APPENDIX B

COMBUSTION CHAMBER RESIDENCE TIME CALCULATIONS

RESIDENCE TIME CALCULATIONS

These calculations show the minimum gas residence time in the hot zones (afterburner chamber or ABC) of Train I. There is no regulatory limit for residence time within HWC MACT regulations, but the regulations do require calculation and reporting of the residence time in the unit. The minimum residence time in the afterburner is related to maximum stack flow (MACT parameter) and DRE, as the ABC residence time is the minimum time that hazardous constituents in the gas stream are in contact with high temperature. ABC minimum temperature is a MACT operating parameter.

Calculations are also shown for the residence that hazardous waste solids are in the kiln. While kiln residence time does not impact hazardous constituent destruction in the gas stream, (DRE), it does relate to the time that hazardous waste solids are in the kiln and the volatilization time for hazardous waste constituents to be removed from the solids so that they can be destroyed in the hot gas as it passes through the kiln and ABC.

TRAIN I - ABC

This volume is defined as the space downstream of the center plane vertically bisecting the Loddby burner in the ABC, to the plane in the exit hot duct where ABC temperature is measured. The necessary dimensions for this calculation are illustrated on facility drawing H-006-MI-001-D.

ABC: Five areas on the drawing, view from above –

1. 6.75' x 12.5' = 84.4 sq ft
2. Triangle, therefore ½ x 3.5 x 12.5 = 21.9 sq ft
3. Second triangle, same as 2 = 21.9 sq ft
4. 27.083' x 12.5' =338.5 sq ft

Total Square Feet 466.7 sq ft

Afterburner floor to ceiling is 13.5'; maximum slag buildup on floor is 1', so use 12.5' as vertical height of the ABC space

Total ABC Volume 5,834 ft^3

Hot Duct: 8.5' diameter, 41.4' equivalent length

Volume = $\pi \times (4.25)^2 \times 41.4 = 2{,}349\ ft^3$

TOTAL VOLUME for DRE = 8,183 ft^3

Train I ABC (continued)

Stack flow maximum = 48,892 dscfm less 1610 dscfm dilution air from WESP insulators, and the SCR heating system

Maximum "normal" operating temperature 2,100^{o}F

Water content, incinerator exhaust, at maximum rates = 16%

Operating pressure of –0.5 inwc does not materially change gas density

Hot duct exit flow = (48,892 – 1610) x (100/(100-16)) x (2,100+460)/520 =

= 277,111 acfm = 4,619 acfs

Residence time at this flow rate = 8,183 ft^3 / 4,619 acfs = 1.77 sec

The stack flow rate of 48,892 dscfm is the 2006 CPT demonstrated maximum hourly rolling average stack flow rate, based on the average of the three runs.

The 2006 CPT demonstrated DRE >99.9999% and low dioxin/furans at this maximum hourly rolling average stack flow of 48,892 dscfm.

The 2021 CPT demonstrated low dioxin/furans at a stack flow rate of 48,634 dscfm, which yields a residence time of 1.81 seconds.

TRAIN I 3.6 METER KILN CLEAN HARBORS DEER PARK

Kiln Flow Model

Solids Residence Time Formula:
T = (1.77 *(A^0.5)*L*FACTOR)/(S*D*N)

Parameter	Definition
A	= Angle of repose of material (degrees)
L	= Length of shell (feet or meters)
FACTOR	= Dimensionless factor = 1.0 for single diameter rotary kilns
D	= Inside shell diameter (feet or meters)
S	= Slope of shell (degrees)
N	= Shell speed (rpm)
T	**= Retention time of solids (minutes)**

Reference:
Allis Mineral Systems Solids Flow Model
Kilns - Flow of Materials
Allis Chalmers Technical Bulletin 22b 1212-2
Perry's Chemical Engineers Handbook

Table 1. Slope Conversion

Slope (in/ft)	Slope (%)	S (Degrees)
1/8"	1.00%	0.596
3/16"	1.60%	0.895
1/4"	2.10%	1.192
5/16"	2.60%	1.491
3/8"	3.10%	1.79
7/16"	3.60%	2.087
1/2"	4.20%	2.385
9/16"	4.70%	2.684
5/8"	5.20%	2.98

Slope to Degree Formula:
Degrees = ATAN(in/ft) * 180/Π

Calculation for Train I 3.6 Meter Kiln

Net Inside Daimeter (feet)	9.67
Kiln Length (feet)	32.78
Kiln Slope (Percent)	4.00
Kiln Slope (Degrees)	2.29

Parameter	Definition	Input Values	Calculated Values	Example Value
A	= Angle of repose of material (degrees)	10.0		
L	= Length of shell (feet)	32.8		
FACTOR	= Dimensionless factor	1.00		1.0 for single diameter rotary kilns
D	= Inside shell diameter (feet)	9.67		Inside diameter with new refractory
S	= Slope of shell (degrees)	2.291		0.596-2.98 See Table 1
N	= Shell speed (rpm)	0.20		Variable
Fill	= Fill fraction	0.060		0.060-0.125 for rotary kilns
T	**= Retention time of solids (minutes)**		41	

Retention Time at Various Rotational Speeds

RPM	Minutes
0.15	55
0.20	41
0.25	33
0.30	28
0.35	24
0.40	21
0.45	18
0.50	17

T = (1.77 *(A^0.5)*L*FACTOR)/(S*D*N)