APPENDIX G
COOLING TOWER EMISSION CALCULATIONS

Cooling Tower Emission Calculations

At the request of the BAAQMD, each refinery submitted information on their facilities cooling towers. In the calculations to determine compliance with BAAQMD Regulation 6, Regulation 8-2, and the Code of Federal Regulations (CFR) for Miscellaneous Process Vents (40 CFR, Subpart CC), only the cooling tower circulating water flow rates and exhaust airflow rates are used. Although the refineries may have supplied additional information, such as drift and total dissolved solids (TDS), EPA AP-42 Compilation of Air Pollution Emission Factors were used to calculate conservative emissions of PM10 and POC. Emission factors from EPA AP-42 Chapter 13.4 Wet Cooling Towers and Chapter 5.1 Petroleum Refining were used as described below.

PM10 Calculations

AP-42 Table 13.4-1 contains the emission factor of 0.019 lb PM10 per 1000 gallons of circulating water for induced draft cooling towers. Assuming the cooling tower operates continuously (24 hours per day, 365 days per year), the annual emission of PM10 is calculated by multiplying the circulating water flow rate by the emission factor. Before determining the grain loading of PM10 in the exhaust air, the reported or actual flow rate must be converted to a dry standard basis at a temperature of 70 degrees F, a pressure of one atmosphere, and no moisture. Since the cooling tower vents to the atmosphere, standard temperature and pressure were assumed. To determine the water content in the exhaust, the drift (water droplets) is calculated by using the emission factor 0.02% gallons of drift per gallon of circulating water (AP-42 Table 13.4-1). The amount of water in the exhaust or drift is divided by the actual total flow rate to determine the volume faction of water in the exhaust. The actual flow rate (acfm) is then converted to the dry standard airflow rate (dscfm). Since the exhaust flow rates are very large, the volume fraction of water is negligible.

dscfm = acfm x (460 R + 70 F)/(460 R + temp in F) x (actual P/ 14.7 psi) x (1- volumetric fraction of water vapor)

dscfm = dry cubic feet per minute at standard conditions (14.7 psi and 70 degrees F)
acfm = actual cubic feet per minute
R = temperature (degrees Rankine)
F = temperature (degrees Fahrenheit) = 70 F
P = pressure (psi) = 14.7 psi

Grain loading is calculated by dividing the PM10 (lb/min) by the exhaust flow rate (dscfm). The data for the grain loading (gr/dscfm) for the refineries show that the highest loading is 0.0067, which is well below the limit of 0.15 dscfm of Regulation 6. Since the conservative estimate of the grain loading is well below the limit, monitoring is not required.

POC Calculations

AP-42 Table 5.1-2 contains the emission factor of 6 lb POC per 1,000,000 gallons of circulating water. This emission factor is very conservative since it is used for 'uncontrolled' emissions. (The controlled emission factor is 0.7 lb of POC per 1,000,000 gallons of circulating water.) Again, assuming the cooling tower operates continuously (24 hours per day, 365 days per year), the annual emission of POC is calculated by multiplying the circulating water flow rate by the emission factor. To convert pounds of POC to volume of POC, the ideal gas law is used.

V = nRT/P

V = volume (cubic feet = ft3)
R = 0.73 atm*ft3/lb-mole*R
T = (460 + temp in F) = (460 + 70)
P = pressure (atm) = 1 atm
n = lb-moles = pounds of POC/12 lb per lb-mole of carbon

A conservative calculation of lb-moles of POC is obtained by dividing the pounds of POC by 12 lb per lb-mole of carbon. Individual organic species will have a higher molecular weight, thereby increasing the denominator and decreasing the POC emission. To obtain POC emissions in the exhaust, the volume of POC is divided by the airflow. The actual airflow (acfm) is converted to dry standard airflow (dscfm) as described in the PM10 emission calculation. From the refinery data, the maximum concentration of POC is 9.67 ppm, which is much lower than the limit of 300 ppm in Regulation 8, Rule 2. Since the conservative calculation of the POC concentration in the cooling tower is much lower than the limit of 300 ppm, monitoring is not required.

40 CFR, Subpart CC, defines a Miscellaneous Process Vent as a gas stream that contains greater than 20 ppm by volume organic HAP that is continuously or periodically discharged during normal operation. As shown in the refinery data, if the POC emission consists of a single HAP, the maximum concentration is less than 10 ppm. The cooling tower exhaust does not qualify as a process vent and 40 CFR, Subpart CC does not apply to cooling towers.

Cooling Tower PM10 and Regulation 6

Plant Data			ACFM to DSCFM conversion				PM-10 Calculations					
Plant & Source Number	Circulation Rate (gpm)	Air Flow (acfm)	Induced Draft* 0.02% circ rate (gal/min drift)	drift rate (ft3/min)	Vol fraction of water in air flow	Air Flow (dscfm)	PM10 emission factor* (lb/1E3gal)	PM10 (lb/yr)	PM10 (tons/yr)	PM10 (gr/min)	grain loading (gr/dscf)	**Reg 6 limit (gr/dscf)**
Chevron												
4173	58000	5350100	11.6	1.5506	2.90E-07	5350098	0.019	579211.20	289.61	7714.00	0.0014	<0.15
4191	5400	110300	1.08	0.1444	1.31E-06	110299.9	0.019	53926.56	26.96	718.20	0.0065	<0.15
4329	19500	2106800	3.9	0.5213	2.47E-07	2106799	0.019	194734.80	97.37	2593.50	0.0012	<0.15
Phillips												
110	750	77500	0.15	0.0201	2.59E-07	77499.98	0.019	7489.80	3.74	99.75	0.0013	<0.15
200	1150	118800	0.23	0.0307	2.59E-07	118800	0.019	11484.36	5.74	152.95	0.0013	<0.15
228	2500	258100	0.5	0.0668	2.59E-07	258099.9	0.019	24966.00	12.48	332.50	0.0013	<0.15
230	9500	190000	1.9	0.2540	1.34E-06	189999.7	0.019	94870.80	47.44	1263.50	0.0067	<0.15
236	9300	927000	1.86	0.2486	2.68E-07	926999.8	0.019	92873.52	46.44	1236.90	0.0013	<0.15
238	9300	927000	1.86	0.2486	2.68E-07	926999.8	0.019	92873.52	46.44	1236.90	0.0013	<0.15
240	30000	3096600	6	0.8020	2.59E-07	3096599	0.019	299592.00	149.80	3990.00	0.0013	<0.15
Tesoro												
975	69000	5200000	13.8	1.8447	3.55E-07	5199998	0.019	689061.60	344.53	9177.00	0.0018	<0.15
976	75000	5000000	15	2.0051	4.01E-07	4999998	0.019	748980.00	374.49	9975.00	0.0020	<0.15
977	22000	1120000	4.4	0.5882	5.25E-07	1119999	0.019	219700.80	109.85	2926.00	0.0026	<0.15
978	4100	500000	0.82	0.1096	2.19E-07	499999.9	0.019	40944.24	20.47	545.30	0.0011	<0.15
979	15000	800000	3	0.4010	5.01E-07	799999.6	0.019	149796.00	74.90	1995.00	0.0025	<0.15
980	12000	1251000	2.4	0.3208	2.56E-07	1251000	0.019	119836.80	59.92	1596.00	0.0013	<0.15
981	14000	1410000	2.8	0.3743	2.65E-07	1410000	0.019	139809.60	69.90	1862.00	0.0013	<0.15
982	18000	1920000	3.6	0.4812	2.51E-07	1920000	0.019	179755.20	89.88	2394.00	0.0012	<0.15
983	64800	3150000	12.96	1.7324	5.50E-07	3149998	0.019	647118.72	323.56	8618.40	0.0027	<0.15
985	16000	600000	3.2	0.4278	7.13E-07	599999.6	0.019	159782.40	79.89	2128.00	0.0035	<0.15
987	15000	1350000	3	0.4010	2.97E-07	1350000	0.019	149796.00	74.90	1995.00	0.0015	<0.15
988	10000	727739	2	0.2673	3.67E-07	727738.7	0.019	99864.00	49.93	1330.00	0.0018	<0.15
Shell												
TBD	2200	164140	0.44	0.0588	3.58E-07	164139.9	0.019	21970.08	10.99	292.60	0.0018	<0.15
1456	410	30590	0.082	0.0110	3.58E-07	30589.99	0.019	4094.42	2.05	54.53	0.0018	<0.15
1457	87000	2467777	17.4	2.3259	9.43E-07	2467775	0.019	868816.80	434.41	11571.00	0.0047	<0.15
1259	3500	261131	0.7	0.0936	3.58E-07	261130.9	0.019	34952.40	17.48	465.50	0.0018	<0.15
1460	3400	253670	0.68	0.0909	3.58E-07	253669.9	0.019	33953.76	16.98	452.20	0.0018	<0.15
1778	36000	4200224	7.2	0.9624	2.29E-07	4200223	0.019	359510.40	179.76	4788.00	0.0011	<0.15
4210	20000	1492178	4	0.5347	3.58E-07	1492177	0.019	199728.00	99.86	2660.00	0.0018	<0.15
Valero												
29	59400	9500000	11.88	1.5880	1.67E-07	9499998	0.019	593192.16	296.60	7900.20	0.0008	<0.15
*EPA AP-42 Table 13.4-1												

Cooling Tower PM10 and Regulation 6

	Plant Data			ACFM to DSCFM conversion				PM-10 Calculations					
	Plant & Source Number	Circulation Rate (gpm)	Air Flow (acfm)	Induced Draft* 0.02% circ rate (gal/min drift)	drift rate (ft3/min)	Vol fraction of water in air flow	Air Flow (dscfm)	PM10 emission factor* (lb/1E3gal)	PM10 (lb/yr)	PM10 (tons/yr)	PM10 (gr/min)	grain loading (gr/dscf)	**Reg limit (gr/ds**
	Chevron												
FCC	4173	58000	5350100	11.60	1.5506	2.90E-07	5350098	0.019	579211.20	289.61	7714.00	0.0014	<0.1
SRU	4191	5400	110300	1.08	0.1444	1.31E-06	110299.9	0.019	53926.56	26.96	718.20	0.0065	<0.1
RLOP	4329	19500	2106800	3.90	0.5213	2.47E-07	2106799	0.019	194734.80	97.37	2593.50	0.0012	<0.1
2Dewax	S-6054	2500	330000	0.50	0.0668	2.03E-07	329999.9	0.019	24966.00	12.48	332.50	0.0010	<0.1
2WDO	S-6055	2500	330000	0.50	0.0668	2.03E-07	329999.9	0.019	24966.00	12.48	332.50	0.0010	<0.1
MTBE	S-6051	23472	1000000	4.69	0.6275	6.28E-07	999999.4	0.019	234400.78	117.20	3121.78	0.0031	<0.1
D&R	S-4073	25694	1155000	5.14	0.6869	5.95E-07	1154999	0.019	256590.56	128.30	3417.30	0.0030	<0.1
3Cat	S-4076	29166	1156000	5.83	0.7797	6.75E-07	1155999	0.019	291263.34	145.63	3879.08	0.0034	<0.1
WRR***	S-4078	2166	xxx	0.43	0.0579	#VALUE!	#VALUE!	0.019	21630.54	10.82	288.08	#VALUE!	<0.1
Isomax	S-4172	70833	7680000	14.17	1.8937	2.47E-07	7679998	0.019	707366.67	353.68	9420.79	0.0012	<0.1
Fcc Poly	S-4187	4861	329000	0.97	0.1300	3.95E-07	328999.9	0.019	48543.89	24.27	646.51	0.0020	<0.1

Cooling Tower POC and Regulation 8-2

	Plant Data			ACFM to DSCFM conversion				POC Calcuations						
	Plant & Source Number	Circulation Rate (gpm)	Air Flow (acfm)	Induced Draft* 0.02% circ rate (gal/min drift)	drift rate (ft3/min)	Vol fraction of water in air flow	Air Flow (dscfm)	POC emission factor (lb/1E6gal)	POC (lb/min)	POC (lb/day)	POC (tons/yr)	POC (ft3/min)	POC (ppm)	**Reg 8-2 limit (ppm)**
	Chevron													
FCC	4173	58000	5350100	11.60	1.5506	2.90E-07	5350098	6	0.3480	501.12	91.45	11.22	2.10	<300
SRU	4191	5400	110300	1.08	0.1444	1.31E-06	110300	6	0.0324	46.66	8.51	1.04	9.47	<300
RLOP	4329	19500	2106800	3.90	0.5213	2.47E-07	2106799	6	0.1170	168.48	30.75	3.77	1.79	<300
2Dewax	S-6054	2500	330000	0.50	0.0668	2.03E-07	330000	6	0.0150	21.60	3.94	0.48	1.47	<300

2 WDO	S-6055	2500	330000	0.50	0.0668	2.03E-07	330000	6	0.0150	21.60	3.94	0.48	1.47	<300
MTBE	S-6051	23472	1000000	4.69	0.6275	6.28E-07	999999	6	0.1408	202.80	37.01	4.54	4.54	<300
D&R	S-4073	25694	1155000	5.14	0.6869	5.95E-07	1154999	6	0.1542	222.00	40.51	4.97	4.30	<300
3Cat	S-4076	29166	1156000	5.83	0.7797	6.75E-07	1155999	6	0.1750	251.99	45.99	5.64	4.88	<300
WRR***	S-4078	2166	xx	0.43	0.0579	#VALUE!	#VALUE!	6	0.0130	18.71	3.42	0.42	#VALUE!	<300
Isomax	S-4172	70833	7680000	14.17	1.8937	2.47E-07	7679998	6	0.4250	612.00	111.69	13.70	1.78	<300
Fcc Poly	S-4187	4861	329000	0.97	0.1300	3.95E-07	329000	6	0.0292	42.00	7.66	0.94	2.86	<300

*EPA AP-42 Table 13.4-1
**EPA AP-42 Table 5.1-2

***Emissions data for the Wax Rerun cooling tower (S-4078) is not included because the source no longer operates, and the entire Wax unit is shut down. Due to this it was not possible to find the records and process data in the amount of time allowed.

Emissions Calculations for S-6054, S-6055, S-6051

The permit limits on these cooling water towers is based on emission calculations included in the Permit Applications (Permit Apps 11925, 12159,and 16822 respectively). These calculations were also used as the basis for offsets during permitting.

The POC calculations completed for the purpose of understanding Reg 8 Rule 2 compliance was based on a conservative 'uncontrolled' tower, therefore using the emission factor of 6 lb POC per 1,000,000 gallons of circulating water. For the purpose of permitting, and the ensuing conditions established, these cooling water tower emissions were calculated using the controlled factor as representative of these installations. Therefore the emission factor of 0.7 lb POC per 1,000,000 gallons of circulating water was used. Additionally more accurate drift loss factors were used, in these cases 0.005% of circulation rate (versus the 0.02% in the uncontrolled model).

Calculations:

S-6054

- Circulation rate – 2500 gpm
- Drift Loss - 0.005% of circulation rate
- Emission Factor – 0.7 lb POC/ 1,000,000 gal circulation

POC: 2500 gal/min * 0.7 lb/1,000,000 gal = 1.75×10^{-3} lb/min

1.75×10^{-3} lb/min * 60 min/hr * 24 hr/day = **2.52 lb/day**

S-6055

- Circulation rate – 2500 gpm
- Drift Loss - 0.005% of circulation rate
- Emission Factor – 0.7 lb POC/ 1,000,000 gal circulation

POC: 2500 gal/min * 0.7 lb/1,000,000 gal = 1.75×10^{-3} lb/min

1.75×10^{-3} lb/min * 60 min/hr * 24 hr/day = **2.52 lb/day**

S-6015

- Circulation rate – 23,500 gpm
- Drift Loss - 0.005% of circulation rate
- Emission Factor – 0.7 lb POC/ 1,000,000 gal circulation

POC: 23,500 gal/min * 0.7 lb/1,000,000 gal = 1.65×10^{-2} lb/min

1.65×10^{-2} lb/min * 60 min/hr * 24 hr/day = **23.69 lb/day**

					Cooling Tower POC and Regulation 8-2								
Plant Data			ACFM to DSCFM conversion				POC Calcuations						
Plant & Source Number	Circulation Rate (gpm)	Air Flow (acfm)	Induced Draft* 0.02% circ rate (gal/min drift)	drift rate (ft3/min)	Vol fraction of water in air flow	Air Flow (dscfm)	POC emission factor (lb/1E6gal)	POC (lb/min)	POC (lb/day)	POC (tons/yr)	POC (ft3/min)	POC (ppm)	**Reg 8-2 limit (ppm)**
Chevron													
4173	58000	5350100	11.60	1.5506	2.90E-07	5350098	6	0.3480	501.12	91.45	11.22	2.10	<300
4191	5400	110300	1.08	0.1444	1.31E-06	110300	6	0.0324	46.66	8.51	1.04	9.47	<300
4329	19500	2106800	3.90	0.5213	2.47E-07	2106799	6	0.1170	168.48	30.75	3.77	1.79	<300
Phillips													
110	750	77500	0.15	0.0201	2.59E-07	77500	6	0.0045	6.48	1.18	0.15	1.87	<300
200	1150	118800	0.23	0.0307	2.59E-07	118800	6	0.0069	9.94	1.81	0.22	1.87	<300
228	2500	258100	0.50	0.0668	2.59E-07	258100	6	0.0150	21.60	3.94	0.48	1.87	<300
230	9500	190000	1.90	0.2540	1.34E-06	190000	6	0.0570	82.08	14.98	1.84	9.67	<300
236	9300	927000	1.86	0.2486	2.68E-07	927000	6	0.0558	80.35	14.66	1.80	1.94	<300
238	9300	927000	1.86	0.2486	2.68E-07	927000	6	0.0558	80.35	14.66	1.80	1.94	<300
240	30000	3096600	6.00	0.8020	2.59E-07	3096599	6	0.1800	259.20	47.30	5.80	1.87	<300
Tesoro													
975	69000	5200000	13.80	1.8447	3.55E-07	5199998	6	0.4140	596.16	108.80	13.35	2.57	<300
976	75000	5000000	15.00	2.0051	4.01E-07	4999998	6	0.4500	648.00	118.26	14.51	2.90	<300
977	22000	1120000	4.40	0.5882	5.25E-07	1119999	6	0.1320	190.08	34.69	4.26	3.80	<300
978	4100	500000	0.82	0.1096	2.19E-07	500000	6	0.0246	35.42	6.46	0.79	1.59	<300
979	15000	800000	3.00	0.4010	5.01E-07	800000	6	0.0900	129.60	23.65	2.90	3.63	<300
980	12000	1251000	2.40	0.3208	2.56E-07	1251000	6	0.0720	103.68	18.92	2.32	1.86	<300
981	14000	1410000	2.80	0.3743	2.65E-07	1410000	6	0.0840	120.96	22.08	2.71	1.92	<300
982	18000	1920000	3.60	0.4812	2.51E-07	1920000	6	0.1080	155.52	28.38	3.48	1.81	<300
983	64800	3150000	12.96	1.7324	5.50E-07	3149998	6	0.3888	559.87	102.18	12.54	3.98	<300
985	16000	600000	3.20	0.4278	7.13E-07	600000	6	0.0960	138.24	25.23	3.10	5.16	<300
987	15000	1350000	3.00	0.4010	2.97E-07	1350000	6	0.0900	129.60	23.65	2.90	2.15	<300
988	10000	727739	2.00	0.2673	3.67E-07	727739	6	0.0600	86.40	15.77	1.93	2.66	<300
Shell													
TBD	2200	164140	0.44	0.0588	3.58E-07	164140	6	0.0132	19.01	3.47	0.43	2.59	<300
1456	410	30590	0.08	0.0110	3.58E-07	30590	6	0.0025	3.54	0.65	0.08	2.59	<300
1457	87000	2467777	17.40	2.3259	9.43E-07	2467775	6	0.5220	751.68	137.18	16.83	6.82	<300
1259	3500	261131	0.70	0.0936	3.58E-07	261131	6	0.0210	30.24	5.52	0.68	2.59	<300
1460	3400	253670	0.68	0.0909	3.58E-07	253670	6	0.0204	29.38	5.36	0.66	2.59	<300
1778	36000	4200224	7.20	0.9624	2.29E-07	4200223	6	0.2160	311.04	56.76	6.96	1.66	<300
4210	20000	1492178	4.00	0.5347	3.58E-07	1492177	6	0.1200	172.80	31.54	3.87	2.59	<300
Valero													
29	59400	9500000	11.88	1.5880	1.67E-07	9499998	6	0.3564	513.22	93.66	11.49	1.21	<300
*EPA AP-42 Table 13.4-1													
**EPA AP-42 Table 5.1-2													