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TECHNICAL MEMORANDUM

DATE: September 9, 2013

TO: All Permitting Staff

FROM: Daren Zigich

THROUGH: Ted Schooley, Permit Program Manager
Ned Jerabek, Major Source Section Manager

SUBJECT: Calculating TSP, PM-10 and PM-2.5 from Cooling Towers

The goal of this memo is to offer a Department approved step-by-step approach for calculating particulate emissions from cooling towers. While the Department encourages using this approach, other approaches, that do not use a droplet settling ratio may be approved on a case-by-case basis.

Due to the variability of methods used by permittees to estimate particulate emissions from cooling towers, a consistent, defensible approach is warranted. For example, some permittees have used a droplet settling ratio from Reference 3 to lower the total potential emissions rate of total particulate matter (PM_{total}). This is unacceptable due to the following:

1. Particulate settling is not appropriate since any verification testing would be completed inside the cooling tower fan stack. All particulate mass that can be measured by an EPA reference method and are emitted to the atmosphere shall be counted as particulate emissions. Particle size distribution can then be used to modify the emission rate of each regulated particulate size.
2. The Department is not aware of information that verifies the droplet settling data is representative for arid climates where evaporation rates are high.
3. The droplet size distribution and % mass data from Reference 1 only consider droplets up to 600 microns. Reference 3 states that settling only exists for droplets greater than 450 microns. Reference 1 lists the % mass of droplets greater than 450 microns to be less than 1 percent of the total mass.

4. Reference 2 test data shows that towers with significant drift droplet diameters greater than 600 microns usually suffer from poor installation of the drift eliminator or from poor water distribution due to issues with the tower packing. Large droplets may indicate that the assumed or guaranteed drift eliminator efficiency is not being met. Providing emissions credit for poor installation, operation or maintenance runs counter to general Department practice.
5. References 1 and 2 make no reference to and assign no credit for the settling theory stated in Reference 3.

For the above reasons, the Reference 3 settling ratio is not an acceptable emissions reduction approach.

Acceptable Calculation Method

Cooling tower particulate emissions are a function of the Drift rate and the concentration of dissolved solids present in the water. The Drift rate is normally listed as a percentage of the circulating water flow rate of the cooling tower.

Step 1 – Establish maximum water circulation rate (Q_{circ}) for the cooling tower. This is usually dependent on the capacity of the circulation pumps and the plant cooling system and should be reported as gallons per minute (gpm). The circulation rate is the sum of the circulation rates for each cell in the tower and thus represents the total flow for the tower.

Step 2 – Establish Drift rate (Q_{drift}) of the cooling tower. This information is dependent on the drift eliminator design and is usually supplied by the tower manufacturer. If manufacturer data is unavailable, the standard drift of 0.02 percent, listed in AP-42, should be used.

Step 3 – Establish maximum Total Dissolved Solids concentration (TDS) in the circulating cooling water. This is dependent on the facility's operations. TDS should be reported as parts per million (ppm) or mg/l.

Step 4 – Calculate total potential hourly particulate emissions (PM_{total}) in pounds per hour (lbs/hr).

$$PM_{total} = TDS(mg/l) \times \frac{1(lbs/mg)}{453{,}600} \times 3.785(l/gal) \times Q_{circ}(gpm) \times \frac{Q_{drift}(\%Q_{circ})}{100} \times 60(min/hr)$$

Example: TDS = 3000 ppm or mg/l, Q_{circ} = 50,000 gpm, Q_{drift} = 0.004%

PM_{total} = 3000 x (1/453,600) x 3.785 x 50,000 x (0.004/100) x 60

PM_{total} = 3.0 lbs/hr

Step 5 – Estimate particulate size distribution of the PM_{total} to determine potential emissions of TSP/PM, PM_{10} and $PM_{2.5}$.

The current estimating technique used in References 1 and 2 employs a formula for determining a potential particulate size (i.e. diameter) for a given set of variables. The variables are:

d_d = Drift droplet diameter, microns
C_{TDS} = Concentration of TDS in the circulating water, ppm x 10^{-6}
ρ_w = Density of Drift droplet, g/cm^3
ρ_{salt} = Density of particle, g/cm^3

The equation for determining particle size/diameter (d_p), in microns is:

$$d_p = \frac{d_d}{(\rho_{salt} / \rho_w C_{TDS})^{1/3}}$$

The tables below list particle size related to droplet size for various concentrations (1000 ppm to 12,000 ppm) of TDS in the circulating cooling water. The density of the water droplet (ρ_w) is assumed to be 1.0 g/cm3 (based on density of pure water) and the average density of the TDS salts is assumed to be 2.5 g/cm3. This assumed density is selected based on the average density of common TDS constituents, $CaCO_3$, $CaSO_4$, $CaCl_2$ NaCl, Na_2SO_4, and Na_2CO_3. If actual circulating water constituents are available, that data may be used to estimate the dissolved solids average density.

To determine the droplet size that generates particulate matter of the applicable regulated diameters, TSP/PM (defined as 30 microns or less per NM AQB definition[1]), PM10 and PM2.5, find the column in the table that matches the maximum circulating water TDS concentration and read the values associated with the PM2.5, PM10 and TSP/PM boxes. Boxed values are not exactly equal to the applicable sizes, but are the values greater than and closest to the applicable sizes, given the listed water droplet values from Reference 1.

The far right column of each table provides mass distribution data from Reference 1. The values indicate what percent of the total particulate mass emission, calculated in Step 4, is associated with the applicable particulate size. Read the value that is on the same line (same color) as the applicable particulate size associated with the specified TDS concentration column.

Note: Although the relationship between droplet size and percent mass is not linear, a linear interpolation of the tabulated data is acceptable between two adjacent rows (particle size) to determine an estimate of percent mass for a specific particle size (i.e. PM30, PM10 and PM2.5). Particle sizes for droplets with a non-listed TDS ppm concentration may be calculated using the equation in Step 5.

Example: Continuing from Step 4,

PM_{total} = 3.0 lbs/hr
C_{TDS} = 3000 ppm

From Table:

$PM_{2.5}$:	d_d = 30	%Mass = 0.226%
PM_{10}:	d_d = 110	%Mass = 70.509%
TSP/PM:	d_d = 270	%Mass = 96.288%

The mass emission of each applicable particulate size is:

$PM_{2.5} = PM_{total}(\%Mass/100) = 3.0(0.00226) = 0.007$ lbs/hr
$PM_{10} = 3.0(.70509) = 2.115$ lbs/hr
TSP/PM = 3.0(.96288) = 2.889 lbs/hr

[1]Definition of TSP for purposes of permitting emission sources, 11/2/09, see P:\AQB-Permits-Section\NSR-TV-Common\Permitting-Guidance-Documents – Index & Links document

Size Distribution

1000 ppm (TDS)		2000 ppm		3000 ppm		% Mass
d_d	d_p	d_d	d_p	d_d	d_p	≤
10	0.7387304	10	0.930527	10	1.0650435	0
20	1.4774608	20	1.8610539	20	2.130087 PM2.5	0.196
30	2.2161912	30	2.7915809 PM2.5	30	3.1951306 PM2.5	0.226
40	2.9549216 PM2.5	40	3.7221079	40	4.2601741	0.514
50	3.693652	50	4.6526349	50	5.3252176	1.816
60	4.4323825	60	5.5831618	60	6.3902611	5.702
70	5.1711129	70	6.5136888	70	7.4553046	21.348
90	6.6485737	90	8.3747427	90	9.5853917	49.812
110	8.1260345	110	10.235797 PM10	110	11.715479 PM10	70.509
130	9.6034953	130	12.096851	130	13.845566	82.023
150	11.080956 PM10	150	13.957905	150	15.975653	88.012
180	13.297147	180	16.749485	180	19.170783	91.032
210	15.513339	210	19.541066	210	22.365914	92.468
240	17.72953	240	22.332647	240	25.561045	94.091
270	19.945721	270	25.124228	270	28.756175	94.689
300	22.161912	300	27.915809	300	31.951306 TSP/PM30	96.288
350	25.855564	350	32.568444 TSP/PM30	350	37.276523	97.011
400	29.549216	400	37.221079	400	42.601741	98.34
450	33.242868 TSP/PM30	450	41.873714	450	47.926958	99.071
500	36.93652	500	46.526349	500	53.252176	99.071
600	44.323825	600	55.831618	600	63.902611	100

Size Distribution

4000 ppm (TDS)			5000 ppm			6000 ppm			% Mass
d_d	d_p		d_d	d_p		d_d	d_p		≤
10	1.1721197		10	1.2625337		10	1.3415607		0
20	2.3442393		20	2.5250675	PM2.5	20	2.6831215	PM2.5	0.196
30	3.516359	PM2.5	30	3.7876012		30	4.0246822		0.226
40	4.6884787		40	5.0501349		40	5.366243		0.514
50	5.8605984		50	6.3126686		50	6.7078037		1.816
60	7.032718		60	7.5752024		60	8.0493645		5.702
70	8.2048377		70	8.8377361		70	9.3909252		21.348
90	10.549077	PM10	90	11.362804	PM10	90	12.074047	PM10	49.812
110	12.893316		110	13.887871		110	14.757168		70.509
130	15.237556		130	16.412938		130	17.44029		82.023
150	17.581795		150	18.938006		150	20.123411		88.012
180	21.098154		180	22.725607		180	24.148093		91.032
210	24.614513		210	26.513208		210	28.172776		92.468
240	28.130872		240	30.300809	TSP/PM30	240	32.197458	TSP/PM30	94.091
270	31.647231	TSP/PM30	270	34.088411		270	36.22214		94.689
300	35.16359		300	37.876012		300	40.246822		96.288
350	41.024188		350	44.18868		350	46.954626		97.011
400	46.884787		400	50.501349		400	53.66243		98.34
450	52.745385		450	56.814018		450	60.370234		99.071
500	58.605984		500	63.126686		500	67.078037		99.071
600	70.32718		600	75.752024		600	80.493645		100

Size Distribution

7000 ppm (TDS)			8000 ppm			9000 ppm			% Mass
d_d	d_p		d_d	d_p		d_d	d_p		≤
10	1.4122241		10	1.4764371		10	1.5354962		0
20	2.8244482	PM2.5	20	2.9528742	PM2.5	20	3.0709923	PM2.5	0.196
30	4.2366724		30	4.4293112		30	4.6064885		0.226
40	5.6488965		40	5.9057483		40	6.1419846		0.514
50	7.0611206		50	7.3821854		50	7.6774808		1.816
60	8.4733447		60	8.8586225		60	9.2129769		5.702
70	9.8855688		70	10.33506	PM10	70	10.748473	PM10	21.348
90	12.710017	PM10	90	13.287934		90	13.819465		49.812
110	15.534465		110	16.240808		110	16.890458		70.509
130	18.358914		130	19.193682		130	19.96145		82.023
150	21.183362		150	22.146556		150	23.032442		88.012
180	25.420034		180	26.575867		180	27.638931		91.032
210	29.656707		210	31.005179	TSP/PM30	210	32.245419	TSP/PM30	92.468
240	33.893379	TSP/PM30	240	35.43449		240	36.851908		94.091
270	38.130051		270	39.863801		270	41.458396		94.689
300	42.366724		300	44.293112		300	46.064885		96.288
350	49.427844		350	51.675298		350	53.742365		97.011
400	56.488965		400	59.057483		400	61.419846		98.34
450	63.550085		450	66.439668		450	69.097327		99.071
500	70.611206		500	73.821854		500	76.774808		99.071
600	84.733447		600	88.586225		600	92.129769		100

Size Distribution

10,000 ppm (TDS)			11,000 ppm			12,000 ppm			% Mass
d_d	d_p		d_d	d_p		d_d	d_p		≤
10	1.5903253		10	1.6416091		10	1.6898701		0
20	3.1806507	PM2.5	20	3.2832181	PM2.5	20	3.3797403	PM2.5	0.196
30	4.770976		30	4.9248272		30	5.0696104		0.226
40	6.3613013		40	6.5664363		40	6.7594806		0.514
50	7.9516267		50	8.2080453		50	8.4493507		1.816
60	9.541952		60	9.8496544		60	10.139221	PM10	5.702
70	11.132277	PM10	70	11.491263	PM10	70	11.829091		21.348
90	14.312928		90	14.774482		90	15.208831		49.812
110	17.493579		110	18.0577		110	18.588572		70.509
130	20.674229		130	21.340918		130	21.968312		82.023
150	23.85488		150	24.624136		150	25.348052		88.012
180	28.625856		180	29.548963		180	30.417663	TSP/PM30	91.032
210	33.396832	TSP/PM30	210	34.47379	TSP/PM30	210	35.487273		92.468
240	38.167808		240	39.398618		240	40.556883		94.091
270	42.938784		270	44.323445		270	45.626494		94.689
300	47.70976		300	49.248272		300	50.696104		96.288
350	55.661387		350	57.456317		350	59.145455		97.011
400	63.613013		400	65.664363		400	67.594806		98.34
450	71.56464		450	73.872408		450	76.044156		99.071
500	79.516267		500	82.080453		500	84.493507		99.071
600	95.41952		600	98.496544		600	101.39221		100

References

1. Calculating Realistic PM10 Emissions from Cooling Towers, Abstract No. 216 Session No. AS-1b, J. Reisman and G. Frisbie, Greyston Environmental Consultants, Inc.
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