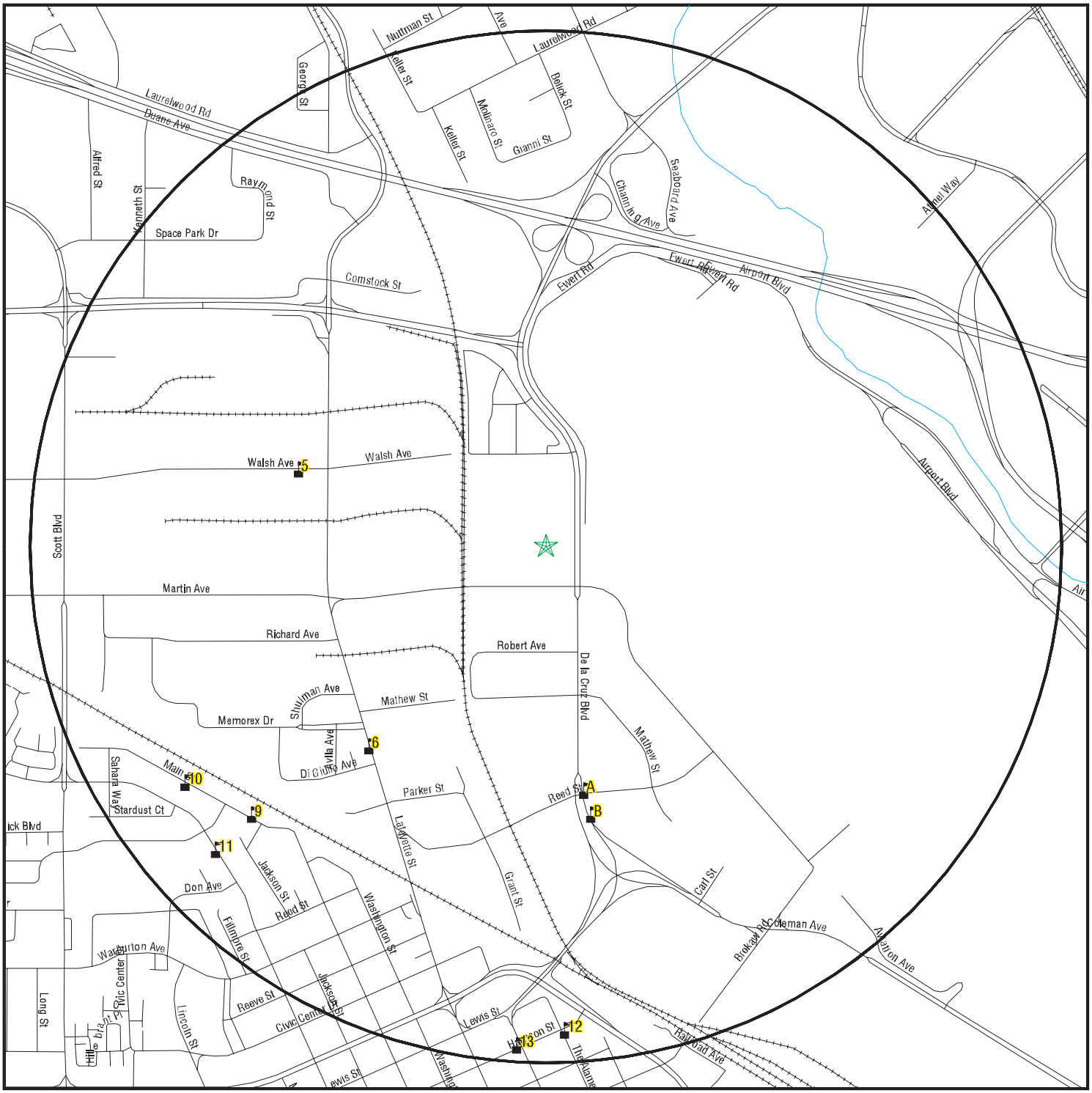
0 1/4 1/2 1 Miles

TARGET PROPERTY:	Cyrusone Data Center	CUSTOMER:	Ramboll
ADDRESS:	2600 DE LA Cruz Blvd	CONTACT:	Lewis Kunik
CITY/STATE/ZIP:	Santa Clara CA 95050	INQUIRY #:	5689568.1s
LAT/LONG:	37.3676 / 121.9426	DATE:	June 19, 2019 5:33 pm

CENSUS FINDINGS

Map ID	Tract Number	Total Population	Population in Radius	Total Area(sq.mi.)	Area in Radius(sq.mi.)
T1	5050.06	3898	161.8	5.37	0.22
T2	5050.07	4083	675.5	1.18	0.19
T3	5052.02	5867	2687.1	3.55	1.63
T4	5051.00	3027	1114.1	2.70	0.99
T5	5053.03	5940	20.0	0.42	0.00
T6	5056.00	3880	700.5	0.37	0.07
T7	5052.03	4809	165.7	0.57	0.02

RECEPTOR MAP - 5689568.1s



- Target Property
- Roads
- Waterways
- Environmental or Public Receptor
- Federal Lands Linear Features
- Federal Lands Area

0 1/4 1/2 1 Miles

N

TARGET PROPERTY:	Cyrusone Data Center	CUSTOMER:	Ramboll
ADDRESS:	2600 DE LA Cruz Blvd	CONTACT:	Lewis Kunik
CITY/STATE/ZIP:	Santa Clara CA 95050	INQUIRY #:	5689568.1s
LAT/LONG:	37.3676 / 121.9426	DATE:	June 19, 2019 5:34 pm

MAP FINDINGS

Map ID Direction Distance Distance (ft.) Elevation	Site		EDR ID Database
A1 South 1/4-1/2 mi 2538 Higher			SRHO20070010522 AHA Hospitals
	Hospital type:	01	
	Num of times COO:	00	
	Owner date:	Not Reported	
	City:	SANTA CLARA	
	Has plan of corr:	1	
	Compliance status:	A	
	SSA county code:	530	
	Cross ref number:	Not Reported	
	FMS survey date:	Not Reported	
	Current survey date:	19850731	
	Medicare/Medicaid:	1	
	Facility name:	HILLVIEW HOME HEALTH AGENCY INC	
	Intermediary/Carrier:	00040	
	Medicaid number:	Not Reported	
	Partcipation date:	19770824	
	Prior COO date:	Not Reported	
	Prior carrier:	00041	
	Provider ID:	057193	
	Record Status:	A	
	Region code:	09	
	Is Partial Record:	Not Reported	
	state abbrev:	CA	
	ssa state:	05	
	state region cd:	SJ	
	street address:	2005 DE LA CRUZ BLVD SUITE 121	
	Phone num:	4089861801	
	Termination reason:	01	
	Term Date:	19861201	
	Purpose of action:	2	
	Provider control:	04	
	Zip:	95050	
	Fips state:	06	
	Fips cnty:	085	
	SSA MSA:	529	
	SSA MSA size code:	B	
	Date accredited:	Not Reported	
	Accred expire date:	Not Reported	
	Accred Org:	0	
	Num beds:	0000	
	Num cert beds:	0000	
	Source:	US_HOSPITAL_POSOTHER	
	Edr id:	SRHO20070010522	

A2 South 1/4-1/2 mi 2538 Higher			SRHO20070008195 AHA Hospitals
	Hospital type:	01	
	Num of times COO:	00	
	Owner date:	Not Reported	
	City:	SANTA CLARA	
	Has plan of corr:	1	
	Compliance status:	A	
	SSA county code:	530	
	Cross ref number:	Not Reported	
	FMS survey date:	Not Reported	
	Current survey date:	19980623	

Medicare/Medicaid:	1
Facility name:	HEARTLAND HOME HEALTH CARE AND HOSPICE
Intermediary/Carrier:	00380
Medicaid number:	Not Reported
Partcipation date:	19960513
Prior COO date:	Not Reported
Prior carrier:	Not Reported
Provider ID:	051690
Record Status:	A
Region code:	09
Is Partial Record:	Not Reported
state abbrev:	CA
ssa state:	05
state region cd:	SJ
street address:	2005 DE LA CRUZ BOULEVARD, SUITE 271
Phone num:	4084507850
Termination reason:	00
Term Date:	Not Reported
Purpose of action:	2
Provider control:	06
Zip:	95050
Fips state:	06
Fips cnty:	085
SSA MSA:	529
SSA MSA size code:	B
Date accredited:	Not Reported
Accred expire date:	Not Reported
Accred Org:	1
Num beds:	0000
Num cert beds:	0000
Source:	US_HOSPITAL_POSOTHER
Edr id:	SRHO20070008195

A3 SRHO20070139863
South AHA Hospitals
1/4-1/2 mi
2538
Higher

Hospital type:	01
Num of times COO:	00
Owner date:	Not Reported
City:	SANTA CLARA
Has plan of corr:	Not Reported
Compliance status:	Not Reported
SSA county code:	530
Cross ref number:	Not Reported
FMS survey date:	Not Reported
Current survey date:	Not Reported
Medicare/Medicaid:	Not Reported
Facility name:	HEARTLAND HOME HEALTH CARE & HOSPICE
Intermediary/Carrier:	Not Reported
Medicaid number:	Not Reported
Partcipation date:	19940609
Prior COO date:	Not Reported
Prior carrier:	Not Reported
Provider ID:	05D0711296
Record Status:	A
Region code:	09
Is Partial Record:	Y

state abbrev:	CA
ssa state:	05
state region cd:	LAB
street address:	2005 DE LA CRUZ BOULEVARD #271
Phone num:	4089861801
Termination reason:	00
Term Date:	20080831
Purpose of action:	Not Reported
Provider control:	04
Zip:	95050
Fips state:	06
Fips cnty:	085
SSA MSA:	529
SSA MSA size code:	B
Date accredited:	Not Reported
Accred expire date:	Not Reported
Accred Org:	Not Reported
Num beds:	0000
Num cert beds:	0000
Source:	US_HOSPITAL_POSCLIA
Edr id:	SRHO20070139863

A4 — SRHO20070010431
South — AHA Hospitals
1/4-1/2 mi
2538
Higher

Hospital type:	01
Num of times COO:	00
Owner date:	Not Reported
City:	SANTA CLARA
Has plan of corr:	Not Reported
Compliance status:	A
SSA county code:	530
Cross ref number:	Not Reported
FMS survey date:	Not Reported
Current survey date:	19981215
Medicare/Medicaid:	2
Facility name:	HEARTLAND HOME HEALTH CARE AND HOSPICE
Intermediary/Carrier:	00380
Medicaid number:	HHA07775G
Partcipation date:	19870609
Prior COO date:	Not Reported
Prior carrier:	00450
Provider ID:	057775
Record Status:	A
Region code:	09
Is Partial Record:	Not Reported
state abbrev:	CA
ssa state:	05
state region cd:	SF
street address:	2005 DE LA CRUZ BLVD STE 271
Phone num:	4089861801
Termination reason:	01
Term Date:	20060528
Purpose of action:	2
Provider control:	04
Zip:	95050
Fips state:	06

Fips cnty:	085
SSA MSA:	529
SSA MSA size code:	B
Date accredited:	Not Reported
Accred expire date:	Not Reported
Accred Org:	0
Num beds:	0000
Num cert beds:	0000
Source:	US_HOSPITAL_POSOTHER
Edr id:	SRHO20070010431

5			SRHO20070154208
WNW	Hospital type:	01	AHA Hospitals
1/2-1 mi	Num of times COO:	00	
2647	Owner date:	Not Reported	
Higher	City:	SANTA CLARA	
	Has plan of corr:	Not Reported	
	Compliance status:	Not Reported	
	SSA county code:	530	
	Cross ref number:	Not Reported	
	FMS survey date:	Not Reported	
	Current survey date:	Not Reported	
	Medicare/Medicaid:	Not Reported	
	Facility name:	US HEALTHWORKS SANTA CLARA 324	
	Intermediary/Carrier:	Not Reported	
	Medicaid number:	Not Reported	
	Partcipation date:	20020214	
	Prior COO date:	Not Reported	
	Prior carrier:	Not Reported	
	Provider ID:	05D0996335	
	Record Status:	A	
	Region code:	09	
	Is Partial Record:	Y	
	state abbrev:	CA	
	ssa state:	05	
	state region cd:	LAB	
	street address:	988 WALSH AVENUE	
	Phone num:	4089886868	
	Termination reason:	00	
	Term Date:	20080213	
	Purpose of action:	Not Reported	
	Provider control:	02	
	Zip:	95050	
	Fips state:	06	
	Fips cnty:	085	
	SSA MSA:	529	
	SSA MSA size code:	B	
	Date accredited:	Not Reported	
	Accred expire date:	Not Reported	
	Accred Org:	Not Reported	
	Num beds:	0000	
	Num cert beds:	0000	
	Source:	US_HOSPITAL_POSCLIA	
	Edr id:	SRHO20070154208	

MAP FINDINGS

Map ID Direction Distance Distance (ft.) Elevation	Site		EDR ID Database
6 SW 1/2-1 mi 2739 Higher			SRHO20070164230 AHA Hospitals
	Hospital type:	01	
	Num of times COO:	00	
	Owner date:	Not Reported	
	City:	SANTA CLARA	
	Has plan of corr:	Not Reported	
	Compliance status:	Not Reported	
	SSA county code:	530	
	Cross ref number:	Not Reported	
	FMS survey date:	Not Reported	
	Current survey date:	Not Reported	
	Medicare/Medicaid:	Not Reported	
	Facility name:	BAY AREA SURGICAL GROUP, INC	
	Intermediary/Carrier:	Not Reported	
	Medicaid number:	Not Reported	
	Partcipation date:	20060622	
	Prior COO date:	Not Reported	
	Prior carrier:	Not Reported	
	Provider ID:	05D1055651	
	Record Status:	A	
	Region code:	09	
	Is Partial Record:	Y	
	state abbrev:	CA	
	ssa state:	05	
	state region cd:	M2	
	street address:	2222 LAFAYETTE STREET, SUITE 101	
	Phone num:	4089880105	
	Termination reason:	00	
	Term Date:	20080621	
	Purpose of action:	Not Reported	
	Provider control:	04	
	Zip:	95050	
	Fips state:	06	
	Fips cnty:	085	
	SSA MSA:	529	
	SSA MSA size code:	B	
	Date accredited:	Not Reported	
	Accred expire date:	Not Reported	
	Accred Org:	Not Reported	
	Num beds:	0000	
	Num cert beds:	0000	
	Source:	US_HOSPITAL_POSCLIA	
	Edr id:	SRHO20070164230	

B7 South 1/2-1 mi 2793 Higher			SRHO20070107732 AHA Hospitals
	Hospital type:	01	
	Num of times COO:	01	
	Owner date:	19970507	
	City:	SANTA CLARA	
	Has plan of corr:	1	
	Compliance status:	A	
	SSA county code:	530	
	Cross ref number:	Not Reported	
	FMS survey date:	Not Reported	
	Current survey date:	19961010	

Medicare/Medicaid:	1
Facility name:	HYGEIA, INC
Intermediary/Carrier:	00140
Medicaid number:	Not Reported
Partcipation date:	19921222
Prior COO date:	Not Reported
Prior carrier:	00040
Provider ID:	557250
Record Status:	A
Region code:	09
Is Partial Record:	Not Reported
state abbrev:	CA
ssa state:	05
state region cd:	SJ
street address:	1825 DE LA CRUZ BOULEVARD, SUITE 100
Phone num:	4089823700
Termination reason:	01
Term Date:	19971207
Purpose of action:	2
Provider control:	04
Zip:	95050
Fips state:	06
Fips cnty:	085
SSA MSA:	529
SSA MSA size code:	B
Date accredited:	Not Reported
Accred expire date:	Not Reported
Accred Org:	0
Num beds:	0000
Num cert beds:	0000
Source:	US_HOSPITAL_POSOTHER
Edr id:	SRHO20070107732

B8 — SRHO20070146036

South — AHA Hospitals

1/2-1 mi

2793

Higher

Hospital type:	01
Num of times COO:	00
Owner date:	Not Reported
City:	SANTA CLARA
Has plan of corr:	Not Reported
Compliance status:	Not Reported
SSA county code:	530
Cross ref number:	Not Reported
FMS survey date:	Not Reported
Current survey date:	Not Reported
Medicare/Medicaid:	Not Reported
Facility name:	HYGEIA, INC
Intermediary/Carrier:	Not Reported
Medicaid number:	Not Reported
Partcipation date:	19950427
Prior COO date:	Not Reported
Prior carrier:	Not Reported
Provider ID:	05D0900479
Record Status:	A
Region code:	09
Is Partial Record:	Y

state abbrev:	CA
ssa state:	05
state region cd:	LAB
street address:	1825 DELA CRUZ BLVD, #100
Phone num:	4089823700
Termination reason:	12
Term Date:	19971209
Purpose of action:	Not Reported
Provider control:	04
Zip:	95050
Fips state:	06
Fips cnty:	085
SSA MSA:	529
SSA MSA size code:	B
Date accredited:	Not Reported
Accred expire date:	Not Reported
Accred Org:	Not Reported
Num beds:	0000
Num cert beds:	0000
Source:	US_HOSPITAL_POSCLIA
Edr id:	SRHO20070146036

9
SW
1/2-1 mi
4079
Higher

SRDCCA200740222
Daycare

EDR ID:	SRDCCA200740222
Facility number:	434409592
Facility name:	"GOMEZ-OLGUIN, CONSUELO "
Facility eval. code:	0525
Facility office number:	07
Facility county number:	43
Facility type code:	810
Facility status code:	03
Address:	2087 MAIN STREET
City:	SANTA CLARA
State:	CA
Zip:	95050
Alt. address:	2087 MAIN STREET
City:	SANTA CLARA
State:	CA
Zip:	95050
Facility investor:	"GOMEZ-OLGUIN, CONSUELO "
Licensee type:	A
License effective date:	70212
License expiration date:	Not Reported
License issue date:	070212
Program type:	"MAX. CAP: 6 - NO MORE THAN 3 INFANTS OR 4 INFANTS ONLY. CAP 8 - NO MORE THAN 2 INFANTS, 1 CHILD IN KINDERGARTEN OR ELEMENTARY SCHOOL AND 1 CHILD AT LEAST AGE 6. "
Original app. received date:	061218
Facility closed date:	Not Reported
Mailing address:	2087 MAIN STREET
Mailing city:	SANTA CLARA
Mailing state:	CA
Mailing zip:	95050
Contact person:	"GOMEZ-OLGUIN, CONSUELO "
Facility capacity:	8

Type of clients served:	960
Facility phone:	4082608040

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10 WSW 1/2-1 mi 4415 Higher			SRDCCA200732426 Daycare
	EDR ID:	SRDCCA200732426	
	Facility number:	434408501	
	Facility name:	"KARONGO,MARY "	
	Facility eval. code:	0525	
	Facility office number:	07	
	Facility county number:	43	
	Facility type code:	810	
	Facility status code:	06	
	Address:	2112 MAIN STREET	
	City:	SANTA CLARA	
	State:	CA	
	Zip:	95050	
	Alt. address:	2112 MAIN STREET	
	City:	SANTA CLARA	
	State:	CA	
	Zip:	95050	
	Facility investor:	"KARONGO, MARY "	
	Licensee type:	A	
	License effective date:	50915	
	License expiration date:	Not Reported	
	License issue date:	050915	
	Program type:	"MAX. CAP: 6 - NO MORE THAN 3 INFANTS OR 4 INFANTS ONLY. CAP 8 - NO MORE THAN 2 INFANTS, 1 CHILD IN KINDERGARTEN OR ELEMENTARY SCHOOL AND 1 CHILD AT LEAST AGE 6. "	
	Original app. received date:	050622	
	Facility closed date:	Not Reported	
	Mailing address:	2112 MAIN STREET	
	Mailing city:	SANTA CLARA	
	Mailing state:	CA	
	Mailing zip:	95050	
	Contact person:	"KARONGO, MARY "	
	Facility capacity:	8	
	Type of clients served:	960	
	Facility phone:	4082607255	

---

11 SW 1/2-1 mi 4598 Higher			SRDCCA200734568 Daycare
	EDR ID:	SRDCCA200734568	
	Facility number:	434408618	
	Facility name:	"MEZA-VASQUEZ, BERTHA "	
	Facility eval. code:	S539	
	Facility office number:	07	
	Facility county number:	43	
	Facility type code:	810	
	Facility status code:	03	
	Address:	2064 MONROE STREET	
	City:	SANTA CLARA	
	State:	CA	
	Zip:	95050	
	Alt. address:	2064 MONROE STREET	
	City:	SANTA CLARA	

State:	CA
Zip:	95050
Facility investor:	"MEZA-VASQUEZ, BERTHA "
Licensee type:	A
License effective date:	70312
License expiration date:	Not Reported
License issue date:	070312
Program type:	"MAX. CAP: 6 - NO MORE THAN 3 INFANTS OR 4 INFANTS ONLY. CAP 8 - NO MORE THAN 2 INFANTS, 1 CHILD IN KINDERGARTEN OR ELEMENTARY SCHOOL AND 1 CHILD AT LEAST AGE 6. "
Original app. received date:	061205
Facility closed date:	Not Reported
Mailing address:	2064 MONROE STREET
Mailing city:	SANTA CLARA
Mailing state:	CA
Mailing zip:	95050
Contact person:	"MEZA-VASQUEZ, BERTHA "
Facility capacity:	8
Type of clients served:	960
Facility phone:	4086158323

12
South
1/2-1 mi
4964
Higher

SRDCCA200700445
Daycare

EDR ID:	SRDCCA200700445
Facility number:	430707912
Facility name:	BILL WILSON CENTER
Facility eval. code:	1122
Facility office number:	26
Facility county number:	43
Facility type code:	730
Facility status code:	03
Address:	3490 THE ALAMEDA
City:	SANTA CLARA
State:	CA
Zip:	95050
Alt. address:	3490 THE ALAMEDA
City:	SANTA CLARA
State:	CA
Zip:	95050
Facility investor:	BILL WILSON CENTER
Licensee type:	C
License effective date:	930909
License expiration date:	Not Reported
License issue date:	930909
Program type:	ALL MAY BE NONAMBULATORY; AGES 6 TO 18
Original app. received date:	930507
Facility closed date:	Not Reported
Mailing address:	3490 THE ALAMEDA
Mailing city:	SANTA CLARA
Mailing state:	CA
Mailing zip:	95050
Contact person:	"FLORES, LORRAINE "
Facility capacity:	20
Type of clients served:	950
Facility phone:	4089845955

MAP FINDINGS

Map ID Direction Distance Distance (ft.) Elevation	Site		EDR ID Database
13 South 1/2-1 mi 5124 Higher			SRDCCA200718462 Daycare
	EDR ID:	SRDCCA200718462	
	Facility number:	434405853	
	Facility name:	"BERG-VIVIT, MARLA "	
	Facility eval. code:	0525	
	Facility office number:	07	
	Facility county number:	43	
	Facility type code:	810	
	Facility status code:	03	
	Address:	809 HARRISON STREET	
	City:	SANTA CLARA	
	State:	CA	
	Zip:	95050	
	Alt. address:	809 HARRISON STREET	
	City:	SANTA CLARA	
	State:	CA	
	Zip:	95050	
	Facility investor:	"BERG-VIVIT, MARLA "	
	Licensee type:	A	
	License effective date:	20625	
	License expiration date:	Not Reported	
	License issue date:	020625	
	Program type:	"MAXIMUM CAPACITY: 12 CHILDREN, WITH NO MORE THAN 4 INFANTS, OR CAPACITY 14 CHILDREN WHEN 2 CHILDREN ARE AT LEAST 6 YEARS OF AGE WITH A MAXIMUM OF 3 INFANTS; PROPERTY OWNER/LANDLORD CONSENT IS REQUIRED "	
	Original app. received date:	020506	
	Facility closed date:	Not Reported	
	Mailing address:	809 HARRISON STREET	
	Mailing city:	SANTA CLARA	
	Mailing state:	CA	
	Mailing zip:	95050	
	Contact person:	"BERG-VIVIT, MARLA "	
	Facility capacity:	14	
	Type of clients served:	960	
	Facility phone:	4082470933	

RECORDS SEARCHED/DATA CURRENCY TRACKING

Census
Source: U.S. Census Bureau
Telephone: 301-763-4636
2010 U.S. Census data was used to estimate residential population following these EPA guidelines:
"Census data are presented by Census tract. If your circle covers only a portion of the tract, you should develop an estimate for that portion...Determine the population density per square mile (total population of the Census tract divided by the number of square miles in the tract) and apply that density figure to the number of square miles within your circle."

FED_LAND: Federal Lands
Source: USGS
Telephone: 888-275-8747
Federal lands data. Includes data from several Federal land management agencies, including Fish and Wildlife Service, Bureau of Land Management, National Park Service, and Forest Service. Includes National Parks, Forests, Monuments; . Wildlife Sanctuaries, Preserves, Refuges; Federal Wilderness Areas.

AHA Hospitals:
Source: American Hospital Association, Inc.
Telephone: 312-280-5991
The database includes a listing of hospitals based on the American Hospital Association's annual survey of hospitals.

Medical Centers: Provider of Services Listing
Source: Centers for Medicare & Medicaid Services
Telephone: 410-786-3000
A listing of hospitals with Medicare provider number, produced by Centers of Medicare & Medicaid Services, a federal agency within the U.S. Department of Health and Human Services.

Nursing Homes
Source: National Institutes of Health
Telephone: 301-594-6248
Information on Medicare and Medicaid certified nursing homes in the United States.

Public Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on elementary and secondary public education in the United States. It is a comprehensive, annual, national statistical database of all public elementary and secondary schools and school districts, which contains data that are comparable across all states.

Private Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on private school locations in the United States.

Colleges - Integrated Postsecondary Education Data
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on integrated postsecondary education in the United States.

Arenas
Source: Dunhill International
EDR indicates the location of buildings and facilities - arenas - where individuals who are public receptors are likely to be located.

Prisons: Bureau of Prisons Facilities
Source: Federal Bureau of Prisons
Telephone: 202-307-3198
List of facilities operated by the Federal Bureau of Prisons.

Daycare Centers: Licensed Facilities
Source: Department of Social Services
Telephone: 916-657-4041

STREET AND ADDRESS INFORMATION

APPENDIX B
CALEEMOD® OUTPUT FILES

CyrusOne Construction

Santa Clara County, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
General Light Industry	702.11	1000sqft	13.73	702,110.00	0
Parking Lot	141.00	Space	1.27	56,400.00	0

1.2 Other Project Characteristics

Urbanization	Urban	**Wind Speed (m/s)**	2.2	**Precipitation Freq (Days)**	58
Climate Zone	4			**Operational Year**	2021
Utility Company	User Defined				
CO2 Intensity (lb/MWhr)	271	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics - Project Characteristics - Utility company is Silicon Valley Power, using 271 lb/MWh based on Santa Clara County projections for 2020. PG&E defaults are used for CH4 and N2O intensity factors.

Land Use - Updated acerage based on Project Description.

Vehicle Trips - Estimating emissions only from Construction. Operational emissions are estimated separately.

Road Dust - Estimating emissions only from Construction. Operational emissions are estimated separately.

Consumer Products - Estimating emissions only from Construction. Operational emissions are estimated separately.

Area Coating - Estimating emissions only from Construction. Operational emissions are estimated separately.

Landscape Equipment - Estimating emissions only from Construction. Operational emissions are estimated separately.

Energy Use - Estimating emissions only from Construction. Operational emissions are estimated separately.

Water And Wastewater - Estimating emissions only from Construction. Operational emissions are estimated separately.

Solid Waste - Estimating emissions only from Construction. Operational emissions are estimated separately.

Mobile Commute Mitigation -

Fleet Mix - Estimating emissions only from Construction. Operational emissions are estimated separately.

Construction Phase - Default construction schedule from CalEEMod.

Demolition - Site is currently vacant and unpaved.

Woodstoves - Estimating emissions only from Construction. Operational emissions are estimated separately.

Operational Off-Road Equipment - Estimating emissions only from Construction. Operational emissions are estimated separately.

CyrusOne Construction - Santa Clara County, Annual

Table Name	Column Name	Default Value	New Value
tblAreaCoating	Area_EF_Parking	150	0
tblAreaCoating	Area_Parking	3384	0
tblEnergyUse	LightingElect	0.35	0.00
tblLandUse	LotAcreage	16.12	13.73
tblProjectCharacteristics	CH4IntensityFactor	0	0.029
tblProjectCharacteristics	CO2IntensityFactor	0	271
tblProjectCharacteristics	N2OIntensityFactor	0	0.006
tblRoadDust	MaterialMoistureContent	0.5	0
tblRoadDust	MaterialSiltContent	4.3	0
tblRoadDust	MeanVehicleSpeed	40	0
tblRoadDust	MobileAverageVehicleWeight	2.4	0
tblRoadDust	RoadSiltLoading	0.1	0
tblSolidWaste	LandfillCaptureGasFlare	94.00	0.00
tblSolidWaste	LandfillNoGasCapture	6.00	0.00
tblVehicleTrips	CC_TL	7.30	0.00
tblVehicleTrips	CNW_TL	7.30	0.00
tblVehicleTrips	CW_TL	9.50	0.00
tblWater	AerobicPercent	87.46	0.00
tblWater	AnaDigestCombDigestGasPercent	100.00	0.00
tblWater	AnaerobicandFacultativeLagoonsPercent	2.21	0.00
tblWater	ElectricityIntensityFactorForWastewaterTreatment	1,911.00	0.00
tblWater	ElectricityIntensityFactorToDistribute	1,272.00	0.00
tblWater	ElectricityIntensityFactorToSupply	2,117.00	0.00
tblWater	ElectricityIntensityFactorToTreat	111.00	0.00
tblWater	SepticTankPercent	10.33	100.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	0.4506	4.3473	3.3770	9.1300e-003	0.5242	0.1679	0.6921	0.1861	0.1569	0.3430	0.0000	827.7394	827.7394	0.1102	0.0000	830.4936
2021	3.8906	2.0129	1.8323	5.3700e-003	0.2087	0.0684	0.2771	0.0566	0.0643	0.1209	0.0000	488.9371	488.9371	0.0519	0.0000	490.2353
Maximum	**3.8906**	**4.3473**	**3.3770**	**9.1300e-003**	**0.5242**	**0.1679**	**0.6921**	**0.1861**	**0.1569**	**0.3430**	**0.0000**	**827.7394**	**827.7394**	**0.1102**	**0.0000**	**830.4936**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	0.4506	4.3473	3.3770	9.1300e-003	0.5242	0.1679	0.6921	0.1861	0.1569	0.3430	0.0000	827.7390	827.7390	0.1102	0.0000	830.4932
2021	3.8906	2.0129	1.8323	5.3700e-003	0.2087	0.0684	0.2771	0.0566	0.0643	0.1209	0.0000	488.9369	488.9369	0.0519	0.0000	490.2351
Maximum	**3.8906**	**4.3473**	**3.3770**	**9.1300e-003**	**0.5242**	**0.1679**	**0.6921**	**0.1861**	**0.1569**	**0.3430**	**0.0000**	**827.7390**	**827.7390**	**0.1102**	**0.0000**	**830.4932**

CyrusOne Construction - Santa Clara County, Annual

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**2-1-2020**	**4-30-2020**	1.5010	1.5010
2	**5-1-2020**	**7-31-2020**	1.2329	1.2329
3	**8-1-2020**	**10-31-2020**	1.2374	1.2374
4	**11-1-2020**	**1-31-2021**	1.2062	1.2062
5	**2-1-2021**	**4-30-2021**	1.0869	1.0869
6	**5-1-2021**	**7-31-2021**	2.7174	2.7174
7	**8-1-2021**	**9-30-2021**	1.7149	1.7149
		Highest	2.7174	2.7174

2.2 Overall Operational

Unmitigated Operational

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Area	3.1126	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161
Energy	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	1,701.2727	1,701.2727	0.0952	0.0339	1,713.7568
Mobile	1.0058	4.4280	12.8669	0.0442	0.5876	0.0378	0.6255	0.2335	0.0354	0.2688	0.0000	4,045.8073	4,045.8073	0.1351	0.0000	4,049.1857
Waste						0.0000	0.0000		0.0000	0.0000	176.7280	0.0000	176.7280	10.4443	0.0000	437.8361
Water						0.0000	0.0000		0.0000	0.0000	51.5103	107.9940	159.5042	5.3022	0.1273	329.9975
Total	**4.2182**	**5.3359**	**13.6374**	**0.0497**	**0.5876**	**0.1069**	**0.6945**	**0.2335**	**0.1044**	**0.3379**	**228.2383**	**5,855.0890**	**6,083.3272**	**15.9769**	**0.1612**	**6,530.7922**

2.2 Overall Operational

Mitigated Operational

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Area	3.1126	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161
Energy	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	1,701.2727	1,701.2727	0.0952	0.0339	1,713.7568
Mobile	1.0058	4.4280	12.8669	0.0442	0.5876	0.0378	0.6255	0.2335	0.0354	0.2688	0.0000	4,045.8073	4,045.8073	0.1351	0.0000	4,049.1857
Waste						0.0000	0.0000		0.0000	0.0000	176.7280	0.0000	176.7280	10.4443	0.0000	437.8361
Water						0.0000	0.0000		0.0000	0.0000	51.5103	107.9940	159.5042	5.3022	0.1273	329.9975
Total	**4.2182**	**5.3359**	**13.6374**	**0.0497**	**0.5876**	**0.1069**	**0.6945**	**0.2335**	**0.1044**	**0.3379**	**228.2383**	**5,855.0890**	**6,083.3272**	**15.9769**	**0.1612**	**6,530.7922**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Demolition	Demolition	2/1/2020	2/28/2020	5	20	
2	Site Preparation	Site Preparation	2/29/2020	3/13/2020	5	10	
3	Grading	Grading	3/14/2020	4/24/2020	5	30	
4	Building Construction	Building Construction	4/25/2020	6/18/2021	5	300	
5	Paving	Paving	6/19/2021	7/16/2021	5	20	
6	Architectural Coating	Architectural Coating	7/17/2021	8/13/2021	5	20	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 75

Acres of Paving: 1.27

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 1,053,165; Non-Residential Outdoor: 351,055; Striped Parking Area: 3,384 (Architectural Coating – sqft)

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Demolition	Concrete/Industrial Saws	1	8.00	81	0.73
Demolition	Excavators	3	8.00	158	0.38
Demolition	Rubber Tired Dozers	2	8.00	247	0.40
Site Preparation	Rubber Tired Dozers	3	8.00	247	0.40
Site Preparation	Tractors/Loaders/Backhoes	4	8.00	97	0.37
Grading	Excavators	2	8.00	158	0.38
Grading	Graders	1	8.00	187	0.41
Grading	Rubber Tired Dozers	1	8.00	247	0.40
Grading	Scrapers	2	8.00	367	0.48
Grading	Tractors/Loaders/Backhoes	2	8.00	97	0.37
Building Construction	Cranes	1	7.00	231	0.29
Building Construction	Forklifts	3	8.00	89	0.20
Building Construction	Generator Sets	1	8.00	84	0.74
Building Construction	Tractors/Loaders/Backhoes	3	7.00	97	0.37
Building Construction	Welders	1	8.00	46	0.45
Paving	Pavers	2	8.00	130	0.42
Paving	Paving Equipment	2	8.00	132	0.36
Paving	Rollers	2	8.00	80	0.38
Architectural Coating	Air Compressors	1	6.00	78	0.48

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Demolition	6	15.00	0.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT
Site Preparation	7	18.00	0.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT
Grading	8	20.00	0.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT
Building Construction	9	319.00	124.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT
Paving	6	15.00	0.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT
Architectural Coating	1	64.00	0.00	0.00	10.80	7.30	20.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

3.2 Demolition - 2020

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0331	0.3320	0.2175	3.9000e-004		0.0166	0.0166		0.0154	0.0154	0.0000	33.9986	33.9986	9.6000e-003	0.0000	34.2386
Total	**0.0331**	**0.3320**	**0.2175**	**3.9000e-004**		**0.0166**	**0.0166**		**0.0154**	**0.0154**	**0.0000**	**33.9986**	**33.9986**	**9.6000e-003**	**0.0000**	**34.2386**

3.2 Demolition - 2020

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	5.0000e-004	3.6000e-004	3.7500e-003	1.0000e-005	1.1900e-003	1.0000e-005	1.2000e-003	3.2000e-004	1.0000e-005	3.2000e-004	0.0000	1.0202	1.0202	3.0000e-005	0.0000	1.0209
Total	**5.0000e-004**	**3.6000e-004**	**3.7500e-003**	**1.0000e-005**	**1.1900e-003**	**1.0000e-005**	**1.2000e-003**	**3.2000e-004**	**1.0000e-005**	**3.2000e-004**	**0.0000**	**1.0202**	**1.0202**	**3.0000e-005**	**0.0000**	**1.0209**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0331	0.3320	0.2175	3.9000e-004		0.0166	0.0166		0.0154	0.0154	0.0000	33.9986	33.9986	9.6000e-003	0.0000	34.2385
Total	**0.0331**	**0.3320**	**0.2175**	**3.9000e-004**		**0.0166**	**0.0166**		**0.0154**	**0.0154**	**0.0000**	**33.9986**	**33.9986**	**9.6000e-003**	**0.0000**	**34.2385**

3.2 Demolition - 2020

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	5.0000e-004	3.6000e-004	3.7500e-003	1.0000e-005	1.1900e-003	1.0000e-005	1.2000e-003	3.2000e-004	1.0000e-005	3.2000e-004	0.0000	1.0202	1.0202	3.0000e-005	0.0000	1.0209
Total	**5.0000e-004**	**3.6000e-004**	**3.7500e-003**	**1.0000e-005**	**1.1900e-003**	**1.0000e-005**	**1.2000e-003**	**3.2000e-004**	**1.0000e-005**	**3.2000e-004**	**0.0000**	**1.0202**	**1.0202**	**3.0000e-005**	**0.0000**	**1.0209**

3.3 Site Preparation - 2020

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.0903	0.0000	0.0903	0.0497	0.0000	0.0497	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0204	0.2121	0.1076	1.9000e-004		0.0110	0.0110		0.0101	0.0101	0.0000	16.7153	16.7153	5.4100e-003	0.0000	16.8505
Total	**0.0204**	**0.2121**	**0.1076**	**1.9000e-004**	**0.0903**	**0.0110**	**0.1013**	**0.0497**	**0.0101**	**0.0598**	**0.0000**	**16.7153**	**16.7153**	**5.4100e-003**	**0.0000**	**16.8505**

3.3 Site Preparation - 2020

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	3.0000e-004	2.1000e-004	2.2500e-003	1.0000e-005	7.1000e-004	0.0000	7.2000e-004	1.9000e-004	0.0000	1.9000e-004	0.0000	0.6121	0.6121	2.0000e-005	0.0000	0.6125
Total	**3.0000e-004**	**2.1000e-004**	**2.2500e-003**	**1.0000e-005**	**7.1000e-004**	**0.0000**	**7.2000e-004**	**1.9000e-004**	**0.0000**	**1.9000e-004**	**0.0000**	**0.6121**	**0.6121**	**2.0000e-005**	**0.0000**	**0.6125**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.0903	0.0000	0.0903	0.0497	0.0000	0.0497	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0204	0.2121	0.1076	1.9000e-004		0.0110	0.0110		0.0101	0.0101	0.0000	16.7153	16.7153	5.4100e-003	0.0000	16.8505
Total	**0.0204**	**0.2121**	**0.1076**	**1.9000e-004**	**0.0903**	**0.0110**	**0.1013**	**0.0497**	**0.0101**	**0.0598**	**0.0000**	**16.7153**	**16.7153**	**5.4100e-003**	**0.0000**	**16.8505**

3.3 Site Preparation - 2020

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	3.0000e-004	2.1000e-004	2.2500e-003	1.0000e-005	7.1000e-004	0.0000	7.2000e-004	1.9000e-004	0.0000	1.9000e-004	0.0000	0.6121	0.6121	2.0000e-005	0.0000	0.6125
Total	**3.0000e-004**	**2.1000e-004**	**2.2500e-003**	**1.0000e-005**	**7.1000e-004**	**0.0000**	**7.2000e-004**	**1.9000e-004**	**0.0000**	**1.9000e-004**	**0.0000**	**0.6121**	**0.6121**	**2.0000e-005**	**0.0000**	**0.6125**

3.4 Grading - 2020

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.1301	0.0000	0.1301	0.0540	0.0000	0.0540	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0668	0.7530	0.4794	9.3000e-004		0.0326	0.0326		0.0300	0.0300	0.0000	81.7264	81.7264	0.0264	0.0000	82.3872
Total	**0.0668**	**0.7530**	**0.4794**	**9.3000e-004**	**0.1301**	**0.0326**	**0.1627**	**0.0540**	**0.0300**	**0.0840**	**0.0000**	**81.7264**	**81.7264**	**0.0264**	**0.0000**	**82.3872**

3.4 Grading - 2020

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.0000e-003	7.2000e-004	7.5100e-003	2.0000e-005	2.3800e-003	2.0000e-005	2.3900e-003	6.3000e-004	1.0000e-005	6.5000e-004	0.0000	2.0405	2.0405	5.0000e-005	0.0000	2.0417
Total	**1.0000e-003**	**7.2000e-004**	**7.5100e-003**	**2.0000e-005**	**2.3800e-003**	**2.0000e-005**	**2.3900e-003**	**6.3000e-004**	**1.0000e-005**	**6.5000e-004**	**0.0000**	**2.0405**	**2.0405**	**5.0000e-005**	**0.0000**	**2.0417**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.1301	0.0000	0.1301	0.0540	0.0000	0.0540	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0668	0.7530	0.4794	9.3000e-004		0.0326	0.0326		0.0300	0.0300	0.0000	81.7263	81.7263	0.0264	0.0000	82.3871
Total	**0.0668**	**0.7530**	**0.4794**	**9.3000e-004**	**0.1301**	**0.0326**	**0.1627**	**0.0540**	**0.0300**	**0.0840**	**0.0000**	**81.7263**	**81.7263**	**0.0264**	**0.0000**	**82.3871**

3.4 Grading - 2020

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.0000e-003	7.2000e-004	7.5100e-003	2.0000e-005	2.3800e-003	2.0000e-005	2.3900e-003	6.3000e-004	1.0000e-005	6.5000e-004	0.0000	2.0405	2.0405	5.0000e-005	0.0000	2.0417
Total	**1.0000e-003**	**7.2000e-004**	**7.5100e-003**	**2.0000e-005**	**2.3800e-003**	**2.0000e-005**	**2.3900e-003**	**6.3000e-004**	**1.0000e-005**	**6.5000e-004**	**0.0000**	**2.0405**	**2.0405**	**5.0000e-005**	**0.0000**	**2.0417**

3.5 Building Construction - 2020

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.1897	1.7172	1.5079	2.4100e-003		0.1000	0.1000		0.0940	0.0940	0.0000	207.2909	207.2909	0.0506	0.0000	208.5552
Total	**0.1897**	**1.7172**	**1.5079**	**2.4100e-003**		**0.1000**	**0.1000**		**0.0940**	**0.0940**	**0.0000**	**207.2909**	**207.2909**	**0.0506**	**0.0000**	**208.5552**

3.5 Building Construction - 2020

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0440	1.2637	0.3366	3.0300e-003	0.0730	6.2600e-003	0.0793	0.0211	5.9900e-003	0.0271	0.0000	290.1492	290.1492	0.0133	0.0000	290.4819
Worker	0.0948	0.0681	0.7145	2.1500e-003	0.2264	1.4600e-003	0.2279	0.0602	1.3500e-003	0.0616	0.0000	194.1861	194.1861	4.7600e-003	0.0000	194.3052
Total	**0.1388**	**1.3318**	**1.0511**	**5.1800e-003**	**0.2995**	**7.7200e-003**	**0.3072**	**0.0813**	**7.3400e-003**	**0.0887**	**0.0000**	**484.3353**	**484.3353**	**0.0181**	**0.0000**	**484.7870**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.1897	1.7172	1.5079	2.4100e-003		0.1000	0.1000		0.0940	0.0940	0.0000	207.2907	207.2907	0.0506	0.0000	208.5550
Total	**0.1897**	**1.7172**	**1.5079**	**2.4100e-003**		**0.1000**	**0.1000**		**0.0940**	**0.0940**	**0.0000**	**207.2907**	**207.2907**	**0.0506**	**0.0000**	**208.5550**

3.5 Building Construction - 2020

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0440	1.2637	0.3366	3.0300e-003	0.0730	6.2600e-003	0.0793	0.0211	5.9900e-003	0.0271	0.0000	290.1492	290.1492	0.0133	0.0000	290.4819
Worker	0.0948	0.0681	0.7145	2.1500e-003	0.2264	1.4600e-003	0.2279	0.0602	1.3500e-003	0.0616	0.0000	194.1861	194.1861	4.7600e-003	0.0000	194.3052
Total	**0.1388**	**1.3318**	**1.0511**	**5.1800e-003**	**0.2995**	**7.7200e-003**	**0.3072**	**0.0813**	**7.3400e-003**	**0.0887**	**0.0000**	**484.3353**	**484.3353**	**0.0181**	**0.0000**	**484.7870**

3.5 Building Construction - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.1150	1.0546	1.0028	1.6300e-003		0.0580	0.0580		0.0545	0.0545	0.0000	140.1406	140.1406	0.0338	0.0000	140.9858
Total	**0.1150**	**1.0546**	**1.0028**	**1.6300e-003**		**0.0580**	**0.0580**		**0.0545**	**0.0545**	**0.0000**	**140.1406**	**140.1406**	**0.0338**	**0.0000**	**140.9858**

3.5 Building Construction - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0245	0.7709	0.2052	2.0300e-003	0.0494	1.7100e-003	0.0511	0.0143	1.6300e-003	0.0159	0.0000	194.3239	194.3239	8.4700e-003	0.0000	194.5356
Worker	0.0595	0.0412	0.4415	1.4000e-003	0.1531	9.6000e-004	0.1540	0.0407	8.9000e-004	0.0416	0.0000	126.7093	126.7093	2.8800e-003	0.0000	126.7813
Total	**0.0839**	**0.8121**	**0.6467**	**3.4300e-003**	**0.2024**	**2.6700e-003**	**0.2051**	**0.0550**	**2.5200e-003**	**0.0575**	**0.0000**	**321.0331**	**321.0331**	**0.0114**	**0.0000**	**321.3169**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.1150	1.0546	1.0028	1.6300e-003		0.0580	0.0580		0.0545	0.0545	0.0000	140.1404	140.1404	0.0338	0.0000	140.9856
Total	**0.1150**	**1.0546**	**1.0028**	**1.6300e-003**		**0.0580**	**0.0580**		**0.0545**	**0.0545**	**0.0000**	**140.1404**	**140.1404**	**0.0338**	**0.0000**	**140.9856**

3.5 Building Construction - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0245	0.7709	0.2052	2.0300e-003	0.0494	1.7100e-003	0.0511	0.0143	1.6300e-003	0.0159	0.0000	194.3239	194.3239	8.4700e-003	0.0000	194.5356
Worker	0.0595	0.0412	0.4415	1.4000e-003	0.1531	9.6000e-004	0.1540	0.0407	8.9000e-004	0.0416	0.0000	126.7093	126.7093	2.8800e-003	0.0000	126.7813
Total	**0.0839**	**0.8121**	**0.6467**	**3.4300e-003**	**0.2024**	**2.6700e-003**	**0.2051**	**0.0550**	**2.5200e-003**	**0.0575**	**0.0000**	**321.0331**	**321.0331**	**0.0114**	**0.0000**	**321.3169**

3.6 Paving - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0126	0.1292	0.1465	2.3000e-004		6.7800e-003	6.7800e-003		6.2400e-003	6.2400e-003	0.0000	20.0235	20.0235	6.4800e-003	0.0000	20.1854
Paving	1.6600e-003					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0142**	**0.1292**	**0.1465**	**2.3000e-004**		**6.7800e-003**	**6.7800e-003**		**6.2400e-003**	**6.2400e-003**	**0.0000**	**20.0235**	**20.0235**	**6.4800e-003**	**0.0000**	**20.1854**

3.6 Paving - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	4.6000e-004	3.2000e-004	3.4300e-003	1.0000e-005	1.1900e-003	1.0000e-005	1.2000e-003	3.2000e-004	1.0000e-005	3.2000e-004	0.0000	0.9848	0.9848	2.0000e-005	0.0000	0.9854
Total	**4.6000e-004**	**3.2000e-004**	**3.4300e-003**	**1.0000e-005**	**1.1900e-003**	**1.0000e-005**	**1.2000e-003**	**3.2000e-004**	**1.0000e-005**	**3.2000e-004**	**0.0000**	**0.9848**	**0.9848**	**2.0000e-005**	**0.0000**	**0.9854**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0126	0.1292	0.1465	2.3000e-004		6.7800e-003	6.7800e-003		6.2400e-003	6.2400e-003	0.0000	20.0235	20.0235	6.4800e-003	0.0000	20.1854
Paving	1.6600e-003					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0142**	**0.1292**	**0.1465**	**2.3000e-004**		**6.7800e-003**	**6.7800e-003**		**6.2400e-003**	**6.2400e-003**	**0.0000**	**20.0235**	**20.0235**	**6.4800e-003**	**0.0000**	**20.1854**

3.6 Paving - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	4.6000e-004	3.2000e-004	3.4300e-003	1.0000e-005	1.1900e-003	1.0000e-005	1.2000e-003	3.2000e-004	1.0000e-005	3.2000e-004	0.0000	0.9848	0.9848	2.0000e-005	0.0000	0.9854
Total	**4.6000e-004**	**3.2000e-004**	**3.4300e-003**	**1.0000e-005**	**1.1900e-003**	**1.0000e-005**	**1.2000e-003**	**3.2000e-004**	**1.0000e-005**	**3.2000e-004**	**0.0000**	**0.9848**	**0.9848**	**2.0000e-005**	**0.0000**	**0.9854**

3.7 Architectural Coating - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Archit. Coating	3.6728					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	2.1900e-003	0.0153	0.0182	3.0000e-005		9.4000e-004	9.4000e-004		9.4000e-004	9.4000e-004	0.0000	2.5533	2.5533	1.8000e-004	0.0000	2.5576
Total	**3.6750**	**0.0153**	**0.0182**	**3.0000e-005**		**9.4000e-004**	**9.4000e-004**		**9.4000e-004**	**9.4000e-004**	**0.0000**	**2.5533**	**2.5533**	**1.8000e-004**	**0.0000**	**2.5576**

3.7 Architectural Coating - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.9700e-003	1.3700e-003	0.0146	5.0000e-005	5.0800e-003	3.0000e-005	5.1100e-003	1.3500e-003	3.0000e-005	1.3800e-003	0.0000	4.2019	4.2019	1.0000e-004	0.0000	4.2043
Total	**1.9700e-003**	**1.3700e-003**	**0.0146**	**5.0000e-005**	**5.0800e-003**	**3.0000e-005**	**5.1100e-003**	**1.3500e-003**	**3.0000e-005**	**1.3800e-003**	**0.0000**	**4.2019**	**4.2019**	**1.0000e-004**	**0.0000**	**4.2043**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Archit. Coating	3.6728					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	2.1900e-003	0.0153	0.0182	3.0000e-005		9.4000e-004	9.4000e-004		9.4000e-004	9.4000e-004	0.0000	2.5533	2.5533	1.8000e-004	0.0000	2.5576
Total	**3.6750**	**0.0153**	**0.0182**	**3.0000e-005**		**9.4000e-004**	**9.4000e-004**		**9.4000e-004**	**9.4000e-004**	**0.0000**	**2.5533**	**2.5533**	**1.8000e-004**	**0.0000**	**2.5576**

3.7 Architectural Coating - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.9700e-003	1.3700e-003	0.0146	5.0000e-005	5.0800e-003	3.0000e-005	5.1100e-003	1.3500e-003	3.0000e-005	1.3800e-003	0.0000	4.2019	4.2019	1.0000e-004	0.0000	4.2043
Total	**1.9700e-003**	**1.3700e-003**	**0.0146**	**5.0000e-005**	**5.0800e-003**	**3.0000e-005**	**5.1100e-003**	**1.3500e-003**	**3.0000e-005**	**1.3800e-003**	**0.0000**	**4.2019**	**4.2019**	**1.0000e-004**	**0.0000**	**4.2043**

4.0 Operational Detail - Mobile

4.1 Mitigation Measures Mobile

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Mitigated	1.0058	4.4280	12.8669	0.0442	0.5876	0.0378	0.6255	0.2335	0.0354	0.2688	0.0000	4,045.8073	4,045.8073	0.1351	0.0000	4,049.1857
Unmitigated	1.0058	4.4280	12.8669	0.0442	0.5876	0.0378	0.6255	0.2335	0.0354	0.2688	0.0000	4,045.8073	4,045.8073	0.1351	0.0000	4,049.1857

4.2 Trip Summary Information

	Average Daily Trip Rate			Unmitigated	Mitigated
Land Use	Weekday	Saturday	Sunday	Annual VMT	Annual VMT
Parking Lot	0.00	0.00	0.00		
General Light Industry	4,893.71	926.79	477.43	10,790,827	10,790,827
Total	4,893.71	926.79	477.43	10,790,827	10,790,827

4.3 Trip Type Information

	Miles			Trip %			Trip Purpose %		
Land Use	H-W or C-W	H-S or C-C	H-O or C-NW	H-W or C-W	H-S or C-C	H-O or C-NW	Primary	Diverted	Pass-by
Parking Lot	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
General Light Industry	9.50	7.30	7.30	59.00	28.00	13.00	92	5	3

4.4 Fleet Mix

Land Use	LDA	LDT1	LDT2	MDV	LHD1	LHD2	MHD	HHD	OBUS	UBUS	MCY	SBUS	MH
Parking Lot	0.607897	0.037434	0.184004	0.107261	0.014919	0.004991	0.012447	0.020659	0.002115	0.001554	0.005334	0.000623	0.000761
General Light Industry	0.607897	0.037434	0.184004	0.107261	0.014919	0.004991	0.012447	0.020659	0.002115	0.001554	0.005334	0.000623	0.000761

5.0 Energy Detail

Historical Energy Use: N

5.1 Mitigation Measures Energy

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Electricity Mitigated						0.0000	0.0000		0.0000	0.0000	0.0000	712.8863	712.8863	0.0763	0.0158	719.4969
Electricity Unmitigated						0.0000	0.0000		0.0000	0.0000	0.0000	712.8863	712.8863	0.0763	0.0158	719.4969
NaturalGas Mitigated	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	988.3864	988.3864	0.0189	0.0181	994.2599
NaturalGas Unmitigated	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	988.3864	988.3864	0.0189	0.0181	994.2599

5.2 Energy by Land Use - NaturalGas

Unmitigated

	NaturalGas Use	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Land Use	kBTU/yr	tons/yr										MT/yr					
General Light Industry	1.85217e+007	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	988.3864	988.3864	0.0189	0.0181	994.2599
Parking Lot	0	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total		**0.0999**	**0.9079**	**0.7627**	**5.4500e-003**		**0.0690**	**0.0690**		**0.0690**	**0.0690**	**0.0000**	**988.3864**	**988.3864**	**0.0189**	**0.0181**	**994.2599**

Mitigated

	NaturalGas Use	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Land Use	kBTU/yr	tons/yr										MT/yr					
General Light Industry	1.85217e+007	0.0999	0.9079	0.7627	5.4500e-003		0.0690	0.0690		0.0690	0.0690	0.0000	988.3864	988.3864	0.0189	0.0181	994.2599
Parking Lot	0	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total		**0.0999**	**0.9079**	**0.7627**	**5.4500e-003**		**0.0690**	**0.0690**		**0.0690**	**0.0690**	**0.0000**	**988.3864**	**988.3864**	**0.0189**	**0.0181**	**994.2599**

5.3 Energy by Land Use - Electricity

Unmitigated

	Electricity Use	Total CO2	CH4	N2O	CO2e
Land Use	kWh/yr	MT/yr			
General Light Industry	5.79943e +006	712.8863	0.0763	0.0158	719.4969
Parking Lot	0	0.0000	0.0000	0.0000	0.0000
Total		**712.8863**	**0.0763**	**0.0158**	**719.4969**

Mitigated

	Electricity Use	Total CO2	CH4	N2O	CO2e
Land Use	kWh/yr	MT/yr			
General Light Industry	5.79943e +006	712.8863	0.0763	0.0158	719.4969
Parking Lot	0	0.0000	0.0000	0.0000	0.0000
Total		**712.8863**	**0.0763**	**0.0158**	**719.4969**

6.0 Area Detail

6.1 Mitigation Measures Area

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Mitigated	3.1126	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161
Unmitigated	3.1126	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161

6.2 Area by SubCategory

Unmitigated

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
SubCategory	tons/yr										MT/yr					
Architectural Coating	0.3661					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Consumer Products	2.7457					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Landscaping	7.3000e-004	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161
Total	**3.1126**	**7.0000e-005**	**7.7800e-003**	**0.0000**		**3.0000e-005**	**3.0000e-005**		**3.0000e-005**	**3.0000e-005**	**0.0000**	**0.0151**	**0.0151**	**4.0000e-005**	**0.0000**	**0.0161**

6.2 Area by SubCategory

Mitigated

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
SubCategory	tons/yr										MT/yr					
Architectural Coating	0.3661					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Consumer Products	2.7457					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Landscaping	7.3000e-004	7.0000e-005	7.7800e-003	0.0000		3.0000e-005	3.0000e-005		3.0000e-005	3.0000e-005	0.0000	0.0151	0.0151	4.0000e-005	0.0000	0.0161
Total	**3.1126**	**7.0000e-005**	**7.7800e-003**	**0.0000**		**3.0000e-005**	**3.0000e-005**		**3.0000e-005**	**3.0000e-005**	**0.0000**	**0.0151**	**0.0151**	**4.0000e-005**	**0.0000**	**0.0161**

7.0 Water Detail

7.1 Mitigation Measures Water

	Total CO2	CH4	N2O	CO2e
Category	MT/yr			
Mitigated	159.5042	5.3022	0.1273	329.9975
Unmitigated	159.5042	5.3022	0.1273	329.9975

7.2 Water by Land Use

Unmitigated

	Indoor/Outdoor Use	Total CO2	CH4	N2O	CO2e
Land Use	Mgal	MT/yr			
General Light Industry	162.363 / 0	159.5042	5.3022	0.1273	329.9975
Parking Lot	0 / 0	0.0000	0.0000	0.0000	0.0000
Total		**159.5042**	**5.3022**	**0.1273**	**329.9975**

7.2 Water by Land Use

Mitigated

	Indoor/Outdoor Use	Total CO2	CH4	N2O	CO2e
Land Use	Mgal	MT/yr			
General Light Industry	162.363 / 0	159.5042	5.3022	0.1273	329.9975
Parking Lot	0 / 0	0.0000	0.0000	0.0000	0.0000
Total		**159.5042**	**5.3022**	**0.1273**	**329.9975**

8.0 Waste Detail

8.1 Mitigation Measures Waste

Category/Year

	Total CO2	CH4	N2O	CO2e
	MT/yr			
Mitigated	176.7280	10.4443	0.0000	437.8361
Unmitigated	176.7280	10.4443	0.0000	437.8361

8.2 Waste by Land Use

Unmitigated

	Waste Disposed	Total CO2	CH4	N2O	CO2e
Land Use	tons	MT/yr			
General Light Industry	870.62	176.7280	10.4443	0.0000	437.8361
Parking Lot	0	0.0000	0.0000	0.0000	0.0000
Total		**176.7280**	**10.4443**	**0.0000**	**437.8361**

Mitigated

	Waste Disposed	Total CO2	CH4	N2O	CO2e
Land Use	tons	MT/yr			
General Light Industry	870.62	176.7280	10.4443	0.0000	437.8361
Parking Lot	0	0.0000	0.0000	0.0000	0.0000
Total		**176.7280**	**10.4443**	**0.0000**	**437.8361**

9.0 Operational Offroad

Equipment Type	Number	Hours/Day	Days/Year	Horse Power	Load Factor	Fuel Type

10.0 Stationary Equipment

Fire Pumps and Emergency Generators

Equipment Type	Number	Hours/Day	Hours/Year	Horse Power	Load Factor	Fuel Type

Boilers

Equipment Type	Number	Heat Input/Day	Heat Input/Year	Boiler Rating	Fuel Type

User Defined Equipment

Equipment Type	Number

11.0 Vegetation

APPENDIX AIR DR-31

EPA Certificate of Conformity

	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY **2019 MODEL YEAR** **CERTIFICATE OF CONFORMITY** **WITH THE CLEAN AIR ACT**	**OFFICE OF TRANSPORTATION** **AND AIR QUALITY** **ANN ARBOR, MICHIGAN 48105**

Certificate Issued To: MTU America, Inc. (U.S. Manufacturer or Importer) **Certificate Number: KMDDL95.4GTR-007**	**Effective Date:** **11/06/2018** **Expiration Date:** **12/31/2019**	**Byron J. Bunker, Division Director** **Compliance Division**	**Issue Date:** **11/06/2018** **Revision Date:** **N/A**

Model Year: 2019 **Manufacturer Type:** Original Engine Manufacturer **Engine Family:** KMDDL95.4GTR	**Mobile/Stationary Indicator:** Stationary **Emissions Power Category:** 560<kW<=2237 **Fuel Type:** Diesel **After Treatment Devices:** No After Treatment Devices Installed **Non-after Treatment Devices:** Electronic Control, Smoke Puff Limiter

Pursuant to Section 111 and Section 213 of the Clean Air Act (42 U.S.C. sections 7411 and 7547) and 40 CFR Part 60, and subject to the terms and conditions prescribed in those provisions, this certificate of conformity is hereby issued with respect to the test engines which have been found to conform to applicable requirements and which represent the following engines, by engine family, more fully described in the documentation required by 40 CFR Part 60 and produced in the stated model year.

This certificate of conformity covers only those new compression-ignition engines which conform in all material respects to the design specifications that applied to those engines described in the documentation required by 40 CFR Part 60 and which are produced during the model year stated on this certificate of the said manufacturer, as defined in 40 CFR Part 60.

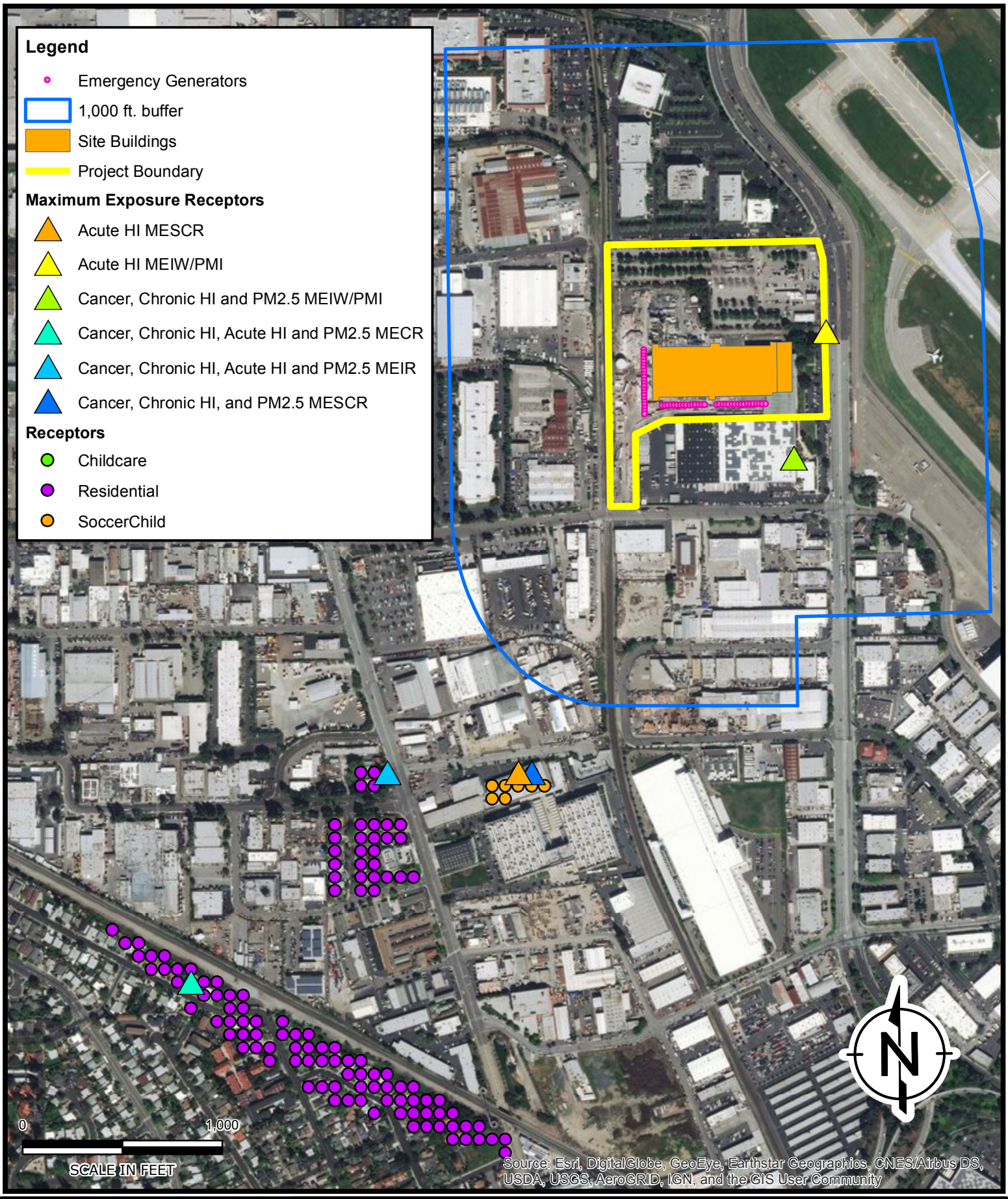
It is a term of this certificate that the manufacturer shall consent to all inspections described in 40 CFR 1068 and authorized in a warrant or court order. Failure to comply with the requirements of such a warrant or court order may lead to revocation or suspension of this certificate for reasons specified in 40 CFR Part 60. It is also a term of this certificate that this certificate may be revoked or suspended or rendered void *ab initio* for other reasons specified in 40 CFR Part 60.

This certificate does not cover engines sold, offered for sale, or introduced, or delivered for introduction, into commerce in the U.S. prior to the effective date of the certificate.

The actual engine power may lie outside the limits of the Emissions Power Category shown above. See the certificate application for details.

APPENDIX PH DR-46

Sensitive Receptor Map



RAMBOLL

DRAFTED BY: MN

DATE: 9/26/2019

Figure for Data Request Response #46, Set 1

CyrusOne

Santa Clara, CA

FIGURE

X

PROJECT:

APPENDIX TP-57

Thermal Plume Analysis

Prepared for
CyrusOne Data Centers
Santa Clara, California

Prepared by
Ramboll US Corporation
San Francisco, CA

Project Number
1690013366

Date
September 2019

PLUME ASSESSMENT

CYRUSONE SEQUOIA DATA CENTER AND BACKUP GENERATING FACILITY
SANTA CLARA, CALIFORNIA

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1.1 Background 1
2. SCREENING ASSESSMENT 2
2.1 Vertical plume velocity guidelines 2
3. MODEL INPUT DATA 3
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4. MODEL RESULTS 6
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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

CyrusOne, LLC has proposed to develop a data center in Santa Clara, California, in a location adjacent the San Jose airport. The data center will involve fifty-four (54) backup emergency diesel generators and fifty-two (52) chillers.

The California Energy Commission (CEC) requires CyrusOne to evaluate the potential implications of the thermal plumes from the proposed stacks on aviation safety. Ramboll has been engaged by CyrusOne 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 also 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 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 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) 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 several atmospheric emission sources consisting of 54 emergency standby diesel generators and 52 chillers.

The emission parameters used within the screening assessment for the four scenarios considered for both emission sources are presented in Table 1.

Table 1. Stack Parameters

	Emergency Generators			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4 (worst case)
Ambient Potential Temperature (°F)	30	59	76	96
Stack Height (feet)	38.75	38.75	38.75	38.75
Stack Diameter (feet)	1.67	1.67	1.67	1.67
Stack Velocity at Exit (m/s)	42.94	42.94	42.94	42.94
Stack Potential Temperature (F)	933.8	933.8	933.8	933.8
	Chillers			
	Scenario 1 (worst case)	Scenario 2	Scenario 3	Scenario 4
Ambient Potential Temperature (°F)	30	59	76	96
Stack Height (feet)	94.89	94.89	94.89	94.89
Equivalent Stack Diameter (feet)	13.42	13.42	13.42	13.42
Stack Velocity at Exit (m/s)	9.11	9.11	9.11	9.11
Stack Potential Temperature (F)	126.90	126.90	126.90	126.90

The 54 generator stacks are arranged in the configuration displayed in Figure 1. Although the project consists of 54 2.75-MW generators with varied release heights, all generators were conservatively assumed to have the same release heights as the tallest generator stacks for ease of calculation.

The chillers are arranged in an irregular layout as shown in Figure 2. Each chiller consists of twenty (20) separate discharge points with a diameter of thirty-six (36) inches. These were

combined into a single point with an equivalent area as listed in Table 1. The chillers were assumed to be adjacent with a centre-to-centre distance of thirty (30) metres.

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 (54)	309 K (96°F)	11.81 m (38.7 ft)	0.51 m (1.7 ft)	42.94 m/s (140.9 ft/s)	19,070 ACFM	774 K (933.8°F)	26.21 m (86 ft)	22.56 m (74 ft)	22.56 m (74 ft)
Chillers (52)	272 K (30°F)	28.92 m (94.9 ft)	4.09 m (13.4 ft)	9.11 m/s (29.9 ft/s)	254,266 ACFM	326 K (126.9°F)	53.34 m (175 ft)	48.46 m (159 ft)	49.07 m (161 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 is presented to represent the worst-case for both the emergency generators and the chillers. 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.

For the emergency generators, the worst-case scenario assumed an ambient temperature of 96°F. Using the Spillane methodology Method 1, the plume-averaged vertical velocity drops below the CEC screening threshold of 5.3 m/s at 86 feet above ground level for a single emergency generator. Method 2 yielded slightly lower heights than Method 1 at 74 feet. Using the CEC methodology of merged plumes, the vertical velocity drops below 5.3 m/s for the 54 generators at 74 feet above ground level.

For the chiller, the worst-case scenario assumed an ambient temperature of 30°F. Using the Spillane methodology Method 1, the plume-averaged vertical velocity drops below the CEC screening threshold of 5.3 m/s at 175 feet above ground level for a single chiller. Method 2 yielded slightly lower heights than Method 1 at 159 feet. Using the CEC methodology of merged plumes, the vertical velocity drops below 5.3 m/s for the 52 chillers at 161 feet above ground level.

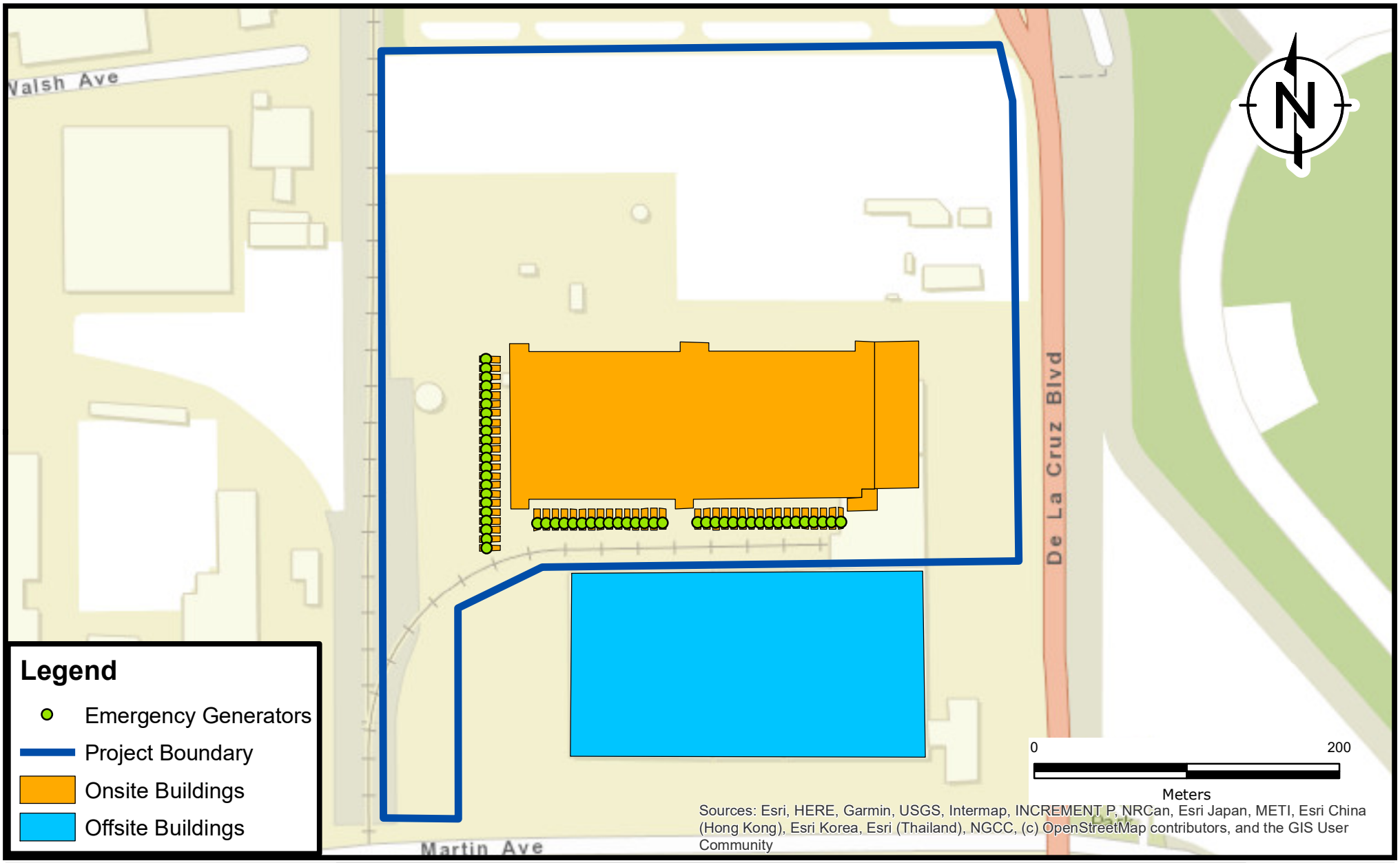
5. SUMMARY AND CONCLUSION

Modelling of the characteristics of the plumes from the diesel emergency generators at the CyrusOne data center has been completed and indicates that under worst-case ambient conditions and calculation methodology, predicted all vertical velocities are below 5.3 m/s for the emergency generators at a height of 86 feet above ground and a height of 175 feet for the chillers.

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: SB

DATE: 7/29/2019

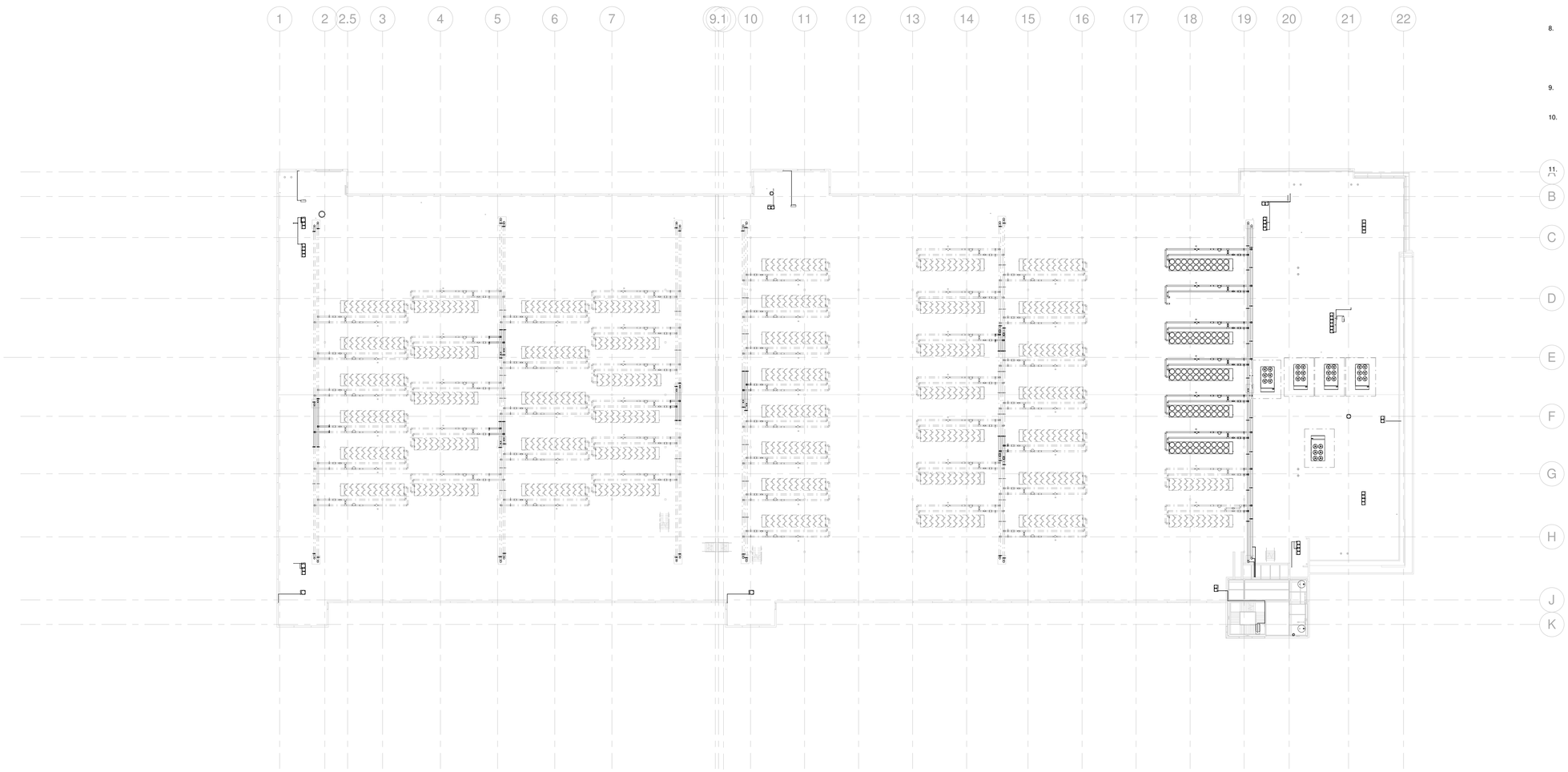
Project Location and Facility Layout
CyrusOne Project
CyrusOne Data Center
Santa Clara, California

FIGURE
1

PROJECT: 1690013366

GENERAL NOTES

1. INSTALL U-SHAPED SEISMICALLY RATED PIPING EXPANSION JOINTS FOR HORIZONTAL SEISMIC BULDING JOINTS. USE EXPANDABLE METRAFLEX CONNECTION FOR VERTICAL EXPANSION JOINTS. REFER TO STRUCTURAL AND ARCHITECTURAL DRAWINGS FOR BUILDING JOINT LOCATIONS. REFER TO DETAIL 6 ON M-05-03 FOR VERTICAL PIPE RISER METRAFLEX EXPANSION JOINT DETAIL.
2. INSTALL FLEXIBLE CONNECTORS BETWEEN PIPING AND ANCHORED EQUIPMENT
3. ALL REFRIGERANT SUCTION LINES BETWEEN ACCU'S AND HRU'S CONSIST OF A HIGH PRESSURE AND LOW PRESSURE SUCTION LINE.
4. REFRIGERANT PIPE LENGTH AND CHANGES IN ELEVATION SHALL BE REVIEWED BY MANUFACTURER FOR CONFORMANCE WITH INSTALLATION GUIDLINES. MANUFACTURER SHALL PROVIDE SIZES FOR ALL REFRIGERANT LINE SETS AND INCLUDE TRAP LOCATIONS AS REQUIRED.
5. MECHANICAL CONTRACTOR IS RESPONSIBLE FOR ADDITIONAL REFRIGERANT AND SYSTEM CHARGING BEYOND FACTORY EQUIPMENT CHARGE. WEIGH ADDITIONAL REFRIGERANT CHARGE ADMINISTERED INTO SYSTEM PER MANUFACTURER'S REQUIREMENTS AS PART OF START-UP AND COMMISIONING. RECORD WEIGHT OF ADDED CHARGE FOR INCLUSION IN START-UP AND COMMISSIONING REPORT.
6. ENTIRE REFRIGERANT SYSTEM SHALL HOLD A 500 MICRON VACUUM FOR AT LEAST 12 HORS PRIOR TO ADDING REFRIGERANT CHARGE.
7. HORIZONTAL RUNS OF CONDENSATE PIPING SHALL HAVE A PTICH OF 1/8" PER FOOT TOWARDS DRAIN TERMINATION AND SHALL BE INSTALLED WITH AIR GAPS TO ENSURE GRAVITY FLOW FROM EQUIPMENT TO DRAIN.
8. ALL VALVING AND PIPING SYSTEM ACCESSORIES ARE TO BE INSTALLED SO THAT THEY ARE ACCESSIBLE FROM THE FLOOR FOR MAINTENANCE. WHERE HEIGHT EXCEEDS WHAT IS ACCESSIBLE FROM A LADDER, VALVES AND ACCESSORIES SHALL BE INSTALLED WITHIN LINE OF SIGHT TO FLOOR BELOW FOR ACCESS FROM LIFT.
9. ALL HALF-TONED AND DASHED PIPING AND EQUIPMENT ARE FOR FUTURE PLANNING PURPOSES AND NOT TO BE INSTALLED DAY 1.
10. ALL MECHANICAL EQUIPMENT SHALL BE SEISMICALLY ANCHORED TO THE STRUCTURE BY THE MECHANICAL CONTRACTOR. THIS CONTRACTOR SHALL ENGAGE THE SERVICES OF A LICENSED STRUCTURAL ENGINEER WHO SHALL PROVIDE STRUCTURAL DETAILS OF ALL INSTALLATIONS.
11. INSTALL ISOLATION VALVES 5'-0" AFF IN ALL PIPE RISERS THAT PENETRATE THE SLAB BELOW.



1 MECHANICAL PIPING PLAN - ROOF - MASTER PLAN
1" = 30'-0"

CORGAN

CORGAN
401 N Houston Street
Dallas, TX 75202
T: 214.748.2000 F: 214.653.8281

kW Mission Critical Engineering, d.p.c.
40 E. Rio Salado Parkway, 4th Floor
Tempe, AZ 85281

Bennett & Pless Inc.
47 Perimeter Central East,
Suite 500 Atlanta, GA 30346

KIER+WRIGHT
2850 Collier Canyon Rd.
Livermore, CA 94551

TCD Design Consulting LLC
103 E Haning St. Howe TX 75459

JETT Landscape Architecture + Design
2 Theatre Square, Suite 218, Orinda, CA 94563

	ISSUES	
1	06/12/2019	DESIGN DEVELOPMENT
2	08/01/2019	ISSUE FOR PERMIT

	REVISIONS	

kW Contact: ROB KING Phone: 518.424.9876

Christopher Kurkjian, P.E..
License #:35948 Expiration Date: 6.30.2020

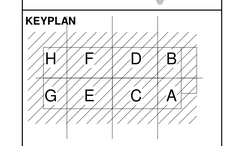
PROFESSIONAL ENGINEER CHRISTOPHER W. KURKJIAN NO. 35948 MECHANICAL STATE OF CALIFORNIA

Date: 08/01/2019

SANTA CLARA
2600 De La Cruz Blvd.
Santa Clara, CA 95050

CyrusOne

KEYPLAN



MECHANICAL PIPING PLAN - ROOF - MASTER PLAN

PROJECT NUMBER 19.030

DATE 08/01/2019

SHEET NUMBER

M03-05

PLAN N

8/1/2019 8:01:05 PM M03-05 MECHANICAL PIPING PLAN - ROOF - MASTER PLAN

TABLES

	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 (54)	272 K (30°F)	11.81 m (38.7 ft)	0.51 m (1.7 ft)	42.94 m/s (140.9 ft/s)	19,070 ACFM	774 K (933.8°F)	26.21 m (86 ft)	22.25 m (73 ft)	22.25 m (73 ft)
Emergencey Diesel Generators (54)	288 K (59°F)	11.81 m (38.7 ft)	0.51 m (1.7 ft)	42.94 m/s (140.9 ft/s)	19,070 ACFM	774 K (933.8°F)	26.21 m (86 ft)	22.25 m (73 ft)	22.25 m (73 ft)
Emergencey Diesel Generators (54)	298 K (76°F)	11.81 m (38.7 ft)	0.51 m (1.7 ft)	42.94 m/s (140.9 ft/s)	19,070 ACFM	774 K (933.8°F)	26.21 m (86 ft)	22.25 m (73 ft)	22.25 m (73 ft)
Emergencey Diesel Generators (54)	309 K (96°F)	11.81 m (38.7 ft)	0.51 m (1.7 ft)	42.94 m/s (140.9 ft/s)	19,070 ACFM	774 K (933.8°F)	26.21 m (86 ft)	22.56 m (74 ft)	22.56 m (74 ft)
Chillers (52)	272 K (30°F)	28.92 m (94.9 ft)	4.09 m (13.4 ft)	9.11 m/s (29.9 ft/s)	254,266 ACFM	326 K (126.9°F)	53.34 m (175 ft)	48.46 m (159 ft)	49.07 m (161 ft)
Chillers (52)	288 K (59°F)	28.92 m (94.9 ft)	4.09 m (13.4 ft)	9.11 m/s (29.9 ft/s)	254,266 ACFM	327 K (126.9°F)	52.73 m (173 ft)	49.68 m (163 ft)	50.90 m (167 ft)
Chillers (52)	298 K (76°F)	28.92 m (94.9 ft)	4.09 m (13.4 ft)	9.11 m/s (29.9 ft/s)	254,266 ACFM	328 K (126.9°F)	52.12 m (171 ft)	50.29 m (165 ft)	51.51 m (169 ft)
Chillers (52)	309 K (96°F)	28.92 m (94.9 ft)	4.09 m (13.4 ft)	9.11 m/s (29.9 ft/s)	254,266 ACFM	329 K (126.9°F)	58.81 m (170 ft)	50.60 m (166 ft)	58.81 m (170 ft)

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	11.81	meters	38.7	feet	λ	1.11	
Stack Diameter D	0.51	meters	1.7	feet		0.3048 meters/feet	1.673248693
Stack Velocity V_{exit}	42.94	m/s	140.9	ft/sec			
Volumetric Flow	9	cu.m/sec	19,070	ACFM	$\pi V_{exit}D^2/4$		Sect.2/¶1
Stack Potential Temp θ_s	774	Kelvins	933.8	°F	Back-Calc'd from Buoyancy Flux		
Initial Stack Buoyancy Flux F_o	18	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			$\lambda^2 gVa^2(1-\theta_a/\theta_o)$ for a,V,θ_o at plume height (not used here)		

Conditions at End (Top) of Jet Phase:

Height above Stack z	3.188	meters*	10.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	14.998	meters	49.2	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	21.470	m/s	70.44	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.020	meters	3.3	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	1.298	meters*	4.3	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top		Sect.2/Eq.6
Height above Ground z_v+h_s	13.108	meters	43.0	feet		where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$=	0.592792823

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 $(Va)_o$	6.491	m^2/s			$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$		

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 = 3.188 meters*	***14.998***	***49.2***	***1.020***		***21.47***
88.190 meters*	**100.000**	328.1	27.805	0.79	**1.83**
138.190 meters*	150.000	492.1	43.805	0.50	1.56
188.190 meters*	**200.000**	656.2	59.805	0.37	**1.41**
238.190 meters*	250.000	820.2	75.805	0.29	1.30
288.190 meters*	**300.000**	984.3	91.805	0.24	**1.22**
338.190 meters*	350.000	1148.3	107.805	0.20	1.16
388.190 meters*	400.000	1312.3	123.805	0.18	1.10
438.190 meters*	450.000	1476.4	139.805	0.16	1.06
488.190 meters*	**500.000**	1640.4	155.805	0.14	**1.02**
538.190 meters*	550.000	1804.5	171.805	0.13	0.99
588.190 meters*	600.000	1968.5	187.805	0.12	0.96
638.190 meters*	650.000	2132.5	203.805	0.11	0.94
688.190 meters*	**700.000**	2296.6	219.805	0.10	**0.91**
738.190 meters*	750.000	2460.6	235.805	0.09	0.89
788.190 meters*	800.000	2624.7	251.805	0.09	0.87
838.190 meters*	850.000	2788.7	267.805	0.08	0.85
888.190 meters*	900.000	2952.8	283.805	0.08	0.84
938.190 meters*	950.000	3116.8	299.805	0.07	0.82
988.190 meters*	**1000.000**	3280.8	315.805	0.07	**0.81**
1038.190 meters*	1050.000	3444.9	331.805	0.07	0.79
1088.190 meters*	1100.000	3608.9	347.805	0.06	0.78
1138.190 meters*	1150.000	3773.0	363.805	0.06	0.77
1188.190 meters*	1200.000	3937.0	379.805	0.06	0.76
1238.190 meters*	1250.000	4101.0	395.805	0.06	0.75

6.478 meters*	18.288	60.0	1.658	13.21	8.28
9.526 meters*	21.336	70.0	2.633	8.32	5.64
9.831 meters*	21.641	71.0	2.731	8.02	5.49
10.136 meters*	21.946	72.0	2.828	7.74	5.35
10.441 meters*	22.251	73.0	2.926	7.49	5.22
10.745 meters*	22.555	74.0	3.023	7.24	5.09
11.050 meters*	22.860	75.0	3.121	7.02	4.98
11.355 meters*	23.165	76.0	3.218	6.80	4.87
11.660 meters*	23.470	77.0	3.316	6.60	4.77
11.965 meters*	23.775	78.0	3.413	6.42	4.68
12.269 meters*	24.079	79.0	3.511	6.24	4.59
12.574 meters*	24.384	80.0	3.608	6.07	4.51
12.879 meters*	24.689	81.0	3.706	5.91	4.43
13.184 meters*	24.994	82.0	3.803	5.76	4.35
13.489 meters*	25.299	83.0	3.901	5.61	4.28
13.793 meters*	25.604	84.0	3.999	5.48	4.22
14.098 meters*	25.908	85.0	4.096	5.35	4.15
14.403 meters*	26.213	86.0	4.194	5.22	4.09
14.708 meters*	26.518	87.0	4.291	5.10	4.04
15.013 meters*	26.823	88.0	4.389	4.99	3.98
15.317 meters*	27.128	89.0	4.486	4.88	3.93
15.622 meters*	27.432	90.0	4.584	4.78	3.88
15.927 meters*	27.737	91.0	4.681	4.68	3.83
16.232 meters*	28.042	92.0	4.779	4.58	3.79
16.537 meters*	28.347	93.0	4.876	4.49	3.74
16.841 meters*	28.652	94.0	4.974	4.40	3.70
17.146 meters*	28.956	95.0	5.071	4.32	3.66
17.451 meters*	29.261	96.0	5.169	4.24	3.62
17.756 meters*	29.566	97.0	5.267	4.16	3.59
18.061 meters*	29.871	98.0	5.364	4.08	3.55
18.365 meters*	30.176	99.0	5.462	4.01	3.52
18.670 meters*	30.480	100.0	5.559	3.94	3.49
18.975 meters*	30.785	101.0	5.657	3.87	3.45
19.280 meters*	31.090	102.0	5.754	3.81	3.42
19.585 meters*	31.395	103.0	5.852	3.74	3.39
19.889 meters*	31.700	104.0	5.949	3.68	3.36
20.194 meters*	32.004	105.0	6.047	3.62	3.34
20.499 meters*	32.309	106.0	6.144	3.56	3.31
20.804 meters*	32.614	107.0	6.242	3.51	3.28
21.109 meters*	32.919	108.0	6.339	3.45	3.26
21.413 meters*	33.224	109.0	6.437	3.40	3.23
21.718 meters*	33.528	110.0	6.534	3.35	3.21
49.151 meters*	60.961	200.0	15.313	1.43	2.26
79.631 meters*	91.441	300.0	25.067	0.87	1.89
110.111 meters*	121.921	400.0	34.820	0.63	1.69
140.592 meters*	152.402	500.0	44.574	0.49	1.56
171.072 meters*	182.882	600.0	54.328	0.40	1.45
201.552 meters*	213.363	700.0	64.081	0.34	1.38
232.033 meters*	243.843	800.0	73.835	0.30	1.31
262.513 meters*	274.323	900.0	83.589	0.26	1.26
292.994 meters*	304.804	1000.0	93.343	0.23	1.21
323.474 meters*	335.284	1100.0	103.096	0.21	1.17
353.954 meters*	365.764	1200.0	112.850	0.19	1.14
384.435 meters*	396.245	1300.0	122.604	0.18	1.11
414.915 meters*	426.725	1400.0	132.357	0.17	1.08
445.395 meters*	457.206	1500.0	142.111	0.15	1.05
475.876 meters*	487.686	1600.0	151.865	0.14	1.03
506.356 meters*	518.166	1700.0	161.619	0.14	1.01
536.837 meters*	548.647	1800.0	171.372	0.13	0.99
567.317 meters*	579.127	1900.0	181.126	0.12	0.97
597.797 meters*	609.607	2000.0	190.880	0.11	0.96
628.278 meters*	640.088	2100.0	200.633	0.11	0.94
658.758 meters*	670.568	2200.0	210.387	0.10	0.93
689.238 meters*	701.049	2300.0	220.141	0.10	0.91
719.719 meters*	731.529	2400.0	229.895	0.10	0.90
750.199 meters*	762.009	2500.0	239.648	0.09	0.89
780.679 meters*	792.490	2600.0	249.402	0.09	0.87
811.160 meters*	822.970	2700.0	259.156	0.08	0.86
841.640 meters*	853.450	2800.0	268.910	0.08	0.85
872.121 meters*	883.931	2900.0	278.663	0.08	0.84
902.601 meters*	914.411	3000.0	288.417	0.08	0.83
933.081 meters*	944.891	3100.0	298.171	0.07	0.82
963.562 meters*	975.372	3200.0	307.924	0.07	0.81
994.042 meters*	1005.852	3300.0	317.678	0.07	0.81
1024.522 meters*	1036.333	3400.0	327.432	0.07	0.80
1055.003 meters*	1066.813	3500.0	337.186	0.06	0.79
1085.483 meters*	1097.293	3600.0	346.939	0.06	0.78
1115.964 meters*	1127.774	3700.0	356.693	0.06	0.78
1146.444 meters*	1158.254	3800.0	366.447	0.06	0.77
1176.924 meters*	1188.734	3900.0	376.200	0.06	0.76
1207.405 meters*	1219.215	4000.0	385.954	0.06	0.76

Stack Distances (ft)	Number of Stacks
15.3	54

ft	m/s	merged cells	Plume Diamter Feet
60	8.28	1.00	5.44
70	5.64	1.00	8.64
71	5.49	1.00	8.96
72	5.35	1.00	9.28
73	5.22	1.00	9.60
74	5.09	1.00	9.92
75	4.98	1.00	10.24
76	4.87	1.00	10.56
77	4.77	1.00	10.88
78	4.68	1.00	11.20
79	4.59	1.00	11.52
80	4.51	1.00	11.84
81	4.43	1.00	12.16
82	4.35	1.00	12.48
83	4.28	1.00	12.80
84	4.22	1.00	13.12
85	4.15	1.00	13.44
86	4.10	1.01	13.76
87	4.07	1.03	14.08
88	4.03	1.05	14.40
89	4.00	1.07	14.72
90	3.97	1.09	15.04
91	3.94	1.11	15.36
92	3.91	1.13	15.68
93	3.88	1.16	16.00
94	3.86	1.18	16.32
95	3.83	1.20	16.64
96	3.81	1.22	16.96
97	3.79	1.24	17.28
98	3.76	1.26	17.60
99	3.74	1.28	17.92
100	3.72	1.30	18.24
101	3.70	1.32	18.56
102	3.69	1.34	18.88
103	3.67	1.36	19.20
104	3.65	1.39	19.52
105	3.63	1.41	19.84
106	3.62	1.43	20.16
107	3.60	1.45	20.48
108	3.59	1.47	20.80
109	3.57	1.49	21.12
110	3.56	1.51	21.44
200	3.06	3.39	50.24
300	2.90	5.48	82.24
400	2.81	7.58	114.24
500	2.74	9.67	146.24
600	2.69	11.76	178.24
700	2.66	13.85	210.24
800	2.62	15.94	242.24
900	2.59	18.03	274.24
1,000	2.57	20.12	306.24
1,100	2.55	22.22	338.24
1,200	2.53	24.31	370.24
1,300	2.51	26.40	402.24
1,400	2.49	28.49	434.24
1,500	2.48	30.58	466.24
1,600	2.47	32.67	498.24
1,700	2.45	34.77	530.24
1,800	2.44	36.86	562.25
1,900	2.43	38.95	594.25
2,000	2.42	41.04	626.25
2,100	2.41	43.13	658.25
2,200	2.40	45.22	690.25
2,300	2.39	47.31	722.25
2,400	2.38	49.41	754.25
2,500	2.37	51.50	786.25
2,600	2.37	53.59	818.25
2,700	2.34	54.00	850.25
2,800	2.31	54.00	882.25
2,900	2.28	54.00	914.25
3,000	2.26	54.00	946.25
3,100	2.23	54.00	978.25
3,200	2.21	54.00	1010.25
3,300	2.19	54.00	1042.25
3,400	2.16	54.00	1074.25
3,500	2.14	54.00	1106.25
3,600	2.12	54.00	1138.25
3,700	2.10	54.00	1170.25
3,800	2.08	54.00	1202.25
3,900	2.07	54.00	1234.25
4,000	2.05	54.00	1266.25

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:

Ambient Potential Temp θ_a	288	Kelvins	59	°F	Assume neutral conditions ($d\theta/dz=0$)	
Plume Exit Conditions:						
Stack Height h_s	11.81	meters	38.7	feet		
Stack Diameter D	0.51	meters	1.7	feet		
Stack Velocity V_{exit}	42.94	m/s	140.9	ft/sec		
Volumetric Flow	9	cu.m/sec	19,070	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	774	Kelvins	933.8	°F	Back-Calc'd from Buoyancy Flux	
Initial Stack Buoyancy Flux F_o	17	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)	

Constants:

Gravity g	9.81	m/s^2
λ	1.11	
	0.3048	meters/feet

Conditions at End (Top) of Jet Phase:

Height above Stack z	3.188	meters*	10.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z+h_s$	14.998	meters	49.2	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	21.470	m/s	70.44	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.020	meters	3.3	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	1.243	meters*	4.1	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	13.053	meters	42.8	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$= 0.610093999	

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 $(Va)_o$	6.680	m^2/s			$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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 = 3.188 meters*	***14.998***	***49.2***	***1.020***		***21.47***
88.190 meters*	**100.000**	328.1	27.823	0.79	**1.81**
138.190 meters*	150.000	492.1	43.823	0.50	1.55
188.190 meters*	**200.000**	656.2	59.823	0.37	**1.39**
238.190 meters*	250.000	820.2	75.823	0.29	1.29
288.190 meters*	**300.000**	984.3	91.823	0.24	**1.21**
338.190 meters*	350.000	1148.3	107.823	0.20	1.14
388.190 meters*	400.000	1312.3	123.823	0.18	1.09
438.190 meters*	450.000	1476.4	139.823	0.16	1.05
488.190 meters*	**500.000**	1640.4	155.823	0.14	**1.01**
538.190 meters*	550.000	1804.5	171.823	0.13	0.98
588.190 meters*	600.000	1968.5	187.823	0.12	0.95
638.190 meters*	650.000	2132.5	203.823	0.11	0.92
688.190 meters*	**700.000**	2296.6	219.823	0.10	**0.90**
738.190 meters*	750.000	2460.6	235.823	0.09	0.88
788.190 meters*	800.000	2624.7	251.823	0.09	0.86
838.190 meters*	850.000	2788.7	267.823	0.08	0.84
888.190 meters*	900.000	2952.8	283.823	0.08	0.83
938.190 meters*	950.000	3116.8	299.823	0.07	0.81
988.190 meters*	**1000.000**	3280.8	315.823	0.07	**0.80**
1038.190 meters*	1050.000	3444.9	331.823	0.07	0.79
1088.190 meters*	1100.000	3608.9	347.823	0.06	0.77
1138.190 meters*	1150.000	3773.0	363.823	0.06	0.76
1188.190 meters*	1200.000	3937.0	379.823	0.06	0.75
1238.190 meters*	1250.000	4101.0	395.823	0.06	0.74

6.478 meters*	18.288	60.0	1.675	13.07	8.39
9.526 meters*	21.336	70.0	2.651	8.26	5.70
9.831 meters*	21.641	71.0	2.748	7.97	5.55
10.136 meters*	21.946	72.0	2.846	7.70	5.40
10.441 meters*	22.251	73.0	2.943	7.44	5.26
10.745 meters*	22.555	74.0	3.041	7.20	5.14
11.050 meters*	22.860	75.0	3.138	6.98	5.02
11.355 meters*	23.165	76.0	3.236	6.77	4.91
11.660 meters*	23.470	77.0	3.333	6.57	4.81
11.965 meters*	23.775	78.0	3.431	6.38	4.71
12.269 meters*	24.079	79.0	3.528	6.21	4.62
12.574 meters*	24.384	80.0	3.626	6.04	4.53
12.879 meters*	24.689	81.0	3.724	5.88	4.45
13.184 meters*	24.994	82.0	3.821	5.73	4.38
13.489 meters*	25.299	83.0	3.919	5.59	4.30
13.793 meters*	25.604	84.0	4.016	5.45	4.24
14.098 meters*	25.908	85.0	4.114	5.32	4.17
14.403 meters*	26.213	86.0	4.211	5.20	4.11
14.708 meters*	26.518	87.0	4.309	5.08	4.05
15.013 meters*	26.823	88.0	4.406	4.97	3.99
15.317 meters*	27.128	89.0	4.504	4.86	3.94
15.622 meters*	27.432	90.0	4.601	4.76	3.89
15.927 meters*	27.737	91.0	4.699	4.66	3.84
16.232 meters*	28.042	92.0	4.796	4.57	3.79
16.537 meters*	28.347	93.0	4.894	4.47	3.75
16.841 meters*	28.652	94.0	4.992	4.39	3.71
17.146 meters*	28.956	95.0	5.089	4.30	3.67
17.451 meters*	29.261	96.0	5.187	4.22	3.63
17.756 meters*	29.566	97.0	5.284	4.14	3.59
18.061 meters*	29.871	98.0	5.382	4.07	3.55
18.365 meters*	30.176	99.0	5.479	4.00	3.52
18.670 meters*	30.480	100.0	5.577	3.93	3.48
18.975 meters*	30.785	101.0	5.674	3.86	3.45
19.280 meters*	31.090	102.0	5.772	3.79	3.42
19.585 meters*	31.395	103.0	5.869	3.73	3.39
19.889 meters*	31.700	104.0	5.967	3.67	3.36
20.194 meters*	32.004	105.0	6.064	3.61	3.33
20.499 meters*	32.309	106.0	6.162	3.55	3.30
20.804 meters*	32.614	107.0	6.260	3.50	3.28
21.109 meters*	32.919	108.0	6.357	3.44	3.25
21.413 meters*	33.224	109.0	6.455	3.39	3.23
21.718 meters*	33.528	110.0	6.552	3.34	3.20
49.151 meters*	60.961	200.0	15.330	1.43	2.23
79.631 meters*	91.441	300.0	25.084	0.87	1.87
110.111 meters*	121.921	400.0	34.838	0.63	1.67
140.592 meters*	152.402	500.0	44.592	0.49	1.54
171.072 meters*	182.882	600.0	54.345	0.40	1.44
201.552 meters*	213.363	700.0	64.099	0.34	1.36
232.033 meters*	243.843	800.0	73.853	0.30	1.30
262.513 meters*	274.323	900.0	83.607	0.26	1.25
292.994 meters*	304.804	1000.0	93.360	0.23	1.20
323.474 meters*	335.284	1100.0	103.114	0.21	1.16
353.954 meters*	365.764	1200.0	112.868	0.19	1.13
384.435 meters*	396.245	1300.0	122.621	0.18	1.10
414.915 meters*	426.725	1400.0	132.375	0.17	1.07
445.395 meters*	457.206	1500.0	142.129	0.15	1.04
475.876 meters*	487.686	1600.0	151.883	0.14	1.02
506.356 meters*	518.166	1700.0	161.636	0.14	1.00
536.837 meters*	548.647	1800.0	171.390	0.13	0.98
567.317 meters*	579.127	1900.0	181.144	0.12	0.96
597.797 meters*	609.607	2000.0	190.897	0.11	0.95
628.278 meters*	640.088	2100.0	200.651	0.11	0.93
658.758 meters*	670.568	2200.0	210.405	0.10	0.92
689.238 meters*	701.049	2300.0	220.159	0.10	0.90
719.719 meters*	731.529	2400.0	229.912	0.10	0.89
750.199 meters*	762.009	2500.0	239.666	0.09	0.88
780.679 meters*	792.490	2600.0	249.420	0.09	0.86
811.160 meters*	822.970	2700.0	259.173	0.08	0.85
841.640 meters*	853.450	2800.0	268.927	0.08	0.84
872.121 meters*	883.931	2900.0	278.681	0.08	0.83
902.601 meters*	914.411	3000.0	288.435	0.08	0.82
933.081 meters*	944.891	3100.0	298.188	0.07	0.81
963.562 meters*	975.372	3200.0	307.942	0.07	0.81
994.042 meters*	1005.852	3300.0	317.696	0.07	0.80
1024.522 meters*	1036.333	3400.0	327.449	0.07	0.79
1055.003 meters*	1066.813	3500.0	337.203	0.06	0.78
1085.483 meters*	1097.293	3600.0	346.957	0.06	0.77
1115.964 meters*	1127.774	3700.0	356.711	0.06	0.77
1146.444 meters*	1158.254	3800.0	366.464	0.06	0.76
1176.924 meters*	1188.734	3900.0	376.218	0.06	0.75
1207.405 meters*	1219.215	4000.0	385.972	0.06	0.75

ft	m/s	merged cells
60	8.39	1.00
70	5.70	1.00
71	5.55	1.00
72	5.40	1.00
73	5.26	1.00
74	5.14	1.00
75	5.02	1.00
76	4.91	1.00
77	4.81	1.00
78	4.71	1.00
79	4.62	1.00
80	4.53	1.00
81	4.45	1.00
82	4.38	1.00
83	4.30	1.00
84	4.24	1.00
85	4.17	1.00
86	4.12	1.01
87	4.08	1.03
88	4.05	1.05
89	4.01	1.08
90	3.98	1.10
91	3.95	1.12
92	3.92	1.14
93	3.89	1.16
94	3.86	1.18
95	3.84	1.20
96	3.81	1.22
97	3.79	1.24
98	3.77	1.26
99	3.75	1.28
100	3.72	1.31
101	3.70	1.33
102	3.68	1.35
103	3.67	1.37
104	3.65	1.39
105	3.63	1.41
106	3.61	1.43
107	3.60	1.45
108	3.58	1.47
109	3.57	1.49
110	3.55	1.51
200	3.03	3.40
300	2.87	5.49
400	2.78	7.58
500	2.71	9.67
600	2.67	11.76
700	2.63	13.85
800	2.59	15.95
900	2.57	18.04
1,000	2.54	20.13
1,100	2.52	22.22
1,200	2.50	24.31
1,300	2.48	26.40
1,400	2.47	28.49
1,500	2.45	30.59
1,600	2.44	32.68
1,700	2.43	34.77
1,800	2.41	36.86
1,900	2.40	38.95
2,000	2.39	41.04
2,100	2.38	43.14
2,200	2.37	45.23
2,300	2.36	47.32
2,400	2.36	49.41
2,500	2.35	51.50
2,600	2.34	53.59
2,700	2.31	54.00
2,800	2.29	54.00
2,900	2.26	54.00
3,000	2.23	54.00
3,100	2.21	54.00
3,200	2.18	54.00
3,300	2.16	54.00
3,400	2.14	54.00
3,500	2.12	54.00
3,600	2.10	54.00
3,700	2.08	54.00
3,800	2.06	54.00
3,900	2.04	54.00
4,000	2.03	54.00

Stack Distances (ft)	Number of Stacks
15.3	54
4.66344	

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	11.81	meters	38.7	feet	λ	1.11	
Stack Diameter D	0.51	meters	1.7	feet		0.3048 meters/feet	
Stack Velocity V_{exit}	42.94	m/s	140.9	ft/sec			
Volumetric Flow	9	cu.m/sec	19,070	ACFM	$\pi V_{exit}D^2/4$		Sect.2/¶1
Stack Potential Temp θ_s	774	Kelvins	933.8	°F	Back-Calc'd from Buoyancy Flux		
Initial Stack Buoyancy Flux F_o	17	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	3.188	meters*	10.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	14.998	meters	49.2	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	21.470	m/s	70.44	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.020	meters	3.3	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	1.211	meters*	4.0	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	13.021	meters	42.7	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$=	0.620011651

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 $(Va)_o$	6.789	m^2/s	$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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 = 3.188 meters*	***14.998***	***49.2***	***1.020***		***21.47***
88.190 meters*	**100.000**	328.1	27.833	0.79	**1.80**
138.190 meters*	150.000	492.1	43.833	0.50	1.54
188.190 meters*	**200.000**	656.2	59.833	0.37	**1.38**
238.190 meters*	250.000	820.2	75.833	0.29	1.28
288.190 meters*	**300.000**	984.3	91.833	0.24	**1.20**
338.190 meters*	350.000	1148.3	107.833	0.20	1.14
388.190 meters*	400.000	1312.3	123.833	0.18	1.09
438.190 meters*	450.000	1476.4	139.833	0.16	1.04
488.190 meters*	**500.000**	1640.4	155.833	0.14	**1.00**
538.190 meters*	550.000	1804.5	171.833	0.13	0.97
588.190 meters*	600.000	1968.5	187.833	0.12	0.94
638.190 meters*	650.000	2132.5	203.833	0.11	0.92
688.190 meters*	**700.000**	2296.6	219.833	0.10	**0.90**
738.190 meters*	750.000	2460.6	235.833	0.09	0.88
788.190 meters*	800.000	2624.7	251.833	0.09	0.86
838.190 meters*	850.000	2788.7	267.833	0.08	0.84
888.190 meters*	900.000	2952.8	283.833	0.08	0.82
938.190 meters*	950.000	3116.8	299.833	0.07	0.81
988.190 meters*	**1000.000**	3280.8	315.833	0.07	**0.79**
1038.190 meters*	1050.000	3444.9	331.833	0.07	0.78
1088.190 meters*	1100.000	3608.9	347.833	0.06	0.77
1138.190 meters*	1150.000	3773.0	363.833	0.06	0.76
1188.190 meters*	1200.000	3937.0	379.833	0.06	0.75
1238.190 meters*	1250.000	4101.0	395.833	0.06	0.74

6.478 meters*	18.288	60.0	1.685	12.99	8.45
9.526 meters*	21.336	70.0	2.661	8.23	5.74
9.831 meters*	21.641	71.0	2.758	7.94	5.58
10.136 meters*	21.946	72.0	2.856	7.67	5.43
10.441 meters*	22.251	73.0	2.953	7.42	5.29
10.745 meters*	22.555	74.0	3.051	7.18	5.16
11.050 meters*	22.860	75.0	3.148	6.96	5.04
11.355 meters*	23.165	76.0	3.246	6.75	4.93
11.660 meters*	23.470	77.0	3.344	6.55	4.83
11.965 meters*	23.775	78.0	3.441	6.36	4.73
12.269 meters*	24.079	79.0	3.539	6.19	4.64
12.574 meters*	24.384	80.0	3.636	6.02	4.55
12.879 meters*	24.689	81.0	3.734	5.87	4.47
13.184 meters*	24.994	82.0	3.831	5.72	4.39
13.489 meters*	25.299	83.0	3.929	5.57	4.32
13.793 meters*	25.604	84.0	4.026	5.44	4.25
14.098 meters*	25.908	85.0	4.124	5.31	4.18
14.403 meters*	26.213	86.0	4.221	5.19	4.12
14.708 meters*	26.518	87.0	4.319	5.07	4.06
15.013 meters*	26.823	88.0	4.416	4.96	4.00
15.317 meters*	27.128	89.0	4.514	4.85	3.95
15.622 meters*	27.432	90.0	4.612	4.75	3.90
15.927 meters*	27.737	91.0	4.709	4.65	3.85
16.232 meters*	28.042	92.0	4.807	4.56	3.80
16.537 meters*	28.347	93.0	4.904	4.47	3.75
16.841 meters*	28.652	94.0	5.002	4.38	3.71
17.146 meters*	28.956	95.0	5.099	4.29	3.67
17.451 meters*	29.261	96.0	5.197	4.21	3.63
17.756 meters*	29.566	97.0	5.294	4.14	3.59
18.061 meters*	29.871	98.0	5.392	4.06	3.55
18.365 meters*	30.176	99.0	5.489	3.99	3.52
18.670 meters*	30.480	100.0	5.587	3.92	3.48
18.975 meters*	30.785	101.0	5.684	3.85	3.45
19.280 meters*	31.090	102.0	5.782	3.79	3.42
19.585 meters*	31.395	103.0	5.879	3.72	3.39
19.889 meters*	31.700	104.0	5.977	3.66	3.36
20.194 meters*	32.004	105.0	6.075	3.61	3.33
20.499 meters*	32.309	106.0	6.172	3.55	3.30
20.804 meters*	32.614	107.0	6.270	3.49	3.27
21.109 meters*	32.919	108.0	6.367	3.44	3.25
21.413 meters*	33.224	109.0	6.465	3.39	3.22
21.718 meters*	33.528	110.0	6.562	3.34	3.20
49.151 meters*	60.961	200.0	15.341	1.43	2.22
79.631 meters*	91.441	300.0	25.094	0.87	1.86
110.111 meters*	121.921	400.0	34.848	0.63	1.66
140.592 meters*	152.402	500.0	44.602	0.49	1.53
171.072 meters*	182.882	600.0	54.355	0.40	1.43
201.552 meters*	213.363	700.0	64.109	0.34	1.35
232.033 meters*	243.843	800.0	73.863	0.30	1.29
262.513 meters*	274.323	900.0	83.617	0.26	1.24
292.994 meters*	304.804	1000.0	93.370	0.23	1.19
323.474 meters*	335.284	1100.0	103.124	0.21	1.15
353.954 meters*	365.764	1200.0	112.878	0.19	1.12
384.435 meters*	396.245	1300.0	122.632	0.18	1.09
414.915 meters*	426.725	1400.0	132.385	0.17	1.06
445.395 meters*	457.206	1500.0	142.139	0.15	1.04
475.876 meters*	487.686	1600.0	151.893	0.14	1.01
506.356 meters*	518.166	1700.0	161.646	0.14	0.99
536.837 meters*	548.647	1800.0	171.400	0.13	0.97
567.317 meters*	579.127	1900.0	181.154	0.12	0.96
597.797 meters*	609.607	2000.0	190.908	0.11	0.94
628.278 meters*	640.088	2100.0	200.661	0.11	0.92
658.758 meters*	670.568	2200.0	210.415	0.10	0.91
689.238 meters*	701.049	2300.0	220.169	0.10	0.90
719.719 meters*	731.529	2400.0	229.922	0.10	0.88
750.199 meters*	762.009	2500.0	239.676	0.09	0.87
780.679 meters*	792.490	2600.0	249.430	0.09	0.86
811.160 meters*	822.970	2700.0	259.184	0.08	0.85
841.640 meters*	853.450	2800.0	268.937	0.08	0.84
872.121 meters*	883.931	2900.0	278.691	0.08	0.83
902.601 meters*	914.411	3000.0	288.445	0.08	0.82
933.081 meters*	944.891	3100.0	298.198	0.07	0.81
963.562 meters*	975.372	3200.0	307.952	0.07	0.80
994.042 meters*	1005.852	3300.0	317.706	0.07	0.79
1024.522 meters*	1036.333	3400.0	327.460	0.07	0.78
1055.003 meters*	1066.813	3500.0	337.213	0.06	0.78
1085.483 meters*	1097.293	3600.0	346.967	0.06	0.77
1115.964 meters*	1127.774	3700.0	356.721	0.06	0.76
1146.444 meters*	1158.254	3800.0	366.474	0.06	0.76
1176.924 meters*	1188.734	3900.0	376.228	0.06	0.75
1207.405 meters*	1219.215	4000.0	385.982	0.06	0.74

Stack Distances (ft)	Number of Stacks
21	48

ft	m/s	merged cells
60	8.45	1.00
70	5.74	1.00
71	5.58	1.00
72	5.43	1.00
73	5.29	1.00
74	5.16	1.00
75	5.04	1.00
76	4.93	1.00
77	4.83	1.00
78	4.73	1.00
79	4.64	1.00
80	4.55	1.00
81	4.47	1.00
82	4.39	1.00
83	4.32	1.00
84	4.25	1.00
85	4.18	1.00
86	4.12	1.00
87	4.06	1.00
88	4.00	1.00
89	3.95	1.00
90	3.90	1.00
91	3.85	1.00
92	3.80	1.00
93	3.75	1.00
94	3.71	1.00
95	3.67	1.00
96	3.63	1.00
97	3.59	1.00
98	3.55	1.00
99	3.52	1.00
100	3.48	1.00
101	3.45	1.00
102	3.42	1.00
103	3.39	1.00
104	3.37	1.01
105	3.35	1.03
106	3.34	1.04
107	3.32	1.06
108	3.31	1.07
109	3.29	1.09
110	3.28	1.10
200	2.79	2.48
300	2.63	4.00
400	2.55	5.52
500	2.49	7.05
600	2.45	8.57
700	2.41	10.10
800	2.38	11.62
900	2.36	13.14
1,000	2.33	14.67
1,100	2.31	16.19
1,200	2.30	17.71
1,300	2.28	19.24
1,400	2.27	20.76
1,500	2.25	22.29
1,600	2.24	23.81
1,700	2.23	25.33
1,800	2.22	26.86
1,900	2.21	28.38
2,000	2.20	29.90
2,100	2.19	31.43
2,200	2.18	32.95
2,300	2.17	34.48
2,400	2.16	36.00
2,500	2.15	37.52
2,600	2.15	39.05
2,700	2.14	40.57
2,800	2.13	42.10
2,900	2.13	43.62
3,000	2.12	45.14
3,100	2.12	46.67
3,200	2.11	48.00
3,300	2.09	48.00
3,400	2.06	48.00
3,500	2.04	48.00
3,600	2.03	48.00
3,700	2.01	48.00
3,800	1.99	48.00
3,900	1.97	48.00
4,000	1.95	48.00

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:

Ambient Potential Temp θ_a	309	Kelvins	96	°F	Constants: Assume neutral conditions ($d\theta/dz=0$)	
Plume Exit Conditions:					Gravity g 9.81 m/s^2	
Stack Height h_s	11.81	meters	38.7	feet	λ 1.11	
Stack Diameter D	0.51	meters	1.7	feet	0.3048 meters/feet	
Stack Velocity V_{exit}	42.94	m/s	140.9	ft/sec		
Volumetric Flow	9	cu.m/sec	19,070	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1
Stack Potential Temp θ_s	774	Kelvins	933.8	°F	Back-Calc'd from Buoyancy Flux	
Initial Stack Buoyancy Flux F_o	16	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	3.188	meters*	10.5	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground $z+h_s$	14.998	meters	49.2	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	21.470	m/s	70.44	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	1.020	meters	3.3	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	1.175	meters*	3.9	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	12.985	meters	42.6	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$=	0.631480092

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 $(Va)_o$	6.915 m^2/s	$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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 = 3.188 meters*	***14.998***	***49.2***	***1.020***		***21.47***	
88.190 meters*	**100.000**	328.1	27.845	0.79	**1.78**	87.90*
138.190 meters*	150.000	492.1	43.845	0.50	1.53	
188.190 meters*	**200.000**	656.2	59.845	0.37	**1.37**	
238.190 meters*	250.000	820.2	75.845	0.29	1.27	
288.190 meters*	**300.000**	984.3	91.845	0.24	**1.19**	
338.190 meters*	350.000	1148.3	107.845	0.20	1.13	
388.190 meters*	400.000	1312.3	123.845	0.18	1.08	
438.190 meters*	450.000	1476.4	139.845	0.16	1.03	
488.190 meters*	**500.000**	1640.4	155.845	0.14	**1.00**	
538.190 meters*	550.000	1804.5	171.845	0.13	0.97	
588.190 meters*	600.000	1968.5	187.845	0.12	0.94	
638.190 meters*	650.000	2132.5	203.845	0.11	0.91	
688.190 meters*	**700.000**	2296.6	219.845	0.10	**0.89**	
738.190 meters*	750.000	2460.6	235.845	0.09	0.87	
788.190 meters*	800.000	2624.7	251.845	0.09	0.85	
838.190 meters*	850.000	2788.7	267.845	0.08	0.83	
888.190 meters*	900.000	2952.8	283.845	0.08	0.82	
938.190 meters*	950.000	3116.8	299.845	0.07	0.80	
988.190 meters*	**1000.000**	3280.8	315.845	0.07	**0.79**	
1038.190 meters*	1050.000	3444.9	331.845	0.07	0.77	
1088.190 meters*	1100.000	3608.9	347.845	0.06	0.76	
1138.190 meters*	1150.000	3773.0	363.845	0.06	0.75	
1188.190 meters*	1200.000	3937.0	379.845	0.06	0.74	
1238.190 meters*	1250.000	4101.0	395.845	0.06	0.73	

6.478 meters*	18.288	60.0	1.697	12.90	8.52
9.526 meters*	21.336	70.0	2.672	8.19	5.78
9.831 meters*	21.641	71.0	2.770	7.91	5.62
10.136 meters*	21.946	72.0	2.868	7.64	5.47
10.441 meters*	22.251	73.0	2.965	7.39	5.33
10.745 meters*	22.555	74.0	3.063	7.15	5.20
11.050 meters*	22.860	75.0	3.160	6.93	5.07
11.355 meters*	23.165	76.0	3.258	6.72	4.96
11.660 meters*	23.470	77.0	3.355	6.53	4.85
11.965 meters*	23.775	78.0	3.453	6.34	4.75
12.269 meters*	24.079	79.0	3.550	6.17	4.66
12.574 meters*	24.384	80.0	3.648	6.00	4.57
12.879 meters*	24.689	81.0	3.745	5.85	4.49
13.184 meters*	24.994	82.0	3.843	5.70	4.41
13.489 meters*	25.299	83.0	3.940	5.56	4.33
13.793 meters*	25.604	84.0	4.038	5.42	4.26
14.098 meters*	25.908	85.0	4.136	5.30	4.20
14.403 meters*	26.213	86.0	4.233	5.17	4.13
14.708 meters*	26.518	87.0	4.331	5.06	4.07
15.013 meters*	26.823	88.0	4.428	4.95	4.01
15.317 meters*	27.128	89.0	4.526	4.84	3.96
15.622 meters*	27.432	90.0	4.623	4.74	3.90
15.927 meters*	27.737	91.0	4.721	4.64	3.85
16.232 meters*	28.042	92.0	4.818	4.55	3.81
16.537 meters*	28.347	93.0	4.916	4.45	3.76
16.841 meters*	28.652	94.0	5.013	4.37	3.72
17.146 meters*	28.956	95.0	5.111	4.28	3.67
17.451 meters*	29.261	96.0	5.208	4.20	3.63
17.756 meters*	29.566	97.0	5.306	4.13	3.59
18.061 meters*	29.871	98.0	5.404	4.05	3.56
18.365 meters*	30.176	99.0	5.501	3.98	3.52
18.670 meters*	30.480	100.0	5.599	3.91	3.48
18.975 meters*	30.785	101.0	5.696	3.84	3.45
19.280 meters*	31.090	102.0	5.794	3.78	3.42
19.585 meters*	31.395	103.0	5.891	3.72	3.39
19.889 meters*	31.700	104.0	5.989	3.66	3.36
20.194 meters*	32.004	105.0	6.086	3.60	3.33
20.499 meters*	32.309	106.0	6.184	3.54	3.30
20.804 meters*	32.614	107.0	6.281	3.49	3.27
21.109 meters*	32.919	108.0	6.379	3.43	3.24
21.413 meters*	33.224	109.0	6.476	3.38	3.22
21.718 meters*	33.528	110.0	6.574	3.33	3.19
49.151 meters*	60.961	200.0	15.352	1.43	2.21
79.631 meters*	91.441	300.0	25.106	0.87	1.85
110.111 meters*	121.921	400.0	34.860	0.63	1.65
140.592 meters*	152.402	500.0	44.613	0.49	1.52
171.072 meters*	182.882	600.0	54.367	0.40	1.42
201.552 meters*	213.363	700.0	64.121	0.34	1.34
232.033 meters*	243.843	800.0	73.875	0.30	1.28
262.513 meters*	274.323	900.0	83.628	0.26	1.23
292.994 meters*	304.804	1000.0	93.382	0.23	1.18
323.474 meters*	335.284	1100.0	103.136	0.21	1.14
353.954 meters*	365.764	1200.0	112.889	0.19	1.11
384.435 meters*	396.245	1300.0	122.643	0.18	1.08
414.915 meters*	426.725	1400.0	132.397	0.17	1.05
445.395 meters*	457.206	1500.0	142.151	0.15	1.03
475.876 meters*	487.686	1600.0	151.904	0.14	1.01
506.356 meters*	518.166	1700.0	161.658	0.14	0.99
536.837 meters*	548.647	1800.0	171.412	0.13	0.97
567.317 meters*	579.127	1900.0	181.166	0.12	0.95
597.797 meters*	609.607	2000.0	190.919	0.11	0.93
628.278 meters*	640.088	2100.0	200.673	0.11	0.92
658.758 meters*	670.568	2200.0	210.427	0.10	0.90
689.238 meters*	701.049	2300.0	220.180	0.10	0.89
719.719 meters*	731.529	2400.0	229.934	0.10	0.88
750.199 meters*	762.009	2500.0	239.688	0.09	0.86
780.679 meters*	792.490	2600.0	249.442	0.09	0.85
811.160 meters*	822.970	2700.0	259.195	0.08	0.84
841.640 meters*	853.450	2800.0	268.949	0.08	0.83
872.121 meters*	883.931	2900.0	278.703	0.08	0.82
902.601 meters*	914.411	3000.0	288.456	0.08	0.81
933.081 meters*	944.891	3100.0	298.210	0.07	0.80
963.562 meters*	975.372	3200.0	307.964	0.07	0.79
994.042 meters*	1005.852	3300.0	317.718	0.07	0.79
1024.522 meters*	1036.333	3400.0	327.471	0.07	0.78
1055.003 meters*	1066.813	3500.0	337.225	0.06	0.77
1085.483 meters*	1097.293	3600.0	346.979	0.06	0.76
1115.964 meters*	1127.774	3700.0	356.732	0.06	0.76
1146.444 meters*	1158.254	3800.0	366.486	0.06	0.75
1176.924 meters*	1188.734	3900.0	376.240	0.06	0.74
1207.405 meters*	1219.215	4000.0	385.994	0.06	0.74

Stack Distances (ft)	Number of Stacks
21	48

ft	m/s	merged cells
60	8.52	1.00
70	5.78	1.00
71	5.62	1.00
72	5.47	1.00
73	5.33	1.00
74	5.20	1.00
75	5.07	1.00
76	4.96	1.00
77	4.85	1.00
78	4.75	1.00
79	4.66	1.00
80	4.57	1.00
81	4.49	1.00
82	4.41	1.00
83	4.33	1.00
84	4.26	1.00
85	4.20	1.00
86	4.13	1.00
87	4.07	1.00
88	4.01	1.00
89	3.96	1.00
90	3.90	1.00
91	3.85	1.00
92	3.81	1.00
93	3.76	1.00
94	3.72	1.00
95	3.67	1.00
96	3.63	1.00
97	3.59	1.00
98	3.56	1.00
99	3.52	1.00
100	3.48	1.00
101	3.45	1.00
102	3.42	1.00
103	3.39	1.00
104	3.37	1.02
105	3.35	1.03
106	3.34	1.05
107	3.32	1.06
108	3.30	1.08
109	3.29	1.09
110	3.28	1.11
200	2.77	2.48
300	2.61	4.00
400	2.53	5.53
500	2.47	7.05
600	2.43	8.57
700	2.39	10.10
800	2.36	11.62
900	2.34	13.14
1,000	2.32	14.67
1,100	2.30	16.19
1,200	2.28	17.72
1,300	2.26	19.24
1,400	2.25	20.76
1,500	2.23	22.29
1,600	2.22	23.81
1,700	2.21	25.34
1,800	2.20	26.86
1,900	2.19	28.38
2,000	2.18	29.91
2,100	2.17	31.43
2,200	2.16	32.95
2,300	2.15	34.48
2,400	2.15	36.00
2,500	2.14	37.53
2,600	2.13	39.05
2,700	2.12	40.57
2,800	2.12	42.10
2,900	2.11	43.62
3,000	2.10	45.14
3,100	2.10	46.67
3,200	2.09	48.00
3,300	2.07	48.00
3,400	2.05	48.00
3,500	2.03	48.00
3,600	2.01	48.00
3,700	1.99	48.00
3,800	1.97	48.00
3,900	1.96	48.00
4,000	1.94	48.00

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	28.92	meters	94.9	feet	λ	1.11			
Stack Diameter D	4.09	meters	13.4	feet		0.3048	meters/feet	13.41657101	
Stack Velocity V_{exit}	9.11	m/s	29.9	ft/sec					
Volumetric Flow	120	cu.m/sec	254,266	ACFM	$\pi V_{exit}D^2/4$			Sect.2/¶1	
Stack Potential Temp θ_s	326	Kelvins	126.9	°F	Back-Calc'd from Buoyancy Flux				
Initial Stack Buoyancy Flux F_o	62	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	1793.6	29.89333333
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_o)$ for a,V,θ_o at plume height (not used here)				area/chiller	
									141.3716694	13.41640786
Conditions at End (Top) of Jet Phase:										4.089321117
Height above Stack z	25.559	meters*	83.9	feet*	6.25D, meters*=meters above stack top			Sect.3/¶1		
Height above Ground z+h_s	54.482	meters	178.7	feet	h_s + 6.25D			"		
Vertical Velocity V_{plume}	4.556	m/s	14.95	ft/sec	$0.5V_{exit}$	$V_{exit}/2$		"		
Plume Top-Hat Diameter 2a	8.179	meters	26.8	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	2.206	meters*	7.2	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top		Sect.2/Eq.6
Height above Ground z_v+h_s	31.129	meters	102.1	feet		where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$=	0.913675175

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 $(Va)_o$	17.022	m^2/s	$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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)	
	Ht above Ground =	h_{plume}+h_s	D_{plume}=2a=	**Method(1)** V_{plume}=	**Method(2)** $\{(Va)_o^3+0.12F_o[(z-z_v)^2$
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 = 25.559 meters*	***54.482***	***178.7***	***8.179***		***4.56***
71.077 meters*	**100.000**	328.1	22.039	1.69	**3.00**
121.077 meters*	150.000	492.1	38.039	0.98	2.48
171.077 meters*	**200.000**	656.2	54.039	0.69	**2.21**
221.077 meters*	250.000	820.2	70.039	0.53	2.02
271.077 meters*	**300.000**	984.3	86.039	0.43	**1.89**
321.077 meters*	350.000	1148.3	102.039	0.37	1.78
371.077 meters*	400.000	1312.3	118.039	0.32	1.70
421.077 meters*	450.000	1476.4	134.039	0.28	1.63
471.077 meters*	**500.000**	1640.4	150.039	0.25	**1.57**
521.077 meters*	550.000	1804.5	166.039	0.22	1.52
571.077 meters*	600.000	1968.5	182.039	0.20	1.47
621.077 meters*	650.000	2132.5	198.039	0.19	1.43
671.077 meters*	**700.000**	2296.6	214.039	0.17	**1.39**
721.077 meters*	750.000	2460.6	230.039	0.16	1.36
771.077 meters*	800.000	2624.7	246.039	0.15	1.33
821.077 meters*	850.000	2788.7	262.039	0.14	1.30
871.077 meters*	900.000	2952.8	278.039	0.13	1.28
921.077 meters*	950.000	3116.8	294.039	0.13	1.25
971.077 meters*	**1000.000**	3280.8	310.039	0.12	**1.23**
1021.077 meters*	1050.000	3444.9	326.039	0.11	1.21
1071.077 meters*	1100.000	3608.9	342.039	0.11	1.19
1121.077 meters*	1150.000	3773.0	358.039	0.10	1.17
1171.077 meters*	1200.000	3937.0	374.039	0.10	1.16
1221.077 meters*	1250.000	4101.0	390.039	0.10	1.14

-10.635 meters*	18.288	60.0	-4.109	-9.07	-6.25
-7.587 meters*	21.336	70.0	-3.134	-11.89	-7.47
-7.282 meters*	21.641	71.0	-3.036	-12.27	-7.64
-6.977 meters*	21.946	72.0	-2.939	-12.68	-7.82
-6.672 meters*	22.251	73.0	-2.841	-13.11	-8.02
-6.368 meters*	22.555	74.0	-2.744	-13.58	-8.23
-6.063 meters*	22.860	75.0	-2.646	-14.08	-8.45
-5.758 meters*	23.165	76.0	-2.549	-14.62	-8.70
-5.453 meters*	23.470	77.0	-2.451	-15.20	-8.97
-5.148 meters*	23.775	78.0	-2.353	-15.83	-9.26
-4.844 meters*	24.079	79.0	-2.256	-16.52	-9.58
-4.539 meters*	24.384	80.0	-2.158	-17.26	-9.93
-4.234 meters*	24.689	81.0	-2.061	-18.08	-10.31
-3.929 meters*	24.994	82.0	-1.963	-18.98	-10.74
-3.624 meters*	25.299	83.0	-1.866	-19.97	-11.21
-3.320 meters*	25.604	84.0	-1.768	-21.07	-11.74
-3.015 meters*	25.908	85.0	-1.671	-22.30	-12.34
-2.710 meters*	26.213	86.0	-1.573	-23.68	-13.01
-2.405 meters*	26.518	87.0	-1.476	-25.25	-13.78
-2.100 meters*	26.823	88.0	-1.378	-27.04	-14.66
-1.795 meters*	27.128	89.0	-1.281	-29.10	-15.67
-1.491 meters*	27.432	90.0	-1.183	-31.50	-16.87
-1.186 meters*	27.737	91.0	-1.086	-34.33	-18.29
-0.881 meters*	28.042	92.0	-0.988	-37.71	-19.99
-0.576 meters*	28.347	93.0	-0.890	-41.85	-22.08
-0.271 meters*	28.652	94.0	-0.793	-46.99	-24.69
0.033 meters*	28.956	95.0	-0.695	-53.58	-28.05
0.338 meters*	29.261	96.0	-0.598	-62.33	-32.52
0.643 meters*	29.566	97.0	-0.500	-74.48	-38.75
0.948 meters*	29.871	98.0	-0.403	-92.51	-48.02
1.253 meters*	30.176	99.0	-0.305	-122.08	-63.25
1.557 meters*	30.480	100.0	-0.208	-179.42	-92.83
1.862 meters*	30.785	101.0	-0.110	-338.31	-174.88
2.167 meters*	31.090	102.0	-0.013	-2957.16	-1528.18
2.472 meters*	31.395	103.0	0.085	438.68	226.74
2.777 meters*	31.700	104.0	0.182	204.19	105.62
3.081 meters*	32.004	105.0	0.280	133.07	68.91
3.386 meters*	32.309	106.0	0.378	98.69	51.20
3.691 meters*	32.614	107.0	0.475	78.43	40.78
3.996 meters*	32.919	108.0	0.573	65.07	33.92
4.301 meters*	33.224	109.0	0.670	55.60	29.08
4.605 meters*	33.528	110.0	0.768	48.54	25.47
7.653 meters*	36.576	120.0	1.743	21.38	11.89
10.701 meters*	39.624	130.0	2.718	13.71	8.28
13.750 meters*	42.673	140.0	3.694	10.09	6.68
16.798 meters*	45.721	150.0	4.669	7.98	5.79
17.102 meters*	46.025	151.0	4.767	7.82	5.72
17.407 meters*	46.330	152.0	4.864	7.66	5.66
17.712 meters*	46.635	153.0	4.962	7.51	5.59
18.017 meters*	46.940	154.0	5.059	7.36	5.53
18.322 meters*	47.245	155.0	5.157	7.23	5.48
18.626 meters*	47.549	156.0	5.254	7.09	5.42
18.931 meters*	47.854	157.0	5.352	6.96	5.37
19.236 meters*	48.159	158.0	5.449	6.84	5.32
19.541 meters*	48.464	159.0	5.547	6.72	5.27
19.846 meters*	48.769	160.0	5.645	6.60	5.22
20.150 meters*	49.073	161.0	5.742	6.49	5.17
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21.370 meters*	50.293	165.0	6.132	6.08	5.00
21.674 meters*	50.597	166.0	6.230	5.98	4.97
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23.198 meters*	52.121	171.0	6.717	5.55	4.79
23.503 meters*	52.426	172.0	6.815	5.47	4.75
23.808 meters*	52.731	173.0	6.913	5.39	4.72
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24.418 meters*	53.341	175.0	7.108	5.24	4.66
24.722 meters*	53.645	176.0	7.205	5.17	4.63
25.027 meters*	53.950	177.0	7.303	5.10	4.60
25.332 meters*	54.255	178.0	7.400	5.04	4.58
25.637 meters*	54.560	179.0	7.498	4.97	4.55
25.942 meters*	54.865	180.0	7.595	4.91	4.52
28.990 meters*	57.913	190.0	8.571	4.35	4.29
32.038 meters*	60.961	200.0	9.546	3.90	4.10
62.518 meters*	91.441	300.0	19.300	1.93	3.14
92.998 meters*	121.921	400.0	29.053	1.28	2.72
123.479 meters*	152.402	500.0	38.807	0.96	2.47
153.959 meters*	182.882	600.0	48.561	0.77	2.29
184.440 meters*	213.363	700.0	58.315	0.64	2.15
214.920 meters*	243.843	800.0	68.068	0.55	2.04
245.400 meters*	274.323	900.0	77.822	0.48	1.95
275.881 meters*	304.804	1000.0	87.576	0.43	1.88
306.361 meters*	335.284	1100.0	97.330	0.38	1.81
336.841 meters*	365.764	1200.0	107.083	0.35	1.76
367.322 meters*	396.245	1300.0	116.837	0.32	1.71
397.802 meters*	426.725	1400.0	126.591	0.29	1.66
428.283 meters*	457.206	1500.0	136.344	0.27	1.62
458.763 meters*	487.686	1600.0	146.098	0.26	1.58
489.243 meters*	518.166	1700.0	155.852	0.24	1.55
519.724 meters*	548.647	1800.0	165.606	0.22	1.52
550.204 meters*	579.127	1900.0	175.359	0.21	1.49
580.684 meters*	609.607	2000.0	185.113	0.20	1.46

Stack Distances (ft)	Number of Stacks
30	52

ft	m/s	merged cells	Plume Diamter Feet
60	-6.25	1.00	-13.48
70	-7.47	1.00	-10.28
71	-7.64	1.00	-9.96
72	-7.82	1.00	-9.64
73	-8.02	1.00	-9.32
74	-8.23	1.00	-9.00
75	-8.45	1.00	-8.68
76	-8.70	1.00	-8.36
77	-8.97	1.00	-8.04
78	-9.26	1.00	-7.72
79	-9.58	1.00	-7.40
80	-9.93	1.00	-7.08
81	-10.31	1.00	-6.76
82	-10.74	1.00	-6.44
83	-11.21	1.00	-6.12
84	-11.74	1.00	-5.80
85	-12.34	1.00	-5.48
86	-13.01	1.00	-5.16
87	-13.78	1.00	-4.84
88	-14.66	1.00	-4.52
89	-15.67	1.00	-4.20
90	-16.87	1.00	-3.88
91	-18.29	1.00	-3.56
92	-19.99	1.00	-3.24
93	-22.08	1.00	-2.92
94	-24.69	1.00	-2.60
95	-28.05	1.00	-2.28
96	-32.52	1.00	-1.96
97	-38.75	1.00	-1.64
98	-48.02	1.00	-1.32
99	-63.25	1.00	-1.00
100	-92.83	1.00	-0.68
101	-174.88	1.00	-0.36
102	-1528.18	1.00	-0.04
103	226.74	1.00	0.28
104	105.62	1.00	0.60
105	68.91	1.00	0.92
106	51.20	1.00	1.24
107	40.78	1.00	1.56
108	33.92	1.00	1.88
109	29.08	1.00	2.20
110	25.47	1.00	2.52
120	11.89	1.00	5.72
130	8.28	1.00	8.92
140	6.68	1.00	12.12
150	5.79	1.00	15.32
151	5.72	1.00	15.64
152	5.66	1.00	15.96
153	5.59	1.00	16.28
154	5.54	1.00	16.60
155	5.49	1.01	16.92
156	5.45	1.02	17.24
157	5.41	1.03	17.56
158	5.37	1.04	17.88
159	5.34	1.05	18.20
160	5.30	1.06	18.52
161	5.27	1.08	18.84
162	5.24	1.09	19.16
163	5.20	1.10	19.48
164	5.17	1.11	19.80
165	5.15	1.12	20.12
166	5.12	1.13	20.44
167	5.09	1.14	20.76
168	5.06	1.15	21.08
169	5.04	1.16	21.40
170	5.01	1.17	21.72
171	4.99	1.18	22.04
172	4.97	1.19	22.36
173	4.95	1.20	22.68
174	4.92	1.21	23.00
175	4.90	1.22	23.32
176	4.88	1.24	23.64
177	4.86	1.25	23.96
178	4.84	1.26	24.28
179	4.83	1.27	24.60
180	4.81	1.28	24.92
190	4.65	1.38	28.12
200	4.53	1.49	31.32
300	3.97	2.56	63.32
400	3.76	3.62	95.32
500	3.63	4.69	127.32
600	3.54	5.76	159.32
700	3.48	6.82	191.32
800	3.42	7.89	223.32
900	3.38	8.96	255.32
1,000	3.34	10.02	287.32
1,100	3.31	11.09	319.32
1,200	3.28	12.16	351.32
1,300	3.25	13.22	383.32
1,400	3.23	14.29	415.32
1,500	3.21	15.36	447.32
1,600	3.19	16.42	479.32
1,700	3.17	17.49	511.32
1,800	3.15	18.56	543.33
1,900	3.13	19.62	575.33
2,000	3.12	20.69	607.33

611.165 meters*	640.088	2100.0	194.867	0.19	1.44
641.645 meters*	670.568	2200.0	204.620	0.18	1.41
672.126 meters*	701.049	2300.0	214.374	0.17	1.39
702.606 meters*	731.529	2400.0	224.128	0.17	1.37
733.086 meters*	762.009	2500.0	233.882	0.16	1.35
763.567 meters*	792.490	2600.0	243.635	0.15	1.33
794.047 meters*	822.970	2700.0	253.389	0.15	1.32
824.527 meters*	853.450	2800.0	263.143	0.14	1.30
855.008 meters*	883.931	2900.0	272.896	0.14	1.28
885.488 meters*	914.411	3000.0	282.650	0.13	1.27
915.968 meters*	944.891	3100.0	292.404	0.13	1.26
946.449 meters*	975.372	3200.0	302.158	0.12	1.24
976.929 meters*	1005.852	3300.0	311.911	0.12	1.23
1007.410 meters*	1036.333	3400.0	321.665	0.12	1.22
1037.890 meters*	1066.813	3500.0	331.419	0.11	1.20
1068.370 meters*	1097.293	3600.0	341.172	0.11	1.19
1098.851 meters*	1127.774	3700.0	350.926	0.11	1.18
1129.331 meters*	1158.254	3800.0	360.680	0.10	1.17
1159.811 meters*	1188.734	3900.0	370.434	0.10	1.16
1190.292 meters*	1219.215	4000.0	380.187	0.10	1.15

2,100	3.10	21.76	639.33
2,200	3.09	22.82	671.33
2,300	3.08	23.89	703.33
2,400	3.07	24.96	735.33
2,500	3.06	26.02	767.33
2,600	3.04	27.09	799.33
2,700	3.03	28.16	831.33
2,800	3.02	29.22	863.33
2,900	3.01	30.29	895.33
3,000	3.01	31.36	927.33
3,100	3.00	32.42	959.33
3,200	2.99	33.49	991.33
3,300	2.98	34.56	1023.33
3,400	2.97	35.62	1055.33
3,500	2.96	36.69	1087.33
3,600	2.96	37.76	1119.33
3,700	2.95	38.82	1151.33
3,800	2.94	39.89	1183.33
3,900	2.94	40.96	1215.33
4,000	2.93	42.02	1247.33

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	28.92	meters	94.9	feet	λ	1.11			
Stack Diameter D	4.09	meters	13.4	feet		0.3048	meters/feet	13.41657101	
Stack Velocity V_{exit}	9.11	m/s	29.9	ft/sec					
Volumetric Flow	120	cu.m/sec	254,266	ACFM	$\pi V_{exit}D^2/4$			Sect.2/¶1	
Stack Potential Temp θ_s	326	Kelvins	126.9	°F	Back-Calc'd from Buoyancy Flux				
Initial Stack Buoyancy Flux F_o	43	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	1793.6	29.89333333
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_o)$ for a,V,θ_o at plume height (not used here)				area/chiller	
									141.3716694	13.41640786

Conditions at End (Top) of Jet Phase:

Height above Stack z	25.559	meters*	83.9	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	54.482	meters	178.7	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	4.556	m/s	14.95	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	8.179	meters	26.8	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	1.525	meters*	5.0	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top		Sect.2/Eq.6
Height above Ground z_v+h_s	30.448	meters	99.9	feet		where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$=	0.940341582

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 $(Va)_o$	17.519	m^2/s			$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$		

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 = 25.559 meters*	***54.482***	***178.7***	***8.179***		***4.56***
71.077 meters*	**100.000**	328.1	22.257	1.67	**2.71**
121.077 meters*	150.000	492.1	38.257	0.97	2.22
171.077 meters*	**200.000**	656.2	54.257	0.69	**1.97**
221.077 meters*	250.000	820.2	70.257	0.53	1.80
271.077 meters*	**300.000**	984.3	86.257	0.43	**1.68**
321.077 meters*	350.000	1148.3	102.257	0.36	1.59
371.077 meters*	400.000	1312.3	118.257	0.32	1.51
421.077 meters*	450.000	1476.4	134.257	0.28	1.45
471.077 meters*	**500.000**	1640.4	150.257	0.25	**1.39**
521.077 meters*	550.000	1804.5	166.257	0.22	1.35
571.077 meters*	600.000	1968.5	182.257	0.20	1.31
621.077 meters*	650.000	2132.5	198.257	0.19	1.27
671.077 meters*	**700.000**	2296.6	214.257	0.17	**1.24**
721.077 meters*	750.000	2460.6	230.257	0.16	1.21
771.077 meters*	800.000	2624.7	246.257	0.15	1.18
821.077 meters*	850.000	2788.7	262.257	0.14	1.16
871.077 meters*	900.000	2952.8	278.257	0.13	1.13
921.077 meters*	950.000	3116.8	294.257	0.13	1.11
971.077 meters*	**1000.000**	3280.8	310.257	0.12	**1.09**
1021.077 meters*	1050.000	3444.9	326.257	0.11	1.08
1071.077 meters*	1100.000	3608.9	342.257	0.11	1.06
1121.077 meters*	1150.000	3773.0	358.257	0.10	1.04
1171.077 meters*	1200.000	3937.0	374.257	0.10	1.03
1221.077 meters*	1250.000	4101.0	390.257	0.10	1.01

-10.635 meters*	18.288	60.0	-3.891	-9.58	-7.53
-7.587 meters*	21.336	70.0	-2.916	-12.78	-9.68
-7.282 meters*	21.641	71.0	-2.818	-13.22	-9.98
-6.977 meters*	21.946	72.0	-2.721	-13.70	-10.30
-6.672 meters*	22.251	73.0	-2.623	-14.20	-10.65
-6.368 meters*	22.555	74.0	-2.526	-14.75	-11.03
-6.063 meters*	22.860	75.0	-2.428	-15.35	-11.44
-5.758 meters*	23.165	76.0	-2.330	-15.99	-11.88
-5.453 meters*	23.470	77.0	-2.233	-16.69	-12.37
-5.148 meters*	23.775	78.0	-2.135	-17.45	-12.89
-4.844 meters*	24.079	79.0	-2.038	-18.28	-13.48
-4.539 meters*	24.384	80.0	-1.940	-19.20	-14.12
-4.234 meters*	24.689	81.0	-1.843	-20.22	-14.83
-3.929 meters*	24.994	82.0	-1.745	-21.35	-15.62
-3.624 meters*	25.299	83.0	-1.648	-22.61	-16.51
-3.320 meters*	25.604	84.0	-1.550	-24.04	-17.51
-3.015 meters*	25.908	85.0	-1.453	-25.65	-18.65
-2.710 meters*	26.213	86.0	-1.355	-27.50	-19.95
-2.405 meters*	26.518	87.0	-1.258	-29.63	-21.47
-2.100 meters*	26.823	88.0	-1.160	-32.12	-23.23
-1.795 meters*	27.128	89.0	-1.062	-35.07	-25.33
-1.491 meters*	27.432	90.0	-0.965	-38.61	-27.85
-1.186 meters*	27.737	91.0	-0.867	-42.96	-30.94
-0.881 meters*	28.042	92.0	-0.770	-48.40	-34.82
-0.576 meters*	28.347	93.0	-0.672	-55.42	-39.83
-0.271 meters*	28.652	94.0	-0.575	-64.82	-46.55
0.033 meters*	28.956	95.0	-0.477	-78.07	-56.03
0.338 meters*	29.261	96.0	-0.380	-98.12	-70.38
0.643 meters*	29.566	97.0	-0.282	-132.04	-94.66
0.948 meters*	29.871	98.0	-0.185	-201.79	-144.62
1.253 meters*	30.176	99.0	-0.087	-427.72	-306.48
1.557 meters*	30.480	100.0	0.010	3574.72	2561.29
1.862 meters*	30.785	101.0	0.108	345.13	247.31
2.167 meters*	31.090	102.0	0.205	181.32	129.95
2.472 meters*	31.395	103.0	0.303	122.96	88.16
2.777 meters*	31.700	104.0	0.401	93.02	66.72
3.081 meters*	32.004	105.0	0.498	74.80	53.69
3.386 meters*	32.309	106.0	0.596	62.55	44.93
3.691 meters*	32.614	107.0	0.693	53.75	38.64
3.996 meters*	32.919	108.0	0.791	47.12	33.91
4.301 meters*	33.224	109.0	0.888	41.95	30.22
4.605 meters*	33.528	110.0	0.986	37.80	27.27
7.653 meters*	36.576	120.0	1.961	19.00	13.98
10.701 meters*	39.624	130.0	2.937	12.69	9.62
13.750 meters*	42.673	140.0	3.912	9.52	7.50
16.798 meters*	45.721	150.0	4.887	7.62	6.27
17.102 meters*	46.025	151.0	4.985	7.47	6.17
17.407 meters*	46.330	152.0	5.082	7.33	6.08
17.712 meters*	46.635	153.0	5.180	7.19	5.99
18.017 meters*	46.940	154.0	5.277	7.06	5.91
18.322 meters*	47.245	155.0	5.375	6.93	5.83
18.626 meters*	47.549	156.0	5.473	6.81	5.75
18.931 meters*	47.854	157.0	5.570	6.69	5.68
19.236 meters*	48.159	158.0	5.668	6.57	5.60
19.541 meters*	48.464	159.0	5.765	6.46	5.54
19.846 meters*	48.769	160.0	5.863	6.36	5.47
20.150 meters*	49.073	161.0	5.960	6.25	5.41
20.455 meters*	49.378	162.0	6.058	6.15	5.34
20.760 meters*	49.683	163.0	6.155	6.05	5.28
21.065 meters*	49.988	164.0	6.253	5.96	5.23
21.370 meters*	50.293	165.0	6.350	5.87	5.17
21.674 meters*	50.597	166.0	6.448	5.78	5.12
21.979 meters*	50.902	167.0	6.545	5.69	5.06
22.284 meters*	51.207	168.0	6.643	5.61	5.01
22.589 meters*	51.512	169.0	6.740	5.53	4.96
22.894 meters*	51.817	170.0	6.838	5.45	4.92
23.198 meters*	52.121	171.0	6.936	5.37	4.87
23.503 meters*	52.426	172.0	7.033	5.30	4.83
23.808 meters*	52.731	173.0	7.131	5.23	4.78
24.113 meters*	53.036	174.0	7.228	5.15	4.74
24.418 meters*	53.341	175.0	7.326	5.09	4.70
24.722 meters*	53.645	176.0	7.423	5.02	4.66
25.027 meters*	53.950	177.0	7.521	4.95	4.62
25.332 meters*	54.255	178.0	7.618	4.89	4.58
25.637 meters*	54.560	179.0	7.716	4.83	4.55
25.942 meters*	54.865	180.0	7.813	4.77	4.51
28.990 meters*	57.913	190.0	8.789	4.24	4.20
32.038 meters*	60.961	200.0	9.764	3.82	3.96
62.518 meters*	91.441	300.0	19.518	1.91	2.86
92.998 meters*	121.921	400.0	29.272	1.27	2.44
123.479 meters*	152.402	500.0	39.025	0.95	2.20
153.959 meters*	182.882	600.0	48.779	0.76	2.04
184.440 meters*	213.363	700.0	58.533	0.64	1.92
214.920 meters*	243.843	800.0	68.286	0.55	1.82
245.400 meters*	274.323	900.0	78.040	0.48	1.74
275.881 meters*	304.804	1000.0	87.794	0.42	1.67
306.361 meters*	335.284	1100.0	97.548	0.38	1.61
336.841 meters*	365.764	1200.0	107.301	0.35	1.56
367.322 meters*	396.245	1300.0	117.055	0.32	1.51
397.802 meters*	426.725	1400.0	126.809	0.29	1.47
428.283 meters*	457.206	1500.0	136.562	0.27	1.44
458.763 meters*	487.686	1600.0	146.316	0.25	1.41
489.243 meters*	518.166	1700.0	156.070	0.24	1.38
519.724 meters*	548.647	1800.0	165.824	0.22	1.35
550.204 meters*	579.127	1900.0	175.577	0.21	1.32
580.684 meters*	609.607	2000.0	185.331	0.20	1.30

Stack Distances (ft)	Number of Stacks
30	52

ft	m/s	merged cells	Plume Diamter Feet
60	-7.53	1.00	-12.77
70	-9.68	1.00	-9.57
71	-9.98	1.00	-9.25
72	-10.30	1.00	-8.93
73	-10.65	1.00	-8.61
74	-11.03	1.00	-8.29
75	-11.44	1.00	-7.97
76	-11.88	1.00	-7.65
77	-12.37	1.00	-7.33
78	-12.89	1.00	-7.01
79	-13.48	1.00	-6.69
80	-14.12	1.00	-6.37
81	-14.83	1.00	-6.05
82	-15.62	1.00	-5.73
83	-16.51	1.00	-5.41
84	-17.51	1.00	-5.09
85	-18.65	1.00	-4.77
86	-19.95	1.00	-4.45
87	-21.47	1.00	-4.13
88	-23.23	1.00	-3.81
89	-25.33	1.00	-3.49
90	-27.85	1.00	-3.17
91	-30.94	1.00	-2.85
92	-34.82	1.00	-2.53
93	-39.83	1.00	-2.21
94	-46.55	1.00	-1.89
95	-56.03	1.00	-1.57
96	-70.38	1.00	-1.25
97	-94.66	1.00	-0.93
98	-144.62	1.00	-0.61
99	-306.48	1.00	-0.29
100	2561.29	1.00	0.03
101	247.31	1.00	0.35
102	129.95	1.00	0.67
103	88.16	1.00	0.99
104	66.72	1.00	1.31
105	53.69	1.00	1.63
106	44.93	1.00	1.95
107	38.64	1.00	2.27
108	33.91	1.00	2.59
109	30.22	1.00	2.91
110	27.27	1.00	3.23
120	13.98	1.00	6.43
130	9.62	1.00	9.63
140	7.50	1.00	12.83
150	6.27	1.00	16.03
151	6.17	1.00	16.35
152	6.08	1.00	16.67
153	6.01	1.01	16.99
154	5.94	1.02	17.31
155	5.88	1.04	17.63
156	5.82	1.05	17.95
157	5.75	1.06	18.27
158	5.70	1.07	18.59
159	5.64	1.08	18.91
160	5.59	1.09	19.23
161	5.53	1.10	19.55
162	5.48	1.11	19.87
163	5.44	1.12	20.19
164	5.39	1.13	20.51
165	5.34	1.14	20.83
166	5.30	1.15	21.15
167	5.26	1.16	21.47
168	5.22	1.17	21.79
169	5.18	1.18	22.11
170	5.14	1.20	22.43
171	5.10	1.21	22.75
172	5.07	1.22	23.07
173	5.03	1.23	23.39
174	5.00	1.24	23.71
175	4.97	1.25	24.03
176	4.94	1.26	24.35
177	4.90	1.27	24.67
178	4.88	1.28	24.99
179	4.85	1.29	25.31
180	4.82	1.30	25.63
190	4.58	1.41	28.83
200	4.39	1.52	32.03
300	3.62	2.58	64.03
400	3.38	3.65	96.04
500	3.25	4.72	128.04
600	3.16	5.78	160.04
700	3.10	6.85	192.04
800	3.05	7.92	224.04
900	3.01	8.98	256.04
1,000	2.97	10.05	288.04
1,100	2.94	11.12	320.04
1,200	2.91	12.18	352.04
1,300	2.89	13.25	384.04
1,400	2.87	14.32	416.04
1,500	2.85	15.38	448.04
1,600	2.83	16.45	480.04
1,700	2.81	17.52	512.04
1,800	2.80	18.58	544.04
1,900	2.78	19.65	576.04
2,000	2.77	20.72	608.04

611.165 meters*	640.088	2100.0	195.085	0.19	1.28
641.645 meters*	670.568	2200.0	204.839	0.18	1.26
672.126 meters*	701.049	2300.0	214.592	0.17	1.24
702.606 meters*	731.529	2400.0	224.346	0.17	1.22
733.086 meters*	762.009	2500.0	234.100	0.16	1.20
763.567 meters*	792.490	2600.0	243.853	0.15	1.19
794.047 meters*	822.970	2700.0	253.607	0.15	1.17
824.527 meters*	853.450	2800.0	263.361	0.14	1.16
855.008 meters*	883.931	2900.0	273.115	0.14	1.14
885.488 meters*	914.411	3000.0	282.868	0.13	1.13
915.968 meters*	944.891	3100.0	292.622	0.13	1.12
946.449 meters*	975.372	3200.0	302.376	0.12	1.10
976.929 meters*	1005.852	3300.0	312.129	0.12	1.09
1007.410 meters*	1036.333	3400.0	321.883	0.12	1.08
1037.890 meters*	1066.813	3500.0	331.637	0.11	1.07
1068.370 meters*	1097.293	3600.0	341.391	0.11	1.06
1098.851 meters*	1127.774	3700.0	351.144	0.11	1.05
1129.331 meters*	1158.254	3800.0	360.898	0.10	1.04
1159.811 meters*	1188.734	3900.0	370.652	0.10	1.03
1190.292 meters*	1219.215	4000.0	380.405	0.10	1.02

2,100	2.76	21.78	640.04
2,200	2.75	22.85	672.04
2,300	2.73	23.92	704.04
2,400	2.72	24.98	736.04
2,500	2.71	26.05	768.04
2,600	2.70	27.12	800.04
2,700	2.69	28.18	832.04
2,800	2.69	29.25	864.04
2,900	2.68	30.32	896.05
3,000	2.67	31.38	928.05
3,100	2.66	32.45	960.05
3,200	2.65	33.52	992.05
3,300	2.65	34.58	1024.05
3,400	2.64	35.65	1056.05
3,500	2.63	36.72	1088.05
3,600	2.63	37.78	1120.05
3,700	2.62	38.85	1152.05
3,800	2.61	39.92	1184.05
3,900	2.61	40.98	1216.05
4,000	2.60	42.05	1248.05

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	28.92	meters	94.9	feet	λ	1.11		
Stack Diameter D	4.09	meters	13.4	feet		0.3048 meters/feet	13.41657101	
Stack Velocity V_{exit}	9.11	m/s	29.9	ft/sec				
Volumetric Flow	120	cu.m/sec	254,266	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1		
Stack Potential Temp θ_s	326	Kelvins	126.9	°F	Back-Calc'd from Buoyancy Flux			
Initial Stack Buoyancy Flux F_o	32	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	1793.6	29.89333333
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_o)$ for a,V,θ_o at plume height (not used here)		area/chiller	
							141.3716694	13.41640786

Conditions at End (Top) of Jet Phase:

Height above Stack z	25.559	meters*	83.9	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground z+h_s	54.482	meters	178.7	feet	h_s + 6.25D		"
Vertical Velocity V_{plume}	4.556	m/s	14.95	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter 2a	8.179	meters	26.8	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	1.134	meters*	3.7	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	30.057	meters	98.6	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$= 0.955627719	

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 $(Va)_o$	17.803	m^2/s			$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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

	Ht above Ground =	h_{plume}+h_s	D_{plume}=2a=	Vert.Vel (m/s) Method(1) V_{plume}=	Method(2) $\{(Va)_o^3+0.12F_o[(z-z_v)^2$
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 = 25.559 meters*	***54.482***	***178.7***	***8.179***		***4.56***
71.077 meters*	**100.000**	328.1	22.382	1.66	**2.52**
121.077 meters*	150.000	492.1	38.382	0.97	2.03
171.077 meters*	**200.000**	656.2	54.382	0.69	**1.79**
221.077 meters*	250.000	820.2	70.382	0.53	1.64
271.077 meters*	**300.000**	984.3	86.382	0.43	**1.53**
321.077 meters*	350.000	1148.3	102.382	0.36	1.44
371.077 meters*	400.000	1312.3	118.382	0.31	1.37
421.077 meters*	450.000	1476.4	134.382	0.28	1.31
471.077 meters*	**500.000**	1640.4	150.382	0.25	**1.27**
521.077 meters*	550.000	1804.5	166.382	0.22	1.22
571.077 meters*	600.000	1968.5	182.382	0.20	1.19
621.077 meters*	650.000	2132.5	198.382	0.19	1.15
671.077 meters*	**700.000**	2296.6	214.382	0.17	**1.12**
721.077 meters*	750.000	2460.6	230.382	0.16	1.10
771.077 meters*	800.000	2624.7	246.382	0.15	1.07
821.077 meters*	850.000	2788.7	262.382	0.14	1.05
871.077 meters*	900.000	2952.8	278.382	0.13	1.03
921.077 meters*	950.000	3116.8	294.382	0.13	1.01
971.077 meters*	**1000.000**	3280.8	310.382	0.12	**0.99**
1021.077 meters*	1050.000	3444.9	326.382	0.11	0.98
1071.077 meters*	1100.000	3608.9	342.382	0.11	0.96
1121.077 meters*	1150.000	3773.0	358.382	0.10	0.95
1171.077 meters*	1200.000	3937.0	374.382	0.10	0.93
1221.077 meters*	1250.000	4101.0	390.382	0.10	0.92

-10.635 meters*	18.288	60.0	-3.766	-9.89	-8.33
-7.587 meters*	21.336	70.0	-2.791	-13.35	-11.00
-7.282 meters*	21.641	71.0	-2.693	-13.84	-11.38
-6.977 meters*	21.946	72.0	-2.596	-14.36	-11.78
-6.672 meters*	22.251	73.0	-2.498	-14.92	-12.22
-6.368 meters*	22.555	74.0	-2.401	-15.52	-12.70
-6.063 meters*	22.860	75.0	-2.303	-16.18	-13.21
-5.758 meters*	23.165	76.0	-2.205	-16.89	-13.78
-5.453 meters*	23.470	77.0	-2.108	-17.68	-14.39
-5.148 meters*	23.775	78.0	-2.010	-18.53	-15.07
-4.844 meters*	24.079	79.0	-1.913	-19.48	-15.81
-4.539 meters*	24.384	80.0	-1.815	-20.53	-16.64
-4.234 meters*	24.689	81.0	-1.718	-21.69	-17.56
-3.929 meters*	24.994	82.0	-1.620	-23.00	-18.60
-3.624 meters*	25.299	83.0	-1.523	-24.47	-19.77
-3.320 meters*	25.604	84.0	-1.425	-26.14	-21.10
-3.015 meters*	25.908	85.0	-1.328	-28.07	-22.63
-2.710 meters*	26.213	86.0	-1.230	-30.29	-24.40
-2.405 meters*	26.518	87.0	-1.133	-32.90	-26.48
-2.100 meters*	26.823	88.0	-1.035	-36.00	-28.95
-1.795 meters*	27.128	89.0	-0.937	-39.75	-31.94
-1.491 meters*	27.432	90.0	-0.840	-44.36	-35.62
-1.186 meters*	27.737	91.0	-0.742	-50.19	-40.28
-0.881 meters*	28.042	92.0	-0.645	-57.78	-46.35
-0.576 meters*	28.347	93.0	-0.547	-68.08	-54.58
-0.271 meters*	28.652	94.0	-0.450	-82.84	-66.39
0.033 meters*	28.956	95.0	-0.352	-105.78	-84.75
0.338 meters*	29.261	96.0	-0.255	-146.29	-117.18
0.643 meters*	29.566	97.0	-0.157	-237.07	-189.88
0.948 meters*	29.871	98.0	-0.060	-624.86	-500.43
1.253 meters*	30.176	99.0	0.038	982.93	787.18
1.557 meters*	30.480	100.0	0.135	275.10	220.33
1.862 meters*	30.785	101.0	0.233	159.93	128.10
2.167 meters*	31.090	102.0	0.331	112.73	90.32
2.472 meters*	31.395	103.0	0.428	87.05	69.76
2.777 meters*	31.700	104.0	0.526	70.89	56.83
3.081 meters*	32.004	105.0	0.623	59.80	47.96
3.386 meters*	32.309	106.0	0.721	51.70	41.49
3.691 meters*	32.614	107.0	0.818	45.54	36.56
3.996 meters*	32.919	108.0	0.916	40.69	32.69
4.301 meters*	33.224	109.0	1.013	36.77	29.56
4.605 meters*	33.528	110.0	1.111	33.54	26.99
7.653 meters*	36.576	120.0	2.086	17.86	14.54
10.701 meters*	39.624	130.0	3.062	12.17	10.08
13.750 meters*	42.673	140.0	4.037	9.23	7.83
16.798 meters*	45.721	150.0	5.012	7.43	6.48
17.102 meters*	46.025	151.0	5.110	7.29	6.37
17.407 meters*	46.330	152.0	5.207	7.16	6.27
17.712 meters*	46.635	153.0	5.305	7.02	6.17
18.017 meters*	46.940	154.0	5.402	6.90	6.08
18.322 meters*	47.245	155.0	5.500	6.77	5.99
18.626 meters*	47.549	156.0	5.598	6.66	5.90
18.931 meters*	47.854	157.0	5.695	6.54	5.82
19.236 meters*	48.159	158.0	5.793	6.43	5.74
19.541 meters*	48.464	159.0	5.890	6.33	5.66
19.846 meters*	48.769	160.0	5.988	6.22	5.59
20.150 meters*	49.073	161.0	6.085	6.12	5.52
20.455 meters*	49.378	162.0	6.183	6.03	5.45
20.760 meters*	49.683	163.0	6.280	5.93	5.38
21.065 meters*	49.988	164.0	6.378	5.84	5.31
21.370 meters*	50.293	165.0	6.475	5.75	5.25
21.674 meters*	50.597	166.0	6.573	5.67	5.19
21.979 meters*	50.902	167.0	6.670	5.59	5.13
22.284 meters*	51.207	168.0	6.768	5.51	5.07
22.589 meters*	51.512	169.0	6.866	5.43	5.02
22.894 meters*	51.817	170.0	6.963	5.35	4.96
23.198 meters*	52.121	171.0	7.061	5.28	4.91
23.503 meters*	52.426	172.0	7.158	5.21	4.86
23.808 meters*	52.731	173.0	7.256	5.14	4.81
24.113 meters*	53.036	174.0	7.353	5.07	4.76
24.418 meters*	53.341	175.0	7.451	5.00	4.72
24.722 meters*	53.645	176.0	7.548	4.94	4.67
25.027 meters*	53.950	177.0	7.646	4.87	4.63
25.332 meters*	54.255	178.0	7.743	4.81	4.59
25.637 meters*	54.560	179.0	7.841	4.75	4.55
25.942 meters*	54.865	180.0	7.938	4.69	4.50
28.990 meters*	57.913	190.0	8.914	4.18	4.15
32.038 meters*	60.961	200.0	9.889	3.77	3.88
62.518 meters*	91.441	300.0	19.643	1.90	2.67
92.998 meters*	121.921	400.0	29.397	1.27	2.25
123.479 meters*	152.402	500.0	39.150	0.95	2.02
153.959 meters*	182.882	600.0	48.904	0.76	1.86
184.440 meters*	213.363	700.0	58.658	0.64	1.75
214.920 meters*	243.843	800.0	68.411	0.54	1.65
245.400 meters*	274.323	900.0	78.165	0.48	1.58
275.881 meters*	304.804	1000.0	87.919	0.42	1.52
306.361 meters*	335.284	1100.0	97.673	0.38	1.46
336.841 meters*	365.764	1200.0	107.426	0.35	1.42
367.322 meters*	396.245	1300.0	117.180	0.32	1.38
397.802 meters*	426.725	1400.0	126.934	0.29	1.34
428.283 meters*	457.206	1500.0	136.688	0.27	1.31
458.763 meters*	487.686	1600.0	146.441	0.25	1.28
489.243 meters*	518.166	1700.0	156.195	0.24	1.25
519.724 meters*	548.647	1800.0	165.949	0.22	1.22
550.204 meters*	579.127	1900.0	175.702	0.21	1.20
580.684 meters*	609.607	2000.0	185.456	0.20	1.18

Stack Distances (ft)	Number of Stacks
30	52

ft	m/s	merged cells	Plume Diamter Feet
60	-8.33	1.00	-12.36
70	-11.00	1.00	-9.16
71	-11.38	1.00	-8.84
72	-11.78	1.00	-8.52
73	-12.22	1.00	-8.20
74	-12.70	1.00	-7.88
75	-13.21	1.00	-7.56
76	-13.78	1.00	-7.24
77	-14.39	1.00	-6.92
78	-15.07	1.00	-6.60
79	-15.81	1.00	-6.28
80	-16.64	1.00	-5.96
81	-17.56	1.00	-5.64
82	-18.60	1.00	-5.32
83	-19.77	1.00	-5.00
84	-21.10	1.00	-4.68
85	-22.63	1.00	-4.36
86	-24.40	1.00	-4.04
87	-26.48	1.00	-3.72
88	-28.95	1.00	-3.40
89	-31.94	1.00	-3.08
90	-35.62	1.00	-2.76
91	-40.28	1.00	-2.44
92	-46.35	1.00	-2.12
93	-54.58	1.00	-1.80
94	-66.39	1.00	-1.48
95	-84.75	1.00	-1.16
96	-117.18	1.00	-0.84
97	-189.88	1.00	-0.52
98	-500.43	1.00	-0.20
99	787.18	1.00	0.12
100	220.33	1.00	0.44
101	128.10	1.00	0.76
102	90.32	1.00	1.08
103	69.76	1.00	1.40
104	56.83	1.00	1.72
105	47.96	1.00	2.04
106	41.49	1.00	2.36
107	36.56	1.00	2.68
108	32.69	1.00	3.00
109	29.56	1.00	3.32
110	26.99	1.00	3.64
120	14.54	1.00	6.84
130	10.08	1.00	10.04
140	7.83	1.00	13.24
150	6.48	1.00	16.44
151	6.38	1.01	16.76
152	6.30	1.02	17.08
153	6.22	1.03	17.40
154	6.14	1.04	17.72
155	6.06	1.05	18.04
156	5.99	1.06	18.36
157	5.92	1.07	18.68
158	5.85	1.08	19.00
159	5.79	1.09	19.32
160	5.73	1.10	19.64
161	5.67	1.11	19.96
162	5.61	1.12	20.28
163	5.55	1.13	20.60
164	5.50	1.14	20.92
165	5.44	1.16	21.24
166	5.39	1.17	21.56
167	5.34	1.18	21.88
168	5.30	1.19	22.20
169	5.25	1.20	22.52
170	5.21	1.21	22.84
171	5.16	1.22	23.16
172	5.12	1.23	23.48
173	5.08	1.24	23.80
174	5.04	1.25	24.12
175	5.00	1.26	24.44
176	4.96	1.27	24.76
177	4.93	1.28	25.08
178	4.89	1.29	25.40
179	4.86	1.30	25.72
180	4.82	1.32	26.04
190	4.53	1.42	29.24
200	4.31	1.53	32.44
300	3.39	2.60	64.45
400	3.11	3.66	96.45
500	2.97	4.73	128.45
600	2.89	5.80	160.45
700	2.82	6.86	192.45
800	2.78	7.93	224.45
900	2.74	9.00	256.45
1,000	2.70	10.06	288.45
1,100	2.67	11.13	320.45
1,200	2.65	12.20	352.45
1,300	2.63	13.26	384.45
1,400	2.61	14.33	416.45
1,500	2.59	15.40	448.45
1,600	2.57	16.46	480.45
1,700	2.56	17.53	512.45
1,800	2.54	18.60	544.45
1,900	2.53	19.66	576.45
2,000	2.52	20.73	608.45

611.165 meters*	640.088	2100.0	195.210	0.19	1.16
641.645 meters*	670.568	2200.0	204.964	0.18	1.14
672.126 meters*	701.049	2300.0	214.717	0.17	1.12
702.606 meters*	731.529	2400.0	224.471	0.17	1.11
733.086 meters*	762.009	2500.0	234.225	0.16	1.09
763.567 meters*	792.490	2600.0	243.978	0.15	1.08
794.047 meters*	822.970	2700.0	253.732	0.15	1.06
824.527 meters*	853.450	2800.0	263.486	0.14	1.05
855.008 meters*	883.931	2900.0	273.240	0.14	1.04
885.488 meters*	914.411	3000.0	282.993	0.13	1.02
915.968 meters*	944.891	3100.0	292.747	0.13	1.01
946.449 meters*	975.372	3200.0	302.501	0.12	1.00
976.929 meters*	1005.852	3300.0	312.254	0.12	0.99
1007.410 meters*	1036.333	3400.0	322.008	0.12	0.98
1037.890 meters*	1066.813	3500.0	331.762	0.11	0.97
1068.370 meters*	1097.293	3600.0	341.516	0.11	0.96
1098.851 meters*	1127.774	3700.0	351.269	0.11	0.95
1129.331 meters*	1158.254	3800.0	361.023	0.10	0.94
1159.811 meters*	1188.734	3900.0	370.777	0.10	0.94
1190.292 meters*	1219.215	4000.0	380.530	0.10	0.93

2,100	2.51	21.80	640.45
2,200	2.50	22.86	672.45
2,300	2.49	23.93	704.45
2,400	2.48	25.00	736.45
2,500	2.47	26.06	768.45
2,600	2.46	27.13	800.45
2,700	2.45	28.20	832.45
2,800	2.44	29.26	864.45
2,900	2.43	30.33	896.46
3,000	2.43	31.40	928.46
3,100	2.42	32.46	960.46
3,200	2.41	33.53	992.46
3,300	2.40	34.60	1024.46
3,400	2.40	35.66	1056.46
3,500	2.39	36.73	1088.46
3,600	2.39	37.80	1120.46
3,700	2.38	38.86	1152.46
3,800	2.37	39.93	1184.46
3,900	2.37	41.00	1216.46
4,000	2.36	42.06	1248.46

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	28.92	meters	94.9	feet	λ	1.11		
Stack Diameter D	4.09	meters	13.4	feet		0.3048 meters/feet	13.41657101	
Stack Velocity V_{exit}	9.11	m/s	29.9	ft/sec				
Volumetric Flow	120	cu.m/sec	254,266	ACFM	$\pi V_{exit}D^2/4$	Sect.2/¶1		
Stack Potential Temp θ_s	326	Kelvins	126.9	°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	1793.6	29.89333333
Plume Buoyancy Flux F	N/A	m^4/s^3			$\lambda^2 gVa^2(1-\theta_a/\theta_o)$ for a,V,θ_o at plume height (not used here)		area/chiller	
							141.3716694	13.41640786
Conditions at End (Top) of Jet Phase:								
Height above Stack z	25.559	meters*	83.9	feet*	6.25D, meters*=meters above stack top	Sect.3/¶1		
Height above Ground z+h_s	54.482	meters	178.7	feet	h_s + 6.25D	"		
Vertical Velocity V_{plume}	4.556	m/s	14.95	ft/sec	$0.5V_{exit}$ $V_{exit}/2$	"		
Plume Top-Hat Diameter 2a	8.179	meters	26.8	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	0.682	meters*	2.2	feet*	$6.25D[1-(\theta_a/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground z_v+h_s	29.605	meters	97.1	feet	where $(\theta_a/\theta_s)^{1/2} = (\theta_a/\theta_s)^{1/2}$= 0.973304097	

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 $(Va)_o$	18.133	m^2/s			$V_{exit}D/2(\theta_a/\theta_s)^{1/2}$	

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 = 25.559 meters*	***54.482***	***178.7***	***8.179***		***4.56***
71.077 meters*	**100.000**	328.1	22.526	1.65	**2.25**
121.077 meters*	150.000	492.1	38.526	0.97	1.76
171.077 meters*	**200.000**	656.2	54.526	0.68	**1.53**
221.077 meters*	250.000	820.2	70.526	0.53	1.40
271.077 meters*	**300.000**	984.3	86.526	0.43	**1.30**
321.077 meters*	350.000	1148.3	102.526	0.36	1.22
371.077 meters*	400.000	1312.3	118.526	0.31	1.16
421.077 meters*	450.000	1476.4	134.526	0.28	1.12
471.077 meters*	**500.000**	1640.4	150.526	0.25	**1.07**
521.077 meters*	550.000	1804.5	166.526	0.22	1.04
571.077 meters*	600.000	1968.5	182.526	0.20	1.01
621.077 meters*	650.000	2132.5	198.526	0.19	0.98
671.077 meters*	**700.000**	2296.6	214.526	0.17	**0.95**
721.077 meters*	750.000	2460.6	230.526	0.16	0.93
771.077 meters*	800.000	2624.7	246.526	0.15	0.91
821.077 meters*	850.000	2788.7	262.526	0.14	0.89
871.077 meters*	900.000	2952.8	278.526	0.13	0.87
921.077 meters*	950.000	3116.8	294.526	0.13	0.86
971.077 meters*	**1000.000**	3280.8	310.526	0.12	**0.84**
1021.077 meters*	1050.000	3444.9	326.526	0.11	0.83
1071.077 meters*	1100.000	3608.9	342.526	0.11	0.81
1121.077 meters*	1150.000	3773.0	358.526	0.10	0.80
1171.077 meters*	1200.000	3937.0	374.526	0.10	0.79
1221.077 meters*	1250.000	4101.0	390.526	0.10	0.78

-10.635 meters*	18.288	60.0	-3.621	-10.29	-9.32
-7.587 meters*	21.336	70.0	-2.646	-14.08	-12.63
-7.282 meters*	21.641	71.0	-2.549	-14.62	-13.10
-6.977 meters*	21.946	72.0	-2.451	-15.20	-13.61
-6.672 meters*	22.251	73.0	-2.353	-15.83	-14.16
-6.368 meters*	22.555	74.0	-2.256	-16.52	-14.76
-6.063 meters*	22.860	75.0	-2.158	-17.26	-15.42
-5.758 meters*	23.165	76.0	-2.061	-18.08	-16.14
-5.453 meters*	23.470	77.0	-1.963	-18.98	-16.93
-5.148 meters*	23.775	78.0	-1.866	-19.97	-17.80
-4.844 meters*	24.079	79.0	-1.768	-21.07	-18.77
-4.539 meters*	24.384	80.0	-1.671	-22.30	-19.86
-4.234 meters*	24.689	81.0	-1.573	-23.68	-21.08
-3.929 meters*	24.994	82.0	-1.476	-25.25	-22.46
-3.624 meters*	25.299	83.0	-1.378	-27.04	-24.04
-3.320 meters*	25.604	84.0	-1.281	-29.10	-25.86
-3.015 meters*	25.908	85.0	-1.183	-31.50	-27.98
-2.710 meters*	26.213	86.0	-1.086	-34.33	-30.48
-2.405 meters*	26.518	87.0	-0.988	-37.71	-33.48
-2.100 meters*	26.823	88.0	-0.890	-41.85	-37.13
-1.795 meters*	27.128	89.0	-0.793	-46.99	-41.69
-1.491 meters*	27.432	90.0	-0.695	-53.58	-47.53
-1.186 meters*	27.737	91.0	-0.598	-62.33	-55.27
-0.881 meters*	28.042	92.0	-0.500	-74.48	-66.03
-0.576 meters*	28.347	93.0	-0.403	-92.52	-82.01
-0.271 meters*	28.652	94.0	-0.305	-122.08	-108.21
0.033 meters*	28.956	95.0	-0.208	-179.42	-159.01
0.338 meters*	29.261	96.0	-0.110	-338.32	-299.83
0.643 meters*	29.566	97.0	-0.013	-2958.01	-2621.40
0.948 meters*	29.871	98.0	0.085	438.66	388.75
1.253 meters*	30.176	99.0	0.182	204.19	180.96
1.557 meters*	30.480	100.0	0.280	133.07	117.94
1.862 meters*	30.785	101.0	0.378	98.69	87.48
2.167 meters*	31.090	102.0	0.475	78.43	69.53
2.472 meters*	31.395	103.0	0.573	65.07	57.70
2.777 meters*	31.700	104.0	0.670	55.60	49.31
3.081 meters*	32.004	105.0	0.768	48.53	43.06
3.386 meters*	32.309	106.0	0.865	43.06	38.21
3.691 meters*	32.614	107.0	0.963	38.70	34.35
3.996 meters*	32.919	108.0	1.060	35.14	31.20
4.301 meters*	33.224	109.0	1.158	32.18	28.58
4.605 meters*	33.528	110.0	1.255	29.68	26.37
7.653 meters*	36.576	120.0	2.231	16.70	14.93
10.701 meters*	39.624	130.0	3.206	11.62	10.48
13.750 meters*	42.673	140.0	4.182	8.91	8.13
16.798 meters*	45.721	150.0	5.157	7.23	6.68
17.102 meters*	46.025	151.0	5.254	7.09	6.57
17.407 meters*	46.330	152.0	5.352	6.96	6.46
17.712 meters*	46.635	153.0	5.449	6.84	6.35
18.017 meters*	46.940	154.0	5.547	6.72	6.25
18.322 meters*	47.245	155.0	5.645	6.60	6.15
18.626 meters*	47.549	156.0	5.742	6.49	6.06
18.931 meters*	47.854	157.0	5.840	6.38	5.97
19.236 meters*	48.159	158.0	5.937	6.28	5.88
19.541 meters*	48.464	159.0	6.035	6.17	5.79
19.846 meters*	48.769	160.0	6.132	6.08	5.71
20.150 meters*	49.073	161.0	6.230	5.98	5.63
20.455 meters*	49.378	162.0	6.327	5.89	5.55
20.760 meters*	49.683	163.0	6.425	5.80	5.48
21.065 meters*	49.988	164.0	6.522	5.71	5.41
21.370 meters*	50.293	165.0	6.620	5.63	5.34
21.674 meters*	50.597	166.0	6.717	5.55	5.27
21.979 meters*	50.902	167.0	6.815	5.47	5.20
22.284 meters*	51.207	168.0	6.913	5.39	5.14
22.589 meters*	51.512	169.0	7.010	5.32	5.08
22.894 meters*	51.817	170.0	7.108	5.24	5.02
23.198 meters*	52.121	171.0	7.205	5.17	4.96
23.503 meters*	52.426	172.0	7.303	5.10	4.90
23.808 meters*	52.731	173.0	7.400	5.04	4.85
24.113 meters*	53.036	174.0	7.498	4.97	4.79
24.418 meters*	53.341	175.0	7.595	4.91	4.74
24.722 meters*	53.645	176.0	7.693	4.84	4.69
25.027 meters*	53.950	177.0	7.790	4.78	4.64
25.332 meters*	54.255	178.0	7.888	4.72	4.59
25.637 meters*	54.560	179.0	7.985	4.67	4.54
25.942 meters*	54.865	180.0	8.083	4.61	4.50
28.990 meters*	57.913	190.0	9.058	4.11	4.10
32.038 meters*	60.961	200.0	10.034	3.71	3.78
62.518 meters*	91.441	300.0	19.787	1.88	2.41
92.998 meters*	121.921	400.0	29.541	1.26	1.97
123.479 meters*	152.402	500.0	39.295	0.95	1.74
153.959 meters*	182.882	600.0	49.049	0.76	1.60
184.440 meters*	213.363	700.0	58.802	0.63	1.49
214.920 meters*	243.843	800.0	68.556	0.54	1.41
245.400 meters*	274.323	900.0	78.310	0.48	1.34
275.881 meters*	304.804	1000.0	88.063	0.42	1.29
306.361 meters*	335.284	1100.0	97.817	0.38	1.24
336.841 meters*	365.764	1200.0	107.571	0.35	1.20
367.322 meters*	396.245	1300.0	117.325	0.32	1.17
397.802 meters*	426.725	1400.0	127.078	0.29	1.14
428.283 meters*	457.206	1500.0	136.832	0.27	1.11
458.763 meters*	487.686	1600.0	146.586	0.25	1.08
489.243 meters*	518.166	1700.0	156.340	0.24	1.06
519.724 meters*	548.647	1800.0	166.093	0.22	1.04
550.204 meters*	579.127	1900.0	175.847	0.21	1.02
580.684 meters*	609.607	2000.0	185.601	0.20	1.00

Stack Distances (ft)	Number of Stacks
30	52

ft	m/s	merged cells	Plume Diamter Feet
60	-9.32	1.00	-11.88
70	-12.63	1.00	-8.68
71	-13.10	1.00	-8.36
72	-13.61	1.00	-8.04
73	-14.16	1.00	-7.72
74	-14.76	1.00	-7.40
75	-15.42	1.00	-7.08
76	-16.14	1.00	-6.76
77	-16.93	1.00	-6.44
78	-17.80	1.00	-6.12
79	-18.77	1.00	-5.80
80	-19.86	1.00	-5.48
81	-21.08	1.00	-5.16
82	-22.46	1.00	-4.84
83	-24.04	1.00	-4.52
84	-25.86	1.00	-4.20
85	-27.98	1.00	-3.88
86	-30.48	1.00	-3.56
87	-33.48	1.00	-3.24
88	-37.13	1.00	-2.92
89	-41.69	1.00	-2.60
90	-47.53	1.00	-2.28
91	-55.27	1.00	-1.96
92	-66.03	1.00	-1.64
93	-82.01	1.00	-1.32
94	-108.21	1.00	-1.00
95	-159.01	1.00	-0.68
96	-299.83	1.00	-0.36
97	-2621.40	1.00	-0.04
98	388.75	1.00	0.28
99	180.96	1.00	0.60
100	117.94	1.00	0.92
101	87.48	1.00	1.24
102	69.53	1.00	1.56
103	57.70	1.00	1.88
104	49.31	1.00	2.20
105	43.06	1.00	2.52
106	38.21	1.00	2.84
107	34.35	1.00	3.16
108	31.20	1.00	3.48
109	28.58	1.00	3.80
110	26.37	1.00	4.12
120	14.93	1.00	7.32
130	10.48	1.00	10.52
140	8.13	1.00	13.72
150	6.70	1.01	16.92
151	6.60	1.02	17.24
152	6.51	1.03	17.56
153	6.42	1.04	17.88
154	6.33	1.05	18.20
155	6.25	1.06	18.52
156	6.17	1.08	18.84
157	6.09	1.09	19.16
158	6.02	1.10	19.48
159	5.94	1.11	19.80
160	5.87	1.12	20.12
161	5.80	1.13	20.44
162	5.74	1.14	20.76
163	5.67	1.15	21.08
164	5.61	1.16	21.40
165	5.55	1.17	21.72
166	5.49	1.18	22.04
167	5.44	1.19	22.36
168	5.38	1.20	22.68
169	5.33	1.21	23.00
170	5.28	1.22	23.32
171	5.23	1.24	23.64
172	5.18	1.25	23.96
173	5.13	1.26	24.28
174	5.08	1.27	24.60
175	5.04	1.28	24.92
176	5.00	1.29	25.24
177	4.95	1.30	25.56
178	4.91	1.31	25.88
179	4.87	1.32	26.20
180	4.83	1.33	26.52
190	4.49	1.44	29.72
200	4.21	1.54	32.92
300	3.06	2.61	64.92
400	2.73	3.68	96.92
500	2.57	4.74	128.92
600	2.48	5.81	160.92
700	2.41	6.88	192.92
800	2.37	7.94	224.92
900	2.33	9.01	256.92
1,000	2.30	10.08	288.92
1,100	2.27	11.14	320.92
1,200	2.25	12.21	352.92
1,300	2.23	13.28	384.92
1,400	2.21	14.34	416.92
1,500	2.20	15.41	448.92
1,600	2.18	16.48	480.92
1,700	2.17	17.54	512.92
1,800	2.16	18.61	544.93
1,900	2.14	19.68	576.93
2,000	2.13	20.74	608.93

611.165 meters*	640.088	2100.0	195.354	0.19	0.98
641.645 meters*	670.568	2200.0	205.108	0.18	0.97
672.126 meters*	701.049	2300.0	214.862	0.17	0.95
702.606 meters*	731.529	2400.0	224.616	0.17	0.94
733.086 meters*	762.009	2500.0	234.369	0.16	0.92
763.567 meters*	792.490	2600.0	244.123	0.15	0.91
794.047 meters*	822.970	2700.0	253.877	0.15	0.90
824.527 meters*	853.450	2800.0	263.630	0.14	0.89
855.008 meters*	883.931	2900.0	273.384	0.14	0.88
885.488 meters*	914.411	3000.0	283.138	0.13	0.87
915.968 meters*	944.891	3100.0	292.892	0.13	0.86
946.449 meters*	975.372	3200.0	302.645	0.12	0.85
976.929 meters*	1005.852	3300.0	312.399	0.12	0.84
1007.410 meters*	1036.333	3400.0	322.153	0.12	0.83
1037.890 meters*	1066.813	3500.0	331.906	0.11	0.82
1068.370 meters*	1097.293	3600.0	341.660	0.11	0.81
1098.851 meters*	1127.774	3700.0	351.414	0.11	0.81
1129.331 meters*	1158.254	3800.0	361.168	0.10	0.80
1159.811 meters*	1188.734	3900.0	370.921	0.10	0.79
1190.292 meters*	1219.215	4000.0	380.675	0.10	0.79

2,100	2.12	21.81	640.93
2,200	2.11	22.88	672.93
2,300	2.11	23.94	704.93
2,400	2.10	25.01	736.93
2,500	2.09	26.08	768.93
2,600	2.08	27.14	800.93
2,700	2.07	28.21	832.93
2,800	2.07	29.28	864.93
2,900	2.06	30.34	896.93
3,000	2.05	31.41	928.93
3,100	2.05	32.48	960.93
3,200	2.04	33.54	992.93
3,300	2.04	34.61	1024.93
3,400	2.03	35.68	1056.93
3,500	2.03	36.74	1088.93
3,600	2.02	37.81	1120.93
3,700	2.02	38.88	1152.93
3,800	2.01	39.94	1184.93
3,900	2.01	41.01	1216.93
4,000	2.00	42.08	1248.93

MANUFACTURER DATA

DIESEL GENERATOR SET
MTU 16V4000 DS2250

2250 kWe / 60 Hz / Standby
380 - 13.8kV

Reference MTU 16V4000 DS2250 (2045 kWe) for Prime Rating Technical Data

SYSTEM RATINGS

Standby

Voltage (L-L)	380V	480V*	600V	4160V	12470V	13200V	13800V
Phase	3	3	3	3	3	3	3
PF	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Hz	60	60	60	60	60	60	60
kW	2250	2250	2250	2250	2250	2250	2250
kVA	2812	2812	2812	2812	2812	2812	2812
Amps	4273	3383	2706	390	130	123	117
skVA@30% Voltage Dip	3625	8400	3900	5000	4120	4120	4900
Generator Model	1020FDL1102	744RSL4058	1020FDS1120	744FSM4376	1020FDH1246	1020FDH1244	1020FDH1246
Temp Rise	130 °C/40 °C	130 °C/40 °C	130 °C/40 °C	130 °C/40 °C	130 °C/40 °C	130 °C/40 °C	130 °C/40 °C
Connection	6 LEAD WYE	4 LEAD WYE	6 LEAD WYE	6 LEAD WYE	6 LEAD WYE	6 LEAD WYE	6 LEAD WYE

* UL 2200 Offered

CERTIFICATIONS AND STANDARDS

// **Emissions –** EPA Tier 2 Certified

// **Generator set is designed and manufactured in facilities certified to standards ISO 9001:2008 and ISO 14001:2004**

// **Seismic Certification – Optional**
- IBC Certification
- OSHPD Pre-Approval

// **UL 2200 Listed – Optional**

// **Performance Assurance Certification (PAC)**
- Generator Set Tested to ISO 8528-5 for Transient Response
- Verified product design, quality and performance integrity
- All engine systems are prototype and factory tested

// **Power Rating**
- Accepts Rated Load in One Step Per NFPA 110
- Permissible average power output during 24 hours of operation is approved up to 85%.

STANDARD FEATURES*

// MTU Onsite Energy is a single source supplier
// Global Product Support
// 2 Year Standard Warranty
// 16V4000 Diesel Engine
- 76.3 Liter Displacement
- Common Rail Fuel Injection
- 4-Cycle

// Complete Range of Accessories
// Generator
- Brushless, Rotating Field Generator
- 2/3 Pitch Windings
- PMG (Permanent Magnet Generator) supply to regulator
- 300% Short Circuit Capability

// Digital Control Panel(s)
- UL Recognized, CSA Certified, NFPA 110
- Complete System Metering
- LCD Display

// Cooling System
- Integral Set-Mounted
- Engine-Driven Fan

STANDARD EQUIPMENT*

// Engine

Air Cleaners
Oil Pump
Oil Drain Extension and S/O Valve
Full Flow Oil Filter
Closed Crankcase Ventilation
Jacket Water Pump
Inter Cooler Water Pump
Thermostats
Blower Fan and Fan Drive
Radiator - Unit Mounted
Electric Starting Motor - 24V
Governor – Electronic Isochronous
Base - Structural Steel
SAE Flywheel and Bell Housing
Charging Alternator - 24V
Battery Box and Cables
Flexible Fuel Connectors
Flexible Exhaust Connection
EPA Certified Engine

// Generator

NEMA MG1, IEEE and ANSI standards compliance for temperature rise and motor starting
Sustained short circuit current of up to 300% of the rated current for up to 10 seconds
Self-Ventilated and Drip-Proof
Superior Voltage Waveform
Digital, Solid State, Volts-per-Hertz Regulator
No Load to Full Load Regulation
Brushless Alternator with Brushless Pilot Exciter
4 Pole, Rotating Field
130 °C Max. Standby Temperature Rise
1 Bearing, Sealed
Flexible Coupling
Full Amortisseur Windings
125% Rotor Balancing
3-Phase Voltage Sensing
±0.25% Voltage Regulation
100% of Rated Load - One Step
5% Max. Total Harmonic Distortion

// Digital Control Panel(s)

Digital Metering
Engine Parameters
Generator Protection Functions
Engine Protection
CANBus ECU Communications
Windows®-Based Software
Multilingual Capability
Remote Communications to RDP-110 Remote Annunciator
Programmable Input and Output Contacts
UL Recognized, CSA Certified, CE Approved
Event Recording
IP 54 Front Panel Rating with Integrated Gasket
NFPA110 Compatible

* Represents standard product only. Consult Factory/MTU Onsite Energy Distributor for additional configurations.

APPLICATION DATA

// Engine

Manufacturer	MTU
Model	16V4000G84S
Type	4-Cycle
Arrangement	16-V
Displacement: L (in^3)	76.3 (4,656)
Bore: cm (in)	17 (6.69)
Stroke: cm (in)	21 (8.27)
Compression Ratio	16.5:1
Rated RPM	1,800
Engine Governor	Electronic Isochronous (ADEC)
Max. Power: kWm (bhp)	2,500 (3,353)
Speed Regulation	±0.25%
Air Cleaner	Dry

// Liquid Capacity (Lubrication)

Total Oil System: L (gal)	300 (79.3)
Engine Jacket Water Capacity: L (gal)	175 (46.2)
After Cooler Water Capacity: L (gal)	50 (13.2)
System Coolant Capacity: L (gal)	547 (145)

// Electrical

Electric Volts DC	24
Cold Cranking Amps Under -17.8 °C (0 °F)	2,800

// Fuel System

Fuel Supply Connection Size	-16 JIC 37° Female 1" NPT Adapter Provided
Fuel Return Connection Size	-16 JIC 37° Female 1" NPT Adapter Provided
Max. Fuel Lift: m (ft)	1 (3)
Recommended Fuel	Diesel #2
Total Fuel Flow: L/hr (gal/hr)	1,200 (317)

// Fuel Consumption

At 100% of Power Rating: L/hr (gal/hr)	617 (163)
At 75% of Power Rating: L/hr (gal/hr)	467 (123)
At 50% of Power Rating: L/hr (gal/hr)	325 (86)

// Cooling - Radiator System

Ambient Capacity of Radiator: °C (°F)	40 (104)
Max. Restriction of Cooling Air: Intake and Discharge Side of Rad.: kPa (in. H_2O)	0.12 (0.5)
Water Pump Capacity: L/min (gpm)	1,350 (357)
After Cooler Pump Capacity: L/min (gpm)	583 (154)
Heat Rejection to Coolant: kW (BTUM)	930 (52,888)
Heat Rejection to After Cooler: kW (BTUM)	680 (38,671)
Heat Radiated to Ambient: kW (BTUM)	206 (11,711)
Fan Power: kW (hp)	95.4 (128)

// Air Requirements

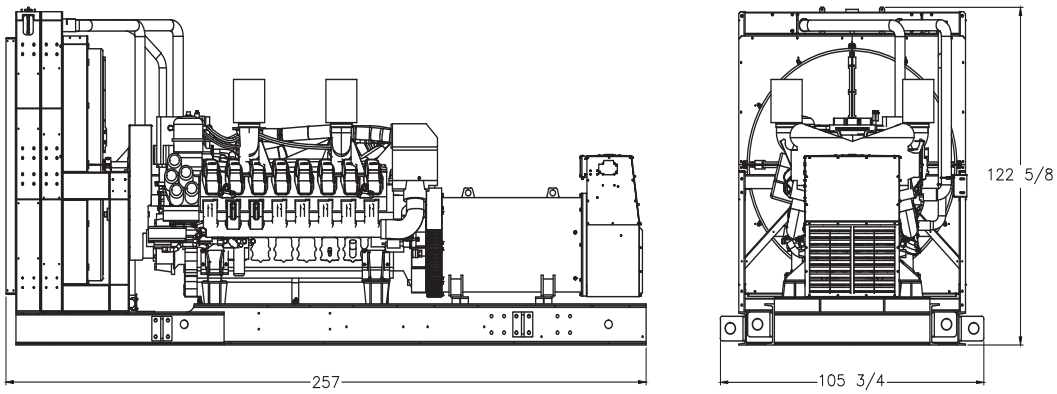
Aspirating: *m^3/min (SCFM)	192 (6,780)
Air Flow Required for Rad. Cooled Unit: *m^3/min (SCFM)	2,053 (72,500)
Remote Cooled Applications; Air Flow Required for Dissipation of Radiated Generator Set Heat for a Max. of 25 °F Rise: *m^3/min (SCFM)	752 (26,412)

* Air density = 1.184 kg/m^3 (0.0739 lbm/ft^3)

// Exhaust System

Gas Temp. (Stack): °C (°F)	505 (941)
Gas Volume at Stack Temp: m^3/min (CFM)	504 (17,799)
Max. Allowable Back Pressure: kPa (in. H_2O)	8.5 (34.1)

WEIGHTS AND DIMENSIONS



Drawing above for illustration purposes only, based on standard open power 480 volt generator set. Lengths may vary with other voltages. Do not use for installation design. See website for unit specific template drawings.

System	Dimensions (L x W x H)	Weight (less tank)
Open Power Unit (OPU)	6,528 x 2,686 x 3,115 mm (257 x 105.7 x 122.6 in)	16,429 kg (36,220 lb)

Weights and dimensions are based on open power units and are estimates only. Consult the factory for accurate weights and dimensions for your specific generator set.

SOUND DATA

Unit Type	Standby Full Load
Level 0: Open Power Unit dB(A)	98.7

Sound data is provided at 7 m (23 ft). Generator set tested in accordance with ISO 8528-10 and with infinite exhaust.

EMISSIONS DATA

NO_x + NMHC	CO	PM
5.07	0.52	0.04

All units are in g/hp-hr and shown at 100% load (not comparable to EPA weighted cycle values).
Emission levels of the engine may vary with ambient temperature, barometric pressure, humidity, fuel type and quality, installation parameters, measuring instrumentation, etc. The data was obtained in compliance with US EPA regulations. The weighted cycle value (not shown) from each engine is guaranteed to be within the US EPA Standards.

RATING DEFINITIONS AND CONDITIONS

// Standby ratings apply to installations served by a reliable utility source. The standby rating is applicable to varying loads for the duration of a power outage. No overload capability for this rating. Ratings are in accordance with ISO 8528-1, ISO 3046-1, BS 5514, and AS 2789. Average load factor: ≤ 85%.

// Deration Factor:
Altitude: Consult your local MTU Onsite Energy Power Generation Distributor for altitude derations.
Temperature: Consult your local MTU Onsite Energy Power Generation Distributor for temperature derations.

C/F = Consult Factory/MTU Onsite Energy Distributor
N/A = Not Available

Inhaltsverzeichnis
Contents

	Genset	Marine	O & G	Rail	C & I
Application	X				
Engine model	16V4000G84S				
Rated power [kW]	2500				
Rated speed [rpm]	1800				
Application group	3D				
Emission Stage/Optimisation	EPA Stationary EMERG T2 (40CFR60)				
Test cycle	D2				
Data Set No.	XZ59554101095				
Data Set Basis	EPA Stationary EMERG T2 (40CFR60)				
Fuel sulphur content [ppm]	8,1				

Inhalt *content*	Notiz *Note*	Seite *Page*	Buchstabe/Revision *change index*
Emissions Daten Blatt (EDS) *emission Data Sheet (EDS)*	O2 gem. *O2 meas.*	2	
Not to exceed Werte *Not to exceed values*	O2 gem. *O2 meas.*	3	

Unterschriftenweg	EDS erstellt	TETC Teamleiter	TET Leiter Org.-Einheit	Baureihen - Teamleiter	Baureihen Leiter Org.-Einheit	Freigabe im Windchill
Datum	07.06.2018	-	-	07.06.2018	07.06.2018	07.06.2018
Org.-Einheit	TETE	-	-	TKFV1	TKF	TKM
Name	T.Lenhof	-	-	Dr. Kneifel	Dr. Baumgarten	Link

Aenderungsbeschreibung/Description of Revision | Kommt vor/Frequency
Freigabe

Buchst./Rev. Ltr.	Aenderungs-Nr./Revision Notice No.	Bearbeitungsstatus/Lifecycle
-.3	PR030109	Freigegeben

MTU Friedrichshafen GmbH

WORD	Datum/ Date	Name
Erstell. Drawn	12.02.2018 13:49:48	link
Bearb. Change	14.06.2018 11:06:11	link
Inhalt Content	07.06.2018	Lenhof
Gepr. Checked	14.06.2018 11:06:11	baumgarten

Motortyp / Engine Type: **16V4000G84S**

Projekt-/Auftrags-Nr. Project/Order No.
Verwendbar f.Typ Applicable to Model
Format/Size: **A3**
Material-Nr./Material No.: **EDS 4000 1234**
Benennung/ Title: **EMISSIONSDATENBLATT**
EMISSION DATA SHEET

Zeichnungs-Nr./Drawing No.: **ZNG00013267**
Beschreibung/Description
Blatt/ Sheet **1** von/of **3**

Revision *Change index*					

Motordaten
engine data

	Genset	Marine	O & G	Rail	C & I
Application	X				
Engine model	16V4000G84S				
Application group	3D				
Emission Stage/Optimisation	EPA Stationary EMERG T2 (40CFR60)				
Test cycle	D2				
fuel sulphur content [ppm]	8,1				
mg/mN³ values base on residual oxygen value of [%]	measured				

Motor Rohemissionen*
*Engine raw emissions**

Cycle point	[-]	n1	n2	n3	n4	n5	n6	n7	n8
Power (P/Pcycle)	[-]	1	0,75	0,50	0,25	0,10			
Power	[kW]	2498	1872	1250	624	250			
Speed (n/nN)	[-]	1	1	1	1	1			
Speed	[rpm]	1800	1800	1801	1801	1801			
Exhaust temperature after turbine	[°C]	501	424	373	335	240			
Exhaust massflow	[kg/h]	14327	13109	11239	8380	5530			
Exhaust back pressure (static)	[mbar]	88	69	48	26	11			
NOx	[g/kWh]	6,5	5,7	4,4	3,0	8,3			
	[mg/mN³]	1533	1076	639	286	483			
CO	[g/kWh]	1,0	0,8	0,7	1,3	4,2			
	[mg/mN³]	244	168	113	131	257			
HC	[g/kWh]	0,17	0,26	0,39	0,80	1,63			
	[mg/mN³]	42	53	61	82	101			
O2	[%]	10,1	12,4	14,1	15,9	17,7			
Particulate measured	[g/kWh]	0,06	0,12	0,12	0,32	0,76			
	[mg/mN³]	15	24	19	33	47			
Particulate calculated	[g/kWh]	-	-	-	-	-			
	[mg/mN³]	-	-	-	-	-			
Dust (only TA-Luft)	[mg/mN³]	-	-	-	-	-			
FSN	[-]	0,6	0,7	0,3	0,7	0,4			
NO/NO2**	[-]	-	-	-	-	-			
CO2	[g/kWh]	659,6	665,6	713,0	854,0	1044,0			
	[mg/mN³]	164166	133820	110475	87696	64408			
SO2	[g/kWh]	0,003	0,003	0,004	0,004	0,005			
	[mg/mN³]	0,8	0,7	0,6	0,5	0,3			
CH2O	[g/kWh]	-	-	-	-	-			
	[mg/mN³]	-	-	-	-	-			

* Emission data measurement procedures are consistent with the respective emission evaluation process. Noncertified engines are measured to sales data (TVU/TEN) standard conditions.
These boundary conditions might not be representative for detailed dimensioning of exhaust gas aftertreatment, in this case it is recommended to contact the responsible department for more information.
Measurements are subject to variation. The nominal emission data shown is subject to instrumentation, measurement, facility, and engine-to-engine variations.
All data applies to an engine in new condition and were measured after combined exhaust streams. Over extended operating time deterioration may occur which might have an impact on emission. Exhaust temperature depends on engine ambient conditions.

** No standard test. To be measured on demand.

Revision *Change index*					

Motordaten

engine data

	Genset	Marine	O & G	Rail	C & I
Application	X				
Engine model	16V4000G84S				
Application group	3D				
Emission Stage/Optimisation	EPA Stationary EMERG T2 (40CFR60)				
Test cycle	D2				
fuel sulphur content [ppm]	8,1				
mg/mN³ values base on residual oxygen value of [%]	measured				

Not to exceed Werte*

*not to exceed values**

Cycle point	[-]	n1	n2	n3	n4	n5	n6	n7	n8
Power (P/Pcycle)	[-]	1	0,75	0,50	0,25				
Power	[kW]	2498	1872	1250	624				
Speed (n/nN)	[-]	1	1	1	1				
Speed	[rpm]	1800	1800	1801	1801				
Exhaust back pressure (static)	[mbar]	88	69	48	26				
NOx	[g/kWh]	8,5	7,4	5,7	4,5				
	[mg/mN³]	1993	1399	831	429				
CO	[g/kWh]	1,7	1,4	1,4	2,6				
	[mg/mN³]	415	286	215	262				
HC	[g/kWh]	0,29	0,45	0,74	1,60				
	[mg/mN³]	71	90	116	164				
O2	[%]	10,1	12,4	14,1	15,9				
Particulate measured	[g/kWh]	0,09	0,19	0,18	0,48				
	[mg/mN³]	23	39	28	50				
CH2O	[g/kWh]	-	-	-	-				
	[mg/mN³]	-	-	-	-				

* Calculated values are not proven by tests and therefore the accuracy cannot be guaranteed.
Emissions data measurement procedures are consistent with those described in the applicable rules and standards.
The NOx, CO, HC and PM emission data tabulated here were taken from a single new engine under the test conditions shown above and are valid for the following conditions:

- Ambient air pressure 1 bar
- Air intake temperature approx. 25°C
- Rel. Humidity 30%-60%
- New Engine
- New standard- air filter
- Exhaust gas back pressure according the given value in this EDS
- Fuel according to EN 590 or US EPA 40CFR89
- Coolant and Lubricants according MTU Fuels and Lubricants Specification
- measured after combined exhaust streams.

The nominal emissions data shown is subject to instrumentation, measurement, facility and engine to engine variations. Emissions data is based on single operating points and thus cannot be used to compare to EPA regulations which use values based on a weighted cycle. Emissions data may vary depending on the type of exhaust gas aftertreatment that may be installed on the engine, therefore it is suggested that the engine manufacturer be contacted directly for further information.
Field emission test data are not guaranteed to these levels. Actual field test results may vary due to test site conditions, installation, fuel specification, test procedures, and instrumentation. Over time deterioration may occur which may have an impact on emission levels. Engine operation with excessive air intake or exhaust restriction beyond published maximum limits, or with improper maintenance, may results in elevated emission levels.
MTU Friedrichshafen GmbH has made efforts to ensure that the information in this data sheet is accurate, but reserves the right to amend specifications and information without notice and without obligation or liability. No liability for any errors, facts or opinions is accepted. Customers must satisfy themselves as to the suitability of this product for their application. No responsibility for any loss as a result of any person placing reliance on any material contained in this data sheet will be accepted.

GASEOUS EMISSIONS DATA MEASUREMENTS ARE CONSISTENT WITH THOSE DESCRIBED IN EPA 40 CFR PART 60 SUBPART IIII FOR MEASURING HC, CO, PM, AND NOX.

Locality	Agency	Regulation	Tier/Stage	Max. Limit G/(kW -HR)		
					T2	T3
U.S. (INCL CALIF)	EPA	Stationary	Emergency Stationary Tier 2 (>560kW) Tier 3 (<560kW)	NOx+ NMHC: CO: PM:	 6,4 3,5 0,20	 4,0 3,5 0,20

** No standard test. To be measured on demand.

Aenderungsbeschreibung/Description of Revision	Kommt vor/Frequency
Freigabe	

Buchst./Rev. Ltr.	Aenderungs-Nr./Revision Notice No.	Bearbeitungsstatus/Lifecycle
-.3	PR030109	Freigegeben

MTU Friedrichshafen GmbH

WORD	Datum/ Date	Name
Erstell. Drawn	12.02.2018 13:49:48	link
Bearb. Change	14.06.2018 11:06:11	link
Inhalt Content	07.06.2018	Lenhof
Gepr. Checked	14.06.2018 11:06:11	baumgarten

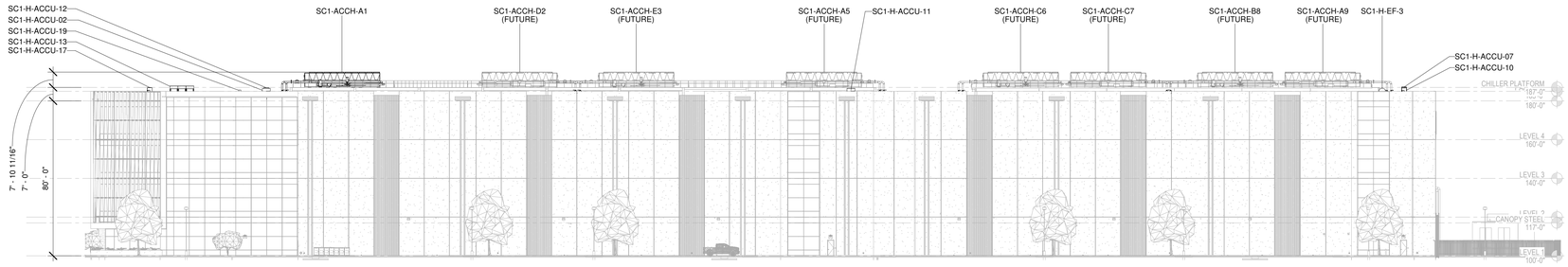
Motortyp / Engine Type: **16V4000G84S**

Projekt-/Auftrags-Nr. Project/Order No.
Verwendbar f.Typ Applicable to Model
Format/Size: **A3**
Material-Nr./Material No.: **EDS 4000 1234**
Benennung/ Title
EMISSIONSDATENBLATT
EMISSION DATA SHEET

Zeichnungs-Nr./Drawing No.: **ZNG00013267**
Beschreibung/Description
Blatt/ Sheet **3** von/of **3**

APPENDIX TP-60

Roof Mechanical Equipment Schematics



1 BUILDING MECHANICAL ELEVATION NORTH
1" = 30'-0"

9/24/2019 11:23:35 AM M04-09 MECHANICAL ELEVATIONS

NOT FOR CONSTRUCTION

PLAN N

CORGAN

CORGAN
401 N Houston Street
Dallas, TX 75202
T: 214.748.2000 F: 214.653.8281

kW Mission Critical Engineering, d.p.c.
40 E. Rio Salado Parkway, 4th Floor
Tempe, AZ 85281

Bennett & Pless Inc.
47 Perimeter Central East,
Suite 500 Atlanta, GA 30346

KIER+WRIGHT
2850 Collier Canyon Rd.
Livermore, CA 94551

TCD Design Consulting LLC
103 E Haning St. Howe TX 75459

JETT Landscape Architecture + Design
2 Theatre Square, Suite 218, Orinda, CA 94563

		ISSUES
1	06/12/2019	DESIGN DEVELOPMENT
2	08/01/2019	ISSUE FOR PERMIT
3	09/19/2019	ISSUE FOR CONSTRUCTION

		REVISIONS

kW Contact: ROB KING Phone: 518.424.9876

NOT FOR CONSTRUCTION

SANTA CLARA
2800 De La Cruz Blvd.
Santa Clara, CA 95050

CyrusOne

KEYPLAN

H F D B
G E C A

MECHANICAL ELEVATIONS

PROJECT NUMBER 19.030
DATE 09/24/19
SHEET NUMBER M04-09

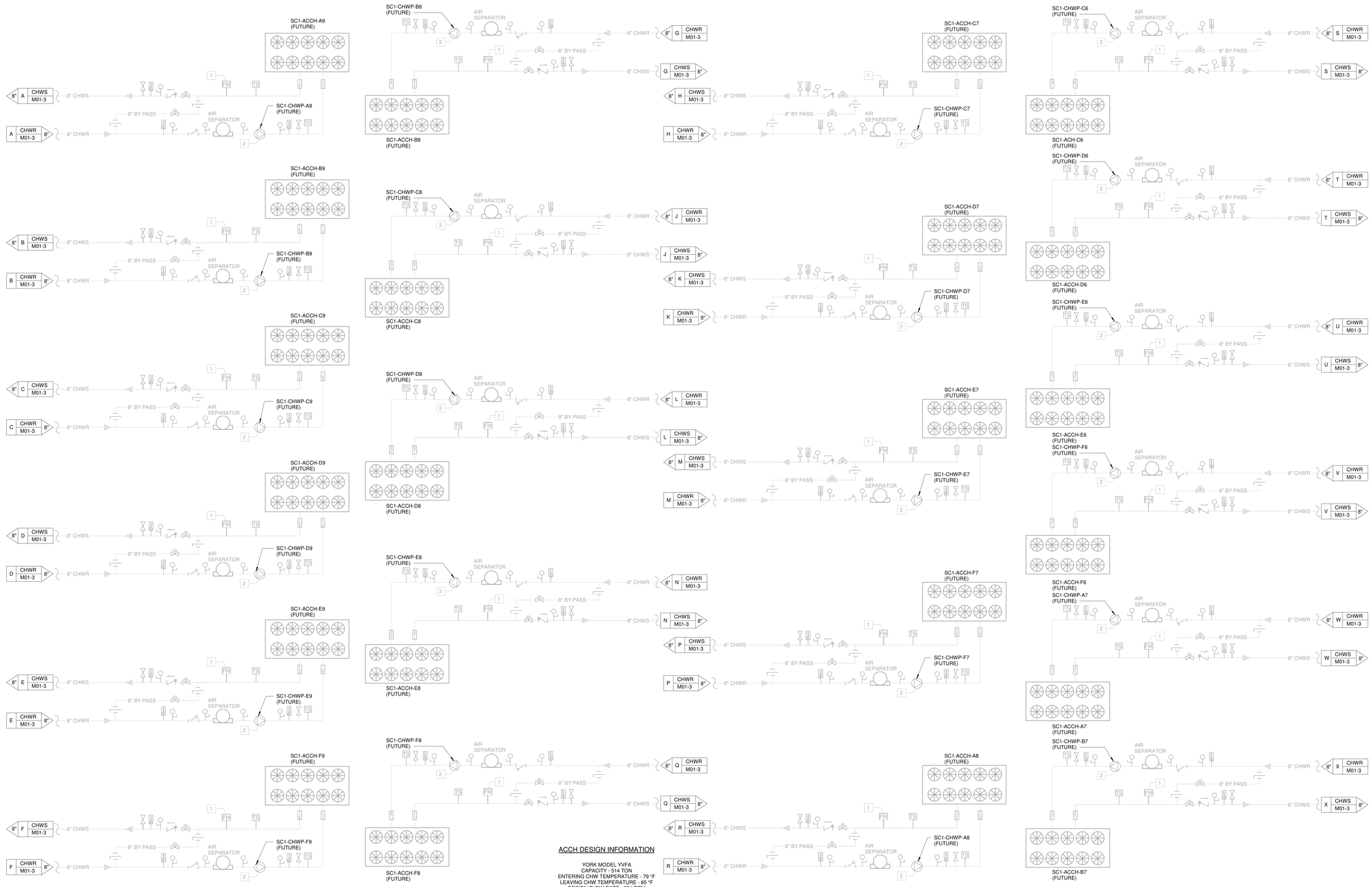
KEY NOTE

1. PROVIDE MANUFACTURER RECOMMENDED DISTANCES FOR INLET AND OUTLET OF FLOW METER TO ENSURE ACCURATE MEASUREMENT.
2. REFER TO PUMP PIPING DETAIL 4 ON SHEET M05-02. (TYPICAL)

GENERAL NOTE

1. A FULL DCRAC UNIT TAG EXAMPLE: SC1-A092300-RAC-03.
2. ALL HALFTONED PIPING AND EQUIPMENT ARE FOR FUTURE PLANNING PURPOSES AND ARE NOT TO BE INSTALLED ON DAY 1.
3. INSTALL ISOLATION VALVES 5'-0" AFF IN ALL PIPE RISERS THAT PENETRATE SLAB BELOW.

MECHANICAL ROOF



ACCH DESIGN INFORMATION

YORK MODEL YVFA
CAPACITY - 514 TON
ENTERING CHW TEMPERATURE - 79 °F
LEAVING CHW TEMPERATURE - 65 °F
DESIGN FLOW RATE - 884 GPM
AMBIENT DESIGN TEMPERATURE - 104 °F
100% FREE COOLING AMBIENT TEMPERATURE - 41.7 °F
UNIT EFFICIENCY(EER) - 10.1

(52) ACC'S
N+7 REDUNDANCY

1 CHILLED WATER PLANT DIAGRAM - WEST
NTS

8/1/2019 7:55:34 PM M01-01 CHILLED WATER PLANT - WEST

CORGAN

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Tempe, AZ 85281

Bennett & Pless Inc.
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Suite 500 Atlanta, GA 30346

KIER+WRIGHT
2850 Collier Canyon Rd.
Livermore, CA 94551

TCD Design Consulting LLC
103 E Haning St. Howe TX 75459

JETT Landscape Architecture + Design
2 Theatre Square, Suite 218, Orinda, CA 94563

	ISSUES	
1	06/12/2019	DESIGN DEVELOPMENT
2	08/01/2019	ISSUE FOR PERMIT

	REVISIONS	

kW Contact: ROB KING Phone: 518.424.9876

Christopher Kurkjian, P.E.
License #:35948 Expiration Date: 6.30.2020

PROFESSIONAL ENGINEER CHRISTOPHER W. KURKJIAN NO. 35948 MECHANICAL STATE OF CALIFORNIA

Date: 08/01/2019

SANTA CLARA
2600 De La Cruz Blvd.
Santa Clara, CA 95050

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CHILLED WATER PLANT - WEST

PROJECT NUMBER	19.030
DATE	08/01/2019
SHEET NUMBER	M01-01

KEY NOTE

1. PROVIDE MANUFACTURER RECOMMENDED DISTANCES FOR INLET AND OUTLET OF FLOW METER TO ENSURE ACCURATE MEASUREMENT.
2. REFER TO PUMP PIPING DETAIL 4 ON SHEET M05-02. (TYPICAL)

GENERAL NOTE

1. A FULL DCRAC UNIT TAG EXAMPLE: SC1-A092300-RAC-03.
2. ALL HALFTONED PIPING AND EQUIPMENT ARE FOR FUTURE PLANNING PURPOSES AND ARE NOT TO BE INSTALLED ON DAY 1.
3. INSTALL ISOLATION VALVES 5'-0" AFF IN ALL PIPE RISERS THAT PENETRATE SLAB BELOW.

1 CHILLED WATER PLANT DIAGRAM - EAST
NTS

8/1/2019 7:55:36 PM M01-02 CHILLED WATER PLANT - EAST

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ISSUES

REVISIONS

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License #:35948 Expiration Date: 6.30.2020

Date: 08/01/2019

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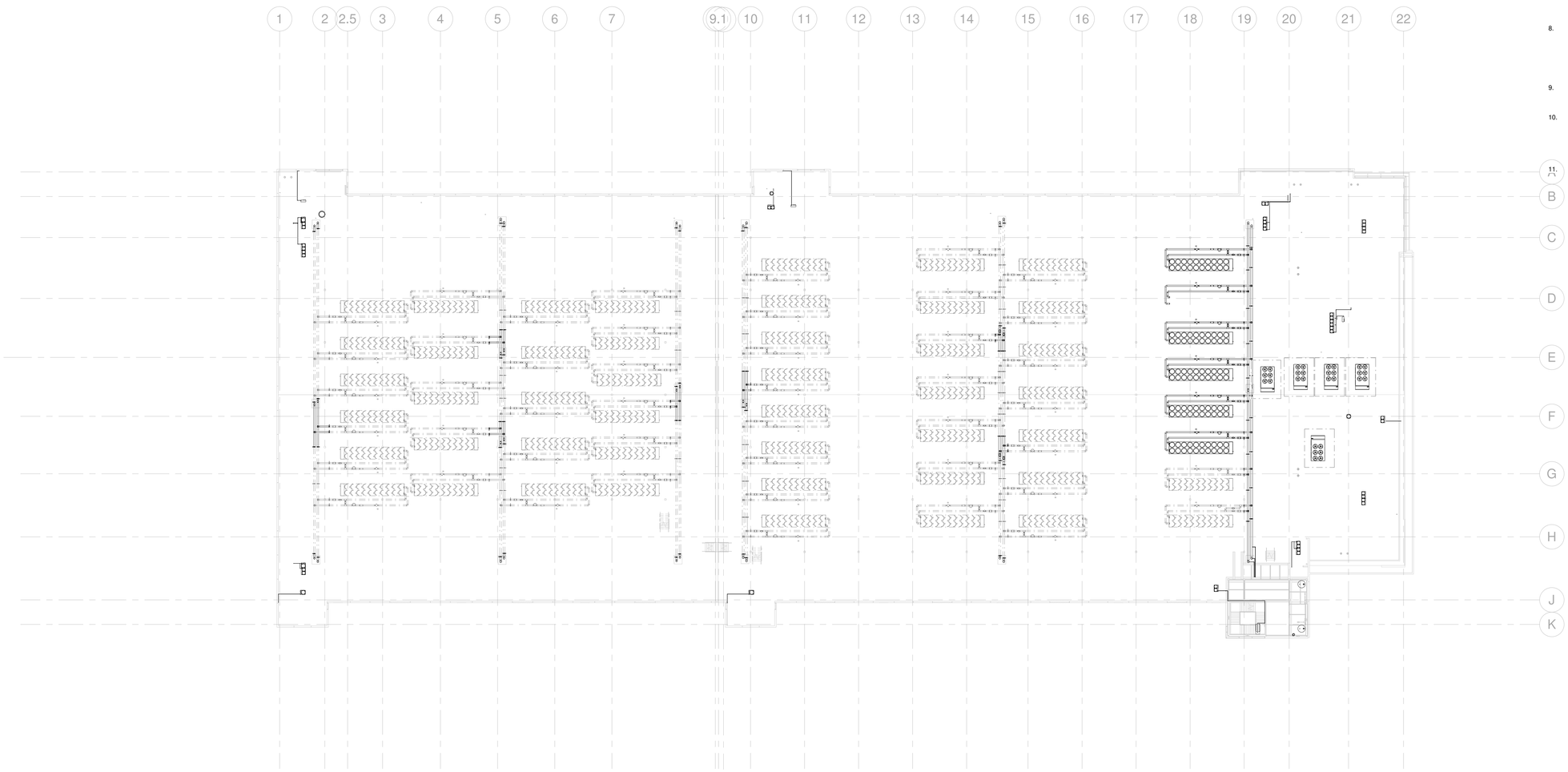
CHILLED WATER PLANT - EAST

PROJECT NUMBER	19.030
DATE	08/01/2019
SHEET NUMBER	M01-02

GENERAL NOTES

1. INSTALL U-SHAPED SEISMICALLY RATED PIPING EXPANSION JOINTS FOR HORIZONTAL SEISMIC BULDING JOINTS. USE EXPANDABLE METRAFLEX CONNECTION FOR VERTICAL EXPANSION JOINTS. REFER TO STRUCTURAL AND ARCHITECTURAL DRAWINGS FOR BUILDING JOINT LOCATIONS. REFER TO DETAIL 6 ON M-05-03 FOR VERTICAL PIPE RISER METRAFLEX EXPANSION JOINT DETAIL.
2. INSTALL FLEXIBLE CONNECTORS BETWEEN PIPING AND ANCHORED EQUIPMENT
3. ALL REFRIGERANT SUCTION LINES BETWEEN ACCU'S AND HRU'S CONSIST OF A HIGH PRESSURE AND LOW PRESSURE SUCTION LINE.
4. REFRIGERANT PIPE LENGTH AND CHANGES IN ELEVATION SHALL BE REVIEWED BY MANUFACTURER FOR CONFORMANCE WITH INSTALLATION GUIDLINES. MANUFACTURER SHALL PROVIDE SIZES FOR ALL REFRIGERANT LINE SETS AND INCLUDE TRAP LOCATIONS AS REQUIRED.
5. MECHANICAL CONTRACTOR IS RESPONSIBLE FOR ADDITIONAL REFRIGERANT AND SYSTEM CHARGING BEYOND FACTORY EQUIPMENT CHARGE. WEIGH ADDITIONAL REFRIGERANT CHARGE ADMINISTERED INTO SYSTEM PER MANUFACTURER'S REQUIREMENTS AS PART OF START-UP AND COMMISIONING. RECORD WEIGHT OF ADDED CHARGE FOR INCLUSION IN START-UP AND COMMISSIONING REPORT.
6. ENTIRE REFRIGERANT SYSTEM SHALL HOLD A 500 MICRON VACUUM FOR AT LEAST 12 HORS PRIOR TO ADDING REFRIGERANT CHARGE.
7. HORIZONTAL RUNS OF CONDENSATE PIPING SHALL HAVE A PTICH OF 1/8" PER FOOT TOWARDS DRAIN TERMINATION AND SHALL BE INSTALLED WITH AIR GAPS TO ENSURE GRAVITY FLOW FROM EQUIPMENT TO DRAIN.
8. ALL VALVING AND PIPING SYSTEM ACCESSORIES ARE TO BE INSTALLED SO THAT THEY ARE ACCESSIBLE FROM THE FLOOR FOR MAINTENANCE. WHERE HEIGHT EXCEEDS WHAT IS ACCESSIBLE FROM A LADDER, VALVES AND ACCESSORIES SHALL BE INSTALLED WITHIN LINE OF SIGHT TO FLOOR BELOW FOR ACCESS FROM LIFT.
9. ALL HALF-TONED AND DASHED PIPING AND EQUIPMENT ARE FOR FUTURE PLANNING PURPOSES AND NOT TO BE INSTALLED DAY 1.
10. ALL MECHANICAL EQUIPMENT SHALL BE SEISMICALLY ANCHORED TO THE STRUCTURE BY THE MECHANICAL CONTRACTOR. THIS CONTRACTOR SHALL ENGAGE THE SERVICES OF A LICENSED STRUCTURAL ENGINEER WHO SHALL PROVIDE STRUCTURAL DETAILS OF ALL INSTALLATIONS.
11. INSTALL ISOLATION VALVES 5'-0" AFF IN ALL PIPE RISERS THAT PENETRATE THE SLAB BELOW.



1 MECHANICAL PIPING PLAN - ROOF - MASTER PLAN
1" = 30'-0"

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	ISSUES	
1	06/12/2019	DESIGN DEVELOPMENT
2	08/01/2019	ISSUE FOR PERMIT

	REVISIONS	

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Christopher Kurkjian, P.E..
License #:35948 Expiration Date: 6.30.2020

PROFESSIONAL ENGINEER CHRISTOPHER W. KURKJIAN NO. 35948 MECHANICAL STATE OF CALIFORNIA

Date: 08/01/2019

SANTA CLARA
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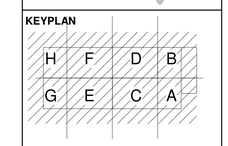
KEYPLAN



MECHANICAL PIPING PLAN - ROOF - MASTER PLAN

PROJECT NUMBER 19.030

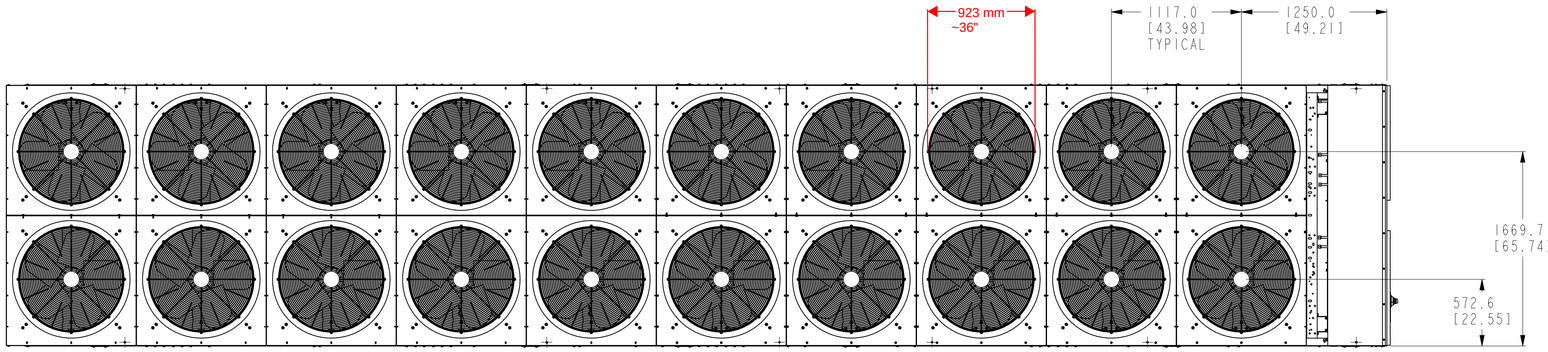
DATE 08/01/2019

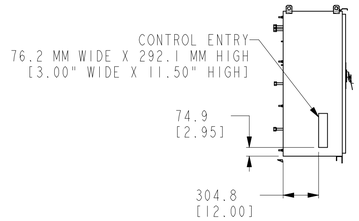
SHEET NUMBER

M03-05

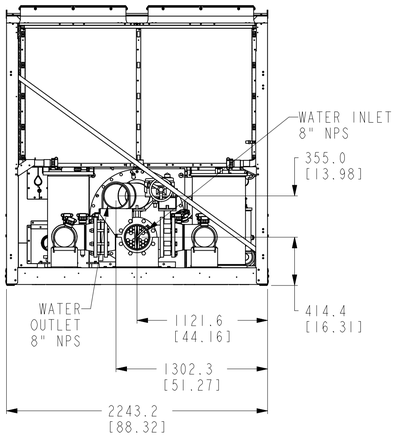
PLAN N

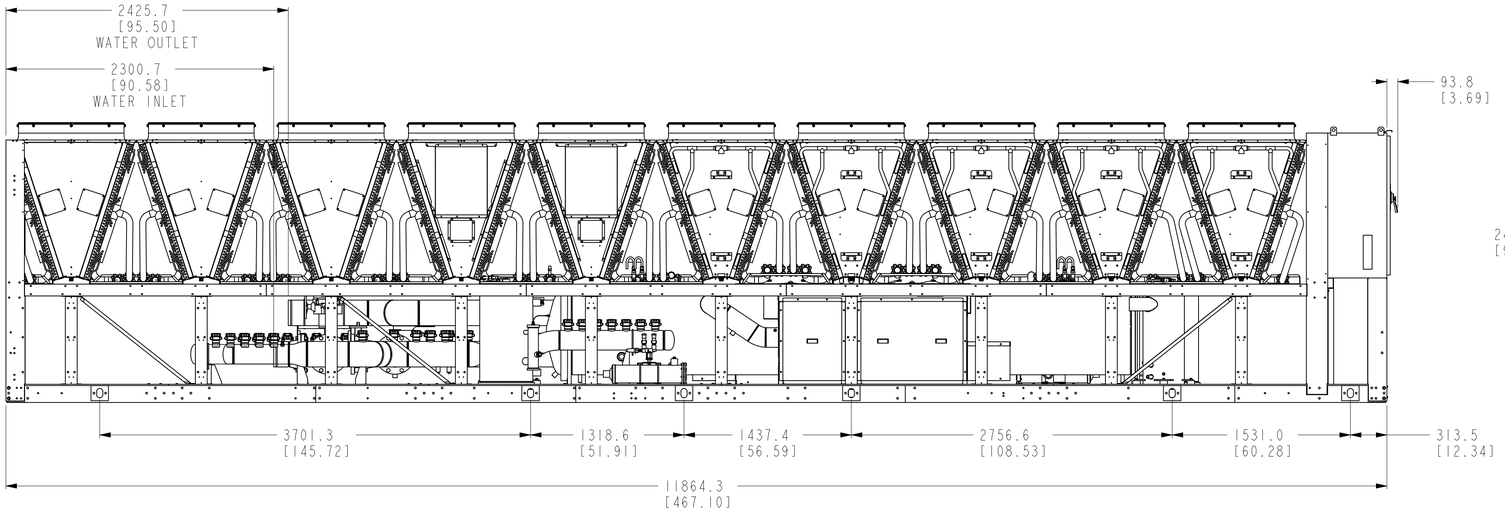
8/1/2019 8:01:05 PM M03-05 MECHANICAL PIPING PLAN - ROOF - MASTER PLAN

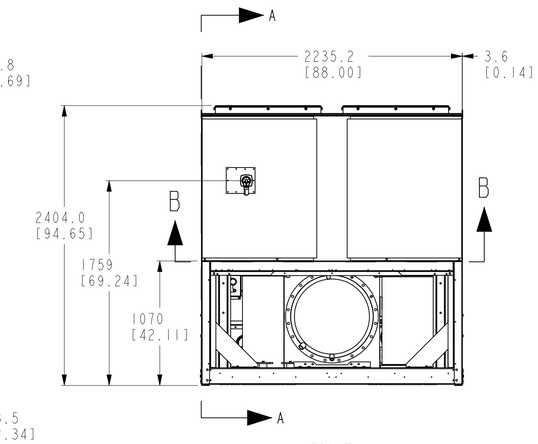




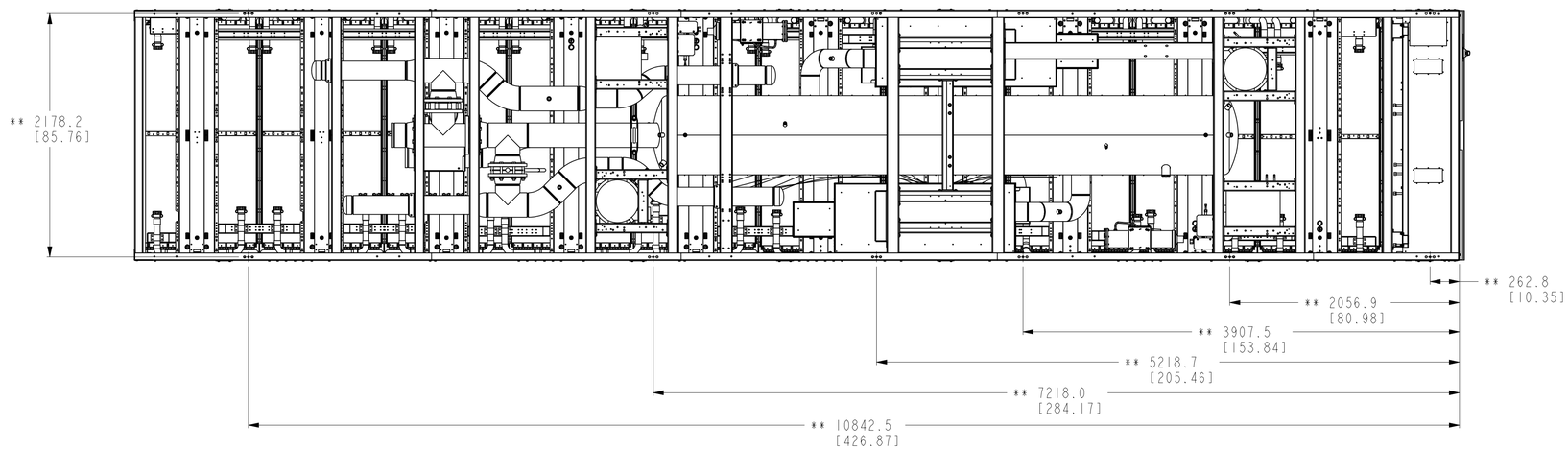
SECTION A-A

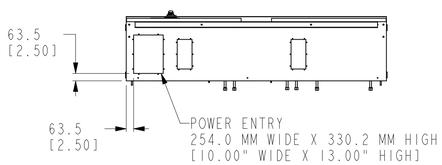






FRONT





SECTION B-B

** = ISOLATOR POSITION DIMENSION

REVISION	REV.	DATE	EC. NO.	DR.	CHK.	ENG.
	B	22-MAR-2018	DX18-0098	GT	RK	
	WATER CONNECTION SIZES ADDED.					

CONTINUED

THIRD ANGLE

Johnson Controls

JOHNSON CONTROLS - BUILDING EFFICIENCY
507 EAST MICHIGAN STREET, MILWAUKEE, WI, 53202 USA

DO NOT SCALE

DRAWN	G.TURNER	23-AUG-2016
MODELER	G.TURNER	23-AUG-2016
CHKD	W.SLAYBAUGH	23-AUG-2016
ENG		

SCALE: 0.038 MASS (kg): 29662720.42

PRODUCT DRAWING
0459/1589
YVFA
OPEN LOOP

MATERIAL
ENG. STD.
PART NO.
CUT SIZE

A1

CAGE NUMBER 66935

DRAWING NUMBER 035-23234-236

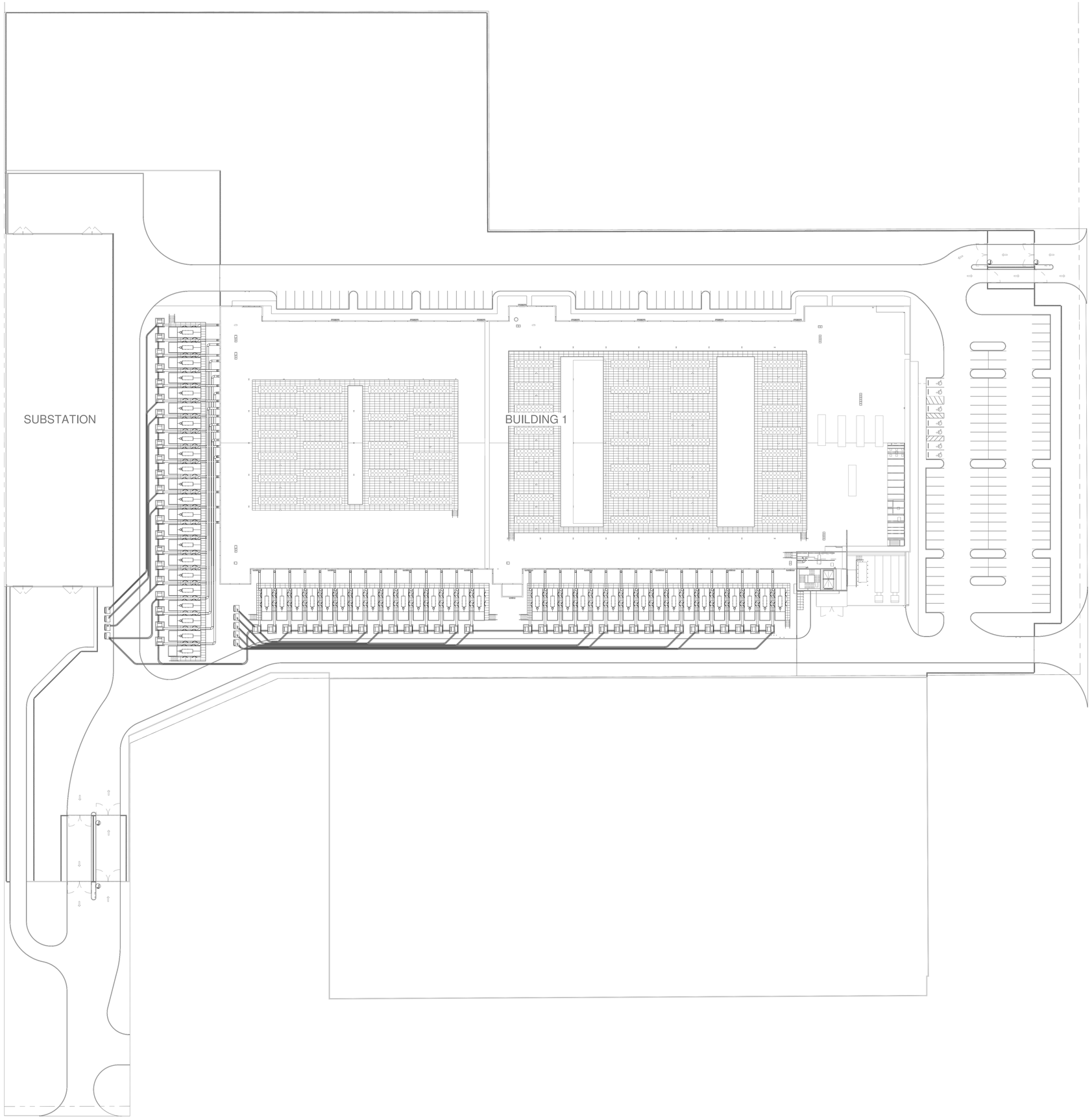
REVISION B
VERSION 1
Released

ORIG. NO.: 035-23234-036

SHEET 1 OF 1

APPENDIX TSE-81

Onsite Utility Routing Plan



1 ELECTRICAL SITE ROUTING AND POWER PLAN - OVERALL
1" = 40'-0"

6/12/2019 3:01:47 PM E00-02 ELECTRICAL SITE ROUTING AND POWER PLAN - OVERALL

NOT FOR CONSTRUCTION

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Design Consulting LLC
103 E Haning St. Howe TX 75459

	ISSUES	
1	06/12/2019	DESIGN DEVELOPMENT

	REVISIONS	

kW Contact: RICK SPARKMAN Phone: 971.221.6819

Stephen Coon, P.E.
License #: E22629 Expiration Date: 03/31/2021

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Santa Clara, CA 95050

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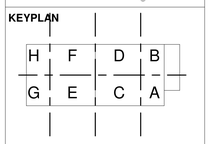
KEYPLAN



ELECTRICAL SITE ROUTING AND POWER PLAN - OVERALL

PROJECT NUMBER 19.030

DATE 06/12/2019

SHEET NUMBER

E00-02

PLAN N
N