South Coast Air Quality Management District

Applied Science and Technology
Source Testing and Engineering

TECHNICAL GUIDANCE DOCUMENT
R-006

Rules:	2011-Protocol for Monitoring, Reporting, and Recordkeeping for Oxides of Sulfur (SO_x) Emissions, Appendix A, Chapter 2. 2012-Protocol for Monitoring, Reporting, and Recordkeeping for Oxides of Nitrogen (NO_x) Emissions, Appendix A, Chapter 2.
Date:	November 18, 2004
Subject:	Mass Emissions RATA Evaluation For Non-Concurrent Concentration and Flow Measurements
References:	40 CFR Part 60

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1. Introduction

Relative accuracy for mass emissions reporting is generally determined using concurrent flow and concentration measurements. On occasion however, the mass emission relative accuracy cannot be determined with standard calculation procedures because practical considerations may require that flow and concentration measurements be made at different times. A common example includes the reporting of sulfur oxides emissions based on the fuel usage and sulfur content. Since it is unreasonable to expect a facility will perform a relative accuracy test on the fuel sulfur detector plus all their fuel meters concurrently, an alternate calculation procedure is necessary to allow a practical testing schedule while providing a means for assessing accuracy.

2. Applicability

The procedure in this technical guidance document applies to facilities with RECLAIM major sources that seek to demonstrate compliance with the emission rate relative accuracy requirement (Protocol for Rule 2011, Chapter 2 (B)(12) and Protocol for Rule 2012, Chapter 2 (B)(11)) using test data (such as the pollutant concentration, fuel or exhaust flow, or oxygen measurements) that cannot be reasonably measured simultaneously to perform the standard mass emission RATA calculations. Issues relating to the administrative aspects for implementing this technical guidance document, such as the timing of report submittals, or the testing schedule of the device, have been addressed in Attachment A. Due to the complex nature of this procedure, the facility shall consult with AQMD staff when applying R-006 to situations not covered in the attachment, to avoid inadvertently creating situations that may conflict with other RECLAIM monitoring, reporting, or recordkeeping requirements.

3. Procedure

This calculation procedure is based on a mathematics theorem which states that the overall uncertainty may be derived from a combination of individual uncertainties. For relative accuracy calculations, uncertainty is expressed in terms of the standard deviation. The use of this procedure assumes that the standard deviations of the measured parameters remain essentially unchanged on each of the testing days, and the unit is operating at a steady state. Due to the complexity of the procedure the CEMS engineer shall be consulted on various issues, such as:

a) What are the anticipated operating conditions during the test? An effort should be made to perform tests at equivalent operating conditions.

b) What data will be measured simultaneously? For example, will the NOx and oxygen analyzers be assessed on one day, and the fuel meter accuracy assessed on a different day?

c) For SOx major sources, how are the mass emissions calculated? The calculation procedure is strongly dependent on whether relative accuracy is determined from stack SO_2 measurements or fuel sulfur analysis.

The CEMS engineer will accept the proposed application of this guidance document if the device can be operated at a steady state, and one of the following criteria is satisfied:

i) The performance of a RATA using standard procedures will deplete the resources of a source testing laboratory to the extent that multiple laboratories would need to be employed.

ii) The application of a RATA procedure referenced by the Rule 2011 or Rule 2012 Appendix A Protocols would result in data loss so that simultaneous measurements are not possible.

Spreadsheets for some common situations are available to assist with the calculations. A derivation and sample calculation follows:

3.1 Flow Relative Accuracy

Flow relative accuracy is defined by the following equation:

$$RA = \frac{\left|d_{avg}\right| + CC}{RM_{avg}} \text{ x } 100 \qquad (1)$$

where:

d_{avg} = absolute value of the mean of the differences between the reference method and the CEMS flow measurement;

CC = confidence coefficient, which is a function of the standard deviation of the differences between the reference method and the CEMS, as calculated by 40CFR60 Appendix B, Performance Specification 2; and,

RM_{avg} = average of the reference method flow measurements.

As seen by the definitions provided above, both the mean and standard deviation of the differences between the reference method and CEMS need to be calculated. These values were most easily found by measuring the flow rate using reference Methods 1.1 through 4.1 at a given time, and then comparing this flow with the CEMS flow measurement during that same time. The difference between the measurements (d), were calculated for each run to determine the mean difference (d_{avg}) and the standard deviation of the differences (σ_{dflow}).

In some circumstances, such as tracer gas testing, this straight-forward approach is not appropriate because comparisons can not be performed for measurements made at the same time. To see this, consider the equation for flow measurement:

$$\text{Flow} = (\text{Fd})(\text{HV})\left(\frac{20.9}{20.9 - \%\text{O2}}\right)(\text{Mtr})\left(\frac{1}{60}\right) \tag{2}$$

where:

Flow = the exhaust flow rate (dscfm);

Fd = the oxygen-base F-Factor (dscf/MMBtu);

HV = the higher heating value of the fuel gas (Btu/scf);

%O2 = the percent oxygen in the exhaust; and,

Mtr = the fuel usage rate (mmscfh).

Suppose, as is sometimes the case for tracer gas testing, that CEMS and Reference Method oxygen measurements are made on one day, and differences in the flow meter measurements are made on a second day. To add some complexity, suppose further that 9 comparisons between the CEMS and reference method are made for oxygen, whereas 12 comparisons are made for the flow meter. Simply combining the Run #1 CEMS oxygen measurement on the *first* day with the Run #1 CEMS flow measurement on the *second* day (in accordance with Equation 2 above), to calculate a Run #1 exhaust flow rate, would not be appropriate. Since the Run #1 measurements are not made simultaneously, an equally valid alternative procedure would be to combine the Run #9 CEMS oxygen measurement with, say, the Run #3 CEMS flow meter measurement. Additionally, how would the 12 flow meter comparisons be incorporated with the 9 oxygen comparisons? Rather than performing endless numbers of permutations and combinations, an alternate, equivalent calculation is presented.

The difference between the CEMS and reference method flow measurements may be expressed using Equation (2) as follows:

$$\text{Flow}_{\text{CEM}} - \text{Flow}_{\text{Ref}} = \frac{20.9}{60}\left[(\text{EF}_{\text{CEM}})\left(\frac{1}{20.9 - \%\text{O2}_{\text{CEM}}}\right)(\text{Mtr}_{\text{CEM}}) - (\text{EF}_{\text{CEM}})\left(\frac{1}{20.9 - \%\text{O2}_{\text{Ref}}}\right)(\text{Mtr}_{\text{Ref}})\right]$$

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where:

EF = expansion factor, which equals the oxygen based F-Factor multiplied by the higher heating value of the fuel gas (dscf/MMscf);

Defining d_{flow} as ($Flow_{CEM}$ – $Flow_{Ref}$), O2’ as [1/(20.9-%O2)], and performing some simplification yields the following equation:

$$d_{flow} = \frac{20.9}{60}\left(EF_{CEM}\right)\left[O2'_{CEM}\left(Mtr_{CEM}\right) - O2'_{Ref}\left(Mtr_{Ref}\right)\right] \tag{3}$$

In the equation above, we will momentarily focus on the terms within the brackets. For the following algebraic relation:

(a1) (b1) – (a2) (b2)

subtracting the term (a1) (b2) on the left of the minus sign and adding that same term to the right of the minus sign yields:

(a1) (b1 – b2) + (b2) (a1 – a2)

Substituting the appropriate values from Equation (3) yields the following equation for the difference between the CEMS measured and the reference method flow:

$$\begin{aligned} d_{flow} &= \frac{20.9}{60}\left(EF_{CEM}\right)\left[O2'_{CEM}\left(Mtr_{CEM} - Mtr_{Ref}\right) + Mtr_{Ref}\left(O2'_{CEM} - O2'_{Ref}\right)\right] \\ &= \frac{20.9}{60}\left(EF_{CEM}\right)\left[O2'_{CEM}\left(d_{Mtr}\right) + Mtr_{Ref}\left(d_{O2'}\right)\right] \qquad (4a) \end{aligned}$$

where:

d_{Mtr} = $Mtr_{CEM} – Mtr_{Ref}$; and,

$d_{O2'}$ = $O2'_{CEM} – O2'_{Ref}$

Alternately, the term (a2) (b1) may be subtracted on the left of the minus sign and added to the right of the minus sign yielding:

(b1) (a1 – a2) + (a2) (b1 – b2)

Again, making the appropriate substitutions the appropriate values from Equation (3) yields:

$$\begin{aligned} d_{flow} &= \frac{20.9}{60}\left(EF_{CEM}\right)\left[Mtr_{CEM}\left(O2'_{CEM} - O2'_{Ref}\right) + O2'_{Ref}\left(Mtr_{CEM} - Mtr_{Ref}\right)\right] \\ &= \frac{20.9}{60}\left(EF_{CEM}\right)\left[Mtr_{CEM}\left(d_{O2'}\right) + O2'_{Ref}\left(d_{Mtr}\right)\right] \qquad (4b) \end{aligned}$$

A theory in Uncertainty Analysis states that for a given result, R, which may be expressed as a function of independent variables, x_1, x_2, x_3, …, x_n, then the uncertainty in the result, w_R, may be calculated by:

$$W_R = \left[\left(\frac{\partial R}{\partial x_1} w_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} w_2 \right)^2 + \ldots + \left(\frac{\partial R}{\partial x_n} w_n \right)^2 \right]^{1/2} \tag{5}$$

where w_1, w_2, … w_n are the uncertainties in the measurements of the independent variables.

Applying Equation (5) to Equation (4a) yields:

$$\begin{aligned} \sigma_{\text{dflow}} = \frac{20.9}{60} (\text{EF}) \Bigg\{ & \left(\frac{\left[(\text{O2'}_{\text{CEM}})(\text{d}_{\text{Mtr}}) + (\text{Mtr}_{\text{Ref}})(\text{d}_{\text{O2'}}) \right]}{\text{EF}} \right)^2 \sigma_{\text{EF}}^2 + (\text{d}_{\text{Mtr}})^2 (\sigma_{\text{O2'CEM}})^2 \\ & + (\text{O2'}_{\text{CEM}})^2 (\sigma_{\text{dMtr}})^2 + (\text{d}_{\text{O2'}})^2 (\sigma_{\text{MtrRef}})^2 + (\text{Mtr}_{\text{Ref}})^2 (\sigma_{\text{dO2'}})^2 \Bigg\}^{1/2} \end{aligned} \tag{6a}$$

where σ denotes standard deviation.

Similarly, Equation (4b) yields:

$$\begin{aligned} \sigma_{\text{dflow}} = \frac{20.9}{60} (\text{EF}) \Bigg\{ & \left(\frac{\left[(\text{Mtr}_{\text{CEM}})(\text{d}_{\text{O2'}}) + (\text{O2'}_{\text{Ref}})(\text{d}_{\text{Mtr}}) \right]}{\text{EF}} \right)^2 \sigma_{\text{EF}}^2 + (\text{d}_{\text{O2'}})^2 (\sigma_{\text{MtrCEM}})^2 \\ & + (\text{Mtr}_{\text{CEM}})^2 (\sigma_{\text{dO2'}})^2 + (\text{d}_{\text{Mtr'}})^2 (\sigma_{\text{O2'Ref}})^2 + (\text{O2'}_{\text{Ref}})^2 (\sigma_{\text{dMtr}})^2 \Bigg\}^{1/2} \end{aligned} \tag{6b}$$

To apply these equations in calculating relative accuracy, either Equation (4a) or (4b) may be used to determine d_{avg} in Equation (2). A root-mean-square average of Equations (6a) and (6b) may be then calculated to determine the standard deviation of the flow differences, which is necessary to calculate the confidence coefficient.

3.2 Mass Emissions Relative Accuracy

The equations for determining mass emissions relative accuracy are derived similarly. A brief derivation is presented below:

Mass emissions is calculated from the following relation:

$$\text{Mass Emission} = (\text{Constant})\ (\text{ppm})\ (\text{flow})$$

The difference between CEMS and Reference Method measurements may be calculated by:

$$E_{cem} - E_{ref} = (\text{Constant})\ [\ (\text{ppm}_{cem})(\text{flow}_{cem}) - (\text{ppm}_{ref})(\text{flow}_{ref})\ ]$$

where:

E_{cem} = Emission calculated using facility CEMS;
E_{ref} = Emission calculated using reference method;
flow_{cem} = Flow measured using facility CEMS;
flow_{ref} = Flow measured using reference method;
ppm_{cem} = Concentration measured with facility CEMS; and,
ppm_{ref} = Concentration measured with reference method.

Through some algebraic manipulations, the following equivalent expressions are derived:

$$d_E = (\text{Constant})\ [\ (\text{ppm}_{cem})(d_{flow}) + (\text{flow}_{ref})(d_{ppm})\ ] \tag{7}$$

$$d_E = (\text{Constant})\ [\ (\text{flow}_{cem})(d_{ppm}) + (\text{ppm}_{ref})(d_{flow})\ ] \tag{8}$$

where:

$d_E = E_{cem} - E_{ref}$
$d_{flow} = \text{flow}_{cem} - \text{flow}_{ref}$
$d_{ppm} = \text{ppm}_{cem} - \text{ppm}_{ref}$

Either Equation (7) or (8) can be used to determine the difference between the CEMS and Reference method mass emissions. The standard deviation of d_E may be estimated assuming independence of variables. Since, two equations are available for determining d_E, there are also two equations for calculating the standard error of d_E.

$$\sigma_{dE} = \text{Const}\left[\text{ppm}^2_{\text{CEM}}\ \sigma^2_{\text{dflow}} + d^2_{\text{flow}}\ \sigma^2_{\text{ppm CEM}} + \text{flow}^2_{\text{ref}}\ \sigma^2_{\text{dppm}} + d^2_{\text{ppm}}\ \sigma^2_{\text{flow ref}}\right]^{1/2} \tag{9}$$

$$\sigma_{dE} = \text{Const}\left[\text{flow}^2_{\text{CEM}}\ \sigma^2_{\text{dppm}} + d^2_{\text{ppm}}\ \sigma^2_{\text{flow cem}} + \text{ppm}^2_{\text{ref}}\ \sigma^2_{\text{dflow}} + d^2_{\text{flow}}\ \sigma^2_{\text{ppm ref}}\right]^{1/2} \tag{10}$$

where:

σ_{dflow} = Standard deviation of the CEMS and Reference flow differences;

$\sigma_{\text{ppm CEM}}$ = Standard deviation of the CEMS concentration data;

σ_{dppm} = Standard deviation of the CEMS and Reference concentration differences;

$\sigma_{\text{flow ref}}$ = Standard deviation of the Reference flow data;

$\sigma_{\text{flow CEM}}$ = Standard deviation of the CEMS flow data; and,

$\sigma_{\text{ppm ref}}$ = Standard deviation of the Reference concentration data.

The standard deviations $\sigma_{\text{flow ref}}$ and $\sigma_{\text{flow CEM}}$ are found by applying Equation (5) to the following equations:

$$\text{Flow}_{\text{CEM}} = \frac{20.9}{60}(\text{EF})(\text{O2'}_{\text{CEM}})(\text{Mtr}_{\text{CEM}}) \tag{11a}$$

$$\text{Flow}_{\text{Ref}} = \frac{20.9}{60}(\text{EF})(\text{O2'}_{\text{Ref}})(\text{Mtr}_{\text{Ref}}) \tag{11b}$$

The standard deviations were found to be:

$$\sigma_{\text{Flow CEM}} = \frac{20.9}{60}\Big[(\text{Mtr}_{\text{CEM}})^2(\text{EF})^2(\sigma_{\text{O2' CEM}})^2 + (\text{O2'}_{\text{CEM}})^2(\text{EF})^2(\sigma_{\text{Mtr CEM}})^2 + (\text{O2'}_{\text{CEM}})^2(\text{Mtr}_{\text{CEM}})^2(\sigma_{\text{EF}})^2\Big]^{1/2} \tag{12a}$$

$$\sigma_{\text{Flow Ref}} = \frac{20.9}{60}\Big[(\text{Mtr}_{\text{Ref}})^2(\text{EF})^2(\sigma_{\text{O2' Ref}})^2 + (\text{O2'}_{\text{Ref}})^2(\text{EF})^2(\sigma_{\text{Mtr Ref}})^2 + (\text{O2'}_{\text{Ref}})^2(\text{Mtr}_{\text{Ref}})^2(\sigma_{\text{EF}})^2\Big]^{1/2} \tag{12b}$$

3.3 Example Calculations

Although the equations appear complex, the formulas are easily implemented into spreadsheet format. As an illustration of the use of these formulas, an example from a RECLAIM facility's RATA is provided below. The fuel meter accuracy was assessed by tracer gas testing, and was conducted on a separate day from oxygen and NOx testing.

Table 1
Oxygen Results (Day #1)

Run No.	O2 CEMS	O2 Ref	O2' CEMS	O2' Ref	O2' Delta
1	12.21	12.65	0.1151	0.1212	-0.0061
2	14.13	14.65	0.1477	0.1600	-0.0123
3	12.41	12.68	0.1178	0.1217	-0.0039
4	11.49	11.87	0.1063	0.1107	-0.0045
5	11.05	11.49	0.1015	0.1063	-0.0047
6	10.45	10.92	0.0957	0.1002	-0.0045
7	11.91	12.55	0.1112	0.1198	-0.0085
8	12.16	12.75	0.1144	0.1227	-0.0083
9	12.17	12.75	0.1145	0.1227	-0.0082
10	12.52	13.18	0.1193	0.1295	-0.0102
Average	12.05	12.55	0.1144	0.1215	-0.0071
Std Dev	0.979	1.009	0.0139	0.0162	0.0028

Table 2
NOx Data (Day #1)

Run No.	NOx CEMS	NOx Ref	NOx Delta
1	20.23	23.43	-3.20
2	18.01	20.16	-2.15
3	20.47	22.96	-2.49
4	22.97	24.90	-1.93
5	23.88	24.34	-0.46
6	24.14	21.99	2.15
7	23.08	23.62	-0.54
8	23.23	23.99	-0.76
9	22.87	23.22	-0.35
10	23.53	24.19	-0.66
Average	22.24	23.28	-1.04
Std Dev	1.990	1.363	1.500

Table 3
Fuel Meter Results (Day #2)

Run No.	mmscfh Mtr CEMS	mmscfh Mtr Ref	mmscfh Mtr Delta
1	0.0194	0.0200	-0.000583
2	0.0192	0.0195	-0.000333
3	0.0191	0.0181	0.001000
4	0.0191	0.0191	0.000042
5	0.0191	0.0192	-0.000042
6	0.0191	0.0188	0.000292
7	0.0190	0.0189	0.000167
8	0.0190	0.0190	-0.000042
9	0.0189	0.0189	0.000000
10	0.0189	0.0198	-0.000833
11	0.0190	0.0192	-0.000167
12	0.0191	0.0190	0.000167
Average	0.0191	0.0191	$-2.78\text{x}10^{-5}$
Std Dev	0.000133	0.000482	0.000458

Table 4
Expansion Factor Data (Day #2)

Run No.	F-Factor dscf/MMBtu	HV Btu/scf	dscf/MMscf Expansion Factor
1	8898	1276	11353848
2	8898	1276	11353848
3	8928	1261	11258208
4	8928	1261	11258208
5	8953	1312	11746336
6	8948	1345	12035060
7	8948	1345	12035060
8	8968	1366	12250288
9	8968	1366	12250288
10	9058	1390	12590620
11	9058	1390	12590620
12	9028	1384	12494752
Average	8965	1331	11,934,761
Std Dev	55.37	51.19	523884

From the tables above, the difference between the CEMS and reference method flows may be calculated using either Equation (4a) or (4b):

$O2'_{CEM} = 0.1144$ $Mtr_{Ref} = 0.0191$
$d_{O2'} = -0.0071$ $d_{Mtr} = -2.78\text{x}10^{-5}$
$EF = 11{,}934{,}761$

Substitution into Equation (4a) yields -579 dscfm for d_{flow}.

As a check, Equation (4b) may be used to calculate d_{flow}. Again, from the tables above,

$O2'_{Ref} = 0.1215$ $Mtr_{CEM} = 0.0191$
$d_{O2'} = -0.0071$ $d_{Mtr} = -2.78\text{x}10^{-5}$
$EF = 11{,}934{,}761$

As expected, Equation (4b) agrees with (4a), within round-off.

Equations (6a) and (6b) may be utilized for determining the standard deviations of the flow differences. For Equation (6a), the following data are required:

$O2'_{CEM} = 0.1144$ $Mtr_{Ref} = 0.0191$
$\sigma_{O2'CEM} = 0.0139$ $\sigma_{Mtr\ Ref} = 0.000482$
$d_{O2'} = -0.0071$ $d_{Mtr} = -2.78\text{x}10^{-5}$
$\sigma_{dO2'} = 0.0028$ $\sigma_{dMtr} = 0.000458$
$EF = 11{,}934{,}761$
$\sigma_{EF} = 523{,}884$

Substitution into Equation (6a) yields 314 dscfm.

For Equation (6b), the following data are required:

$O2'_{Ref} = 0.1215$ $Mtr_{CEM} = 0.0191$
$\sigma_{O2'Ref} = 0.0162$ $\sigma_{Mtr\ CEM} = 0.000133$
$d_{O2'} = -0.0071$ $d_{Mtr} = -2.78\text{x}10^{-5}$
$\sigma_{dO2'} = 0.0028$ $\sigma_{dMtr} = 0.000458$
$EF = 11{,}934{,}761$
$\sigma_{EF} = 523{,}884$

These data yield 323 dscfm when the substitutions are made into Equation (6b). The root-mean-square average of the results from Equations (6a) and (6b) is then found to be 319 dscfm. The standard deviation of the differences between the CEMS flow and reference method flow rates is therefore 319 dscfm.

The flow relative accuracy may now be calculated. The confidence coefficient (for 10 test runs) is:

$$\text{CC} = \frac{2.262\,(319\ \text{dscfm})}{\sqrt{10}} = 228$$

The flow rate, as calculated by the CEMS is found from Equation (2) by taking the average values for oxygen concentration, fuel usage, and the expansion factor:

$$\text{Flow}_{\text{CEM}} = (11{,}934{,}761)\left(\frac{20.9}{20.9-12.05}\right)(0.0191)\left(\frac{1}{60}\right)$$

where:

Flow_{CEM} = the exhaust flow rate as measured by the CEMS (dscfm);

11,934,761 = the expansion factor (EF) = (Fd)(HV);

12.05 = the percent oxygen in the exhaust; and,

0.0191 = the fuel usage rate (mmscfh).

Flow_{CEM} is calculated to be 8966 dscfm.

The flow measured by the reference method, Flow_{Ref}, is simply the difference between Flow_{CEM} and d_{flow} (which was calculated from Equations (4a) or (4b)). Flow_{Ref}, therefore, is:

$$\begin{aligned}\text{Flow}_{\text{Ref}} &= \text{Flow}_{\text{CEM}} - d_{\text{Flow}}\\ &= 8966\ \text{dscfm} - (-579\ \text{dscfm})\\ &= 9545\ \text{dscfm}\end{aligned}$$

The flow relative accuracy may now be found through use of Equation (1):

$$\text{RA} = \frac{\left|d_{\text{avg}}\right| + \text{CC}}{\text{RM}_{\text{avg}}}\ \text{x}\ 100$$

$$= \frac{\left|-579\right| + 228}{9545}\ \text{x}\,100 \quad = 8.45\,\%$$

Mass emissions relative accuracy is calculated similarly to the flow relative accuracy. From Table #2 and the flow results above, the difference between the CEMS and reference method flows may be calculated using either Equation (7) or (8):

ppm_{CEM} = 22.24

d_{ppm} = -1.04

Flow_{Ref} = 9545

d_{Flow} = -579

Substitution into Equation (7) yields –0.1631 for d_E.

Next, the standard deviations of the exhaust flow as measured by the CEMS or reference methods must be calculated using Equations (12a) and (12b). Using results previously found and Equation (12a), $\sigma_{FlowCEM}$ is found from the following values:

$O2'_{CEM}$ = 0.1144
$\sigma_{O2'CEM}$ = 0.0139
EF = 11,934,761
σ_{EF} = 523,884

Mtr_{CEM} = 0.0191
$\sigma_{Mtr\ CEM}$ = 0.000133

The value for $\sigma_{FlowCEM}$ was calculated to be 1174 dscfm.

Alternately, $\sigma_{FlowRef}$ is found from Equation (12b) and the following values:

$O2'_{Ref}$ = 0.1215
$\sigma_{O2'Ref}$ = 0.0162
EF = 11,934,761
σ_{EF} = 523,884

Mtr_{Ref} = 0.0191
$\sigma_{Mtr\ Ref}$ = 0.000133

The value for $\sigma_{FlowRef}$ was calculated to be 1375 dscfm.

Equations (9) and (10) are next used to calculate estimates of the standard deviation of the differences between the CEMS and reference methods. The following values are required for using Equation (9):

ppm_{CEM} = 22.24 ppm
$\sigma_{ppm\ CEM}$ = 1.990

$Flow_{Ref}$ = 9545 dscfm
$\sigma_{Flow\ Ref}$ = 1375

d_{ppm} = -1.04 ppm
σ_{dppm} = 1.50
Constant = $7.158\text{x}10^{-6}$

d_{Flow} = -579 dscfm
σ_{dFlow} = 319

Substitutions into Equation (9) yields 0.1151 for σ_{dE}.

Similarly, for Equation (10), the following values are necessary:

ppm_{Ref} = 23.28 ppm
$\sigma_{ppm\ Ref}$ = 1.363
d_{ppm} = -1.04 ppm
σ_{dppm} = 1.50
Constant = $7.158\text{x}10^{-6}$

$Flow_{CEM}$ = 8966 dscfm
$\sigma_{Flow\ CEM}$ = 1174
d_{Flow} = -579 dscfm
σ_{dFlow} = 319

Substitutions into Equation (10) yields 0.1104 for σ_{dE}. The root-mean-square average of the results from Equations (9) and (10) is then found to be 0.1128 lb/hr. This value may now be used to determine the confidence coefficient. The confidence coefficient (for 10 test runs) is:

$$\mathrm{CC} = \frac{2.262\,(0.1128\,\mathrm{lb/hr})}{\sqrt{10}} = 0.0807$$

The mass emissions as reported by the CEMS is:

$$\begin{aligned}\text{Mass Emission}_{\text{CEM}} &= (\text{Constant})\,(\text{ppm}_{\text{CEM}})\,(\text{flow}_{\text{CEM}}) \\ &= (7.158\text{x}10^{-6})\,(22.24\text{ ppm})\,(8966\text{ dscfm}) \\ &= 1.427\text{ lb/hr}\end{aligned}$$

The mass emissions as reported by the reference method is:

$$\begin{aligned}\text{Mass Emission}_{\text{Ref}} &= \text{Mass Emission}_{\text{CEM}} - d_E \\ &= 1.427\text{ lb/hr} - (-0.1631\text{ lb/hr}) \\ &= 1.591\text{ lb/hr}\end{aligned}$$

The flow relative accuracy is now found through use of Equation (1):

$$\mathrm{RA} = \frac{\left|d_{\mathrm{avg}}\right| + \mathrm{CC}}{\mathrm{RM}_{\mathrm{avg}}} \text{ x } 100$$

$$= \frac{\left|-0.1631\right| + 0.0807}{1.591} \text{ x } 100 \quad = 15.32\,\%$$

APPROVED

Chung S. Liu
Deputy Executive Officer
Science and Technology Advancement Division

Date

R-006R09.doc

Attachment A

Guidelines For Applying Technical Guidance Document R-006

This attachment was prepared to address issues regarding the application of this guidance document that were raised during the review by representatives of affected facilities and industrial parties, and the AQMD. Most of these issues involved the timing of test report submittals, and how the compliance status of a device would be affected by tests that have yet to be performed. Because the calculation procedure described by R-006 can apply to a wide variety of testing applications, a comprehensive list of concerns for all RECLAIM facilities cannot be presented in a single document. Instead, the following list of issues were developed to address the most common of the administrative issues relating to R-006. Due to the complex nature of this calculation procedure, the Executive Officer, or designee, should be consulted when applying Technical Guidance Document R-006 to unique situations specific at an individual facility.

Issue #1: Some facilities employ sulfur analyzers at a mixing drum and a flow meter at a specific device to determine sulfur mass emissions from that device. If the sulfur analyzers and a flow meter are tested at different times, when are the RATA reports required?

> The fuel sulfur analyzer and the flow meter reports shall be submitted after testing, on or before the end of the quarter following the date of the required test (Protocol for Rule 2011, Chapter 2 (B)(20) and Protocol for Rule 2012, Chapter 2 (B)(20)). There is no need to delay report submittals so that the sulfur analyzer and flow meter RATA results are issued simultaneously.

Issue #2: For the scenario presented above, when is the mass emissions relative accuracy of a particular device calculated? After the fuel sulfur analyzer is tested, or after the flow meter is tested?

> It is recommended that the mass emissions relative accuracy of a device be calculated and reported after the flow meter is tested. This recommendation seeks to avoid a potentially large and cumbersome test report if mass emission relative accuracies for many SOx emitting devices are combined with the RATA of one fuel sulfur analyzer. By adopting this recommended procedure, the scheduling for either semi-annual or annual testing of a device will be based on the test date of the previous flow relative accuracy.

Issue #3: How much information should be included in RATA reports? Specifically, will the District essentially require a redundant set of reports (to calculate mass relative accuracies) if say, the fuel sulfur and flow meter RATA reports are submitted at separate times?

Assuming the recommendation in Issue #2 above is followed, the contents of the test report for the fuel sulfur analyzer will remain unaffected. For the flow meter reports however, some duplication in the data submission will be necessary in order for the District to check the mass emission calculations. The amount of duplicate submittals should be minimal, requiring only summary pages of the results from the fuel sulfur analyzer tests, along with test tracking information such as the test date.

Issue #4: How will this procedure affect the electronic data reporting of RATAs?

This document will not affect the schedule for submitting RATA results in the District's EDR format. It is expected there will be little or no changes in the amount or type of information requested by the EDR system.

Issue #5: In applying the R-006 calculation procedure, would it be acceptable to rely on the heating value and F-Factor data provided by the facility?

For some applications of R-006, the calculations will need to rely on facility-provided F-Factor and heating value data. One example is when the sulfur is evaluated at the fuel drum, while the flow is evaluated at the stack. F-Factor and heating value data are required for converting the fuel sulfur to a stack concentration basis, or the stack flow to a fuel flow basis. Since the facility F-Factor and heating value data are essentially checked during the stack flow RATA, an independent analysis of the F-Factor and heating value for the mass emissions RATA is not warranted. Additionally, it was found from applications at a major Southland refinery that variations in the F-Factor and heating value were not strong contributors to the relative accuracy calculation.

Issue #6: If the number of concentration and flow RATA runs are unequal, how should the "degrees of freedom" be selected in order to determine the t-value for mass emissions RATA?

The smaller of the two numbers of test runs shall be used to calculate the t-value. As an example, if the NOx concentration RATA had 9 test runs, while the flow RATA had 12 test runs, then the t-value would be calculated based on 9 test runs (or 8 degrees of freedom). The calculation in Section 3.3 of R-006 includes an example of specifying the degrees of freedom.

Issue #7: Fuel sulfur analyzers undergo a cylinder gas audit (CGA) every quarter. How will this data be applied to a mass emissions RATA calculation?

For both semi-annual and annual mass emission RATA calculations, the two most recent CGA data shall be utilized. The quarterly CGA audit comprises of three runs at a high span, and three runs at a low span value. The average reference method concentration is determined by averaging both the high and low span data over the two CGA audits. The average CEMS concentration is calculated similarly. The overall standard deviation of either the reference method or CEMS concentrations however, should not be calculated by simply applying the standard deviation formula for both the high and low span data. Instead, the standard deviation calculation is modified as illustrated below:

The following table presents results of a CGA at a fuel sulfur analyzer. Note that the Low Span gas in the first quarter is different from the Low Span Gas in the second quarter.

Quarter #	**Span Gas**	**CEM Data (ppm)**	**Std Dev of Data**	**Difference (ppm)**
1	Low (28 ppm)	26.3 25.4 28.2	1.43	1.70 2.60 -0.20
1	High (75 ppm)	65.5 68.0 67.7	1.37	9.50 7.00 7.30
2	Low (35 ppm)	32.1 31.5 34.3	1.47	2.90 3.50 0.70
2	High (75 ppm)	70.1 67.7 67.5	1.45	4.90 7.30 7.50
Average	53.25	48.7		4.56

The averages are calculated in a straight-forward manner. The average standard deviation however, must be "pooled" using the following equation:

$$\text{Pooled SD} = \sqrt{\frac{(n_{1L}-1)\,S_{1L}^2 + (n_{1H}-1)\,S_{1H}^2 + (n_{2L}-1)\,S_{2L}^2 + (n_{2H}-1)\,S_{2H}^2}{(n_{1L} + n_{1H} + n_{2L} + n_{2H} - 4)}}$$

where:

n_{1L}, n_{2L} = the number of samples at Low Span, 1st Quarter and Low Span, 2nd Quarter, respectively;

n_{1H}, n_{2H} = the number of samples at High Span, 1st Quarter and High Span, 2nd Quarter, respectively;

S_{1L}, S_{2L} = Data Standard Deviation at Low Span, 1st Quarter and Low Span, 2nd Quarter, respectively;

S_{1H}, S_{2H} = Data Standard Deviation at High Span, 1st Quarter and High Span, 2nd Quarter, respectively;

For the data presented in the table, the pooled standard deviation is:

$$\text{Pooled SD} = \sqrt{\frac{(3-1)1.43^2 + (3-1)1.37^2 + (3-1)1.47^2 + (3-1)1.45^2}{(3+3+3+3-4)}}$$

$$= 1.43$$

The error (or standard deviation) in the accuracy of the calibration gas should also be included in the R-006 procedure. Per recent discussions with District Laboratory personnel, the standard deviation for calibration gas consisting of a three-component mixture is approximately 1% of the total sulfur concentration. For the example above, the overall accuracy error is simply assumed to be 1% of the average span gas value, or 0.53 ppm. The Standard Deviation of the Differences may then be calculated as follows:

$$\text{SD Differences} = \sqrt{\text{SD}^2_{\text{Pooled CEM}} + \text{SD}^2_{\text{Cal Gas}}} = \sqrt{1.43^2 + 0.53^2}$$

$$= 1.53$$

Using the averages and standard deviations calculated above, the R-006 procedure may be applied to calculate the mass emissions relative accuracy. Spreadsheets may be developed to quickly perform these calculations.

Issue #8: For some devices which qualify for annual testing, some non-concurrent concentration and flow data used to calculate the mass emissions RATA may be nearly one year old. Is the use of this data acceptable?

Yes, the use of the data is acceptable, as long as the CEMS was not significantly modified. In all cases, the most recent data shall be used; hence, for devices which qualify for annual testing, the most recent data will be one year old.

Issue #9: How will R-006 affect the use of bias adjustment factors (BAFs) as applied on a concentration and flow basis, versus on a mass emissions basis?

In order to avoid confusion relating to record-keeping, all BAFs for the tested device (i.e., either the flow BAF and concentration BAF combination, or mass BAF only) shall be updated whenever a RATA is conducted on that device or concentration monitor. However, the device's status for annual and semi-annual testing will not be altered. As an illustration, consider a typical set-up at a refinery with a fuel sulfur analyzer at a mixing drum and multiple lines to various devices (say, Devices "A" through "F"). Suppose all the device flow meters are tested in January, and the combinations of the fuel sulfur analyzer with Devices "A" and "B" qualify for annual testing. Since only the flow meters are tested, then BAFs are updated for the meters of Devices "A" through "F" if the concentration/ flow BAF option applies. However, the mass BAFs for those devices shall be updated if the BAF applies on a mass emissions basis.

Suppose further, that the fuel sulfur analyzer is tested 3 months later (April). The new BAF of the fuel sulfur analyzer then, is simply applied to the sulfur concentration data for all connecting devices if the concentration/ flow BAF option applies. Again, each mass BAF shall be updated if the BAF applies on a mass emissions basis. Note that only one BAF may be assigned to a monitor (i.e.- a sulfur analyzer or flow meter) at any given time. Multiple BAFs for a device are not allowed; hence, even though Devices "A" and "B" retain their annual test schedule, a new mass BAF will be applicable using the new test results of the sulfur analyzer.

Issue #10: Suppose Device "A" qualifies for annual testing using the most recent fuel sulfur data. A couple months later however, a test is performed on the fuel sulfur analyzers. Now had the mass emissions calculation been performed using the newest fuel sulfur data, Device "A" would not have qualified. Will Device "A" require a semi-annual RATA test?

No, the annual test status is retained as long as the fuel sulfur analyzer does not fail the 20% concentration relative accuracy requirement. The appropriate bias adjustment factors however, will need to be revised (see Issue #9, above).

Issue #11: Extending the scenario in Issue #10, what happens if the fuel sulfur analyzer fails RATA?

All devices relying on the concentration input from the fuel sulfur analyzer will be considered out of control and the missing data procedures shall be applied, regardless of the incentive status of a device. This action is consistent with current RECLAIM administrative policies.