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APPENDIX TRANS DR-64

Thermal Plume Analysis

Plume Vertical Velocity Assessment

Walsh Backup Generating Facility

Santa Clara, California

Submitted to California Energy Commission

Submitted by

651 Walsh Partners, LLC

Prepared by Atmospheric Dynamics, Inc.



ATMOSPHERIC DYNAMICS, INC Meteorological & Air Quality Modeling

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Introduction

651 Walsh Partners, LLC (WP LLC) is proposing to develop the Walsh Backup Generating Facility (WBGF). The backup generating facility will utilize 32 three-megawatt (MW) diesel fired generators along with 54 rooftop air cooled chillers. The proposed WBGF site encompasses 7.87-acres and is located at 651 Walsh Avenue in Santa Clara, California. The property is zoned Heavy Industrial. The site is currently developed with a one-story 171,259-square foot warehouse complex and associated paved parking and loading areas. The Norman Y. Mineta San José International Airport is located approximately 0.3 miles east of the site.

Based on the stack parameter data, an analysis of the potential plume characteristics from the routine operation the diesel engines and rooftop chillers on vertical winds was prepared and compared to the California Energy Commission (CEC) significance criteria of 5.3 meters per second (m/s) for the average vertical plume velocities as described below.

Atmospheric Dynamics, Inc. (ADI) prepared a screening level plume vertical velocity assessment which are based on the calm wind Spillane methodology outlined in the "Aviation Safety and Buoyant Plumes" paper (Peter Best, et. al., presented at the Clean Air Conference, Newcastle, New South Wales, Australia, 2003). This methodology is also recognized as a screening tool for aviation safety set out by the Australian Civil Aviation Safety Authority (CASA) and presented in "AC 139-5(1) Plume Rise Assessments (CASA, 2012)".

The aim of this screening assessment is to conservatively determine the potential for turbulence generated by the diesel engines and rooftop chillers waste heat exhaust plumes. Part 139.370 of the Australian Civil Aviation Safety Regulations (1998, 2004) provides that CASA may determine that plume velocities in excess of 4.3 m/s is or will be a potential hazard to aircraft operations. The *Manual of Aviation Meteorology* (Australian Bureau of Meteorology 2003) defines severe turbulence as a vertical wind gust velocity in excess of 10.6 m/s. The assumed critical vertical velocity used as a CEC significance threshold is 5.3 meters per second* (m/s) but it should be noted that the basis of the original CASA derived threshold of 4.3 m/s has been lost in antiquity and that CASA no longer relies on the 1998 and 2004 regulations that established this critical threshold other than to note that a more rigorous analysis, which includes site specific meteorology, should be used if the 4.3 m/s and 10.6 m/s screening thresholds are exceeded. The screening method uses absolute worst-case assumptions of calm winds and neutral atmospheric conditions for the entire vertical extent of the plume to determine these worst-case impacts. It should be noted that these results are extremely conservative in that these worst-case conditions typically only occur during a few hours each year.

The Spillane methodology is generally applied to a limited number of plume source geometry's (turbines, power plant boilers, etc.) with the stacks arranged linearly (in a single straight-line) and separated by distances that typically exceed the individual stack diameters. For the diesel engines, this assumption was maintained. Only one engine stack was modeled consistent with the normal operational testing schedule of the emergency generator engines. For the chiller assessment, a conservative assumption was made in order to use the Spillane methodology on an atypical chiller plume configuration, which is made up of 54 chillers arranged on a two-dimensional surface. Here, the methodology, as described below, assumed that all sixteen chiller cells for each chiller were merged into a single stack with an effective diameter based on the combined area of all sixteen chiller cells. In other words, a single stack was assumed to initially describe the release parameters of the combined chiller cells in each of the 54 individual chillers.



The effective plume diameter is appropriate for each individual chiller based on the close proximity and arrangement of the sixteen chiller cells.

Screening Methodology and Vertical Plume Velocity Calculations

The Spillane methodology is based on worst-case calm wind neutral stability conditions to assess the average plume vertical velocity as a function of height. The methodology is based on wellverified laboratory and theoretical treatments of the rise and spread of a buoyant jet, both into a still ambient environment and into a light crosswind. This treatment covers in detail the initial dynamics of the plume as it exits the stack and the entrainment of ambient air into the plume as it rises directly above the stack. In addition to providing clarifications and algebraic solutions to the Spillane methodology, the 2003 Peter Best paper provides additional methodologies that also consider the enhancement of vertical velocities that may occur if the plumes from multiple identical stacks merge and form a higher buoyancy combined plume (referred to here as the enhanced Spillane methodology).

The vertical plume assessment will involve several stages of development. For individual plumes, the stages are:

- (a) In the first stage very close to the stack exit, the high plume momentum will result in a short section in which the conditions at the center of the plume are relatively unaffected by ambient and plume buoyancy conditions. This jet phase extends from the stack exit to approximately a distance of 6.25 D above the stack (where D is the stack diameter) in calm conditions. At the end of this stage, the plume-averaged vertical velocity has decreased to half of the stack exit velocity, with a corresponding increase, or doubling, in effective plume diameter.
- (b) In the second stage, the plume responds to differences between ambient and plume buoyancy conditions, with much cooler and less turbulent ambient air being entrained into the plume from the outside regions of the plume towards the plume centerline. The momentum and buoyancy of the plume significantly influences plume rise and subsequently the dilution of the stack exhaust to decrease plume vertical velocities. This dilution is very sensitive to ambient wind speed, so the calm wind conditions considered here are extremely conservative.
- (c) In the third stage of plume development, plume rise is due entirely to the buoyancy of the plume and continues from some distance until there is an equalization of turbulence conditions within and outside the plume. This final rise is often only achieved at considerable heights/distances from the stack where the effective average vertical velocity is then close to zero. Since there is very little turbulence and near-zero vertical velocities, this stage of plume development is usually not considered for this type of analysis.

In the second stage of development, the analytical solution of the governing equations under these conditions is given by:



Where the subscript 'o' refers to values of the parameters at the stack outlet and the variables are:

- a plume radius (m)
- V average vertical velocity (m/s)
- z height above stack top (m)
- z_v virtual source height (m)
- D stack diameter (m)
- F_o buoyancy flux evaluated at the stack outlet (m⁴s⁻³)

These are the two primary equations governing the growth of a single plume in the second stage of development under neutral calm wind conditions. Additional equations governing the first stage of single plume development as well as the interaction of multiple plumes in the second stage of development are discussed in detail in the Best paper.

For multiple stacks in the enhanced Spillane methodology, the equations governing the second stage are calculated from the point when the plumes begin to merge until they are fully merged. The plume merging begins at the height where the plume diameters equal the stack separations and the plumes are fully merged at the height where the plume diameters are equal to 2d(N-1)/2 for three or more stacks or 2d for two stacks. At the fully merged height, the merged plume diameter and velocity is enhanced by the fourth root of the number of stacks. Above the fully merged plume height, the enhanced plume diameter and plume velocities follow the regular equations given for the second stage. Below the fully merged plume height for the merging phase, plume velocities are linearly interpolated by height from the single plume velocity at the height where the plumes begin to merge to the enhanced plume velocity at the fully merged plume height.

Vertical Plume Velocity Calculations for the Diesel Engines

The WBGF is comprised of 32 individual large diesel emergency generator stacks, arranged as 16 double stacked units. The 33rd diesel emergency generator is smaller than the other 32 emergency generators, which would have lesser plume vertical velocities, and therefore was not considered further. Generator stack parameter data (plume exit velocity, plume exit temperature and stack exit diameter) were provided by Cummins. Only one (1) engine will be tested during any one hour. While the engines will be tested at minimum loads, the 100 percent load case was utilized for the worst-case plume analysis. For the engine analysis, two ambient conditions were considered: 41.0°F, the minimum monthly mean of daily minimum temperatures, and 84.3°F, the maximum monthly mean of daily maximum temperatures for the San Jose Airport (*"Climatology of the United States No. 81 – Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000 – California"*, February 2002, and *"Climatology of the United States No 20 – Monthly Station Climate Summaries, 1971-2000 – California"*, February 2002, and *"Climatology of the United States No 20 – Monthly Station Climate Summaries, 1971-2000 – California"*, February 2004). These data is summarized in Table 1.

Case #	1	2
		2
Ambient Temperature (°F)*	41.0	84.3
Stack Diameter (m)	0.5588	0.5588
Exhaust Velocity (m/s)*	44.96	44.96
Exhaust Temperature (K)*	716.48	716.48



Stack Release Height (m)	16.03	16.03
Stack Buoyancy Flux (m ⁴ /s ³)	21.06	19.91
*Stack data provided by Cummins at 100% load		

Screening level vertical plume velocity assessments were made for two ambient temperatures with calm winds and neutral atmospheric conditions for the cases presented in Table 1 which are based on 100 percent load. The results based on the two ambient conditions are presented in Table 2 and the output from the calculation spreadsheet provided in Attachment A.

The initial jet phase extends to a height of about 64 feet above grade level (ft-agl) for both cases. After the jet phase, plume temperature buoyancy characteristics modeled in the Spillane methodology cause a uniform decrease in plume-averaged vertical velocities, with the critical plume-averaged vertical velocity of 5.3 m/s occurring at about 92 ft-agl for Case 1 and about 93 ft-agl for Case 2. Again, the plume-averaged vertical velocities are shown in the spreadsheets provided in Attachment A.

Table 2 Diesel Engine Vertical Plume Velocity A Height	nalysis Results f	for Reference
Case #	1	2
Ambient Temperature (°F)	41.0	84.3
Single Plume Results:		
Plume-Averaged Vertical Velocity at 940 feet- agl (m/s)	1.32	1.30
Height of 5.3 m/s Plume-Averaged Vertical Velocity (feet-agl)	92.2	92.9

These screening results indicate that mechanical and thermal turbulence levels due to the flow from the diesel engine always remain in the light turbulence category and below the significance level of 5.3 m/s at all heights above about 100 ft-agl. Even light wind speeds can dramatically decrease the predicted plume-averaged vertical velocities so the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical calculations, as shown in the tables above, are likely to overestimate the expected vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear when realistically, there is a considerable variation with height, especially in light winds;
- Worst-case scenarios are based on very light-wind, near-neutral atmospheric conditions with maximum loading.

Vertical Plume Velocity Calculations for the Rooftop Chillers

The 54 rooftop chillers are each comprised of 16 individual cells, with a cell fan diameter of 36.6 inches. Thus, the 54 chillers are generally arranged six along the longer building length (averaging 49 feet between adjacent chillers) by nine along the shorter building width (averaging 27 feet between adjacent chillers). Chiller stack parameter data (exit velocity and temperature) were provided by the applicant. An effective stack diameter for all sixteen cells was utilized for each chiller. The chillers will utilize variable speed fans and the number of fans that are operational are dependent upon ambient temperature and plant load. However, to be conservative, all



chillers/cells were assumed to be operating at full load. These data is summarized in Table 3 for the same ambient temperatures used for the engine analysis.

Case #	1	2
Ambient Temperature (°F)*	41.0	84.3
Effective Stack Diameter (m)**	3.7186	3.7186
Exhaust Velocity (m/s)*	9.82	9.82
Exhaust Temperature (K)*	289.26	313.32
Stack Release Height (m)	30.30	30.30
Stack Buoyancy Flux (m ⁴ /s ³)	12.79	11.81
*Chiller stack data provided by the applicant ** Calculated value based on the cell diameter of 3 number of operating cells, or $D_{eff} = 36.6$ "* $\sqrt{16}$	36.6 inches multiplied by the s	quare of the

The Spillane methodology was originally developed to treat multiple individual stacks that are arranged along a linear x or y direction, but not both directions at once, with stack separations much greater than the stack diameters, typical of boilers/turbines at large power plants. As noted above, the 54 chillers are generally arranged in a 6 x 9 pattern. Therefore, the enhanced Spillane methodology was based on calculating the total merging height for the largest linear direction of chiller placements (which is six chillers spaced 49 feet apart along the longer length of the building). All 54 chillers were considered in the calculation of vertical velocity plume enhancement (both at and above the totally merged height, and for the interpolation down to the plume touching height. Again, the effective single stack diameter of each chiller was based on the combined 16 cells.

Screening level vertical plume velocity assessments were made for the same ambient temperatures with calm winds and neutral atmospheric conditions as was done for the emergency generator engines. The results are presented in Table 4 and the output from the calculation spreadsheets are provided in Attachment A.

The initial jet phase extends to a height of about 176 ft-agl for both cases. The critical plumeaveraged vertical velocity of 5.3 m/s occurs in the jet phase at about 170 ft-agl for both cases. The plumes touch (begin to merge) at about 254 ft-agl and are fully merged at about 867 ft-agl for both cases. Under the enhanced Spillane methodology, the merged plume-averaged vertical velocities never approach 5.3 m/s (either above the totally merged height or when interpolated down to the touching height).

Table 4 Chiller Vertical Plume Velocity Analysis I		
Case #		2
Ambient Temperature (°F)	41.0	84.3
Single Plume Results:		
Height of 5.3 m/s Plume-Averaged Vertical	175.7	175.7
Velocity (Within the Jet Phase, feet-agl)	mon	
Merged Plume Results:		
Plume-Averaged Vertical Velocity at 940 feet-	3.20	3.16
agi (m/s)	5.20	3.10

From these results and for each ambient condition, the vertical plume velocities are less than the threshold value of 5.3 m/s for all heights above about 175 ft-agl and above for the chillers. The heights at which plume-averaged vertical velocities exceed 5.3 m/s only occur during the jet phase



for both cases. These cases also represent worst-case conditions of calm winds at all levels of a neutral atmosphere.

These screening results indicate that mechanical and thermal turbulence levels due to the flow from the chillers always remain in the light turbulence category and below the significance level of 5.3 m/s at all heights above about 175 ft-agl. Even light wind speeds can dramatically decrease the predicted plume-averaged vertical velocities so the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical calculations, as shown in the tables above, are likely to overestimate the expected vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear when realistically, there is a considerable variation with height, especially in light winds;
- Worst-case scenarios are based on very light-wind, near-neutral atmospheric conditions with maximum loading.



Attachment A Spillane Method Plume Velocity Calculations



-,	Aviation Salet	y and Buoya	nt Plumes," F	eter Best	et al.			
						at Verious Heights in the Plun	70	
	1	rom a Gas-Ti	urbine Power	Station at		sland, Australia ," Dr. K.T. Spil		
mbient Conditions:					Constants: As	sume neutral conditions (d8/dz=	0 or $\theta_a = \theta_e$ }	
Ambient Potential Temp 0 _e	278.15 #	(elvins	41.0 *	F		0.3048 meters/feet		
ume Exit Conditions:					Gravity g	9.81 m/s ²		
Maximum Stack Height h _a	16.03 n		52 7/12 6		A	1.11		
Stack Diameter D	0.558B m			nches	λ _o	~1.0		
Stack Velocity V _{stol}	44.96 n		147.52 f					
Volumetric Flow		u.m/sec	23,365 /		πV _{eel} D ² /4		Sect_2/	1
Stack Potential Temp 0 ₈	716.48 H		830 *	F				
Initial Stack Buoyancy Flux Fa	21.0642 m					$_{\rm b}/4 = Vol.Flow(g/\pi)(1-\theta_0/\theta_{\rm b})$	Sect_2/	71
Plume Buoyancy Flux F	N/A n	n ⁴ /s ³) for a,V,Op at plume height (see	below)	
No.of Stacks N	1			1,000	Multiple Stack	Multiplication Factor (N ^{0 25})		
onditions at End (Top) of Jet Phase:					0.050		A A	
Height above Stack z _{jet} Height above Ground z _{int} +h _a	3.493 n 19.523 n		11.5 f		z _{jet} = 0.25D, m	eters*=meters above stack top	Sect.3/	ll i
Vertical Velocity Viet	22.480 п		73.75 f		V ₁₀₁ = 0.5V _{eut} =	W D		
Plume Top-Hat Diameter 2a _{int}	1.118 m		3.7 f		28jet = 2D	Conservation of moment	ab un	
Fibrie Top-Hat Diameter Zajęt	1.110 1	Heleis	3.71	eet	anjet - an	Conservation of moment	nom	
illene Methodology Appliciant Solutions for Ca	Conditions	for Diumo M	alabia abava	let Dhene				
pillane Methodology - Analytical Solutions for Cal Single Plume-averaged Vertical Velocity V giver			-		a riken hu em	ations below:		
Plume Top-Hat Radius a		olutions in Ta		. rounct V		near increase with height	Sect.2/E	0.6
Virtual Source Height z,	1.316 n		4.3 f	eet*) ^{1/2}], meters*=meters above stack top	Sect_2/E	
Height above Ground Z,+h,	17.345 m		4.3 1 56.9 f		a. toni 1. (0%)0) [, meters writtens above stack top where (0./0.) ^{1/2} = (0./		4.0
Vertical Velocity V		olutions in Ta			I(Va).3 + 0 + 0	where $(c_a/c_b)^2 = (c_a/c_b)^2$ $F_0 [(z-z_a)^2 - (6.25D-z_a)^2]]^{(1/8)} / a$	Sect.2.	1(6)
Product (Va) _e	7.827		and South		$((Va)_0^2 + 0.12)$ $V_{ent}D/2(\theta_e/\theta_c)^3$		OBGLZ.	. (4)
Finance (AB) ⁰	FIGET S	1 13			* BUHLWK (D& QE)			
Solve for plume-averaged vertical veloc	ity at beint	940.0 1	laet	288 540	meters above	mound (2*+h_)		
Gives the following Height above Stack z'	270.482 n		887.4 f			o		
Plume Top-Hat Diameter 2a'	86.133 m		282.6 1		2a'=2*0.18(z'-	2.)	Sect.2/E	9.6
Ventical Velocity V	1.320 п		4.33 f			// 2F_{(z-z,) ² -(6.25D-z,) ²]) ^(1/3) /(2a'/2)		
Voltical Volicity V	1.920 1		4.001	0000	4-((48)0 +0.1.	ci alteret) dorsonerth it u(sais)	OFOL DI	40
Solve for Height of CASC critical vertical	velocity V	5 30 (m/s plume-ave	taged ver	tical velocity	Gr	Hical VV > Tor	o of Jet (Spillane)
Find Height above Stack zon	12.080		39.6 f	-		z.) simultaneously in both eqs. (i		o or oor (opinizito)
Height above Ground z _{crit} +h _a	28.110 1		92.2 f			using the cubic equation ax ³ +bx ²		
Logit appro crossid 201 mg	20.110		94.4 1	eet		a=1, c=0, and b=-(0,12F_)/(4.3 ³ 0		-4.1451
Interpolated Height of critical vertical veloc	ity in .let Pha	-				=[0.12F ₀ (6.25D-z _c) ² -(Va) ₀ ³]/(4.3 ³ 0		-766.69
Find Height above Stack zert	#N/A п		#NVA f	eet	owing G	[0.111 8(0.200-20) (40)6 P(4.0 0		728.org/cubic.htm
Height above Ground z _{cal} +h _e	#N/A n		#N/A f			gives the real solution x =		10.7632
						or z(m/above st		12.080
sble of Plume Top-Hat Diameters (2a) and Plume-						z(ft/above gro	und) =	92.2
we are tuble top-ratio anteens tast and Plume-	Averaged Ver	tical Velociti	es starting at	and of let	phase:	z(ft/above gro	und) =	92.2
			-			z(fl/above gro	und) =	92.2
Height (feet)	Averaged Ver (meters) above stack	Plume	SingleStk	Plume		z(ft/above gro	und) =	92.2
Height (feet)	(meters)	Plume	-			z(fi/above gro	und) =	92.2
Height (feet) above ground	(meters) above stack	Plume Radius(m)	SingleStk VertVel(m/s)	Plume		z(fl/above gro Jet Phase Eqs:	und) =	
Height (feet) above ground a Stack.Rel.Ht = 52.6	(meters) above stack 0.00	Plume Radius(m) 0.279	SingleStk VertVel(m/s) 44.96	Plume				5 foot intervals
Height (feet) above ground a <u>Stack.Rei.Ht = 52.6</u> 55.0	(meters) above stack 0.00 0.73	Plume Radius(m) 0.279 0.338	SingleStk VertVel(m/s) 44.96 40.24	Plume		Jet Phase Eqs:		5 foot intervals
Height (feet) above ground Stack.Rel.Ht = 52.6 65.0 60.0	(meters) above stack 0.00 0.73 2.26	Plume Radius(m) 0.279 0.338 0.459	SingleStk VertVel(m/s) 44.96 40.24 30.48	Plume		Jet Phase Eqs: Linearly interpolated from Sta	ick Rel.Ht to Top o	5 foot intervals
Height (feet) above ground a Stack.Rel.Ht = 52.6 65.0 60.0 Top of jet = 64.1	(meters) above stack 0.00 0.73 2.26 3.51	Plume Radius(m) 0.279 0.338 0.459 0.559	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48	Plume Temp(K)		Jet Phase Eqs: Linearly hitspolated from Sta Spillane Equations:	ick Rel.Ht to Top o	5 foot intervals
Height (feet) above ground Stack.Rel.H = 52 55.0 60.0 Top of jet = 64.1 70.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31	Plume Radius(m) 0.279 0.338 0.459 0.559 0.638	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50	Plume Temp(K) 373.34		Jet Phase Eqs: Linearly interpolated from Site Spillane Equations: V _{plane} ={(Va), ² +0.12F,{[2,2,3]*	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	<mark>5 foot intervals</mark> f Jet
Height (feet) above ground a Steck,Rei.Ht = 52.6 60.0 Top of jet = 84.1 70.0 80.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35	Plume Radius(m) 0.279 0.338 0.459 0.559 0.638 1.128	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48	Plume Temp(K) 373.34 329.40		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	<mark>5 foot intervals</mark> f Jet
Height (feet) above ground a Stack, Rei.Ht = 52.6 65.0 60.0 Top of jet = 64.1 70.0 80.0 90.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40	Plume Radius(m) 0.279 0.338 0.459 0.659 0.638 1.128 1.614	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57	Plume Temp(K) 373.34 329.40 311.59		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	<mark>5 foot intervals</mark> f Jet
Height (feet) above ground a Stack.Rel.H= 52 65.0 60.0 Top of jet = 64.1 70.0 80.0 90.0 Spillane 5.3 m/s Height = 92.2	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40 12.08	Plume Radius(m) 0.279 0.338 0.459 0.638 1.128 1.614 1.722	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30	Plume Temp(K) 373.34 329.40 311.59 308.99		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	<mark>5 foot intervals</mark> f Jet
Height (feet) above ground a Stack.Rei.Ht 52,6 60,0 Top of jet e 64,1 70,0 80,0 90,0 Spillene 5.3 m/s Height = 92,2 100,0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40 12.08 14.45	Plume Radius(m) 1 0.279 0.338 0.459 0.638 1.126 1.614 1.722 2.101	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30 4.60	Plume Temp(K) 373.34 329.40 311.59 308.99 302.01		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	<mark>5 foot intervals</mark> f Jet
Height (feet) above ground a Stack.Rei.Ht = 52.6 65.0 60.0 Top of jet = 64.1 70.0 80.0 80.0 Spitlane 5.3 m/s Height = 92.2 0.0 1 0.0 10.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40 12.08 14.45 17.50	Plume Radius(m) 0.279 0.336 0.459 0.638 1.126 1.614 1.722 2.101 2.589	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30 4.60 4.02	Plume Temp(K) 373.34 329.40 311.59 308.99 302.01 298.13		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot Intervals Jet 10 foot Intervals
Height (feet) above ground a Stack.Rel.H= 52 65.0 60.0 Top of jet = 64.1 70.0 80.0 90.0 Spillane 5.3 m/s Height = 92.2 100.0 110.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40 12.08 14.45 17.50 20.55	Plume Radius(m) 0.279 0.336 0.459 0.638 1.128 1.614 1.722 2.101 2.589 3.077	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30 4.60 4.60 4.02 3.84	Plume Temp(K) 373.34 329.40 311.59 308.99 302.01 296.13 292.23		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot Intervals Jet 10 foot Intervals
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Height (feet) above ground a Stack,Rei,Ht = 52.6 65.0 65.0 70p af jet = 84.1 80.0 90.0 Spitlane 5.3 m/e Height = 92.2 100.0 110.0 120.0 120.0 140.0	(meters) above stack 0.00 0.73 2.26 3.51 5.31 8.35 11.40 12.08 14.45 17.50 20.55 23.59 26.64	Ptume Radius(m) 0.279 0.338 0.459 0.638 1.614 1.722 2.101 2.589 3.077 3.564 4.052	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30 4.60 4.02 3.64 3.64 3.38 3.15	Plume Temp(K) 373.34 329.40 316.99 302.01 296.13 292.23 289.50 287.51		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot intervals 18 foot intervals 10 foot intervals Max<5.30 m/s
Height (fee) above ground a Steck.Rei.H = 5.2 65.0 60.0 70p of jet = 64.1 80.0 90.0 Spitlane 5.3 m/a Height = 92.2 100.0 110.0 120.0 130.0 130.0 200.0	(meters) above stack 0.00 0.73 2.26 3.61 5.31 8.35 11.40 12.08 14.45 17.50 20.55 23.59 28.64 29.69 44.93	Ptume Radius(m) 0.279 0.338 0.459 0.659 0.638 1.128 1.614 1.722 2.610 2.689 3.077 3.564 4.640 6.978	SingleStk VertVet(m/s) 44,96 40,24 40,24 40,24 40,24 40,24 40,24 5,57 6,30 4,02 3,84 4,02 3,84 3,36 3,15 2,99 2,249	Plume Temp(K) 373.34 329.40 311.59 308.99 302.01 296.13 296.50 287.51 286.01 282.14		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot intervals Jet 10 foot intervals
Height (fee) above ground a Stack.Rel.H= 52 65.0 60.0 Top of jet = 64.1 70.0 80.0 90.0 Spillane 5.3 m/s Height = 92.2 100.0 110.0 120.0 130.0 140.0	(meters) above stack 0.00 0.73 2.28 3.61 5.31 8.35 11.40 12.08 14.45 17.50 20.55 23.59 28.64 29.69 44.93 60.17	Ptume Radius(m) 0.328 0.459 0.638 1.614 1.722 2.101 2.599 3.077 3.564 4.052 4.540 6.978 9.417	SingleStk VertVel(m/s) 44.96 40.24 30.48 22.48 12.50 7.48 5.57 5.30 4.60 4.02 3.64 3.36 3.15 2.99	Pluma Temp(K) 373.34 329.40 311.55 308.90 302.01 298.13 292.23 288.50 287.51 286.01 282.14 280.80		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot intervals 18 foot intervals 10 foot intervals Max<5.30 m/s
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Height (fee) above ground a Stack.Rel.H = 55.0 65.0 70p of jet = 64.1 700 80.0 90.0 5ptillare 5.3 m/a Height = 92.2 100.0 120.0 130.0 130.0 200.0 260.0 260.0 350.0	(meters) above stack 0.00 73 2.26 3.31 8.35 11.40 14.45 17.50 20.55 23.59 28.64 29.69 44.93 60.17 75.41 90.66	Ptume Radius(m) 0.279 0.338 0.459 0.638 1.128 2.101 2.589 3.077 3.564 4.605 4.540 6.978 9.417 11.855 14.293	SingleStk VertVet(mis) 440,24 40,24 30,48 12,50 7,48 5,57 6,30 4,60 4,60 4,60 4,60 4,60 4,60 4,60 4,6	Pluma Temp(K) 373.34 329.40 311.55 308.96 302.01 298.13 289.50 287.51 286.01 282.14 286.02 287.51 286.02 287.51 286.02 287.51 286.02 287.51 286.02 287.53 289.55 299.55 29		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck Rel.Ht to Top o (6.250-z,) ²]} ¹⁰ / a	5 foot Intervals 18 foot Intervals 10 foot Intervals Max<5.30 m/s
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Height (fee) sbork ground a Stack Rei Het 35 60.0 Top of jet 44.1 70.0 80.0 50.0 50.0 50.0 50.0 50.0 100.0 1	(meters) above stack 0.00 0.73 2.26 3.84 5.31 15.31 15.31 14.40 20.55 23.59 24.55 23.59 24.69 44.93 60.17 7.541 90.65 105.66 105.66 121.13	Ptume Radius(m) 0.279 0.338 0.659 0.658 0.658 1.614 1.722 2.501 2.509 3.077 3.564 4.052 4.540 6.978 9.417 11.855 14.233 14.732 19.770	SingleŠtk VertVet(mis) 44.024 40.24 30.46 5.57 5.30 4.02 3.84 3.36 3.36 3.36 2.99 2.49 2.23 2.05 1.92 2.05 1.92 1.92 1.92 1.92	Plume Temp(K) 373.34 329.40 311.55 308.95 302.01 298.13 289.50 287.51 286.01 282.14 280.80 279.83 279.93 279.10 287.81		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
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Height (fee) above ground a Steck.Rei.Ht = 52.6 60.0 70p of jet = 64.1 80.0 5ptitiene 5.3 m/e Height = 92.2 100.0 110.0 120.0 130.0 140.0 250.0 250.0 250.0 300.0 250.0 300.0 400.0 400.0	(meters) above stack 0.00 0.73 2.28 3.51 8.35 11.40 12.08 14.45 17.50 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.89 121.13 128.85 128.8	Ptume Radius(m) 0.279 0.338 0.459 0.638 1.128 2.101 2.589 3.077 3.564 4.502 4.540 6.978 9.417 11.855 14.293 16.732 19.732	SingleŠtk VertVet(m/s) 44024 30,46 22,48 12,50 7,48 5,57 6,30 4,80 4,80 4,80 4,80 4,80 4,80 4,80 4,8	Pluma Temp(K) 373,34 329,40 311,55 302,01 298,13 292,22 289,51 286,01 282,14 282,14 280,51 282,14 282,14 289,55 289,51 288,71 289,71 278,87 278,87		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) above ground a Steck.Rel.H = 550 60.0 7op of jet = 64.1 700 5ptillare 5.3 m/a Height = 92.2 100.0 120.0 130.0 120.0 130.0 200.0 200.0 250.0 350.0 350.0 350.0 350.0 350.0 350.0 350.0	(meters) above stack 0.0073 2.26 3.51 13.00 14.06 14.45 17.50 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.68 121.13 138.37 166.65 197.33 128.37	Ptume Radius(m) 0.279 0.338 0.459 0.659 0.638 1.128 1.728 2.101 2.509 3.077 3.564 4.540 6.978 9.417 11.855 14.293 16.732 19.770 21.809 24.845 31.362 31.362 36.239	SingleStk VertVet(mis) 440.24 40.24 30.46 22.48 12.50 7.48 6.57 6.57 6.30 4.60 4.60 4.60 4.60 4.02 3.64 3.36 2.99 2.249 2.205 1.92 2.49 2.205 1.92 1.82 1.82 1.82 1.82 1.85 1.86 1.85 1.86 1.86 1.86 1.86 1.86 1.86 1.86 1.86	Pluma Temp(K) 373.34 329.40 311.52 308.96 302.01 298.13 292.23 289.50 298.15 288.01 288.01 288.01 288.01 288.01 288.01 288.01 288.02 279.39 279.39 279.39 278.55 278.55 278.54		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) above ground a Steck.Rei.H = 5.5 65.0 60.0 7op of jet = 64.1 700 5ptilare 5.3 m/a Height = 92.2 100.0 110.0 120.0 130.0 140.0 120.0 130.0 140.0 130.0 140.0 150.0 130.0 140.0 150.0 150.0 100.0	((resters) above stack 0.00 0.73 2.28 3.51 8.35 11.40 12.08 14.45 17.50 20.55 23.59 26.64 29.69 20.55 23.59 26.64 29.69 10.17 75.41 90.665 105.89 121.13 138.37 166.85 197.33 227.81 128.25 225.2	Ptume Radius(m) 0.338 0.459 0.638 1.128 1.	SingleŠtk VertVel(m/s) 440,24 40,24 30,46 22,48 5,57 5,30 4,60 4,60 4,60 3,84 4,80 4,80 4,80 4,80 4,80 4,80 4,80 4	Plume Temp(K) 313,34 329,40 300,96 302,01 269,13 282,21 282,21 282,21 282,21 282,21 282,21 282,21 282,21 282,21 282,21 282,21 283,51 278,36 278,36 278,36 278,34 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,44 278,35 278,45 27		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) sbook ground a Stack.Rel.H = 55 60.0 70p of jet 64.1 70.0 80.0 90.0 Spillane 5.3 m/s Height = 92.2 100.0 100.0 120.0 130.0	(meters) above stack 0.00 0.73 2.26 3.84 5.31 8.35 11.40 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.89 121.13 138.37 166.85 107.33 227.81 225.22 828.27 82.82 82.82 82.82 82.82 83.83 84.83 84.84 84.83 84.84 84.85 84.84 84.85 84.84 84.85 85.85 8	Ptume Radius(m) 0.279 0.338 0.659 0.659 0.658 1.614 1.722 2.600 3.077 3.564 4.052 4.540 6.978 9.417 11.855 14.293 14.732 19.170 21.809 26.465 31.362	SingleStk VertVet(mis) 44.024 40.24 40.24 30.46 5.57 5.30 4.02 3.84 3.15 2.299 2.299 2.299 2.299 2.299 2.299 2.299 1.922 1.929 1.922 1.929	Plume Temp(K) 3294(30294) 30291 20895 20955 20805 209555 209555 20955 2005 20055 20		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot Intervals 10 foot Intervals Nax<5.30 m/s 50 foot Intervals
Height (fee) above ground a Steck.Rel.H = 550 60.0 7op of jet = 64.1 70.0 80.0 5ptilare 5.3 n/s Height 92.2 100.0 120.0 130.0 140.0 130.0 140.0 130.0 140.0 150.0 200.0	(meters) above stack 0.0073 2.26 3.51 13.50 11.40 14.45 17.50 20.55 23.59 28.64 29.669 44.93 60.17 75.41 90.65 105.68 121.13 138.37 166.66 107.38 227.81 228.77 319.25	Ptume Radius(m) 0.279 0.338 0.459 0.659 0.658 1.128 1.728 2.101 2.507 3.564 4.540 6.878 9.417 11.855 14.293 16.732 19.770 21.809 26.485 31.362 33.2629 4.543 35.289 4.593 50.869	SingleStk VertVet(mis) 44.024 40.24 40.24 12.50 7.48 5.57 6.30 4.60 4.60 4.60 4.60 4.60 4.60 4.62 3.64 3.36 3.36 2.99 2.249 2.205 1.92 1.82 1.92 1.82 1.82 1.82 1.84 1.84 1.84 1.84 1.84 1.84 1.84 1.84	Plume Temp(K) 329.40 311.56 308.96 302.01 228.21 2299.55 229.55 229.55 229.55 229.55 229.55 229.55 229.55 279.86 279.82 279.82 279.82 278.91 278.54 278.54 278.33 278.33 278.34		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot Intervals 10 foot Intervals Nax<5.30 m/s 50 foot Intervals
Height (fee) above ground a Steck.Rei.H = 5.3 65.0 60.0 70p of jet = 64.1 700 5ptilare 5.3 m/a Height = 92.2 100.0 5ptilare 5.3 m/a Height = 92.2 100.0 110.0 120.0 130.0 140.0 130.0 140.0 130.0 140.0 130.0 140.0 150.0 140.0 150.0 150.0 150.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0	((resters) above stack 0.007 2.26 3.51 8.35 14.45 17.50 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.66 105.89 121.13 128.37 166.85 107.33 227.81 128.29 228.29 28.49 29.69 121.13 128.37 166.85 197.33 227.81 225.829 28.877 319.25 349.73	Ptume Radius(m) 0.338 0.459 0.638 1.128 1.	SingleČtk VertVel(m/s) 440,24 40,24 30,48 12,50 7,48 5,57 6,30 4,60 4,60 4,60 4,60 4,60 4,60 4,60 4,6	Plume Temp(K) 373,34 329,40 308,96 302,01 269,11 269,01 279,30 279,30 279,30 279,30 279,30 279,30 279,30 279,30 278,40 278,37 278,56 278,44 278,36 278,32 27		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ck ReLH to Top o (#.250-zy ²)f ^{1/2} / e (*.250-zy ²)f ^{1/2} / (*. (*.)	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) sbork result of Stack Rei Het 35 60.0 70p of jet 84.1 70.0 80.0 70p of jet 84.1 70.0 80.0 700 of jet 84.1 100.0 1	(meters) above stack 0.0.0 0.73 2.26 3.84 5.31 8.35 11.40 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.89 105.89 105.81 121.13 138.37 166.85 105.83 77.81 28.92 80.17 139.25 28.97 139.25 28.97 349.73 349.73 349.23 349.73	Ptume Radius(m) 0.279 0.338 0.659 0.659 0.658 1.614 1.722 2.601 2.600 3.077 3.564 4.052 4.540 6.978 9.417 11.855 14.293 16.732 19.170 21.809 26.465 31.362 3	SingleStk VertVel(mis) 44.024 40.24 40.24 30.46 5.57 5.30 4.02 3.84 3.15 2.299 2.299 2.299 2.299 2.299 2.299 2.299 1.82 2.205 1.92 1.92 1.92 1.92 1.92 1.92 1.92 1.92	Plume Temp(K) 3294(30294) 30291 20895 209555 209555 20955 2005 20055 20		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) sbore ground a Steck.Rel.H = 55.0 60.0 Top af jet = 64.1 70.0 80.0 5pillare 5.3 m/a Height = 92.2 100.0 120.0 130.0 140.0 130.0 140.0 150.0 250.0 350.0 350.0 350.0 350.0 350.0 350.0 350.0 140.0 100.0 120.0 10	(meters) above stack 0.0073 2.26 3.51 5.31 8.35 11.40 14.45 17.50 20.55 23.59 28.64 29.669 44.93 60.17 75.41 90.65 105.68 121.13 138.37 166.66 107.33 227.81 228.77 319.25 249.73 349.73 349.73 349.73	Ptume Radius(m) 0.279 0.338 0.459 0.659 0.638 1.128 1.728 2.101 2.509 3.077 3.564 4.540 6.978 9.417 11.855 14.293 16.732 19.770 21.809 26.485 31.362 36.239 41.116 45.993 50.869 55.748 60.623 65.500	SingleStk VertVel(mis) 44,024 40,24 40,24 12,50 7,48 12,50 4,60 4,60 4,60 4,60 4,60 4,60 4,60 4,6	Plume Temp(K) 373,34 329,40 311,56 303,96 302,01 298,131,56 303,96 302,01 298,21 299,55 208,55 208,55 209,56 209,57 209,56 209,57 209,56 209,57 200,57 200,5		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) above ground a Steck.Rel.H = 55.0 65.0 70p of jet = 64.1 700 80.0 90.0 5ptilane 5.3 m/a Height = 92.2 100.0 110.0 120.0 130.0 130.0 140.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0 260.0 200.0	(meters) above stack 0.0073 2.26 3.51 8.35 1.40 12.06 14.45 17.50 20.55 23.59 28.64 29.66 44.93 60.17 75.41 99.66 105.89 121.13 138.37 166.85 107.33 125.829 225.829 228.877 319.25 349.73 360.21 41.06 44.41,17	Plume Radius(m) 0.338 0.459 0.638 1.128 1.128 2.101 2.589 3.077 3.584 4.540 6.978 9.417 11.655 14.293 18.732 19.752 19.75	SingleČtk VertVel(m/s) 440,24 40,24 30,48 22,48 5,57 5,30 4,60 4,60 4,60 4,60 4,60 4,60 4,60 4,6	Plume Temp(K) 373,34 329,40 308,96 302,01 269,61 269,61 269,61 279,83 279,10 279,84 279,10 278,87 279,30 279,10 278,37 278,55 278,44 278,36 278,32 278,32 278,32 278,22 27		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) above ground Steck.Rei.Ht = 52.6 60.0 7op of jet = 64.1 700 5ptitene 5.3 m/e Height = 92.2 100.0 5ptitene 5.3 m/e Height = 92.2 100.0 110.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 100	(meters) above stack 0.00 0.73 2.26 3.84 5.31 8.35 11.40 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.80 121.13 138.37 166.85 105.80 121.13 138.37 166.85 107.33 227.81 225.22 23.97.81 225.22 23.97.81 225.22 23.97.33 227.81 225.22 23.97.33 227.81 225.22 23.9.73 349.73 349.25 349.73 340.21 410.69 441.17	Ptume Radius(m) 0.279 0.338 0.659 0.659 0.659 0.658 1.614 1.722 2.601 2.600 3.077 3.564 4.052 4.540 6.978 9.417 11.855 14.293 16.732 19.170 21.809 26.465 31.362 31	SingleStk VertVel(mis) 44.024 40.24 30.46 5.57 5.30 4.02 3.84 3.15 2.299 2.299 2.299 2.299 2.299 2.299 2.299 2.299 1.922 1.02 1.92 1.92 1.92 1.92 1.92 1.92 1.92 1.9	Plume Temp(K) 3294(30294) 2001 2001 2001 2001 2001 2001 2001 200		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	5 foot intervals 10 foot intervals Max<5.30 m/s 50 foot intervals
Height (fee) sborck.Rol.H = 55 550 60.0 70p af jet = 64.1 70.0 80.0 5pitiare 5.3 m/a Height = 92.2 100.0 110.0 120.0 130.0 140.0 130.0 140.0 150.0 500.0 350.0 350.0 350.0 350.0 350.0 140.0 150.0 100.0 140.0 150.0 100.0	(meters) above stack 0.0073 2.26 3.51 12.08 14.45 17.50 20.55 23.59 28.64 29.66 44.93 60.17 75.41 90.65 105.68 122.13 138.37 166.86 107.33 227.81 228.77 319.25 349.73 369.21 410.69 44.17 471.65 502.13	Ptume Radius(m) 0.279 0.338 0.459 0.659 0.658 1.128 1.128 1.128 0.659 0.638 0.638 0.63900000000000000000000000000000000000	SingleStk VertVel(mis) 44,024 40,24 40,24 12,50 7,48 2,248 4,60 4,60 4,60 4,60 4,60 4,60 4,60 4,60	Plume Temp(K) 373,34 329,40 311,56 303,96 302,01 298,131,56 303,96 302,01 298,21 299,50 208,51 208,51 208,52 279,30 279,30 279,30 279,30 279,30 279,30 279,31 278,51 278,32 278,32 278,32 278,2		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	10 foot intervals Max<5.30 m/s
Height (fee) above ground Stack.Rei.Ht = 55.0 60.0 7op of jet = 64.1 700 5pitiane 5.3 m/a Height = 92.2 100.0 5pitiane 5.3 m/a Height = 92.2 100.0 110.0 120.0 120.0 120.0 250	(meters) above stack 0.00 0.73 2.26 3.84 5.31 8.35 11.40 20.55 23.59 26.64 29.69 44.93 60.17 75.41 90.65 105.80 121.13 138.37 166.85 105.80 121.13 138.37 166.85 107.33 227.81 225.22 23.97.81 225.22 23.97.81 225.22 23.97.33 227.81 225.22 23.97.33 227.81 225.22 23.9.73 349.73 349.25 349.73 340.21 410.69 441.17	Ptume Radius(m) 0.279 0.338 0.659 0.659 0.659 0.658 1.614 1.722 2.601 2.600 3.077 3.564 4.052 4.540 6.978 9.417 11.855 14.293 16.732 19.170 21.809 26.465 31.362 31	SingleStk VertVel(mis) 44.024 40.24 30.46 5.57 5.30 4.02 3.84 3.15 2.299 2.299 2.299 2.299 2.299 2.299 2.299 2.299 1.922 1.02 1.92 1.92 1.92 1.92 1.92 1.92 1.92 1.9	Plume Temp(K) 3294(30294) 2001 2001 2001 2001 2001 2001 2001 200		Jet Phase Eqs: Linearly interpolated from Sta Spillane Equations: $\nabla_{p_{Low}} = (Va_{N}^{2} \circ a) \cdot 2F_{2} [V \sim x_{1}]^{2}$ $a = 0.16(r.x_{s})$	ск Rен 1 10 Тор о (#.250-г./) ⁹ 1 ^{1/2} / ө (Ч _{ранис} 14 ⁺ /k ³)))	5 foot Intervals 10 foot Intervals Nax<5.30 m/s 50 foot Intervals

¹Winter Min = Monthly Mean of Minimum Daily Temperatures for 1971-2000 (Lowest in December)
NOAA Sources: Climatography of the United States No.81 "Monthly Station Normals of Temperatures, Precipitation, and Heating
and Cooling Degree Days, 1971-2000 California" and Climatography of the United States No. 20 "Monthly Station Climate
Summaries, 1971-2000 California"

			ty and Buoya						
	"The E						at Various Heights in the Plume		
- black Can distance.		1	from a Gas-Tu	irbine Power	Station at		land, Australia," Dr. K.T. Spillane sume neutral conditions (d0/dz=0 or		
mblent Conditions: Ambient Potential Ter	mp 0.	302.21 1	Kelvine	84.3	F	Constance: Ass	0.3048 meters/feet	0 a-0a)	
ume Exit Conditions:	mp vs	JULLI I	VOLVILIO	04.0		Gravity g	9.81 m/s ²		
Maximum Stack Heij	ght h.	16.03 r	meters	52 7/12	leet-inches	λ	1.11		
Stack Diame	ater D	0.5588	meters	22	inches	Ao	~1.0		
Stack Velocity	ly V _{edt}	44.96	m/s	147.52	t/sec				
Volumetric	: Flow	11.03 (cu.m/sec	23,365	ACFM	$\pi V_{quar} D^2/4$		Sect.2/1	
Steck Potential Ter		716.48		830	°F				
Initial Stack Buoyancy Fl		9.9080					$4 = Vol.Flow(g/\pi)(1-\theta_{s}/\theta_{s})$	Sect.2/1	
Plume Buoyancy F		N/A r	m ^a /aa				for a, V, Bp at plume height (see belo	w)	
No.of Sta	CK8 N	1			1.000	Multiple Stack N	Iultiplication Factor (N ^{0.25})		
onditione at End (Top) of Jet Phase:									
Height above Star	ck z	3 493 1	meters*	11.5	feet*	z	ters*=metera above stack top	Sect.3/11	
Height above Ground z		19.523		64.1					
Vertical Veloci	10. 0	22.480	m/s	73.75	ft/sec	Viet = 0.5Vacit = 1	/ moi/2		
Plume Top-Hat Diameter	r 2a _{jet}	1.118 1	meters	3.7	feet	2apr = 2D	Conservation of momentum	n "	
billane Methodology - Analytical Solution				-					
Single Plume-averaged Vertical Velocity					Product V				
Plume Top-Hat Rac			olutions in Te				ear increase with height	Sect.2/Eq.6	
Virtual Source Hei		1.224 1		4.0		5.25D[1-(0,/0,)	⁽²], meters*=meters above etack top	Sect 2/Eq.6	
Height above Ground		17.254 1	meters olutions in Ta	56.6	Rel	(6) - 3 - 0	where $(\theta_a/\theta_a)^{1/2} = (\theta_a/\theta_a)^{1/2}$ ($t_a = \sqrt{2}$, $t_a = \sqrt{2} \sqrt{2} \sqrt{2} \sqrt{2}$		
Vertical Velo Product		8.158		ING DRIOM		{(Va)," + 0.12F, ValiD/2(6,/0,) ^{1/2}	{ (z-z,) ² - (6.25D-z,) ²]} ⁽¹⁴⁰ / a	Sect.2.1(6)	
Product	1.241/0	0.100 (78			A WILTER (G ⁶ /G ⁸)			
Solve for plume-averaged vertic	al velocity at	height	940.0 f	eet	286 512	meters above g	round (z'+h_)		
Gives the following Height above Sta		70.482		887.4			·····		
Plume Top-Hat Diamet		86.162		282.7		2a'=2*0.16(z'-z,)	Sect 2/Eq 6	
Vertical Velo		1.295		4.25			F_[(z-z _v) ² -(6.25D-z _v) ²]} ^(1/3) /(2a ¹ /2)	Sect 2/Eq.6	
Solve for Height of CASC critical	vertical velo	city V _{orit}	5.30 m	n/s plume-av	eraged ver	rtical velocity	Critica	al VV > Top of Je	t (Spilla
Find Height above Stac	ck z _{crit}	12.272	meters	40.3	feet	Solve for x=(z-z) simultaneously in both eqs. (i.e.,)	Va and a)	
Height above Ground z	or +hs	28.302 r	meters	92.9	leet		sing the cubic equation as 3+bx2+cx		
							=1, c=0, and b=-(0.12F_)/(4.3 ³ 0.16		-3.91
Interpolated Height of critical vertic						and d=	0.12Fo(6.25D-zy)2-(Va)o3/(4.330.16		-870.
Find Height above Stac		#N/A r		#N/A				ttp://www.1728.on	
Height above Ground z	crt+Ds	#N/A 1	meters	#N/A	feet		gives the real solution x = z-zv		11.04
							or z(m/above stack)		12.2
ble of Plume Top-Hat Diameters (2a) and	d Plume-Aver	aged Ve	riical Valociti	es starting si	end of let	phase:	z(ft/above ground)	-	94
Height		neters)	Plume	SingleStk	Plume				
above gr		e stack	Radius(m)		Temp(K)				
Stack.Rel.Ht =		0.00	0.279	44.96					
	55.0	0.73	0.338	40.24			Jet Phase Eqs:		ot interva
	60.D	2.26	0.459	30.48			Linearly Interpolated from Slack R	tel.HI to Top of Jel	
Top of jet =		3.51	0.559	22.48			Spillane Equations:	- 17x18 -	
	70.0	5.31	0.653	12.70	394.11		Vphane = [(Va)o ³ +0.12Fo[(z-z_o) ² -(8.25		
	80.0	8 35	1.141	7.60	352.53		s = 0.16(z-z,)		ot Interva
Spillers 5 2 min Unista	90.0	11.40	1.628	5.65	335.44		$\Theta_{g} = \Theta_{g} (1 + (1 - (\Theta_{g}/\Theta_{h}))^{*} (V_{evel}D^{2}/(4V_{g}/\omega_{f}))^{*})$	10 ⁻⁸⁻¹ ((^,*'))}	
Spillane 5.3 m/s Height =		12.27	1.768	5.30	332.27				
	100.0 110.0	14.45 17.50	2.116	4.64	320.15				
	110.0	20.55	3.091	3.64	320.39			pie -	x<5.30 r
	130.0	23.59	3.679	3.35	313.80			N14	
	140.0	28.64	4.067	3.14	313.80				
	150.0	29.69	4.555	2.97	310.30				
		44.93	6.993	2.46	306.35			50 for	ot Interv
	200.0							0010	
	200.0 250.0		9.431		304.76				
	250.0	60.17	9.431 11.870	2.19	304.76				
			9.431 11.870 14.308	2.01	304.76 303.96 303.50				
	250.0 300.0 350.0	60.17 75.41	11.870	2.01	303.96				
	250.0 300.0 350.0 400.0	60.17 75.41 90.65	11.870 14.308	2.01 1.89	303.96 303.50				
	250.0 300.0 350.0 400.0 450.0	60.17 75.41 90.65 105.89	11.87D 14.308 16.747	2.01 1.89 1.76	303.96 303.50 303.20				
	250.0 300.0 350.0 400.0 450.0 500.0	60.17 75.41 90.65 105.89 121.13	11.870 14.308 16.747 19.185	2.01 1.89 1.76 1.70	303.96 303.50 303.20 303.00			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0	60.17 75.41 90.65 105.89 121.13 136.37	11.870 14.308 16.747 19.185 21.823	2.01 1.89 1.76 1.70 1.63	303.96 303.50 303.20 303.00 302.86			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 700.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85	11.870 14.308 16.747 19.185 21.823 26.500	2.01 1.89 1.76 1.70 1.63 1.53	303.96 303.50 303.20 303.00 302.88 302.67			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 700.0 600.0 900.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33	11.870 14.308 16.747 19.185 21.823 26.500 31.377	2.01 1.89 1.76 1.70 1.63 1.53 1.44	303.96 303.50 303.20 303.00 302.86 302.67 302.55			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 700.0 600.0 900.0 900.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77	11.870 14.308 16.747 19.185 21.823 26.500 31.377 36.254 41.131 46.007	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27	303.96 303.20 303.20 302.86 302.67 302.56 302.49 302.43 302.40			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 700.0 600.0 900.0 900.0 100.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25	11.870 14.308 18.747 19.185 21.823 26.500 31.377 36.254 41.131 46.007 50.884	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22	303.96 303.20 303.20 302.86 302.87 302.56 302.49 302.43 302.40 302.37			100 for	ot Interv
	250.0 300.0 350.0 400.0 500.0 600.0 700.0 600.0 900.0 900.0 100.0 100.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25 349.73	11.870 14.308 16.747 19.185 21.823 26.500 31.377 36.254 41.131 46.007	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27	303.96 303.50 303.20 302.86 302.67 302.56 302.49 302.43 302.40 302.37 302.34			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 700.0 600.0 900.0 900.0 100.0 200.0 300.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25 349.73 380.21	11.870 14.308 16.747 19.185 21.823 26.500 31.377 36.254 41.131 46.007 50.884 55.761 60.638	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22 1.19 1.16	303.96 303.50 303.20 303.00 302.86 302.67 302.56 302.49 302.43 302.40 302.37 302.34 302.32			100 toi	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 600.0 900.0 900.0 900.0 100.0 200.0 300.0 400.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25 349.73 380.21 410.69	11.870 14.308 18.747 19.185 21.823 26.500 31.377 36.254 41.131 46.007 50.884 55.761 60.638 65.515	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22 1.19 1.16 1.13	303.96 303.50 303.20 303.00 302.88 302.67 302.56 302.49 302.49 302.43 302.40 302.31 302.43 302.43 302.31			100 fo	ot Interva
	250.0 300.0 350.0 400.0 440.0 500.0 600.0 700.0 600.0 900.0 100.0 200.0 300.0 300.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25 349.73 380.21 410.69 441.17	11.870 14.308 16.747 19.185 21.623 26.500 31.377 36.254 41.131 46.007 50.884 55.761 60.638 65.515 70.391	2.01 1.89 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22 1.19 1.16 1.13 1.10	303,96 303,50 303,20 303,00 302,86 302,67 302,56 302,49 302,40 302,40 302,43 302,40 302,43 302,40 302,31 302,30			100 for	ot Interv
	250.0 300.0 350.0 400.0 450.0 500.0 500.0 700.0 500.0 900.0 100.0 200.0 300.0 300.0 400.0 500.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.29 288.77 319.25 349.73 360.21 410.69 441.17 471.65	11.870 14.308 16.747 19.185 21.623 26.500 31.377 36.254 41.131 46.007 50.884 55.761 60.638 65.515 70.391 75.268	2.01 1.89 1.76 1.63 1.53 1.44 1.37 1.22 1.19 1.16 1.13 1.40 1.13	303.96 303.60 303.20 303.00 302.86 302.65 302.49 302.43 302.40 302.37 302.34 302.34 302.34 302.30 302.31 302.30			100 to	ot Interv
	250.0 300.0 355.0 460.0 500.0 500.0 600.0 700.0 600.0 200.0 200.0 200.0 300.0 400.0 500.0 500.0 500.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.27 319.25 349.73 349.73 349.73 349.73 349.73 349.73 5360.21	11.870 14.308 16.747 19.185 21.823 26.600 31.377 36.254 41.131 46.007 50.884 55.761 60.638 65.515 70.391 75.266 80.145	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22 1.19 1.16 1.13 1.10 1.07	303.96 303.50 303.20 302.86 302.87 302.56 302.49 302.43 302.40 302.37 302.34 302.33 302.31 302.30 302.29 302.29			10D for	ot Interv
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	250.0 300.0 400.0 450.0 500.0 500.0 600.0 600.0 600.0 900.0 200.0 300.0 300.0 500.0 500.0 500.0 500.0	60.17 75.41 90.65 105.89 121.13 136.37 166.85 197.33 227.81 258.27 319.25 349.73 349.73 349.73 349.73 349.73 349.73 5360.21	11.870 14.308 16.747 19.185 21.823 26.600 31.377 36.254 41.131 46.007 50.884 55.761 60.638 65.515 70.391 75.266 80.145	2.01 1.89 1.76 1.70 1.63 1.53 1.44 1.37 1.32 1.27 1.22 1.19 1.16 1.13 1.10 1.07	303.96 303.50 303.20 302.86 302.87 302.56 302.49 302.43 302.40 302.37 302.34 302.33 302.31 302.30 302.29 302.29			100 tor	ot Interv

Summer Max = Monthly Mean of Maximum Daily Temperatures for 197-2000 (Highest II July)
 NOAA Sources: Climatography of the United States No.81 "Monthly Station Normals of Temperatures; Precipitation, and Heating
 end Cooling Degree Days, 1971-2000 California" and Climatography of the United States No. 20 "Monthly Station Climate
 summaries; 1971-2000 California"

	"Aviation Safet						Maladata I. M. D.		
f.diam for each chiller with each cell at 36.6" ID 26,000 ACFM total for each chiller}							Heights in the Plu ralis," Dr. K.T. Spi		
mblent Conditions:							al conditions (d0/dz=		
Ambient Potential Temp 8a	278.15 K	elvins	41.0 *	=		0.3048 me			
ume Exit Conditions:					Gravity g	9.81 m/	8 ²		
Stack Height h _s Individual Chiller Stack Diameter D	30.30 n 3.7186 n		99 5/12 fe 146.4 ir		A Ap	1.11			
Stack Velocity Vert	9.82 n		32.22 ft		4Vol/(60mD ²)	-1,0			
Individual Chiller Volumetric Flow	106.66 c		228,000 A		TrV and D2/4			Sec	1.2/¶1
Stack Potential Temp 8s	289.25 ×	leivins	61.0 °	F					
Initial Stack Buoyancy Flux Fe	12.7935 m		20.0 A	T(*F)	gV _{ext} D ² (1-0,/0,				1.2/¶1
Plume Buoyancy Flux F Number of Chillers n	N/A n 54	n*/8 ³		2 744	λ ⁴ gVa ⁴ (1-θ _a /θ _p) Multiple Stack I		st plume height (see	below)	
Number of Chillers h	94			2.711	MURIPIE SCECK	Antibicatio	n Factor (n°)		
onditions at End (Top) of Jet Phase:									
Height above Stack zjet	23.241 n	neters*	78.3 fr	eet*	z _{jet} = 6.25D, me	etere*=mete	rs above stack top	Sec	t 3/¶1
Height above Ground z _{jet} +h _p	53.543 n		175.7 ft						*
Vertical Velocity V _{jet}	4.911 n		16.11 ft		V _{pt} = 0.5V _{pt} =			-	÷
Plume Top-Hat Diameter 2a _{jet}	7.437 n	neters	24.4 ft	et	2a _{jat} = 2D	Çe	inservation of mome	intum	•
pillane Methodology - Analytical Solutions for G	alm Conditions	for Plume H	eights above .	let Phase					
Single Plume-averaged Vertical Velocity V giv			-		a given by equa	ntions below	WC.		
Plume Top-Hat Radius a	Sc	olutions in Ta	ble Below		0.18(z-z_), or lin	near increas	e with height		2/Eq.6
Virtual Source Height z _v	0.451 m		1.5 fe		6.25D(1-(0,/0))		meters above stack top		2/Eq.6
Height above Ground z _v +h _s	30.753 n		100.9 fe	tet			where $(\theta_a/\theta_a)^{1/2} = (\theta_a)^{1/2}$		
Vertical Velocity V Product (Va)		olutions in Ta	ible Below				6.25D-z,) ²]] ^(1/3) / a	Sec	1.2.1(8)
Product (Va), ingle Chiller Results:	17.906 n	17/3			V_D/2(8_/8_)1/2				
Solve for plume-averaged vertical velo	city at height	940.0 1	eet	286 512	meters above g	round (z'+h	L)		
Gives the following Height above Stack z'	256.210 n		840.8 fr						
Plume Top-Hat Diameter 2a'	61.843 n	neters	268.5 fr		2a'=2*0.16(z'-z				L2/Eq.6
Ventical Velocity V	1.154 n	n/s	3.79 ft	/sec	V={(Va) ₀ ³ +0.12	F _c ((z-z _y) ² -(6	.25D-z,) ²]] ^(1/3) /(2a'/2) Seci	.2/Eq.6
Solve for Height of CASC critical vertica			n/s plume-ave	-		- to - loss of the second	eously in both eqs. (Critical VV	
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _e	#N/A n #N/A n		#N/A fo #N/A fo				equation ax ³ +bx ³ +c		
Height above croatia 128, 115		ICIO10	WIND I				d b=-(0.12F_)/(V_ctl ³		-2.5
Internal start Links to a state of surgicity of									
Interpolated Height of critical vertical vel	ocity in Jet Pha	80:					5D-z,)2-(Va),3V(Vent		-810
Find Height above Stack z _{ort}	ocity in Jet Pha 21.398 n		70.2 fe	et			5D-z _v) ² -(Va) _o ³]/(V _{crit} ³) http://		
		neters	70.2 fr 169.6 fr			(0.12F ₀ (6.2		0.16 ³)=	org/cubic
Find Height above Stack z _{ort}	21.398 п	neters				(0.12F ₀ (6.2	http:// the real solution x = or z(m/above s	0.16 ³)= (www.1728.0 : z-zv = (tack) =	org/cu/bic 20.9 21
Find Height above Stack z _{ert} Height above Ground z _{ert} ∻h _s	21.398 m 51.700 m	neters neters	169.6 fr	et	and d=	(0.12F ₀ (6.2	http://	0.16 ³)= (www.1728.0 : z-zv = (tack) =	org/cu/bic 20.9 21
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (2a) and Plum	21.398 m 51.700 m	neters neters tical Velociti	169.6 fo	end of jet	and d=	(0.12F ₀ (6.2	http:// the real solution x = or z(m/above s	0.16 ³)= (www.1728.0 : z-zv = (tack) =	org/cu/bic 20.9 21
Find Height above Stack z _{ort} Height above Ground z _{on} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet)	21.398 m 51.700 m	neters neters tical Velociti Plume	169.6 fo es starting at SingleStk	and of jet Plume	and d=	(0.12F ₀ (6.2	http:// the real solution x = or z(m/above s	0.16 ³)= (www.1728.0 : z-zv = (tack) =	org/cu/bic 20.9 21
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (2a) and Plum	21.398 m 51.700 m e-Averaged Ver (meters)	neters neters tical Velociti Plume	169.6 fo	end of jet	and d=	(0.12F ₀ (6.2	http:// the real solution x = or z(m/above s	0.16 ³)= (www.1728.0 : z-zv = (tack) =	org/cu/bic 20.9 21
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (Za) and Plum Height (feet) above ground	21.398 m 51.700 m e-Averaged Ver (meters) above stack	neters neters tical Velociti Plume Radius(m) '	169.6 fo es starting at SingleStk VertVel(m/s)	and of jet Plume	and d=	(0.12F _o (6.2	http:// the real solution x = or z(m/above s	0.16 ³)= (www.1728. (www.1728. (www.1728. (www.1728. (www.1728. (www.1728.) (org/cubic 20.9 21 1
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Hr = 99.4 100.0 120.0	21.398 m 51.700 m (meters) above stack 0.00 0.18 6.27	neters neters tical Velociti Plume Radius(m) 1 1.859 1.874 2.361	169.6 fr es starting at SingleStk VertVel(m/s) 9.82 9.78 8.50	and of jet Plume	and d=	(0.12F _o (6.25 gives Je Line	http:// the real solution x = ar z(m/above s z(tl/above gro t Phase Eqs: early Interpolated from St	0.16 ³)= (www.1728.0 : z-zv = ttack) = pund) = 20 f	org/cubic 20.9 21 1 1
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37	neters neters tical Velociti Plume Radius(m) 1 1.859 1.874 2.361 2.849	169,6 fr es starting at a SingleStk VertVel(m/s) 9,82 9,78 8,50 7,21	and of jet Plume	and d=	(0.12F _o (6.2 gives Je Lin Sp	http:// the real solution x = or z(m/above s z(tf/above gro t Phase Eqs: early Interpolated from St williane Equations:	0.18 ³)= (www.1728. (20.9 20.9 21 1 1 1 1 1 1 1
Find Height above Stack z _{ort} Height above Ground z _{ont} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (fed) above ground Stack.Rel.Mr = 99.4 100.0 120.0 140.0 160.0	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37 18.47	neters heters tical Velociti Plume Radius(m) 1.859 1.874 2.361 2.849 3.337	169,6 fr es starting at SingleStk VertVel(m/s) 9,82 9,78 8,50 7,21 5,92	and of jet Plume	and d=	(0.12F _a (6.2 gives Je Lin Sp V _{ja}	http:// the real solution x = or z(m/above s z(t/above gro t Phase Eqs: early harpointed from St Mane Equations: 	0.18 ³)= (www.1728. (20.9 20.9 21 1 1 1 1 1 1 1
Find Height above Stack z _{ext} Height above Ground z _{ext} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 168.6	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40	neters neters tical Velociti Plume Radius(m) 1 1.859 1.874 2.361 2.849 3.337 3.571	169,6 fr es starting at SingleStk VertVel(m/s) 9,76 8,50 7,21 5,92 5,30	and of jet Plume	and d=	(0.12F ₀ (6.2 gives Je Lin Sp V _m a =	http:// the real solution x = or z(m/above s z(ft/above or t Phase Eqs: early histopiated horn SI Nilane Equations: ((vs)_x^3-0.12f_(zc.z))	0.16 ³)= <u>twww.1728.</u> <u>twww.1728.</u> <u>z-zv =</u> <u>ttack</u>) = <u>yund</u>) = 20 f ack RoLH to Tr <u>20 f</u> <u>20 f</u> <u>20 f</u> <u>20 f</u>	20.5 20.5 21 1 1 It Interva op of Jet
Find Height above Stack z _{ort} Height above Ground z _{ort} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 198.8 Top of Single jet = 178.7	21.398 m 51.700 m e-Averaged Ver (metars) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24	tical Velociti Plume Radius(m) 1 1.859 1.874 2.361 2.849 3.337 3.571 3.719	169.6 fr SingleStk VertVel(m/s) 9.82 9.76 8.50 7.21 5.92 8.30 4.91	eet end of jet Plume Temp(K)	and d=	(0.12F ₀ (6.2 gives Je Linu Sp v _{pk} a = 9 _p	http:// the real solution tax = s or Z(m/above grader) t Phase Eqs: style="text-align: circle;">style="text-align: circle;" t Phase Eqs: style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;"style="text-align: circle;"styl	0.16 ³)= <u>twww.1728.</u> <u>twww.1728.</u> <u>z-zv =</u> <u>ttack</u>) = <u>yund</u>) = 20 f ack RoLH to Tr <u>20 f</u> <u>20 f</u> <u>20 f</u> <u>20 f</u>	20.: 20.: 21 1 1 it interva op of Jet
Find Height above Stack z _{ext} Height above Ground z _{ext} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 168.6	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40	neters neters tical Velociti Plume Radius(m) 1 1.859 1.874 2.361 2.849 3.337 3.571	169,6 fr es starting at SingleStk VertVel(m/s) 9,76 8,50 7,21 5,92 5,30	and of jet Plume	and d=	(0.12F ₀ (6.2 gives Line Sp V _{ps} a = 6 p ⁻ CE	http:// the real solution x = or z(m/slowe s z(ft/above sr z(ft/above sr z(ft/above sr z(ft/above sr early hterpolated hom SL Nilane Equations: $m_{e}^{-1}(Ve)_{a}^{-3} + 12F_{a}[x,z_{c}]^{-2}$ $0.16(x,z_{c})$ $= 6_{d}(1+(1-(g-\theta_{0}))^{1}V_{c}$ (C Staff Equation:	0.16 ³)= <u>twww.1728.</u> <u>twww.1728.</u> <u>z-zv =</u> <u>ttack</u>) = <u>yund</u>) = 20 f ack RoLH to Tr <u>20 f</u> <u>20 f</u> <u>20 f</u> <u>20 f</u>	20.5 20.5 21 1 1 It Interva op of Jet
Find Height above Stack z _{ort} Height above Ground z _{ort} +h, able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 12	21.398 m 51.700 m e-Averaged Ver (meters) above size(0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.55	tical Velociti Plume Radius(m) 1.889 1.874 2.861 2.849 3.377 3.571 3.571 3.558	169.6 fr SingleStk VertVel(m/s) 9.78 8.50 7.21 5.92 5.30 4.91 4.67	eet end of jet Plume Temp(K) 282.39	and d=	(0.12F _n (6.2 gives Je Linu Sp V _{pn} a = 0 _p CE V _{rn}	http:// the real solution tax = s or Z(m/above grader) t Phase Eqs: style="text-align: circle;">style="text-align: circle;" t Phase Eqs: style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;">style="text-align: circle;"style="text-align: circle;"styl	0.16 ³)= <u>twww.1728.</u> <u>twww.1728.</u> <u>z-zv =</u> <u>ttack</u>) = <u>yund</u>) = 20 f ack RoLH to Tr <u>20 f</u> <u>20 f</u> <u>20 f</u> <u>20 f</u>	20.5 20.5 21 1 1 It Interva op of Jet
Find Height above Stack z _{ext} Height above Ground z _{ent} +h _s able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 Single Jet 5.3 m/s Height = 169.6 Top of Single jet = 175.7 180.0 20.0	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.58 30.66	neters neters tical Velociti Plume Radius(m) 1.889 1.874 2.361 2.849 3.337 3.571 3.719 3.858 4.833	169.6 fr SingleStk VertVel(m/s) 9.78 9.78 8.50 7.21 5.92 8.30 4.91 4.67 3.83	and of jet Plume Temp(K) 282.39 281.44	and d=	(0.12F ₀ (6.2; gives Je Lin Sp v _{an} e e p f CE CE Var v _{an}	$\label{eq:response} \begin{array}{l} http://\\ http://withouting.com/anti-energy (fill above a cit/m/above a ci$	0.16 ³)= 1.16 ³)= 1.22.17	<u>org/cubic</u> 20.9 21 1 1 λ Interva op of Jet ⁹ /a (*9 ² *λ ²)))
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Find Height above Stack z _{ext} Height above Ground z _{ext} +h, able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 178.7 180.0 200.0 220.0 240.0 280.0	21.398 m 51.700 m e-Averaged Ver (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.56 30.66 36.75 42.85 55.04	heters heters tical Velociti Plume Radius(m) 1.889 1.874 2.361 2.849 3.377 3.571 3.571 3.571 3.571 3.578 3.585 4.833 5.808 6.784 7.759 8.735	169,8 f SingleStk VertVel(ms) 9,82 9,82 9,78 8,50 7,21 6,92 3,30 4,91 4,67 3,83 3,29 2,91 2,84 2,43	and of jet Plume Temp(K) 282.39 281.44 280.80 280.35 280.01 279.74	and d=	(0.12F ₀ (6.2; gives Je Lin Sp v _{an} e e p f CE CE Var v _{an}	$\label{eq:response} \begin{array}{l} http://\\ http://withouting.com/anti-energy (fill above a cit/m/above a ci$	0.16 ³)= 1.16 ³)= 1.22.17	org/outbic 20.9 21 1 1 t Interva op of Jet ⁹ /a (*θ ² *λ ²))}
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Find Height above Stack z _{ext} Height above Ground z _{ext} +h, able of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 178.7 180.0 200.0 220.0 244.0 260.0 250.0 250.0 250.0 200.	21.398 m 51.700 m meta-Averaged Ver (metars) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.56 30.66 36.75 42.85 55.04 61.14 78.38 91.62 106.88 122.10 137.34 152.58 167.82 106.88 122.10 137.34 152.58 163.06 213.54 244.02 274.50 304.99 335.46 365.94 396.42 426.90 579.30 731.70 884.10	neters neters neters tical Velociti Plume Radius(m) 1.859 1.874 2.361 2.849 3.337 3.571 3.719 3.858 4.833 5.808 6.784 7.759 8.735 9.710 12.168 7.759 8.735 9.710 12.168 7.759 8.735 9.710 12.168 4.775 9.710 12.480	169.6 f starting at SingleSik VertVel(wis) 9.82 9.76 8.50 7.21 5.92 8.30 4.91 4.67 3.83 3.29 2.91 4.67 3.83 3.29 2.91 4.67 3.83 3.29 2.91 4.67 1.65 1.55 1.47 1.65 1.55 1.47 1.38 1.36 1.55 1.47 1.47 1.38 1.36 1.55 1.47 1.47 1.48 1.38 1.24 1.18 1.26 1.05 1.05 1.05 1.05 1.27 1.47 1.47 1.28 1.28 1.26 1.55 1.47 1.47 1.28 1.28 1.26 1.55 1.47 1.47 1.28 1.28 1.29 1.65 1.55 1.47 1.47 1.28 1.28 1.28 1.29 1.65 1.55 1.47 1.47 1.28 1.28 1.28 1.28 1.55 1.47 1.47 1.28 1.28 1.28 1.28 1.55 1.47 1.47 1.28 1.28 1.28 1.28 1.28 1.28 1.28 1.55 1.47 1.47 1.28 1.28 1.28 1.28 1.28 1.28 1.28 1.28 1.28 1.55 1.47 1.47 1.28 1	ett Plume Temp(K) 282.30 281.44 280.80 280.35 280.01 280.35 280.01 278.50 278.50 278.50 278.50 278.55 278.55 278.45 278.55 278.35 278.55 278.35 278.55 278.35 278.35 278.2	and d=	(0.12F ₀ (6.2; gives Je Lin Sp v _{an} e e p f CE CE Var v _{an}	$\label{eq:constraints} \begin{array}{l} http://\\ http://doi.org/10.10000000000000000000000000000000000$	0.16 ³)= <u>www.1728.</u> <u>www.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728. <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.1728.</u> <u>yww.172</u></u>	20.5 21. 11 R Interval op of Jet ⁹ /a (*θ ² *λ ²))}

augulo 1483.70 238.920 0.63 278.15 "Winter Min = Monthly Mean of Minimum Dally Temperatures for 1971-2000 (Lowest in December) NOAA Sources: Climatography of the United States No.61 "Monthly Station Normals of Temperatures, Precipitation, and Heating and Cooling Degree Days, 1971-2000 California" and Climatography of the United States No. 20 "Monthly Station Climate Summaries, 1971-2000 California"



MERGED (along length) Plume Average Vertical Velocities for Walsh Chillers using CEC Staff Methodology - Winter Min* "Aviation Safety and Buoyant Plumes," Peter Best, et. al. "The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia," Dr. K.T. Spillane Ambient Conditions Constants: Assume neutral conditions (d8/dz=0 or $\theta_a = \theta_e)$ Ambient Potential Temp θ_a 278 15 Kelvins 41.0 °F 0.3048 meters/feet 9.81 m/s² Plume Exit Conditions: Gravity g 99 5/12 feet-inches Stack Height h. 30 30 meters 1.11 λ Individual Stack Diameter D 3.71856 meters 146.4 inches ~1.0 Stack Velocity Vest 9 82 m/s 32 22 ft/sec 4Vol/(60πD²) Individual Volumetric Flow 106.66 cu.m/sec 226,000 ACFM $\pi V_{ext} D^2/4$ Sect.2/11 Stack Potential Temp 0. 289 26 Kelvins 61.0 °E Initial Stack Buoyancy Flux Fo 20.0 **ΔT(*F**) $gV_{ext}D^2(1-\theta_a/\theta_a)/4 = Vol.Flow(g/\pi)(1-\theta_a/\theta_a)$ 12.79 m⁴/s³ Sect.2/11 $\lambda^2 g V a^2 (1 - \theta_{\mu} / \theta_p)$ for a V θ_p at plume height (see below) Plume Buoyancy Flux F N/A m⁴/s³ Total Number of Stacks n 54 Average Adjacent Stack Separation d 49.0 feet Calcs based on multiple plume treatment in Peter Best Paper. 14.94 meters Number of Stacks along Orientation N 6 ume velocities increased by N^{e 25} at the height where plumes fully merged (interp. below ht, single merged stack above ht) Conditions at End (Top) of Jet Phase: Height above Stack z_{jet} z_{jel} ≈ 6.25D, meters*=meters above stack top 23.241 meters* 76.3 feet* Sect.3/11 Height above Ground ziet+h, 53.543 meters 175.7 feet $V_{\rm pet} = 0.5 V_{\rm dust} = V_{\rm exc}/2$ Vertical Velocity Viet 4.911 m/s 16.11 ft/sec Plume Top-Hat Diameter 2aja 7.437 meters 24.4 feet 2a_{et} = 2D Conservation of momentum Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heights above Jet and Merging Phases Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below: Single Plume Values: Plume Top-Hat Radius a Used in Plume Merging Only a = 0.16(z-z_), or linear increase with height Sect 2/Eq.6 $\begin{array}{c|c} & -e^{-y_{c}} & y_{c} & \text{meltrs} \ \text{shows stack two} \\ & & \text{shows} & \text{shows} \ \text{shows$ Virtual Source Height z., 0.451 meters* 1.5 feet* Sect 2/Eq.6 Height above Ground z,+h, 100.9 feet 30.753 meters Vertical Velocity V Single Plume Values: Used in Plume Merging Only Sect 2 1(6) Product (Va) $17.906 \text{ m}^2/\text{s}$ Plume Merging - Based on Single Plume Calculations where Sect.3/]]3 Begin Merging Plume Top-Hat Diameter 2a_{south} Height above Stack z_{touch} 14.940 meters 49.0 feet 2a_{touc*}=d, (or a_{touch}=d/2) $z_{\text{touch}} = z_v + d/(2^*0.16)$, meters*=meters above stack top 47.138 meters* 154.7 feet 77.440 meters Height above Ground z_{tourr}+h_s 254.1 feet Vertical Velocity Venuch $V_{totot} = \{ (Va)_o^{-3} + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2] \}^{1/3} / a$ 2.709 m/s 8.9 ft/sec d(N-1)/2, (or a_{tuli}=d(N-1)/2) FOR 2 STACKS, 2a_{tuli}=2d Total Merging Plume Top-Hat Diameter 2atul 74.700 meters 245.1 feet 28 ...= Height above Stack Zs.d 233.888 meters* 767.3 feet* z₆ = z.+2d/(2*0.16), meters*=meters above stack top Height above Ground z_{full}+h_s 264.190 meters 866.8 feet Vertical Velocity Ven 1.194 m/s 3.9 ft/sec $V_{tul} = \{ (Va)_{o}^{3} + 0.12F_{o} \left[(z_{tul} - z_{v})^{2} - (6.25D - z_{v})^{2} \right] \}^{(1/3)} / a_{tul}$ 64 m⁴/s³ Product (V3a)_{but} Conditions at End (Top) of Merging Phase - Define new values for V_{hill} and a_{ha} in Merged Plume calculations (based on TOTAL number of stacks): Merged Plume Values: Plume Diameter 2a Solutions in Table Below $2a = 2 \times (a_m + 0.16(z-z_{tull}))$, or linear increase with height Revised Merged Plume Radius a, 101.249 meters 332.2 feet where a_m = n^{0.25}a_{full} where Total Merging Occurs Revised Merged Plume Velocity V. and $V_m = n^{0.25} V_{sull}$ where Total Merging Occurs 3.236 m/s 10.62 ft/sec Revised Virtual Source Height ziul 233.888 meters* 767.3 feet* Height above stack where Total Merging Occurs (shown above) Solutions in Tables Below
$$\begin{split} & V{=}\{n(V^3a)_{f_0H}/a\}^{4/3} \text{ for heights above total merging elevation} \\ & V{=}V_{touch}{+}(V_{in}{-}V_{louch})^*(z{-}z_{touch})/(z_{hu}{-}z_{louch}) \end{split}$$
Revised Vertical Velocity V

Multiple Plume Calculations for heights below total merging elevation Solve for plume-averaged vertical velocity at height 940.0 feet 286.512 meters above ground (z+h_s) 840.6 feet* Gives the following Height abeve Stack z 256 210 meters* REGULAR EONS Plume Top-Hat Radius a 104.820 meters 343.9 feet a=a_+0.16(z-z_{kill}) if z>z_{full} Vertical Velocity V 3.198 m/s 10.49 ft/sec $V={n(V^3a)_{full}/a}^{1/3}$ if $z>z_{full}$ V=V_{touch}+(V_m-V_{touch})+(z'-z_{touch})/(z_{tul}-z_{touch}) if z_{touch}<z<z_{fall} V=single plume values if z<z_{touch} Solve for Height of GASC critical vertical velocity V_{crit} Critical VV < Top of Jet 5.30 m/s BEFORE TOUCHING -Find Height above Stack z_{cril} JET meters JET feet $z_{cr1} = z_{tull} + \{[n(V^3a)_{tull}/(V_{cr1})^3] - a_m\}/0.16 \text{ If } V_{cr1} < V_m$ Height above Ground z_{out}+h_s JET meters JET feet zeri=ziouch+(ziui-ziouch)*(Veri-Viouch)/(Vri-Viouch) If Verit>Vri Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height: Single Plume Eqns (see Single Plume spreadsheet) Verl. Vptama={(Va)₀³+0.12F₃[(z-z₀)²-(6.25D-z₀)²])^{3/5}/a Height (feet) (meters) Plume above ground above stack Radius(m) Vel(m/s) a = 0.16(z-z..) Begin Merging (touch) = 254.1 $\theta_{p} = \theta_{s}(1 + (1 - (\theta_{e}/\theta_{s}))^{*}(V_{exil}D^{2}/(4V_{plume}^{*}a^{2*}\lambda^{2})))$ 47.15 7.470 2.71 260.0 48 95 271 terpolated Layer Eqns 20 ft Intervals #N/A $V = V_{\text{touch}} + (V_m - V_{\text{touch}})^* (z' - z_{\text{touch}}) / (z_{\text{full}} - z_{\text{touch}})$ 280.0 55.04 #N/A 2.73 61 14 300.0 #N/A 2 75 350.0 76.38 #N/A 2.79 50 ft Intervals 400.0 91 62 #N/A 2 83 450.0 106.86 #N/A 2.88 500.0 122.10 #N/A 2.92 550.0 137.34 #N/A 2.96 600.0 152.58 #N/A 3.01 650.0 167.82 #N/A 3.05 #N/A 700.0 183.06 3.09

800.0 213.54 #N/A 3 18 End Merging (full/mp) = 866.8 233.90 101.249 3.24 900.0 244.02 102.869 3 22 1000.0 274.50 107.746 3.17 1100.0 304.98 112.623 3.12 1200.0 335.46 117.500 3.08 1300.0 365.94 122.377 3.04 1400.0 395 42 127.253 3 00 1500.0 426.90 132.130 2.96

156.514

180.898

205.282

229.666

254.050

278.434

302.818

579.30

731.70

884 10

1036.50

1188.90

1341.30

1493.70

2000.0

2500.0

3000.0

3500.0

4000.0

4500.0

5000.0

Merged Plume Eqns V={n(V³a),_{ul}/a)^{1/3}

a≕a_m+0.16(z-z_{tull})

500 ft Intervals

100 ft Intervals



2 80

2.67

2.56

2.46

2.38

2 31

2.25

Bear	SLE/Approximated Plume Average Vartical Vi ed on 54 chillers w/ 16 cells/chiller. Calc	Aviation Safe					AMIN			
	iam for each chiller with each cell at 36.6" ID		-				at Vario	us Heights in the Plun	18	
	,000 ACFM total for each chiller)							stralis," Dr. K.T. Spil		
mb	lient Conditions:							rtral conditions (d0/dz=		
	Ambient Potential Temp 0a	302.21	Kelvina	84.3				meters/feet		
un	ne Exit Conditions:					Gravity g	9.81	m/s ²		
	Stack Height hs	30.30	meters	99 5/12	eet-inches	À	1.11			
	Individual Chiller Stack Diameter D	3.7186	meters	146.4	nches	Ao	~1.0			
	Stack Velocity Vert	9.82	m/s	32.22	t/sec	4Vol/(60mD2)				
	Individual Chiller Volumetric Flow	106.66	cu.m/sec	228,000	ACFM	TV and D2/4			Sec	.2/11
	Stack Potential Temp 8s	313.32	Kelvins	104.3	F					
	Initial Stack Buoyancy Flux Fo	11.8065	m ⁴ /s ³	20.0	ΔT(*F)	gVad D2(1-0,/0,)/4 = Vol.	Flow(g/π)(1-8,/9,)	Sec	.2/11
	Plume Buoyancy Flux F	N/A	m ⁴ /s ³			λ ² gVa ² (1-θ_/θ_)	for a,V,8	, at plume height (see	below)	
	Number of Chillens n	54			2.711	Multiple Stack	Multiplicar	tion Factor (nº 25)		
on	ditions at End (Top) of Jet Phase:									
	Height above Stack z _{jet}	23.241	meters*	76.3		z _{jet} = 6.25D, m	sters*=ma	sters above stack top	Sec	3/11
	Height above Ground z _{jet} +h _p	53.543	meters	175.7	feet					-
	Vertical Velocity V _{jst}	4.911	m/s	16.11	t/sec	V _{ptl} = 0.5V _{pull} =	V_22			•
	Plume Top-Hat Diameter 2aja	7.437	meters	24.4	feet	2ajat = 2D		Conservation of mome	ntum	*
bill	ane Methodology - Analytical Solutions for C	alm Conditions	s for Plume H	leights above	Jet Phase					
S	ingle Plume-averaged Vertical Velocity V giv				Product V					
	Plume Top-Hat Radius a	S	olutions in T	able Below				ase with height	Sect	2/Eq.6
	Virtual Source Height z _v	0.416	meters*	1.4 1	feet*	6.25D[1-(0,/0)	1/2], metars	*=meters above stack top	Sect	2/Eq.6
	Height above Ground zy+hs	30.718	meters	100.8	leet			where $(\theta_a/\theta_a)^{1/2} = (\theta_a/\theta_a)^{1/2}$	(0 ₆) ^{1/2} = 0.98	21
	Vertical Velocity V	S	olutions in T	able Below		{(Va),3 + 0.12F	[(Z-Z_) ²	- (6.25D-z,) ²]] ^(1/3) / a		.2.1(6)
	Product (Va) _o	17.934				V_D/2(8,/8)"	2			
np	le Chiller Results:									
1	Solve for plume-averaged vertical velo	city at height	940.0	feet	286.512	meters above ;	pround (z'	+h_)		
	Gives the following Height above Stack z'	256.210		840.8				100 C		
	Plume Top-Hat Diameter 2a'	81.854		268.6		2a'=2*0.16(z'-z)		Sect	2/Eq.6
	Vertical Velocity V	1.128		3.69				-(6.25D-z,)2]](1/3)/(2a/2)	Sect	2/Eq.6
							and the			
	Solve for Height of CASC critical vertica	velocity V	5.30	m/s plume-av	eraged ver	tical velocity			Critical VV	< Top of
	Find Height above Stack zet	#N/A		#N/A	-		z.) simulta	aneously in both eqs. (i		
	Height above Ground zen+hs	#N/A	meters	#N/A				ic equation ax3+bx2+cx		
						Carrie		and b=-(0.12F_)/(Vatt 30		-2.32
	Interpolated Height of critical vertical velo	city in Jet Phy								-8248
						end de	(0 12E (6		1631=	
	Find Height above Stack z			70.2	eet	and d=	(0.12F _o (6	.25D-z _v) ² -(Va) _o ³)/(V _{crit} ³ 0		
	Find Height above Stack z _{ort}	21.398	meters	70.2		and d=		http://s	MWW.1728.0	org/cubic.
	Find Height above Stack $z_{\rm ort}$ Height above Ground $z_{\rm crit} + h_{\rm s}$		meters	70.2 1		and d=		http://w es the real solution x =	www.1728.c z-zv =	21.0
		21.398	meters			and d=		http:// es the real solution x = or z(m/above st	www.1728.c z-zv = ack) =	21.0 21.0 21.
b	Height above Ground $z_{\text{eff}} + h_s$	21.398 51.700	meters meters	169.6	leet			http://w es the real solution x =	www.1728.c z-zv = ack) =	21.0
ıbi	Height above Ground 2 _{off} +h _s ie of Plume Top-Hat Diameters (2a) and Plum	21.398 1 51.700 1	meters meters rtical Velocit	169.6 ies starting at	leet	phase:		http:// es the real solution x = or z(m/above st	www.1728.c z-zv = ack) =	21.0 21.0 21.
ıbl	Height above Ground $z_{\text{eff}} + h_s$	21.398 51.700	meters meters rtical Velocit Plume	169.6 ies starting at SingleStk	end of jet Plume	phase:		http:// es the real solution x = or z(m/above st	www.1728.c z-zv = ack) =	21.0 21.0 21.
bi	Height above Ground z _{on} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground	21.398 (51.700) Averaged Ve (meters) above stack	meters meters rtical Velocit Plume Radius(m)	169.6 ies starting at SingleStk VertVel(m/s)	leet end of jet	phase:		http:// es the real solution x = or z(m/above st	www.1728.c z-zv = ack) =	21.0 21.0 21.
ы	Height above Ground z _{en} +h _s le of Plume Top-Hat Diametars (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4	21.398 (51.700) Averaged Ve (meters) above stack 0.00	meters meters rtical Velocit Plume Radius(m) 1.859	169,6 ies starting at SingleStk VertVel(m/s) 9,82	end of jet Plume	phase:	giv	http:// es the real solution x = or z(m/above st z(ft/above gro	www.1728.c z-zv = ack) = und) =	21.0 21.0 21. 1
ы	Height above Ground z _{on} +h _s ie of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0	21.398 (51.700) e-Averaged Ve (meters) above stack 0.00 0.18	meters meters rtical Velocit Plume Radius(m) 1.869 1.874	169,6 ies starting at SingleStk VertVel(m/s) 9,82 9,76	end of jet Plume	phase:	giv	http:// es the real solution x = or z(m/above st z(ft/above gro Jet Phase Eqa:	www.1728.c z-zv = ack) = und) = 20 ft	21.0 21.0 21. 10 11
ы	Height above Ground z _{off} +h _s te of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack:Rel.Ht = 99.4 100.0 120.0	21.398 (51.700 (e-Averaged Ve (meters) above stack 0.00 0.18 6.27	ntical Velocit Plume Radiua(m) 1.859 1.874 2.361	169.6 dies starting at SingleStk VertVel(m/s) 9.82 9.78 8.50	end of jet Plume	phase:	giv	http:// es the real solution x = ar z(m/above st z(fl/above gro Jet Phase Eqs: Linearly Interpolated from Sta	www.1728.c z-zv = ack) = und) = 20 ft	21.0 21.0 21 1 1
ы	Height above Ground z _{en} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0	21.398 (51.700 (e-Averaged Ve (metere) above stack 0.00 0.18 6.27 12.37	ntical Velocit Plume Radiua(m) 1.859 1.874 2.361 2.849	169.6 f ies starting at SingleStk VertVel(m/s) 9.78 9.78 8.50 7.21	end of jet Plume	phase:	ĝiv	http:// bes the real solution x = ar z(M/abave st z(M/abave gro Jet Phase Eqa: Livesty hispolated from Sta Spillane Equations:	www.1728.c z-zv = ack) = und) = 20 ft ck ReLHt to Te	21.0 21.0 21 1 1 1 1 1
ы	Height above Ground z _{en} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 120.0 120.0 120.0	21.398 (51.700 ((metare) above stack 0.00 0.18 6.27 12.37 18.47	meters meters rtical Velocii Plume Radiua(m) 1.859 1.874 2.361 2.849 3.337	169.6 ies starting at SingleStk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92	end of jet Plume	phase:	giv	http:// es the real solution x = ar z(m/above st z(f/above gro Jet Phase Eqs: Linearly Interpointed from Sta Splitane Equations: v _{mene} =((ve), ² +0.12F, J(x=), ² .	www.1728.c z-zv = ack) = und) = 20 ft ck ReLHt to Te	21.0 21.0 21 1 1 1 1 1
ы	Height above Ground z _{on} +h, e of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 140.0 Single Jet 5.3 m/s Height = 169.6	21.398 51.700 e-Averaged Ve (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40	meters meters rtical Velocit Plume Radiua(m) 1.889 1.874 2.361 2.849 3.337 3.571	169.6 ies starting at Single&tk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92 5.30	end of jet Plume	phase:	giv	http:// es the real solution x = ar z (m/above si z(fVabove gro z(fVabove gro Jet Phase Eqs: Linearly Interpointed from Sta Splitane Equations: y_mme = (0.16/2.45.4); A = 0.16(2.45.4); A	<u>mmw: 1728.c</u> z-zv = ack) = und) = 20 ft ck ReLHt to Te (8.25D-z _a ³) ^{1/1}	21.(21.(21 1 t Interva op of Jet
ы	Height above Ground 2 ₀₆ +h, le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 189.6 Top of Single jet = 178.7	21.398 51.700 e-Averaged Ve (metara) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24	neters meters rtical Velocit Plume Radiua(m) 1.859 1.874 2.361 2.849 3.337 3.571 3.719	169.6 1 ises starting at SingleStk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92 5.92 5.30 4.91	ieet end of jet Plume Temp(K)	phase:	giv	http:// bes the real solution x = ar z (n//above si z (tl/above gro Jet Phase Eqs: Linearly Interpolated from Sta Spillane Equations: y _{mam} (l/ab) ²⁺⁰ (12F, 3)(-2); y _{mam} (l/ab) ²⁺⁰ (12F, 3)(-2); 9) _p = 0, 4(+(1/G, 9_0))^{1}(V_{est})	<u>mmw: 1728.c</u> z-zv = ack) = und) = 20 ft ck ReLHt to Te (8.25D-z _a ³) ^{1/1}	t Interva
ы	Height above Ground z _{ent} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.ft = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/s Height = 169.8 Top of Single j = 175.7 180.0	21.398 51.700 above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.58	meters meters rtical Velocii Plume Radius(m) 1.859 1.874 2.861 2.849 3.337 3.571 3.719 3.863	169.6 1 ies starting at SingleStk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92 5.30 4.91 4.67	end of jet Plume Temp(K) 306.45	phase:	giv	http:// es the real solution $x =$ ar z(m/above st z(ft/above gro Jet Phase Eqs: Linearly interpointed from Sta Spliane Equations: $V_{maxe} = [(Ve)_{a}^{2+0}, 12F_{a}](x < z)^{2},$ $a = 0.16(x < z_{a})$ $e_{p} = e_{a}(1 + (1 < g_{e_{a}}))^{*}(V_{e_{a}})$	<u>mmw: 1728.c</u> z-zv = ack) = und) = 20 ft ck ReLHt to Te (8.25D-z _a ³) ^{1/1}	t Interva
ы	Height above Ground z _{ent} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rei.Hr = 99.4 100.0 120.0 140.0 160.0 Single Jet 5.3 m/a Height = 188.8 Top of Single jet = 178.7 180.0 200.0	21.398 51.700 / e-Averaged Ve (meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.56 30.66	meters meters rtical Velocit Plume Radius(m) 1.859 1.874 2.849 3.337 3.571 3.571 3.719 3.883 4.839	169.6 1 SingleStk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92 5.30 4.91 4.67 3.82	end of jet Plume Temp(K) 306.45 305.51	phase:	ĝiv	http:// es the real solution $x =$ or zr(Mabove si zr(Mabove gro Jet Phase Eqs: Linearly Interpointed from Sile Splitane Equations: Splitane Equations: $a_{\mu} = 0.16(z, z_{\mu})$ $a_{\mu} = 0.16(z, z_{\mu})$ $a_{\mu} = 0.16(z, z_{\mu})$ $a_{\mu} = 0.16(z, z_{\mu})$	<u>mmw: 1728.c</u> z-zv = ack) = und) = 20 ft ck ReLHt to Te (8.25D-z _a ³) ^{1/1}	21.(21.(21 1 t Interva op of Jet
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ы	Height above Ground z _{ee} +h _s le of Plume Top-Hat Diametars (2a) and Plum Height (feet) above ground Stack.Rel.Hr = 99.4 100.0 120.0 Single Jet 5.3 m/s Height = 169.6 Top of Single jet = 178.7 180.0 220.0 224.0	21.398 (51.700 ((meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.56 30.66 36.75 42.85	meters meters Plume Radius(m) 1.889 1.874 2.361 2.849 3.337 3.571 3.719 3.883 4.839 5.814 6.789	169.6 1 iss starting at SingleStk VertVel(m/s) 9.82 8.78 8.50 7.21 5.92 5.92 4.91 4.67 3.82 3.27 2.89	end of jet Plume Temp(K) 306.45 305.51 304.88 304.42	phase:	ĝiv	http:// besthe real solution x = ar z(m/above st z(ft/above gro Jet Phase Eqa: Linearly interpolated from Sta Spillane Equations: $V_{max} = (10^{k} k_{m}^{-2} \cdot 12^{k} J_{m} k_{m}^{-2} \cdot 12^{$	20 ft ck RoLHt to To (8.25D-z _a) ² /1 ⁴	21.(21. 21 1 1 t Interva op of Jol '/ a *s ²⁼ Å ²))}
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ы	Height above Ground z _{ee} +h _s le of Plume Top-Hat Diametars (2a) and Plum Height (feet) above ground Stack.Rel.Hr = 99.4 100.0 120.0 Single Jet 5.3 m/s Height = 169.6 Top of Single jet = 178.7 180.0 220.0 224.0	21.398 (51.700 ((meters) above stack 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.56 30.66 36.75 42.85	meters meters Plume Radius(m) 1.889 1.874 2.361 2.849 3.337 3.571 3.719 3.883 4.839 5.814 6.789	169.6 1 iss starting at SingleStk VertVel(m/s) 9.82 8.78 8.50 7.21 5.92 5.92 4.91 4.67 3.82 3.27 2.89	end of jet Plume Temp(K) 306.45 305.51 304.88 304.42	phase:	ĝiv	http:// besthe real solution x = ar z(m/above st z(ft/above gro Jet Phase Eqa: Linearly interpolated from Sta Spillane Equations: $V_{max} = (10^{k} k_{m}^{-2} \cdot 12^{k} J_{m} k_{m}^{-2} \cdot 12^{$	20 ft ck RoLHt to To (8.25D-z _a) ² /1 ⁴	**************************************
ы	Height above Ground z _{ent} +h _s le of Plume Top-Hat Diameters (2a) and Plum Height (feet) above ground Stack.Rel.Ht = 99.4 100.0 120.0 5ingle Jet 5.3 m/s Height = 198.6 Top of Single jet = 178.7 180.0 220.0 220.0 220.0 220.0	21.398 (51.700 ((metors) above stack 0.00 0.18 6.27 12.37 12.40 23.24 24.56 30.66 36.75 42.85 48.95	meters meters rtical Velocifi Plume Radiua(m) 1.859 1.874 2.849 3.337 3.571 3.719 3.863 4.839 5.814 6.789 7.765	169.6 1 SingleStk VertVel(m/s) 9.78 8.50 7.21 5.92 5.30 4.91 4.67 3.82 3.27 2.89 2.61	end of jet Plume Temp(K) 308.45 305.51 30.68 304.42 304.08	phase:	ĝiv	http:// besthe real solution x = ar z(m/above st z(ft/above gro Jet Phase Eqa: Linearly interpolated from Sta Spillane Equations: $V_{max} = (10^{k} k_{m}^{-2} \cdot 12^{k} J_{m} k_{m}^{-2} \cdot 12^{$	20 ft ck RoLHt to To (8.25D-z _a) ² /1 ⁴	21.(21.) 21 1 1 1 t Interva op of Jel ¹ /a *e ²⁼ λ ² })}
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ы	Height above Ground z _{eef} +h _s le of Plume Top-Hat Diametars (2a) and Plum Height (feet) 3bove ground Stack.Rel.Ht 99.4 100.0 120.0 140.0 140.0 160.0 Single Jet 5.3 m/a Height = 168.6 Top of Single jet = 178.7 180.0 220.0 240.0 240.0 260.0 300.0	21.398 (51.700 ((meters) above stack 4 0.00 0.18 6.27 12.37 18.47 21.40 23.24 24.58 30.66 30.75 42.86 40.95 55.04 61.14	meters meters rtical Velocit Plume Radius(m) 1.889 1.874 2.849 3.337 3.571 3.719 3.883 4.839 5.814 6.789 7.765 8.740 9.716	169.6 1 SingleStk VertVel(m/s) 9.82 9.78 8.50 7.21 5.92 8.30 4.91 4.67 3.82 3.27 2.99 2.61 2.40 2.24	eet end of jet Plume Temp(K) 306.45 305.51 304.68 304.42 304.08 303.82 303.61	phase:	ĝiv	http:// besthe real solution x = ar z(m/above st z(ft/above gro Jet Phase Eqa: Linearly interpolated from Sta Spillane Equations: $V_{max} = (10^{k} k_{m}^{-2} \cdot 12^{k} J_{m} k_{m}^{-2} \cdot 12^{$	$\frac{200 \text{ ft}}{200 \text{ ft}} = \frac{200 \text{ ft}}{200 \text{ ft}}$ $\frac{200 \text{ ft}}{200 \text{ ft}} = \frac{200 \text{ ft}}{200 \text{ ft}}$ $\frac{200 \text{ ft}}{200 \text{ ft}} = \frac{200 \text{ ft}}{200 \text{ ft}}$ $\frac{200 \text{ ft}}{200 \text{ ft}} = \frac{200 \text{ ft}}{200 \text{ ft}}$ $\frac{200 \text{ ft}}{200 \text{ ft}} = \frac{200 \text{ ft}}{200 \text{ ft}}$	21.(12) 21.(12
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"Summer Max = Monthly Mean of Maximum Daily Temperatures for 1971-2000 (Highest in July) NOAA Sources: Climatography of the United States No.61 "Monthly Station Normals of Temperatures. Precipitation, and Heating and Cooling Degree Days, 1971-2000 California" and Climatography of the United States No. 20 "Monthly Station Climate Summarise, 1971-2000 California"



MERGED (along length) Plume Average Vertical Velocities for Walsh Chillers using CEC Staff Methodology - Winter Min* "Aviation Safety and Buoyant Plumes," Peter Best, et. al.

"The Evaluation of Maximum Updraft Speeds for Calm Conditions at Various Heights in the Merged Plume from Two Gas-Turbine Power Station at Oakey, Queensland, Australia," Dr. K.T. Spillane Ambient Conditions: Constants: Assume neutral conditions (d8/dz=0 or $\theta_a = \theta_e)$ Ambient Potential Temp θ_a 302 21 Kelvins 84.3 °F 0.3048 meters/feet 9.81 m/s² Plume Exit Conditions: Gravity g 99 5/12 feet-inches Stack Height h. 30 30 meters 1.11 λ Individual Stack Diameter D 3.71856 meters 146.4 inches ~1.0 Stack Velocity Vest 9 82 m/s 32 22 ft/sec 4Vol/(60πD²) Individual Volumetric Flow 106.66 cu.m/sec 226,000 ACFM $\pi V_{ext} D^2/4$ Sect.2/11 Stack Potential Temp 0. 313.32 Kelvins 104.3 °E Initial Stack Buoyancy Flux Fo 20.0 ΔT(*F) $gV_{ext}D^2(1-\theta_a/\theta_a)/4 = Vol.Flow(g/\pi)(1-\theta_a/\theta_a)$ 11.81 m⁴/s³ Sect.2/11 $\lambda^2 g V a^2 (1 - \theta_{\mu} / \theta_p)$ for a V θ_p at plume height (see below) Plume Buoyancy Flux F N/A m⁴/s³ Total Number of Stacks n 54 Average Adjacent Stack Separation d 49.0 feet Calcs based on multiple plume treatment in Peter Best Paper. 14.94 meters Number of Stacks along Orientation N 6 ume velocities increased by N^{e 25} at the height where plumes fully merged (interp. below ht, single merged stack above ht) Conditions at End (Top) of Jet Phase: Height above Stack z_{jet} z_{jel} ≈ 6.25D, meters*=meters above stack top 23.241 meters* 76.3 feet* Sect.3/11 Height above Ground ziet+h, 53.543 meters 175.7 feet $V_{\rm pet} = 0.5 V_{\rm dust} = V_{\rm exc}/2$ Vertical Velocity Viet 4.911 m/s 16.11 ft/sec Plume Top-Hat Diameter 2aja 7.437 meters 24.4 feet 2a_{et} = 2D Conservation of momentum Spillane Methodology - Analytical Solutions for Calm Conditions for Plume Heighte above Jat and Merging Phases Single Plume-averaged Vertical Velocity V given by Analytical Solution in Paper where Product Va given by equations below: Single Plume Values: Plume Top-Hat Radius a Used in Plume Merging Only a = 0.16(z-z_), or linear increase with height Sect 2/Eq.6 Virtual Source Height z., 0.416 meters* 1.4 feet* Sect 2/Eq.6 Height above Ground z,+h, 100.8 feet 30.718 meters Vertical Velocity V Single Plume Values: Used in Plume Merging Only Sect 2 1(6) Product (Va) 17.934 m²/s Plume Merging - Based on Single Plume Calculations where Sect.3/]]3 Begin Merging Plume Top-Hat Diameter 2a_{south} Height above Stack z_{touch} 14.940 meters 49.0 feet 2a_{touc*}=d, (or a_{touch}=d/2) $z_{totch} = z_v + d/(2^*0.16)$, meters*=meters above stack top 47.103 meters* 154.5 feet 77.405 meters Height above Ground z_{tourr}+h_s 254.0 feet Vertical Velocity Venuch $V_{totot} = \{ (Va)_o^{-3} + 0.12F_o [(z-z_v)^2 - (6.25D-z_v)^2] \}^{1/3} / a$ 2.690 m/s 8.8 ft/sec 2d(N-1)/2, (or an =d(N-1)/2) FOR 2 STACKS, 2a full=2d Total Merging Plume Top-Hat Diameter 2atur 74.700 meters 245.1 feet 28...= Height above Stack Zsa 233.853 meters* 767.2 feet* z₆ = z.+2d/(2*0.16), meters*=meters above stack top Height above Ground z_{full}+h_s 264.155 meters 866.7 feet Vertical Velocity Ved 1.164 m/s 3.8 ft/sec $V_{tul} = \{ (Va)_{o}^{3} + 0.12F_{o} [(z_{tul} - z_{v})^{2} - (6.25D - z_{v})^{2}] \}^{(1/3)} / a_{tul} \}$ 59 m⁴/s³ Product (V3a)_{but} Conditions at End (Top) of Merging Phase - Define new values for V_{hill} and a_{ha} in Merged Plume calculations (based on TOTAL number of stacks): Merged Plume Values: Plume Diameter 2a Solutions in Table Below $2a=2 \times (a_{\rm m} \pm 0.16(z{-}z_{\rm tull})),$ or linear increase with height Revised Merged Plume Radius a, 101.249 meters 332.2 feet where a_m = n^{0.25}a_{full} where Total Merging Occurs Revised Merged Plume Velocity V. and $V_m = n^{0.25} V_{sull}$ where Total Merging Occurs 3.156 m/s 10.35 ft/sec Revised Virtual Source Height ziul 233.853 meters* 767.2 feet* Height above stack where Total Merging Occurs (shown above) Solutions in Tables Below
$$\begin{split} & V{=}\{n(V^3a)_{f_0f}/a\}^{4/3} \text{ for heights above total merging elevation} \\ & V{=}V_{touch}{+}(V_{in}{-}V_{louch})^*(z{-}z_{touch})/(z_{hu}{-}z_{louch}) \end{split}$$
Revised Vertical Velocity V Multiple Plume Calculations for heights below total merging elevation Solve for plume-averaged vertical velocity at height 940.0 feet 286.512 meters above ground (z+h_s) 840.6 feet* Gives the following Height abeve Stack z 256 210 meters* REGULAR EONS Plume Top-Hat Radius a 104.826 meters 343.9 feet a=a_+0.16(z-z_{kill}) if z>z_{full} Vertical Velocity V 3.120 m/s 10.24 ft/sec $V={n(V^3a)_{full}/a}^{1/3}$ if $z>z_{full}$ V=V_{touch}+(V_m-V_{touch})⁺(z'-z_{touch})/(Z_{tull}-z_{touch}) if z_{touch}<z<z_{full} V=single plume values if z<z_{touch} Solve for Height of GASC critical vertical velocity V_{crit} Critical VV < Top of Jet 5.30 m/s BEFORE TOUCHING -Find Height above Stack z_{cril} JET meters JET feet $z_{cr1} = z_{tull} + \{[n(V^3a)_{tull}/(V_{cr1})^3] - a_m\}/0.16 \text{ If } V_{cr1} < V_m$ Height above Ground z_{out}+h_s JET meters JET feet zeri=ziouch+(ziui-ziouch)*(Veri-Viouch)/(Vri-Viouch) If Verit>Vri Table of MERGED Plume-Averaged Vertical Velocities starting at Touching Height: Single Plume Eqns (see Single Plume spreadsheet) Vert. Vptama={(Va)₀³+0.12F₃[(z-z₀)²-(6.25D-z₀)²])³⁵/a Height (feet) (meters) Plume above ground above stack Radius(m) Vel(m/s) a = 0.16(z-z..) Begin Merging (touch) = 254.0 $\theta_{p} = \theta_{s}(1 + (1 - (\theta_{e}/\theta_{s}))^{*}(V_{exil}D^{2}/(4V_{plume}^{*}a^{2*}\lambda^{2})))$ 47.12 7.470 2.69 260.0 48 95 terpolated Layer Eqns 20 ft Intervals #N/A 2 70 $V = V_{\text{touch}} + (V_m - V_{\text{touch}})^* (z' - z_{\text{touch}}) / (z_{\text{full}} - z_{\text{touch}})$ 280.0 55.04 #N/A 2.71 61 14 300.0 #N/A 2 73 350.0 76.38 #N/A 2.76 50 ft Intervals 400.0 91 62 #N/A 2 80 450.0 106.86 #N/A 2.84 500.0 122.10 #N/A 2.88 550.0 137.34 #N/A 2.92 600.0 152.58 #N/A 2.95 650.0 167.82 #N/A 2.99 #N/A 700.0 183.06 3.03 800.0 213.54 #N/A 100 ft Intervals 3 1 1 End Merging (full/mp) = 866.7 233.87 101.249 3.16 900.0 244.02 102.875 3.14 Merged Plume Eqns 1000.0 274.50 107.752 3.09 $V = \{n(V^3a)_{t,n}/a\}^{1/2}$ a=a_m+0.16(z-z_{kill}) 1100.0 304.98 112.629 3.05 1200.0 335.46 117.505 3.00 1300.0 365.94 122.382 2.96 1400.0 395 42 127.259 2 92 1500.0 426.90 132.136 2.89 2000.0 579.30 156.520 500 ft Intervals 2 73 2500.0 731.70 180,904 2.60 3000.0 884 10 205.288 2 49 3500.0 1036.50 229.672 2.40 1188.90 4000.0 254.056 2.32 4500.0 1341.30 278.440 2 25



2.19

5000.0

1493.70

302.824