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Laurelwood Data Center
(19-SPPE-01)

Data Response Set 5

Submitted to
California Energy Commission

Prepared by
MECP1 Santa Clara 1, LLC

with technical assistance from

JACOBS

July 2019

Contents

Introduction

On July 16, 2019, California Energy Commission (CEC) Staff submitted a Second *Motion for Leave to File Additional Data Requests* (Motion), which included an appendix with additional data requests in the subject areas of Transportation and Hazards and Hazardous Materials: Thermal Plume Analysis regarding the Laurelwood Data Center (LDC) (19-SPPE-01) Small Power Plant Exemption (SPPE). (Transaction Number [TN] 228999). For ease of reference, these data requests appended to the Motion are referred to collectively as CEC Staff Data Request, Set 5.

As acknowledged in Staff's Motion, the period for discovery and issuance of data requests has ended. Without waiving its rights to object to the issuance of any other data requests, MECP1 Santa Clara 1, LLC's (MECP or the Applicant) provides the attached responses to CEC Staff Data Request, Set 5. The responses are grouped by individual discipline or topic area. Within each discipline area, the responses are presented in the same order as presented by CEC Staff and are keyed to the Data Request numbers.

New or revised graphics or tables are numbered in reference to the Data Request number. For example, the first table used in response to Data Request 28 would be numbered Table DR28-1. The first figure used in response to Data Request 28 would be Figure DR28-1, and so on. Figures or tables from the LDC SPPE that have been revised have "R1" following the original number, indicating revision 1.

Additional tables, figures, or documents submitted in response to a data request (for example, supporting data, stand-alone documents such as plans, folding graphics, etc.) are found at the end of each discipline-specific section and are not sequentially page-numbered consistently with the remainder of the document, though they may have their own internal page numbering system.

Transportation and Hazards and Hazardous Materials: Thermal Plume Analysis

Jacquelyn Record and Gerry Bemis

BACKGROUND

In the updated project description (TN 228823) docketed on June 21, 2019, water demand was reduced from 640 gallons per minute (336 million gallons per year[1]) to 5.4 million gallons per year. This significant reduction in cooling water demand suggests the potential for thermal plumes with different characteristics from the higher water demand in the original project description. This could potentially be a hazard for local aircraft.

The updated project description added details about the building cooling system, specifically on page 2-19, it states: *"Building cooling will be accomplished using cooling towers with adiabatic cooling technology installed. The adiabatic cooling technology uses* a *radiator-style cooling system with wetted pre-cooling pads installed upstream of the cooling tube bundle. During lower ambient conditions, the tower operates without using water on the wetted pads. However, during higher ambient temperatures, the precooling pads are wetted to reduce the incoming air temperature, resulting in greater heat rejection. The expected project water demand drops significantly to approximately* 5. *4 million gallons per year, excluding negligible landscaping and other maintenance uses."* ·

On page 2-2 of this updated project description, the applicant states: *"Heating/ventilation and air-conditioning equipment, including chiller units, will be located on the roof of each building and screened using perforated corrugated steel panels."*

In light of the change in the cooling system, staff took a closer look at the original application (TN 227273-1), specifically Figure 2-2c and Figure 2-3c. The cooling system in Figure 2-2c shows what appears to be a row of four large individual stacks. Figure, 2-3c appears to include five (or ten) large stacks. McLaren's cooling system included 72 individual chillers, which is not directly comparable to that shown on LDCs Figures 2-2c and 2-3c.

In addition, Figure 2-2c only includes building 1 and not building 2; both of which are part of the proposed project. Therefore, staff requests the following information in order to complete its evaluation of thermal plumes from the currently proposed building/server cooling system to ensure air traffic safety and analyze any potentially significant impacts from such plumes.

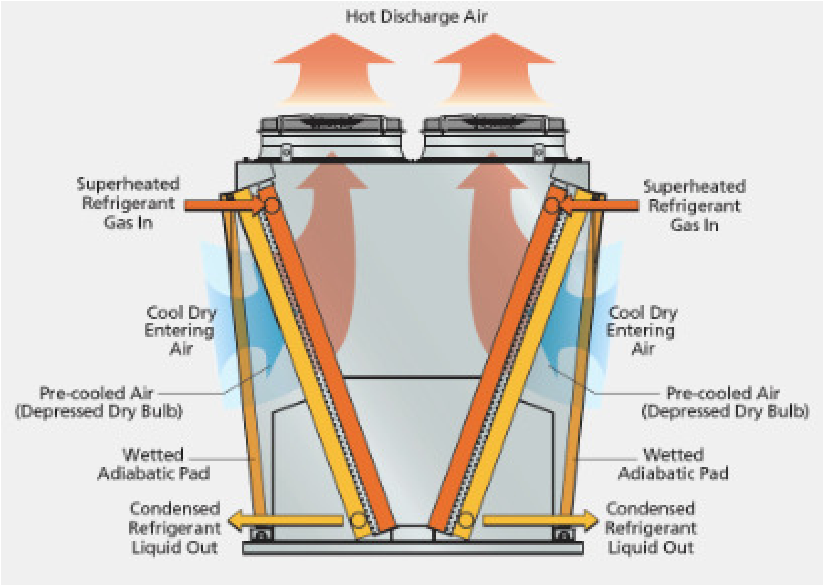
Data Requests

1. *Please describe in detail the HVAC equipment, including adiabatic cooling towers and chiller units, with enough detail to conduct thermal plume modeling.*

Response: The heating, ventilation, and air conditioning (HVAC) equipment proposed for LDC will use a refrigerant (R-134A) to cool the electronic equipment housed in the two buildings. The HVAC system will include 72, 4-cell adiabatic condensers installed on the roof of each LDC building (for a total of 144) to condense the refrigerant. The adiabatic condenser uses both evaporative and air-cooling to remove heat from the refrigerant. Exhibit 1 provides a schematic of the proposed adiabatic condenser. The wetted adiabatic pads are used when ambient conditions require additional cooling to condense the refrigerant. This cooling technology is the reason for the significant reduction in water use noted by Staff.

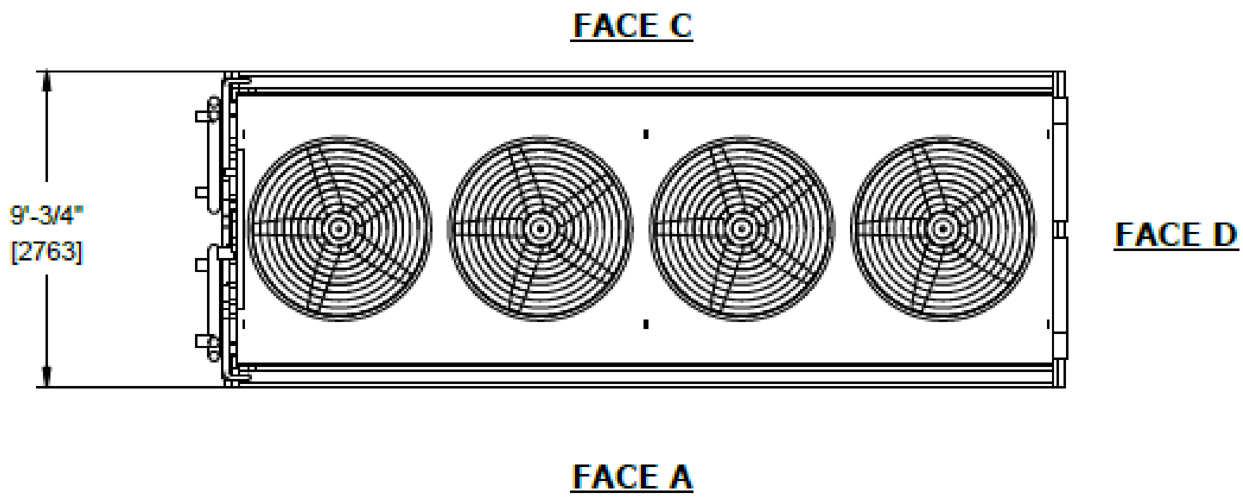
[1] Energy Commission Staff estimate

Exhibit 1 Schematic Drawing of Proposed Adiabatic Condenser



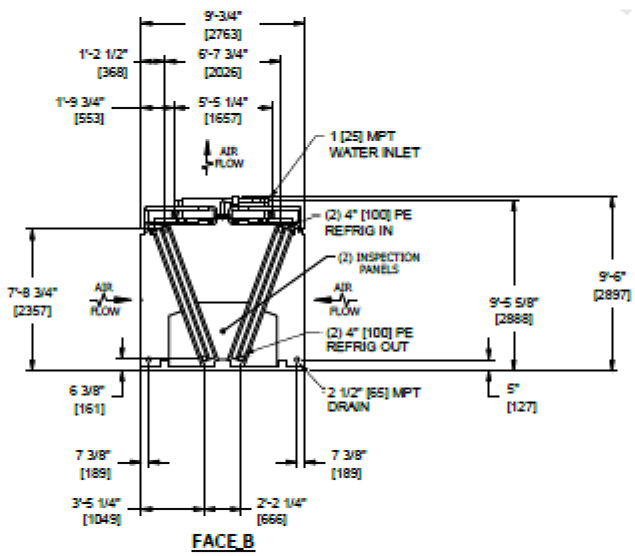
With the exception of the wetted adiabatic pads, the proposed LDC condensers function identical to HVAC systems commonly used in residential and commercial installations. Each adiabatic condenser consists of four "cells", each with a 10-horsepower fan (for a total of 40 horsepower per condenser) and a stack exit velocity of 9.76 meters per second (for a total air flow of 178,423 cubic feet per minute per condenser) at 105 degrees Fahrenheit (314 Kelvin). As shown in Exhibit 2a, condensers typically employed for these systems are approximately 9 feet wide, 24 feet long, and 9.5 feet high. The cell fan openings are typically approximately 5 feet and 5-1/4 inches in diameter and, in this application at LDC, will be 117.5 feet above grade (35.81 meters), as shown in Exhibit 2b.[2]

Exhibit 2a Schematic Dimensions of Proposed Condenser



[2] Per the CEC's typical process, detailed design will occur post-Exemption. The exact HVAC equipment will be selected based on the then available equipment that meets -- or performs better than -- the specifications set forth in these Data Responses.

Exhibit 2b Schematic Dimensions of Proposed Condenser



2. *Please perform thermal plume modeling of the equipment used to chill the building and data servers.*

Response: Based on the thermal plume modeling methodology used in the CEC's previous data center case, the Applicant assessed the thermal plume velocities for the LDC. Attachment DR 5-1 presents the thermal plume calculations based on the "Aviation Safety and Buoyant Plumes," prepared by Peter Best, et. al., which was used in the McLaren Backup Generating Facility Commission Decision (TN# 225970).

The LDC calculations of the thermal plume velocities presented in Attachment DR 5-1 show that the condenser exhaust velocity is below the 10.6[3] meters per second peak rate used in the McLaren Final Commission Decision at 135.5 feet above grade, or 18 feet above the condenser fan outlet. Aircraft will not be operating 18 feet above the condenser fan outlet. Furthermore, LDC calculations of the thermal plume velocities shows that the condenser exhaust velocity is below the 5.3 meters per second average rate at 161.5 feet above grade, or 44 feet above the condenser fan outlet. Aircraft are not expected to operate within 44 feet above either LDC building.

3. *Please confirm the number of stacks on each building and update Figure 2-2c and Figure 2-3c, accordingly.*

Response: Each building will have 72 condenser fan exhausts for a total of 144 condenser fan exhausts.

4. *Please provide a figure for building 2, showing all mechanical equipment and the number of stacks.*

Response: Figure DR 5-1 presents a plan view of Building 2's roof showing the 72 condenser fan exhausts. Each condenser has four circular fan outlets and are shown in pairs, with each pair of condensers having 8 fan outlets.

3 Noted that the Australian Civil Aviation Safety Authority has issued a new Advisory Circular (AC 139-05v3.0) in January 2019 with a new critical plume velocity of 6.1 meters per second.

5. *Please provide at least the following to support the thermal plume analysis (provide equivalent data if necessary):*

   a. *Stack (or cooling tower fan cowl) Height (m)*

   Response: Each cell fan exit is approximately 35.81 meters above grade.

   b. *Exhaust Temp (K)*

   Response: The fan exhaust is expected to be approximately 314 Kelvin.

   c. *Exit Velocity (m/s)*

   Response: The fan exhaust velocity is expected to be approximately 9.76 meters per second.

   d. *Stack Diameter (m)*

   Response: The fan exhaust diameter is expected to be approximately 1.66 meters.

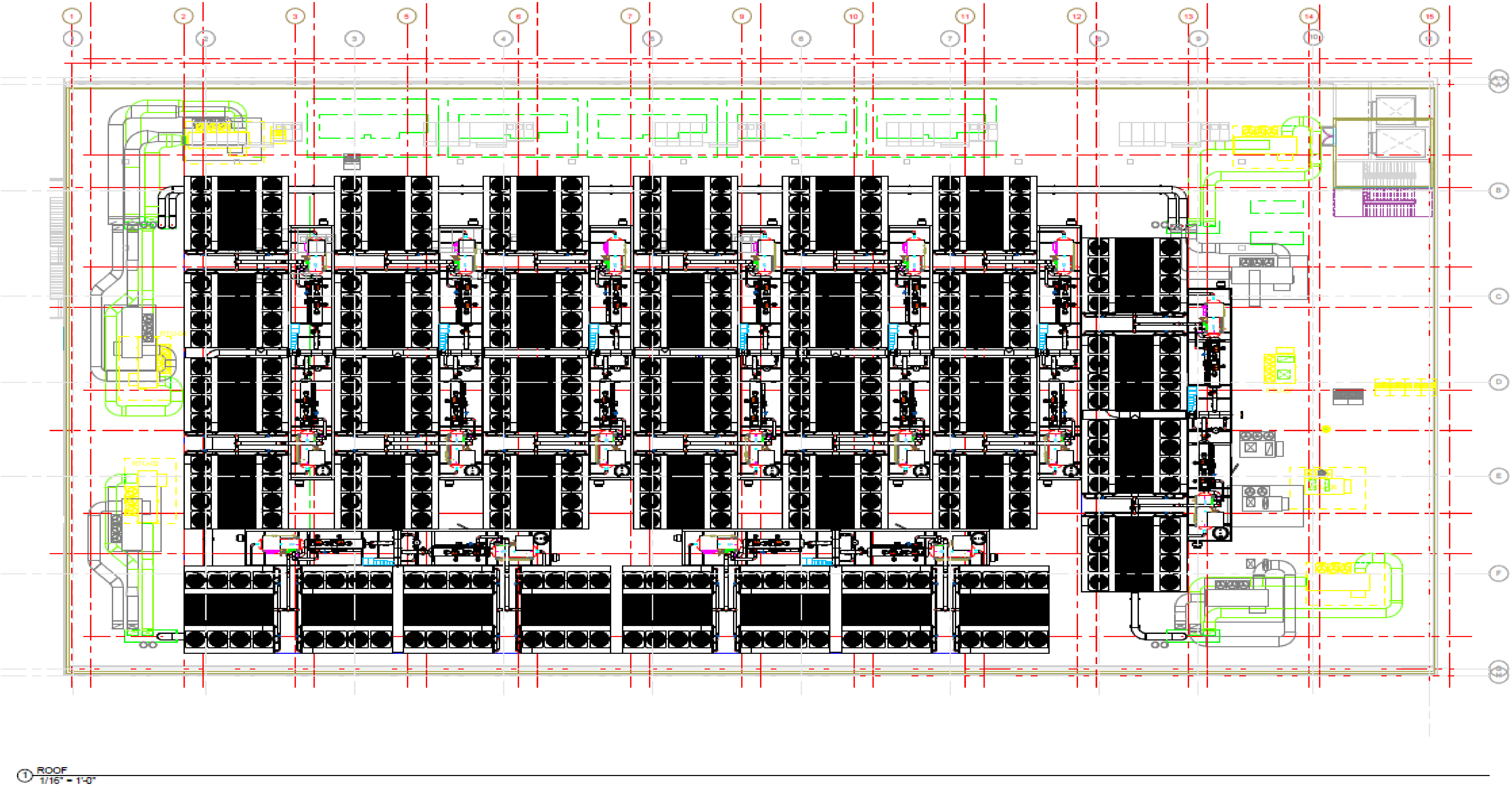
   e. *Number of Stacks*

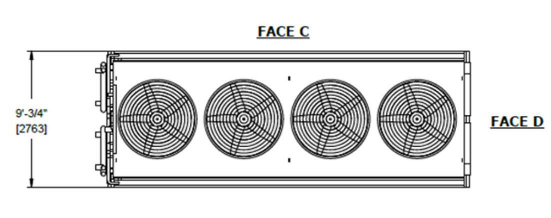
   Response: The number of fan exhausts are 72 per building or a total of 144.

   f. *Distance Between Stacks (m)*

   Response: The distance between fan center points is approximately 2.27 meters.

Figures





Example of a Chiller Unit.

Figure DR5--1 Building 2 Roof Plan
Laurelwood Data Center
Santa Clara, California

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Attachment DR5-1
LDC HVAC Condenser Thermal Plume Calculations

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	272	Kelvins	30	°F		
Plume Exit Conditions:						
Stack Height, h_s	35.81	meters	117.5	feet		
Stack Diameter, D	1.66	meters	5.4	feet		
Stack Velocity, V_{exit}	9.76	m/s	32.0	ft/sec	Back-Calc'd from Volumetric Flow	
Volumetric Flow	21	cu.m/sec	44,606	ACFM	$\pi V_{exit} D^2/4$	Sect.2/¶1
Stack Potential Temp, θ_s	314	Kelvins	105.0	°F	Back-Calc'd from Buoyancy Flux	
Initial Stack Buoyancy Flux, F_o	9	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:

Assume neutral conditions ($d\theta/dz=0$)

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	10.375	meters*	34.0	feet*	6.25D, meters*=meters above stack top		Sect.3/¶1
Height above Ground, z+h_s	46.189	meters	151.5	feet	h_s + 6.25D		"
Vertical Velocity, V_{plume}	4.879	m/s	16.01	ft/sec	$0.5V_{exit}$	$V_{exit}/2$	"
Plume Top-Hat Diameter, 2a	3.320	meters	10.9	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	0.683	meters*	2.2	feet*	$6.25D[1-(\theta_e/\theta_s)^{1/2}]$, meters*=meters above stack top	Sect.2/Eq.6
Height above Ground, z_v+h_s	36.497	meters	119.7	feet*	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$= 0.93412399	

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

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

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

Vertical Velocity, V	**Solutions in Table Below**	$\{(Va)_o^3 + 0.12F_o[(z-z_v)^2 - (6.25D-z_v)^2]\}^{(1/3)}$ / a	Sect.2.1(6)
Product, $(Va)_o$	7.566 m^2/s	$V_{exit}D/2(\theta_e/\theta_s)^{1/2}$	

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

from 100 meters above ground in increments of 50.0 meters

		Ht above Ground = $h_{plume}+h_s$		D_{plume}=2a=	Vert.Vel (m/s) Method (1)	Vert.Vel (m/s) Method (2)
Height above stack top, meters*		meters	feet	2*0.16(z-z_v)	$V'=V_{exit}*D/2a'$	$V= \{(Va)_o^3+0.12F_o[(z-z_v)^2-(6.25D-z_v)^2]\}^{1/3}$ / a
End of jet phase at 6.25D = 10.375 meters*		***46.189***	***151.5***	***3.320***		***4.88***
64.186	meters*	100.000	328.1	20.321	0.80	1.63
114.186	meters*	150.000	492.1	36.321	0.45	1.32
164.186	meters*	200.000	656.2	52.321	0.31	1.17
214.186	meters*	250.000	820.2	68.321	0.24	1.07
264.186	meters*	300.000	984.3	84.321	0.19	0.99
314.186	meters*	350.000	1148.3	100.321	0.16	0.94
364.186	meters*	400.000	1312.3	116.321	0.14	0.89
414.186	meters*	450.000	1476.4	132.321	0.12	0.85
464.186	meters*	500.000	1640.4	148.321	0.11	0.82
514.186	meters*	550.000	1804.5	164.321	0.10	0.79
564.186	meters*	600.000	1968.5	180.321	0.09	0.77
614.186	meters*	650.000	2132.5	196.321	0.08	0.75
664.186	meters*	700.000	2296.6	212.321	0.08	0.73
714.186	meters*	750.000	2460.6	228.321	0.07	0.71
764.186	meters*	800.000	2624.7	244.321	0.07	0.70
814.186	meters*	850.000	2788.7	260.321	0.06	0.68
864.186	meters*	900.000	2952.8	276.321	0.06	0.67
914.186	meters*	950.000	3116.8	292.321	0.06	0.66
964.186	meters*	1000.000	3280.8	308.321	0.05	0.64
1014.186	meters*	1050.000	3444.9	324.321	0.05	0.63
1064.186	meters*	1100.000	3608.9	340.321	0.05	0.62
1114.186	meters*	1150.000	3773.0	356.321	0.05	0.61
1164.186	meters*	1200.000	3937.0	372.321	0.04	0.60
1214.186	meters*	1250.000	4101.0	388.321	0.04	0.60

0.000	meters*	35.814	117.5	-0.219	-74.06	-63.80
0.305	meters*	36.119	118.5	-0.121	-133.68	-115.12
0.610	meters*	36.424	119.5	-0.024	-685.32	-590.08
0.914	meters*	36.728	120.5	0.074	219.20	188.74
1.219	meters*	37.033	121.5	0.171	94.49	81.38
1.524	meters*	37.338	122.5	0.269	60.22	51.89
1.829	meters*	37.643	123.5	0.367	44.20	38.11
2.134	meters*	37.948	124.5	0.464	34.91	30.12
2.438	meters*	38.252	125.5	0.562	28.84	24.91
2.743	meters*	38.557	126.5	0.659	24.58	21.25
3.048	meters*	38.862	127.5	0.757	21.41	18.54
3.353	meters*	39.167	128.5	0.854	18.96	16.45
3.658	meters*	39.472	129.5	0.952	17.02	14.79
3.962	meters*	39.776	130.5	1.049	15.44	13.44
4.267	meters*	40.081	131.5	1.147	14.12	12.32
4.572	meters*	40.386	132.5	1.244	13.02	11.38
4.877	meters*	40.691	133.5	1.342	12.07	10.58
5.182	meters*	40.996	134.5	1.439	11.25	9.89
5.486	meters*	41.300	135.5	1.537	10.54	9.29
5.791	meters*	41.605	136.5	1.634	9.91	8.76
6.096	meters*	41.910	137.5	1.732	9.35	8.29
6.401	meters*	42.215	138.5	1.830	8.85	7.87
6.706	meters*	42.520	139.5	1.927	8.41	7.50
7.010	meters*	42.824	140.5	2.025	8.00	7.16
7.315	meters*	43.129	141.5	2.122	7.63	6.86
7.620	meters*	43.434	142.5	2.220	7.30	6.581
7.925	meters*	43.739	143.5	2.317	6.99	6.329
8.230	meters*	44.044	144.5	2.415	6.71	6.097
8.534	meters*	44.348	145.5	2.512	6.45	5.885
8.839	meters*	44.653	146.5	2.610	6.21	5.689
9.144	meters*	44.958	147.5	2.707	5.98	5.507
9.449	meters*	45.263	148.5	2.805	5.78	5.339
9.754	meters*	45.568	149.5	2.902	5.58	5.183
10.058	meters*	45.872	150.5	3.000	5.40	5.038
10.363	meters*	46.177	151.5	3.098	5.23	4.902
10.668	meters*	46.482	152.5	3.195	5.07	4.775
10.973	meters*	46.787	153.5	3.293	4.92	4.656
11.278	meters*	47.092	154.5	3.390	4.78	4.544
11.582	meters*	47.396	155.5	3.488	4.64	4.439
11.887	meters*	47.701	156.5	3.585	4.52	4.341
12.192	meters*	48.006	157.5	3.683	4.40	4.247
12.497	meters*	48.311	158.5	3.780	4.29	4.159
12.802	meters*	48.616	159.5	3.878	4.18	4.076
13.106	meters*	48.920	160.5	3.975	4.07	3.997
13.411	meters*	49.225	161.5	4.073	3.98	3.922
13.716	meters*	49.530	162.5	4.170	3.88	3.851
14.021	meters*	49.835	163.5	4.268	3.80	3.783
14.326	meters*	50.140	164.5	4.365	3.71	3.719

Number of Stacks	144	
Distance Between Stacks	2	feet
Center to Center Distance Between Stacks	7.4	feet

Ht above Ground = $h_{plume}+h_s$	**Vert.Vel (m/s) Method (3)**	**Number of Stacks**	**Plume Diameter**
feet	V = V'*Number of Stacks$^{0.25}$	**(within plume)**	feet
117.5	-68.93	1	-0.72
118.5	-124.40	1	-0.40
119.5	-637.70	1	-0.08
120.5	203.97	1	0.24
121.5	87.93	1	0.56
122.5	56.06	1	0.88
123.5	41.15	1	1.20
124.5	32.51	1	1.52
125.5	26.88	1	1.84
126.5	22.91	1	2.16
127.5	19.97	1	2.48
128.5	17.71	1	2.80
129.5	15.90	1	3.12
130.5	14.44	1	3.44
131.5	13.22	1	3.76
132.5	12.20	1	4.08
133.5	11.33	1	4.40
134.5	10.57	1	4.72
135.5	9.91	1	5.04
136.5	9.33	1	5.36
137.5	8.82	1	5.68
138.5	8.36	1	6.00
139.5	7.95	1	6.32
140.5	7.58	1	6.64
141.5	7.25	1	6.96
142.5	6.94	1	7.28
143.5	6.73	1	7.60
144.5	6.61	1	7.92
145.5	6.49	1	8.24
146.5	6.38	1	8.56
147.5	6.28	1	8.88
148.5	6.18	2	9.20
149.5	6.09	2	9.52
150.5	6.00	2	9.84
151.5	5.92	2	10.16
152.5	5.84	2	10.48
153.5	5.77	2	10.80
154.5	5.70	2	11.12
155.5	5.63	2	11.44
156.5	5.57	3	11.76
157.5	5.51	3	12.08
158.5	5.45	3	12.40
159.5	5.40	3	12.72
160.5	5.34	3	13.04
161.5	5.29	3	13.36
162.5	5.25	3	13.68
163.5	5.20	4	14.00
164.5	5.15	4	14.32