Appendix 4: Cooling Tower Hydrocarbon Emissions Estimates

Objective:

Calculate potential impacts on ROG emissions and associated cost impacts (i.e. cost effectiveness) for the draft amendments to Rule 11-10.

- Estimated emissions and emissions impacts of draft amendments to Rule 11-10 require a probabilistic assessment of future heat exchange leaks into cooling water systems, as the occurrence of leaks is speculative due to their variable nature. In addition, draft amendments to Rule 11-10 include further monitoring period extensions if the cooling tower demonstrates consistently that it has no leaking heat exchangers. This provision complicates the probabilistic assessment, because the timing of a future leak can impact the number of weeks monitored at a normal frequency and the number of weeks monitored at an extended frequency.
- Estimate impacts on emissions for more frequent monitoring. Maximum Achievable Control Technology (EPA 40 CFR 63.654) study estimated emissions for no monitoring, annual, quarterly, and monthly monitoring.
- Three different approaches are used to estimate average annual emissions (via emission factors) for monthly, twice-monthly, weekly and daily monitoring.

In addition, the current Rule 11-10 requires quicker response to cooling tower leaks than the MACT required by limiting repair time to 21 days, rather than 45 days as provided in the MACT analysis. Estimated emissions are adjusted to include this difference in repair periods, as described below.

Basis for Estimated Emission Reductions – Current Rule 11-10 (as adopted):

Estimated emission reductions included in the Staff Report for Rule 11-10 as adopted in December 2015 were based on MACT-defined Emission Factors (EF):

- No monitoring EF = 6.0 lb ROG/Million gallons water circulation
- Monthly monitoring EF = 0.7 lb ROG/Million gallons water circulation

During the Rule 11-10 rule development process, staff used the MACT emission factor of 6.0 lb ROG per million gallons of circulating water for the "no monitoring" base case, and the improved emission factor of 0.7 lb ROG per million gallons of circulating water for the "active monitoring" case to estimate emission reductions. This approach resulted in emission estimates as follows:

Baseline emissions = 978 tpy Final estimated emissions = 117 tpy
Emission reductions = 978 X (6.0 – 0.7)/6.0 = 978 X 0.88 = 861 tpy

Note that the MACT emission factor used for the "active monitoring" case represents a monthly monitoring schedule. Rule 11-10 (as adopted) requires daily monitoring, however, staff did not estimate any further reduction in emissions from monitoring more frequently than monthly. Rule

11-10 also requires that leaks be repaired within 21 days, which is a shorter repair period than that required by the MACT (45 days); staff also did not estimate any further reduction in emissions from this shorter repair period of 21 days.

Updated Estimate of Emission Reductions – Current Rule 11-10 (as adopted):

Staff has identified appropriate emission factors for weekly and daily monitoring to update the estimates of emission reductions associated with Rule 11-10 (as adopted).

These emission factors are based on information provided by EPA's staff work during development of the MACT, as described above. Air District staff used three different methods to extrapolate emission factors from monthly to more frequent monitoring periods:

1. Method 1: Use the "no monitoring" EF (6.0 lb ROG/M gallons of cooling tower recirculating water) and "monthly monitoring" EF (0.7 lb ROG/M gallons) to back calculate the likely leak magnitude and frequency of a "typical" cooling tower.
2. Method 2: Extrapolate directly (linear extrapolation) from the "no monitoring" EF through "monthly monitoring" EF to derive EFs for twice-monthly, weekly, and daily monitoring.
3. Method 3: Extrapolate directly (linear extrapolation) from the EFs for annual, quarterly, and monthly monitoring periods. The staff report supporting the MACT development from RTI International to EPA provided leak rate and emission reduction estimates for annual, quarterly, and monthly monitoring periods. This information provided the basis for extrapolating estimated emission factors for twice-monthly, weekly, and daily monitoring.

Staff used all three of these methods to develop estimated emission factors for more frequent monitoring. These methods are documented at the end of this appendix. Staff also developed an EF adjustment to account for the reduced repair period from 45 days to 21 days, resulting in a consistent reduction in emission factor of 0.207 lb/M gallons for all three methods used to estimate emission factors. This adjustment is shown in the calculations for Method 1 Emission Factors at the end of this appendix.

Table 4-1 shows the summary of estimated emission factors:

Table 4-1: Estimated Emission Factors for other monitoring periods:

Monitoring Period (days)	Repair Period (days)	MACT Emission Factors (lb/M gal)	Method 1 Emission Factors (lb/M gal)	Method 2 Emission Factors (lb/M gal)	Method 3 Emission Factors (lb/M gal)
None	45	6.0			
30	45	0.7	0.7	0.7	0.7
15	45		0.577	0.655	0.692
7	45		0.511	0.631	0.688
1	45		0.462	0.613	0.684
30	21		0.493	0.493	0.493
15	21		0.370	0.448	0.485
7	21		0.304	0.424	0.481
1	21		0.255	0.406	0.477

Updated estimates of emissions and emission reductions from Rule 11-10 (as adopted) depend on the emission factors used for weekly and daily monitoring.

Current Rule 11-10 requires cooling tower monitoring as follows:

< 500 gpm cooling towers: monitor every other week

< 2,500 gpm cooling towers: monitor weekly

> 2,500 gpm cooling towers: monitor continuously, or daily

Applying the emission factors shown in Table 4-1 to the population of cooling towers in the Bay Area, updated estimates of the emissions and emission reductions from Rule 11-10 (as adopted) were calculated and are shown in Table 4-2. As shown, estimates of emission reductions from current Rule 11-10 range from 861 tons per year to 930 tons per year.

Table 4-2: Updated Estimated Emissions and Emission Reductions – Current Rule 11-10 (as adopted):

Estimated Emissions Impact	Baseline Emissions (tpy)	MACT Emission Factors (tpy)	Method 1 Emission Factors (tpy)	Method 2 Emission Factors (tpy)	Method 3 Emission Factors (tpy)
Baseline Emissions	978	-	-	-	-
Controlled Emissions (Current Rule 11-10 – as adopted)		117	48	76	90
Emission Reductions		861	930	902	888

Estimated Emission Impacts Associated with Draft Amendments to Rule 11-10:

Estimated emission impacts associated with the draft amendments to Rule 11-10 also depend on the emission factors used for twice-monthly, weekly, and daily monitoring.

Draft amendments to Rule 11-10 require cooling tower monitoring as follows:

< 500 gpm cooling towers: monitor weekly, monthly after 4 successful weekly samples

< 2,500 gpm cooling towers: monitor weekly, monthly after 4 successful weekly samples

> 2,500 gpm cooling towers: monitor weekly, twice-monthly after 26 successful weekly samples

Estimated annual average emission factors are based on the following monitoring schedule assumptions for base monitoring and extended monitoring frequencies:

< 500 gpm cooling towers:

- 6 weeks of weekly monitoring
- 46 weeks of monthly monitoring

< 2,500 gpm cooling towers:

- 6 weeks of weekly monitoring
- 46 weeks of monthly monitoring

> 2,500 gpm cooling towers:

- 27 weeks of weekly monitoring
- 25 weeks of twice-monthly monitoring

Applying the emission factors shown in Table 4-1 to the population of cooling towers in the Bay Area, estimates of the emissions and emission impacts from the draft amendments to Rule 11-10 were calculated and are shown in Table 4-3.

Table 4-3: Estimated Emissions and Emission Reductions – Draft Amendments to Rule 11-10:

Estimated Emissions Impact	Baseline Emissions (tpy)	MACT Emission Factors (tpy)	Method 1 Emission Factors (tpy)	Method 2 Emission Factors (tpy)	Method 3 Emission Factors (tpy)
Baseline Emissions					
Baseline Emissions	978	-	-	-	-
Current Rule 11-10 (as adopted)					
Controlled Emissions		117	48	76	90
Emission Reductions		861	930	902	888
Costs		$2,187,350	$2,187,350	$2,187,350	$2,187,350
Draft Amendments to Rule 11-10					
Controlled Emissions			64	82	91
Emission Reductions			-16	-6	-1
Costs			$506,600	$506,600	$506,600
Cost Impacts[1]			-$1,680,750	-$1,680,750	-$1,680,750
Cost Effectiveness			$110,000	$300,000	$1,600,000

Notes:
[1] Cost impacts that are negative represent a cost savings due to reduced monitoring (as compared to monitoring required by current Rule 11-10).

Potential Foregone Emission Reductions:

Staff used three methods to define the range of sensitivity cases to estimate emissions impacts and costs impacts. Reduced frequency of monitoring cooling towers can theoretically allow an increase in ROG emissions (i.e. foregone emission reductions). Using the three methods, estimates of foregone emission reductions range from 1 ton per year to 16 tons per year, with the greatest impact on emissions estimated using Emission Factors from Method 1.

Staff also calculated the cost effectiveness of the draft amendments using the three methods. Using the foregone emission reduction estimates and the estimated cost savings of $1,680,750 from reduced monitoring associated with the draft amendments, estimates of cost effectiveness ranged from $110,000 to $1.6 million dollars of savings per ton of theoretical foregone emission reductions. Since the range of cost effectiveness savings are significant and beyond normal cost effectiveness thresholds, the draft amendments to Rule 11-10 are supported by the cost-benefits analysis.

Alternatives for draft amendments to Rule 11-10 – estimated impacts on emissions and costs:

Alternatives:

1. Do not extend monitoring period from weekly to monthly after 4 weeks below the leak threshold for cooling towers smaller than 2,500 gpm
2. Do not extend monitoring period from weekly to twice-monthly after 26 weeks below the leak threshold for cooling towers larger than 2,500 gpm

Table 4-4: Estimated Emissions and Emission Reductions – Alternatives to Draft Amendments to Rule 11-10:

Estimated Emissions Impact	Method 1 Emission Factors (tpy)	Method 2 Emission Factors (tpy)	Method 3 Emission Factors (tpy)
Draft Amendments to Rule 11-10			
Controlled Emissions	64	82	91
Costs	$506,600	$506,600	$506,600
Alternate 1: No extension of monitoring period for CWT < 2,500 gpm			
Controlled Emissions	63.5	81.8	90.9
Emission Reductions	0.5	0.2	0.1
Costs	$558,350	$558,350	$558,350
Cost Impacts	$51,750	$51,750	$51,750
Cost Effectiveness	$100,000	$250,000	$500,000+
Alternate 2: No extension of monitoring period for CWT > 2,500 gpm			
Controlled Emissions	57.9	79.7	90.6
Emission Reductions	6.1	2.3	0.4
Costs	$569,100	$569,100	$569,100
Cost Impacts	$62,500	$62,500	$62,500
Cost Effectiveness	$10,200	$27,200	$156,000

Alternatives to extending monitoring period:

Extending the monitoring period is appropriate for the small (< 2,500 gpm) cooling towers. Eliminating the extension of the monitoring period from weekly to monthly results in an emission reduction estimated to be 0.1 – 0.5 tons per year, but increases monitoring costs by $51,750 annually. Cost effectiveness for eliminating the extension of the monitoring period ranges from $100,000 - $500,000 per ton of emission reductions, and it not justified.

Eliminating the extension of the monitoring period for large (> 2,500 gpm) cooling towers from weekly to twice monthly is less clear. Eliminating the extension of the monitoring period from weekly to twice-monthly for roughly half of each year results in an emission reduction estimated to be 0.4 – 6.1 tons per year but increases monitoring costs by $62,500 annually. Cost effectiveness for eliminating the extension of the monitoring period ranges from:

- $10,200 per ton of foregone emission reductions when using Estimated Emission Factors 1,
- $27,200 per ton of foregone emission reductions when using Estimated Emission Factors 2, and
- $156,000 per ton of foregone emission reductions when using Estimated Emission Factors 3.

Staff used three methods to define the range of sensitivity cases to estimate emissions impacts, and costs impacts. The greatest impact on costs is identified using Estimated Emission Factors 3. Based on the highest cost impact of $156,000 per ton of emission reductions, eliminating the extension of the monitoring period is not justified.

Method 1 Emission Factors:

Assume no more than 1 leak into each cooling tower each year (reasonable assumption)

Use MACT basis (above) to extrapolate emission factors for more frequent monitoring:

- X days leaking each year before leak discovered by other factors
- 365-X days not leaking
- (6.0 x X days) + ((365-X) x 0) = 365 x 0.7
- X = 42.6 days leaking each year

Monitoring period = 30 days.

- On average, will detect leak on 15th day, confirm with sample on 16th day.
- 16 days to identify leak: 42.6 – 16 = 26.6 days to repair leak (59% of 45-day repair period provided in MACT requirements)

Method 1 Emission Factors:

Monitoring Period days	Average time to ID leak days	Time for lab analysis days	Repair time days	Total Leak period days	Emission Factor lb/M gal.
None					6.0
30	15	1	26.6	42.6	0.7
15	7.5	1	26.6	35.1	0.577
7	3.5	1	26.6	31.1	0.511
1	0.5	1	26.6	28.1	0.462

However, Rule 11-10 included a 21-day repair period, or must notify APCO

- Estimated average repair time = 14 days (67% of repair period provided, slightly more than 59% of the 45-day repair period in the MACT because the timeframe is shorter)

Method 1 Emission Factors with 21-day repair period:

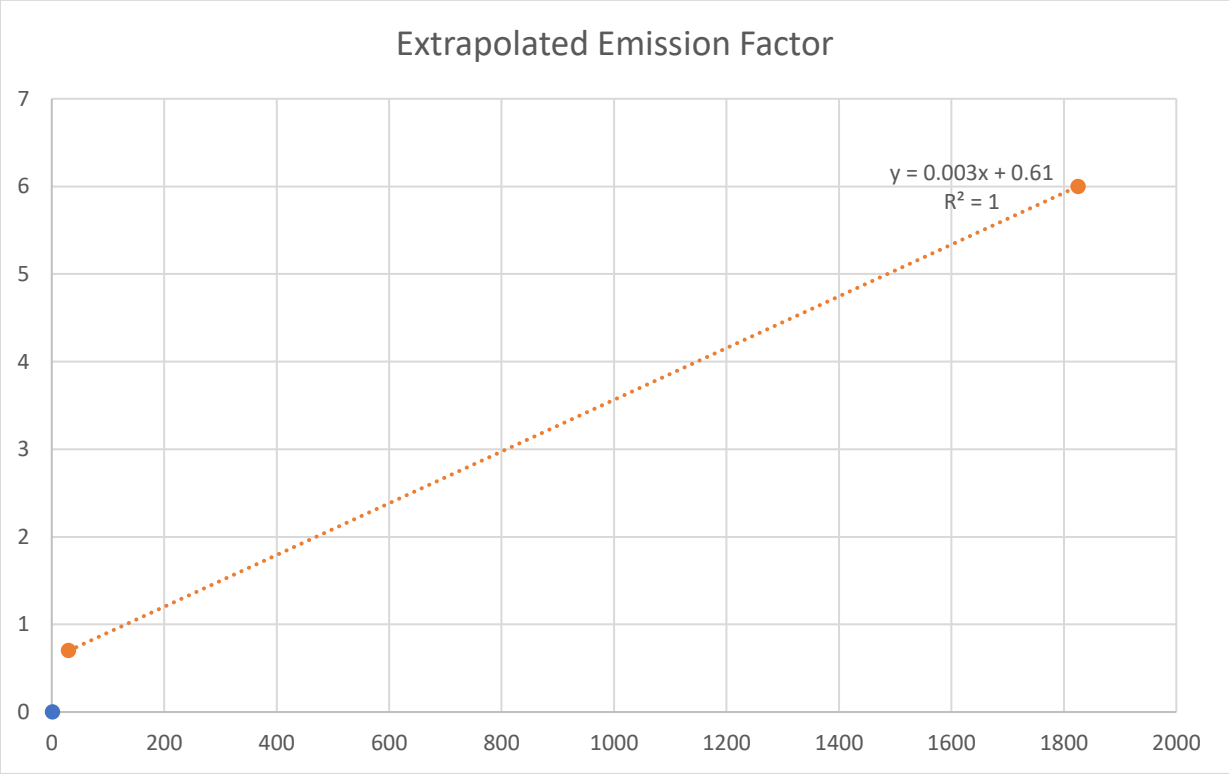
Monitoring Period days	Average time to ID leak days	Time for lab analysis days	Repair time days	Total Leak period days	Emission Factor lb/M gal.
30	15	1	14	30	0.493
15	7.5	1	14	22.5	0.370
7	3.5	1	14	18.5	0.304
1	0.5	1	14	15.5	0.255

Note – 21-day repair (14-day repair time) requirement reduces EF by 0.207 #/M gallons across all monitoring periods.

Method 2 Emission Factors:

Second Extrapolation of CWT emissions factors:

EF = 6.0 #/MM gallons with no monitoring, 0.7 #/MM gallons with monthly monitoring



Extrapolation		Monitoring Cycle - days		MACT	adj for 21-day repair	EF2
No Monitoring	6	1825	(~5 years)	6.0850		
Monthly	0.7	30		0.7000	0.207	0.493
Semi-monthly		15		0.6550	0.207	0.448
bi-weekly		14		0.6520	0.207	0.445
weekly		7		0.6310	0.207	0.424
daily		1		0.6130	0.207	0.406

Method 3 Emission Factors:

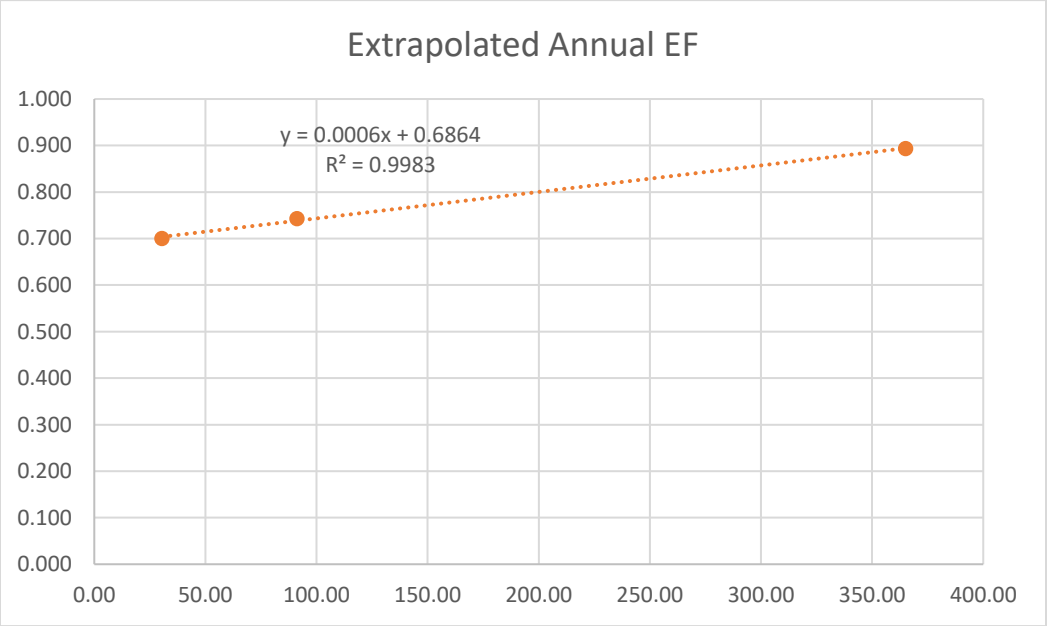
Third Extrapolation of CWT emissions factors:

MACT 40 CFR 63.654
Memorandum: RTI International
Jeff Coburn to Brenda Shine
EPA Docket No. EPA-HQ-OAR-2011-0002
July 12, 2011
Technology Review for Heat Exchange Systems

Table 10. Detailed Results from Option Cost-Effectiveness Evaluation

110,000 gpm cooling tower: 40-day repair / 800 ppm threshold

- Annual EF = 0.893
- Quarterly EF = 0.743
- Monthly EF = 0.700



				adj for 21-day repair
		check		
monthly	30		0.700	0.207	0.493
twice monthly	15		0.692	0.207	0.485
weekly	7		0.688	0.207	0.481
daily	1		0.684	0.207	0.477
		corrected by -.003 to 0.700		