W.0 EVALUATION OF RCA DATA

W.1 WHAT IS THE PURPOSE OF AN RCA?

A response correlation audit (RCA) is a periodic evaluation of PM CEMS responses to determine if the responses are consistent with the correlation equation developed for the PM CEMS. RCAs are used to evaluate the long-term stability of the correlation. If the PM CEMS satisfies the performance criteria for an RCA, it can be assumed that the correlation equation is still valid. If the PM CEMS fails an RCA, that indicates that the correlation cannot be used to provide an accurate measurement of PM emissions. RCA failures can result from changes in emission characteristics or changes in the operation of the emission source, control device, or PM CEMS. In the case of an RCA failure, the correlation equation must be revised. Other corrective actions may also be necessary.

W.2 HOW DO I PERFORM AN RCA?

The procedure for conducting an RCA is the same as the procedure used to conduct an initial correlation test for a PM CEMS. The only difference between an RCA and a correlation test is that a minimum of 12 test runs must be performed for an RCA, instead of the 15 runs required for the correlation test. Refer to Sections 10.3(8) and 10.4(5) of Procedure 2 for the general procedures and performance criteria for RCAs. For details on the testing requirements for RCAs, refer to Section 8.6 of PS-11, which specifies the procedures for performing correlation tests. The main requirements for conducting an RCA include

- Recording PM CEMS responses simultaneously with sampling for PM using the reference method specified in the applicable regulation (use of paired reference method sampling trains is recommended);

- Coordinating process operations, reference method sampling, and PM CEMS operation; and

- Performing a minimum of 12 test runs.

Section 8.6(3) of PS-11 allows you to discard the results of up to five test runs without explanation. You can reject additional test runs if the basis for rejecting them is specified in the test method, PS-11, or the QA plan for the source. Also note that it is not necessary to conduct the RCA over the three levels of PM concentration described in Section 8.6(4) of PS-11.

W.3 WHAT ARE THE PERFORMANCE CRITERIA FOR AN RCA?

Section 10.4(5) of Procedure 2 specifies three performance criteria for an RCA. First, the PM CEMS response value for any RCA test run can be no greater than the greatest PM CEMS response value used to develop the correlation. For example, if the correlation equation is based on PM CEMS responses that ranged from 5.1 mA to 35.7 mA, the maximum allowable PM CEMS response for an RCA is 35.7 mA. If the PM CEMS response exceeds 35.7 mA for any RCA test run, the results of that run must be discarded.

The second criterion, which is specified in Section 10.4(5)(ii), is that nine of the 12 PM CEMS responses must be within the range of response values used to develop the correlation. For the example cited above, this means that the PM CEMS response for up nine of the 12 test runs must be within the range of 5.1 mA to 35.7 mA. Otherwise, additional RCA test runs must be conducted.

The final criterion, which is specified in Section 10.4(5)(iii), is that the measured PM concentrations for at least 75 percent of the test runs for an RCA must be within a band defined by the PM concentration calculated from the correlation equation, plus or minus 25 percent of the numerical emission limit. For any test run, this criterion can be expressed as follows:

$$\hat{y} - 0.25EL \le y_{RCA} \le \hat{y} + 0.25EL \qquad \text{(Equation W-1)}$$

where

$\hat{y}$ = PM concentration calculated from the correlation equation using the PM CEMS response (x value) recorded during the RCA test run
EL = value of emission limit (concentration)
y_{RCA} = PM concentration (y value) measured during the RCA test run.

For example, assume that the emission limit is 34 mg/dscm, and the correlation equation developed for a PM CEMS is

$$\hat{y} = 1.14x + 2.68$$

where

x = PM CEMS response.

Substituting the emission limit and correlation equation into Equation W-1, each test run of the RCA must then satisfy the following expression:

$$1.14x + 2.68 - (0.25 \times 34) \le y_{RCA} \le 1.14x + 2.68 + (0.25 \times 34)$$

This expression can be simplified to the following:

$$1.14x + 2.68 - 8.5 \le y_{RCA} \le 1.14x + 2.68 + 8.5$$

$$1.14x - 5.82 \le y_{RCA} \le 1.14x + 11.18$$

If the PM CEMS response value (x) during an RCA run was 18.2 mA, the PM concentration would have to fall within the following range for the RCA run to be counted toward the 75 percent criterion:

$$(1.14 \times 18.2) - 5.82 \le y_{RCA} \le (1.14 \times 18.2) + 11.18$$

$$20.75 - 5.82 \le y_{RCA} \le 20.75 + 11.18$$

$$14.9 \le y_{RCA} \le 31.9$$

For this example, y_{RCA}, the PM concentration for the RCA test run, would have to be within the range of 14.9 mg/dscm to 31.9 mg/dscm for the run to be counted toward the criterion that 75 percent of the test run values fall within the band defined by the correlation equation plus or minus 25 percent of the emission limit.

W.4 EXAMPLE PROBLEM: HOW DO I EVALUATE THE RESULTS OF AN RCA?

The correlation equation developed during the initial correlation test for a PM CEMS installation is linear and is expressed as follows:

$$\hat{y} = 0.65x - 1.00$$

The PM CEMS response data used to develop the correlation equation ranged from 4.9 mA to 32.2 mA. The emission limit is 22.6 mg/dscm. To demonstrate that the installation meets the criteria for the RCA, 13 test runs were performed. The RCA test data are summarized in Table W-1.

The first step in determining if the test results satisfy the RCA criteria is to compare the PM CEMS response values to the maximum response value used to develop the correlation. In this example, the maximum allowable PM CEMS response value is 32.2 mA. A review of the data indicates that the PM CEMS response for Run 7 was 33.6 mA, which exceeds the maximum allowable value. Therefore, Run 7 must be discarded. All other runs satisfy the criterion for maximum PM CEMS response.

The next step is to determine if the PM CEMS response values for at least nine test runs fall within the range of values used to determine the correlation, which is 4.9 mA to 32.2 mA for this example. After discarding Run 7, the PM CEMS responses for the remaining 12 runs range from 7.2 to 31.9 mA and satisfy this criterion.

Table W-1. Results of RCA Test Runs

Run	PM CEMS response, mA	Measured PM Concentration, mg/dscm
1	7.2	7.6
2	10.9	7.4
3	10.2	2.8
4	26.8	23.5
5	27.7	14.2
6	31.9	22.7
7	33.6	25.1
8	12.6	8.0
9	16.8	8.5
10	17.3	6.2
11	19.2	14.6
12	23.3	10.9
13	28.4	18.1

The third step is to determine the number of test runs for which the measured PM concentrations are within the band defined by the correlation equation plus or minus 25 percent of the numerical emission limit, as shown by Equation W-1. Substituting the emission limit and correlation equation, Equation W-1 can be simplified as follows:

$$0.65x - 1.00 - (0.25 \times 22.6) \le y_{RCA} \le 0.65x - 1.00 + (0.25 \times 22.6)$$

$$0.65x - 6.65 \le y_{RCA} \le 0.65x + 4.65$$

Substituting the PM CEMS response values for x, the allowable range for each test run can be calculated and compared to the PM concentration for that run. The results of these calculations are summarized in Table W-2 and illustrated graphically in Figure W-1.

Table W-2. Comparison of PM Concentration to Allowable Concentrations for RCA

Run No.[a]	PM CEMS response value (x), mA	Measured PM concentration (y_{RCA}), mg/dscm	Allowable range for y_{RCA}		Is y_{RCA} within range?
			Minimum	Maximum	
1	7.2	7.6	-1.97	9.33	Yes
2	10.9	7.4	0.44	11.74	Yes
3	10.2	2.8	-0.02	11.28	Yes
4	26.8	23.5	10.77	22.07	No

Table W-2. (continued)

Run No.[a]	PM CEMS response value (x), mA	Measured PM concentration (y_{RCA}), mg/dscm	Allowable range for y_{RCA}		Is y_{RCA} within range?
			Minimum	Maximum	
5	27.7	14.2	11.36	22.66	Yes
6	31.9	22.7	14.09	25.39	Yes
8	12.6	8	1.54	12.84	Yes
9	16.8	8.5	4.27	15.57	Yes
10	17.3	6.2	4.6	15.9	Yes
11	19.2	14.6	5.83	17.13	Yes
12	23.3	10.9	8.5	19.8	Yes
13	28.4	18.1	11.81	23.11	Yes

[a] Note that Run 7 has been discarded because it failed criterion 1.

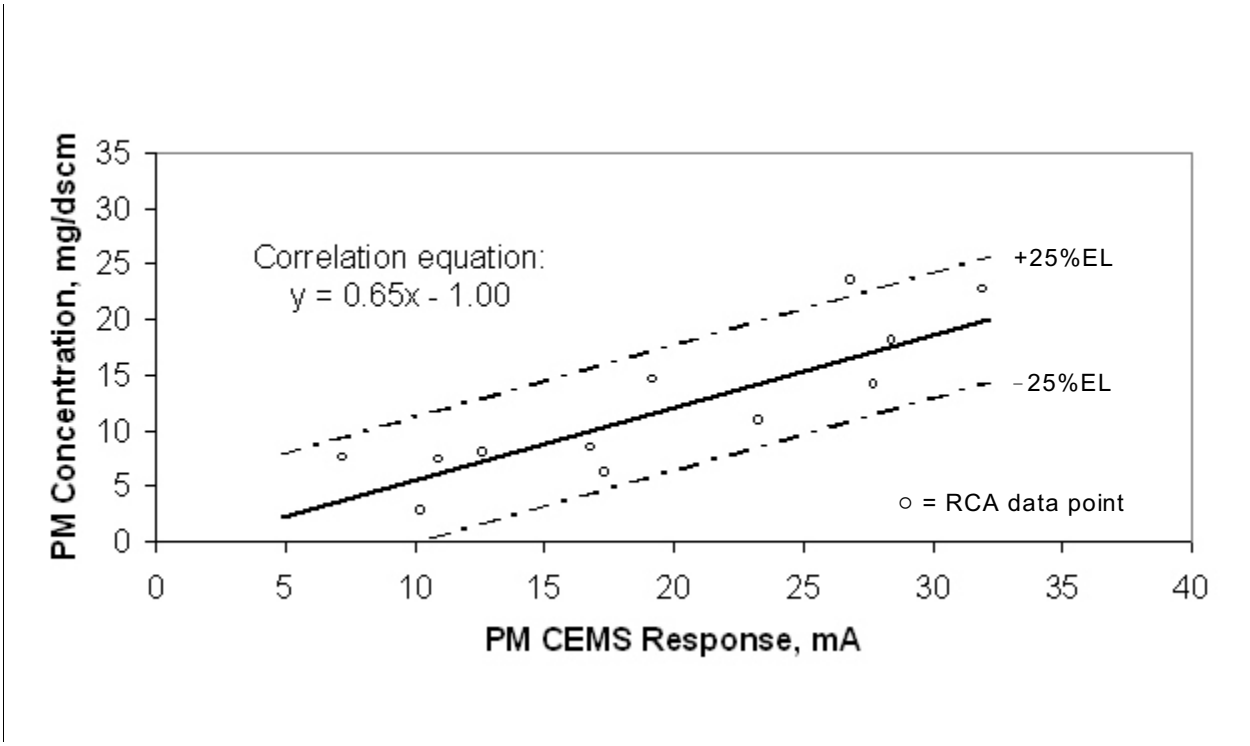

Figure W-1. Graphical representation of example RCA test results.

As indicated in Table W-2, of the remaining 12 RCA test runs (following removal of Run 7), all but Run 4 meet the criterion that the measured PM concentration is within the band defined by the correlation equation plus or minus 25 percent of the emission limit. For Run 4, the measured PM concentration was 23.5 mg/dscm, and the allowable range is 10.77 mg/dscm to 22.07 mg/dscm. In Figure W-1, the correlation equation is represented by the solid line, and the dashed lines represent the ± 25 percent band. Run 4 (26.8 mA and 23.5 mg/dscm) lies outside of this band.

In summary, 11 of the 12 test runs (or 91.7 percent of the runs) were within the band defined by the correlation equation plus or minus 25 percent of the emission limit. Because more than 75 percent of the test runs were within the allowable range, the third criterion has been satisfied. Therefore, the PM CEMS satisfied the three RCA performance criteria, and no changes to the correlation equation are required.

W.5 WHAT MUST I DO IF I FAIL AN RCA?

Section 10.6 of Procedure 2 specifies a series of corrective actions that must be taken following the failure of an RCA. The first step following a failed RCA, as noted in Section 10.6(1), is to combine the RCA data with the data used to develop the current correlation and develop a new correlation equation using the combined data (original correlation test data plus RCA data). The new correlation equation must be developed using the procedures specified in Section 12.3 of PS-11. If the correlation equation developed from the combined data meets the criteria specified in Section 13.2 of PS-11, the revised correlation equation should be used. No further testing or corrective action is needed.

If the combined data do not meet the criteria specified in Section 12.3 of PS-11, a revised correlation equation must be developed using only the results from the RCA. If this revised correlation equation meets the criteria specified in Section 13.2 of PS-11, the revised correlation equation should be used, and additional testing or corrective action is unnecessary. However, it is still advisable to investigate why the correlation changed. One possible explanation for such a shift in the correlation is a change in control device or process operation. For example, a difference in fuel properties could change the characteristics of the exhaust stream, thereby altering how the PM CEMS responds to sampled emissions. In such cases, it may be more appropriate to develop and use separate correlations for the different operating conditions and calculate emissions based on the correlation that corresponds to the specific operating conditions.

If neither the correlation equation developed from the combined data nor the correlation equation developed from only the RCA data satisfies Section 13.2 of PS-11, other corrective actions must be taken. First, the PM CEMS must be inspected and repaired as needed. If this inspection indicates that the PM CEMS is operating properly, it may be necessary to relocate the PM CEMS and perform a new correlation test. An alternative to relocating the PM CEMS is to install a new PM CEMS that uses a measurement technology that is more appropriate for the source operating parameters and emissions characteristics. As explained above, it is also possible that a single correlation is inadequate for characterizing different source or control device operating conditions, and it may be necessary to develop multiple correlations. If none of these measures corrects the problem, the final option is to petition the permitting authority for alternative monitoring.

W.6 EXAMPLE PROBLEM: HOW DO I DEVELOP A NEW CORRELATION FOLLOWING A FAILED RCA?

A successful correlation test is performed on a hazardous waste incinerator. The incinerator must meet an emission limit of 22.6 mg/dscm. The correlation test consisted of 15 runs. Table W-3

summarizes the data from the correlation test. Figure W-2 shows a plot of the correlation test data. The correlation coefficient for the data is 0.93, and the linear correlation equation is

$$\hat{y} = 0.792x - 2.01$$

Table W-3. Summary of Initial Correlation Test Results

Run No.	PM CEMS Response, mA	Measured PM Concentration, mg/dscm
1	5.2	3.2
2	7.8	2.9
3	8.2	6.1
4	10.4	5.2
5	14.8	6.8
6	14.1	12.6
7	19.2	9.2
8	20.3	18.8
9	19.5	12.1
10	26.4	15.1
11	21.9	16.4
12	28.7	17.8
13	29.3	23.2
14	33.5	23.9
15	31.8	27.2

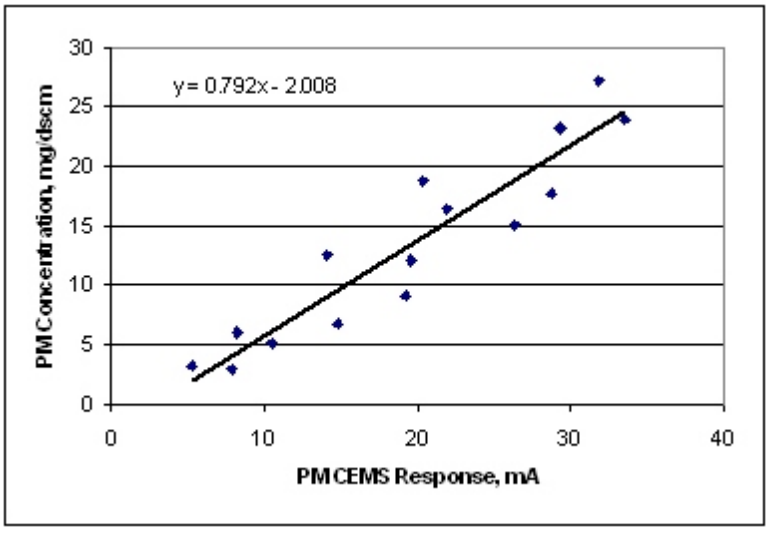

Figure W-2. Initial correlation test data and resulting correlation equation.

A year after the PM CEMS is brought on line, an RCA is performed. The RCA consisted of 12 test runs. The results of the RCA are summarized in Table W-4. The PM CEMS response values for the RCA range from 7.2 to 31.9 mA. All of these values fall within the range of PM CEMS values used to develop the correlation (5.2 to 33.5 mA). Therefore, the RCA data meet the first two criteria specified in Section 10.4(5)(i) and (ii) for the allowable data range.

Table W-4. Results of RCA

Run	PM CEMS response x	Measured PM concentration, mg/dscm y_{RCA}	Allowable range for y_{RCA}, mg/dscm		Is y_{RCA} within allowable range?
			Minimum	Maximum	
RCA-1	7.2	5.7	-1.95	9.35	Yes
RCA-2	10.9	6.2	0.98	12.28	Yes
RCA-3	10.2	2.4	0.42	11.72	Yes
RCA-4	26.8	12.5	13.57	24.87	No
RCA-5	27.7	11.9	14.29	25.59	No
RCA-6	31.9	14.8	17.61	28.91	No
RCA-7	28.2	9.9	14.68	25.98	No
RCA-8	12.6	6.7	2.32	13.62	Yes
RCA-9	16.8	7.1	5.65	16.95	Yes
RCA-10	17.3	5.2	6.05	17.35	No
RCA-11	19.2	8.7	7.55	18.85	Yes
RCA-12	23.3	9.2	10.8	22.1	No

To determine if the RCA meets the requirements of Section 10.4(5)(iii) of Procedure 2, the band defined by the correlation line plus or minus 25 percent of the emission limit can be simplified to the following:

$$0.792x - 7.66 \leq y_{RCA} \leq 0.792x + 3.64$$

Table W-4 shows the applicable range for each run of the RCA based on the above expression. When the values for the PM CEMS responses for the RCA are compared to these ranges, only 6 of the 12 runs (50 percent) fall within the acceptable band. Figure W-3 shows a plot of the correlation line and the lines that define the plus or minus 25 percent band around the correlation line. As indicated in the figure, six of the data points for the RCA (indicated by the ○ symbols) fall below the band.

As specified in Section 10.6(1) of Procedure 2, the next step is to combine the data used to develop the correlation and the RCA data and determine if the resulting correlation satisfies the criteria of Section 13.2 of PS-11. A plot of the combined data is shown in Figure W-4.

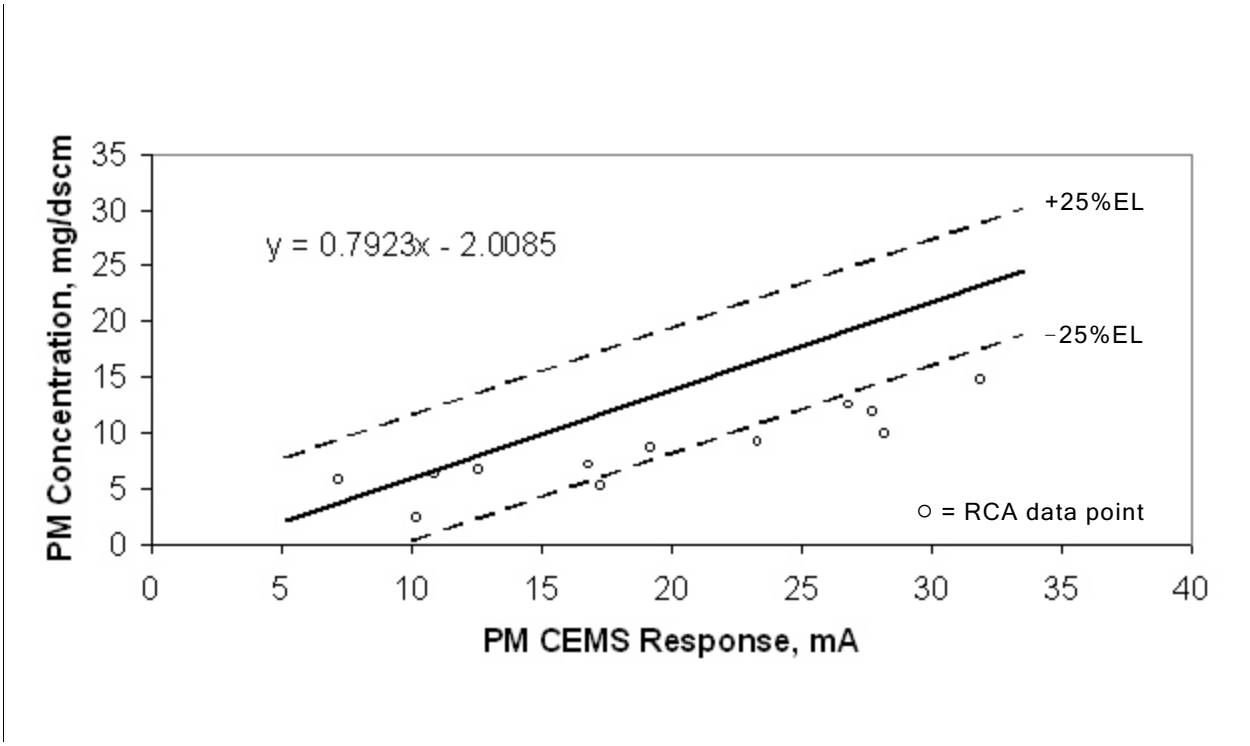

Figure W-3. Results of RCA.

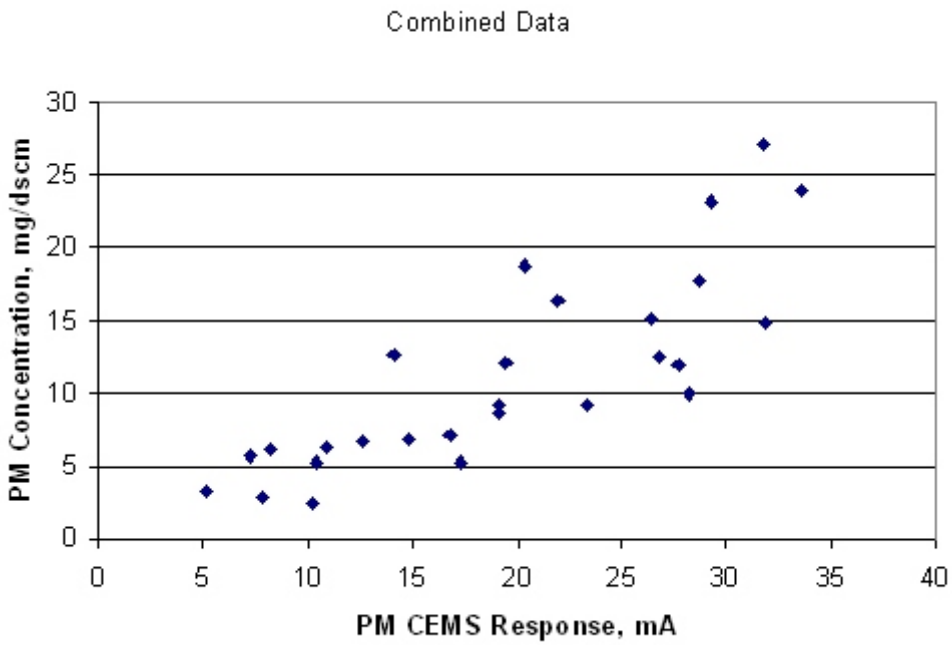

Figure W-4. Plot of combined correlation test data and RCA data.

When the correlation is performed using the combined data, none of the five correlation models meet the criteria of PS-11. The correlation coefficients are all less than 0.85, and three of the five models fail to meet the criterion for a tolerance interval half range of 25 percent. Table W-5 shows the outcome of the correlation analysis for the five models.

Table W-5. Results of Correlation Analysis for Combined Correlation Test and RCA Data

Model	Equation	Correlation coefficient	Confidence interval half range	Tolerance interval half range
Acceptance Criteria for PS-11		≥0.85	≤10%	≤25%
Linear	$\hat{y} = 0.638x - 1.22$	0.813	6.81 %	26.3 %
Polynomial	$\hat{y} = 0.0135x^2 + 0.111x + 2.94$	0.816	9.11 %	26.6 %
Logarithmic	$\hat{y} = 9.92\text{Ln}(x) - 17.12$	0.765	7.54 %	29.1 %
Exponential	$\hat{y} = 2.70e^{0.0636x}$	0.844	5.63 %	22.7 %
Power	$\hat{y} = 0.477x^{1.042}$	0.838	5.72 %	23.1 %

When the correlations developed from the combined data do not meet the criteria specified in PS-11, Section 10.6(2) of Procedure 2 requires developing a new correlation using only the data from the RCA test runs. A plot of the RCA data and the new linear correlation equation developed from these data are shown in Figure W-5. The results of the analysis for the five correlation models are summarized in Table W-6. The linear and polynomial correlation models both satisfy the correlation criteria of PS-11 and either equation can be used to determine compliance with the emission limit.

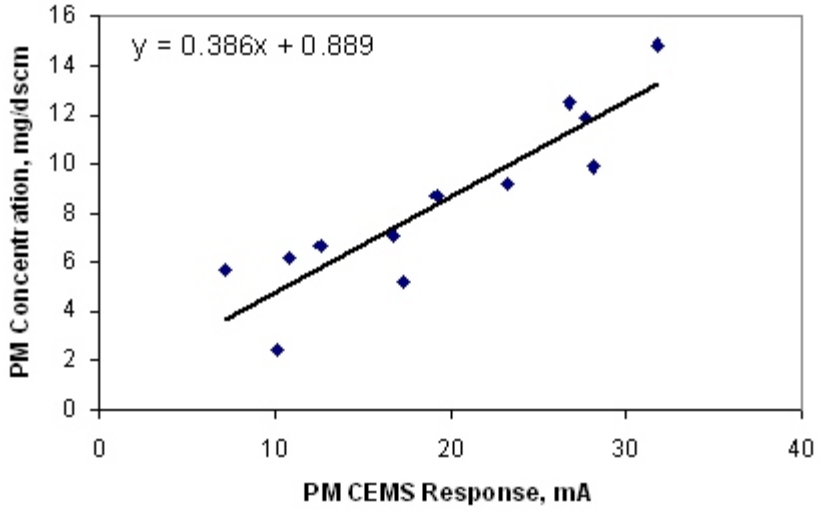

Figure W-5. Plot of correlation curve for RCA data only.

Table W-6. Results of Correlation Analysis for RCA Data Only

Model	Equation	Correlation coefficient	Confidence interval half range	Tolerance interval half range
Acceptance Criteria for PS-11		≥0.85	≤10%	≤25%
Linear	$\hat{y} = 0.889x + 0.386$	0.888	4.61 %	13.6 %
Polynomial	$\hat{y} = 0.0131x^2 - 0.123x + 5.06$	0.900	5.96 %	13.5 %
Logarithmic	$\hat{y} = 6.24\mathrm{Ln}(x) - 9.53$	0.826	5.64 %	16.6 %
Exponential	$\hat{y} = 2.92e^{0.0496x}$	0.809	6.25 %	19.3 %
Power	$\hat{y} = 0.726x^{0.819}$	0.772	6.77 %	21.0 %