

Severn Power Limited

Quality assurance testing of continuous emissions  
monitoring systems serving two gas turbines

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## QUALITY ASSURANCE TESTING OF CONTINUOUS EMISSIONS MONITORING SYSTEMS SERVING TWO GAS TURBINES

Permit No. HP3737UE

Operator Severn Power Limited

Installation West Nash Road  
Nash  
Newport  
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## Section 1 Executive Summary

### 1.1 Summary of results

Severn Power Limited contracted Environmental Scientifics Group Limited (ESG) to undertake a quality assurance test (QAL 2) on the continuous emissions monitoring (CEM) systems serving the exhausts of the two gas turbines (emission points A1 and A2) at their Nash site. This testing is undertaken to calibrate the CEM systems once they have been installed and at three yearly intervals following the initial QAL 2 assessment.

The assessment was undertaken in accordance with the requirements of BS EN 14181:2014, amended according to TGN M20, which includes MID 14181 as Annex A.

One CEM system operates on each of the gas turbine exhausts.

Both systems have already undergone a QAL 2 assessment and subsequent annual surveillance tests:

AST	27 to 28 March 2012	Report 120325 14 May 2012
AST	22 to 25 April 2013	Report 130409, 27 August 2013
AST	9 & 10 June 2014	Report 140311, 23 June 2104
AST	22 & 23 June 2015	Report 150613, 12 November 2015

The QAL 2 assessment comprised the following activities:

- Installation of the CEM systems - undertaking of a functional test.
- Calibration of the CEM systems – by means of parallel measurements with standard reference methods (SRMs) and where appropriate using of the CEM's response to reference materials.
- Determination of the variability of the CEM systems – check of compliance with required uncertainty

All tasks were undertaken by ESG staff with the exception of certain activities associated with the functional test which were undertaken by Siemens, Severn Power's regular service provider.

All SRM measurements and the subsequent data evaluation in accordance with BS EN 14181 methodology are within the scope of UKAS accreditation. All opinions and interpretations are outside the scope of UKAS accreditation.

The following tables summarise the main results of the assessment.

Table 1.1

Summary of Results – HRSG 10 – A1 Duty CEM

BS EN 14181 QAL 2							
HRSG 10 exhaust (A1)							
Duty CEM							
31 May to 2 June 2016							
Determinand	Calibration function (y = bx + a)		Valid calibration	Extrapolated	Units	Variability Test	Regression Coefficient
	b	a					
Oxygen (duty) <sup>1</sup>	1.0340	0	16	21	% O <sub>2</sub>	Pass	1.00
Nitrogen monoxide <sup>2</sup>	0.8135	2.25	24	-	mgNO/m <sup>3</sup>	Pass	0.74
Carbon monoxide <sup>3</sup>	1.0027	2.42	10	50	mgCO/m <sup>3</sup>	Pass	1.00

The above calibration functions, once applied, only remain valid as long as the QAL 3 data remains within control limits and as long as there are no manual adjustments made to the CEM other than those allowed to bring the settings back within QAL 3 control limits.

Table 1.2

Summary of Results – HRSG 20 – A2 Duty CEM

BS EN 14181 QAL 2							
HRSG 20 exhaust (A2)							
Duty CEM							
3 to 7 June 2016							
Determinand	Calibration function (y = bx + a)		Valid calibration	Extrapolated	Units	Variability Test	Regression Coefficient
	b	a					
Oxygen (duty) <sup>1</sup>	1.0296	0	16	21	% O <sub>2</sub>	Pass	1.00
Nitrogen monoxide <sup>2</sup>	1.1036	-3.60	21	33	mgNO/m <sup>3</sup>	Pass	0.90
Carbon monoxide <sup>3</sup>	1.0429	0.62	10	50	mgCO/m <sup>3</sup>	Pass	0.99

The above calibration functions, once applied, only remain valid as long as the QAL 3 data remains within control limits and as long as there are no manual adjustments made to the CEM other than those allowed to bring the settings back within QAL 3 control limits.

Notes

- 1 Although a calibration function is reported for oxygen, this is a peripheral measurement which does not strictly require a calibration function (M20, 3.5.17). The QAL 2 assessment for this parameter may be viewed as confirmation of satisfactory CEM
- 2 In accordance with current guidance (M20, 6.5) the calibration function is determined based on a comparison of CEM and SRM total nitrogen oxides (NO + NO<sub>2</sub>) measurements. The calibration function derived should be applied to the total NO<sub>x</sub> measurement, although it should be recognised that the calibration function is based on nitrogen monoxide rather than nitrogen dioxide and as such should be applied before the nitrogen monoxide value is converted to nitrogen dioxide for final reporting.

- 3 The range of the standardised SRM concentrations was less than the confidence interval of the applicable emission limit value and the minimum standardised SRM concentration was less than 15% of the emission limit value. The data scatter was such that a meaningful calibration function could not be derived. The average of the CEM and SRM parallel measurements differed by less than the confidence interval of the ELV indicating that the CEM responds with an acceptable degree of accuracy and precision to low levels of emissions. Calibration functions for carbon monoxide have been determined using Procedure c (EN 14181 6.4.3 c) using a combination of parallel measurements and the CEMs' response to applied reference materials at zero and at a value close to the emission limit value.
- 4 The valid calibration range is that range over which the calibration function is considered to be valid. The extrapolated range is a higher level at which the calibration function is considered valid during occasional excursions above the valid calibration range. Frequent exceedences of the valid calibration range, as defined in BS EN 14181, 6.5, may indicate the need for a reassessment.

In cases where reference materials have been employed to determine the calibration function, the extrapolated range is assumed to be lesser of the applicable ELV and maximum concentration of reference gas applied. The calibrated range is taken as the maximum calibrated CEM value achieved in the corresponding parallel testing plus 10% or 20% of the emission limit value, whichever is the higher.

## 1.2 Deviations and discussion

In the following section any deviations from the requirements of the standard reference methods and BS EN 14181 and their impact on the results obtained are highlighted and discussed.

### 1.2.1 Compliance with standard reference methods

Measurements undertaken using all standard reference methods met the requirements of the relevant standards with no deviations. The standard reference methods employed are described in Section 3.2.

### 1.2.2 Compliance with BS EN 14181

The assessment undertaken for all analysers complied fully with the requirements of BS EN 14181:2004, with the following exceptions:

All equipment associated with the permanent analytical systems has MCERTs certification and all analysers were operated within their lower certified ranges. The certified ranges are within the maximum allowable based on a 2.5 multiple of the daily average ELV, with the exception of that for carbon monoxide which has a lower certified range in excess of the maximum.

Direct reading analysers employed as SRMs have MCERTs certification. All analysers were operated within their lower certified ranges.

### 1.2.3 Impact on results

For determinands with specified emission limit values (nitrogen oxides and carbon monoxide) and those where default ELVs are specified in general guidance (oxygen) calibration functions have been derived which meet the QAL 2 acceptability criteria for the CEM systems serving both exhaust streams. These calibration functions are suitable for implementation.

It is notable that the normal operating concentrations of carbon monoxide met the requirements for a low level data cluster (the range of standardised SRM concentrations was less than the confidence interval (CI) of the applicable emission limit value (ELV) and the minimum standardised SRM concentration was less than 15% of the ELV). In such cases the calibration functions derived can quite often be unreliable due to the significant influence of normal measurement uncertainty. It has generally been found here that the assessment of these parameters has resulted in a poor regression coefficient. In accordance with EN 14181, 6.4.3, Procedure c, which uses the existing parallel data and zero and near ELV span data from the CEMs' response to reference materials, has been employed to determine calibration functions for carbon monoxide. In all cases the CEM and SRM readings are considered acceptable as the average of the parallel CEM and SRM measurements made in the tests differs by no more than the confidence interval of the ELV in each case (MID 14181, 6.5 ii).

The regression coefficients for the calibration functions for both nitrogen oxides on both systems are low and in the case of HRSG 10 below 0.9. While this can sometimes indicate doubt as to the suitability of the calibration function, it is recognised in M20 3.5.19 that with relatively low concentrations regression coefficients can be below 0.9 and still provide a valid calibration function. As such M20 3.5.19 uses the variability test as the definitive measure of QAL 2 compliance. In both cases the variability test is passed and most SRM and CEM measurement pairs differ by less than the confidence interval of the emission limit value. This provides confidence in the representativeness of the calibration functions determined.

Oxygen is a peripheral measurement which does not strictly require a calibration function (M20, 3.5.17), although a QAL 2 assessment for this parameter provides confidence in the analyser performance.

## 1.2.4 Required actions

The following actions are recommended:

### HRSG 10 (A1) - Duty CEM

Parameter	Comment	Action
O <sub>2</sub>	Met QAL 2 acceptance criteria (B).	Calibration function is suitable for implementation.
NO NO <sub>2</sub>	Met QAL 2 acceptance criteria based on measurement of total nitrogen oxides (A).	Calibration function is suitable for implementation.
CO	Met QAL 2 acceptance criteria (C) with supplementary surrogate zero and span points.	Calibration function is suitable for implementation.

### HRSG 20 (A2) - Duty CEM

Parameter	Comment	Action
O <sub>2</sub>	Met QAL 2 acceptance criteria (B).	Calibration function is suitable for implementation.
NO NO <sub>2</sub>	Met QAL 2 acceptance criteria based on measurement of total nitrogen oxides (A).	Calibration function is suitable for implementation.
CO	Met QAL 2 acceptance criteria (C) with supplementary surrogate zero and span points.	Calibration function is suitable for implementation.

## Section 2 Information about the regulated installation

### 2.1 Regulatory information

Table 2.1 provides information on the installation and its regulation.

Table 2.1

#### Regulatory Information

Operator	Severn Power Limited				
Installation	Nash				
Address	West Nash Road Nash Newport Gwent NP18 2BZ				
Industry sector	Power generation				
Permit No.	HP3737UE				
Date of last QAL 2 or AST	22 and 23 June 2015				
Regulated determinands and emission limit values (STP, 15% oxygen, dry gas basis)					
HRSO exhaust stacks (A1 & A2)					
Determinand		Short term ELV	Daily average ELV	Maximum allowable certified CEM range	Uncertainty requirement (%)
Oxygen	%	-	(21)	-	(10)
Nitrogen oxides	mgNO <sub>2</sub> /m <sup>3</sup>	-	50	125	20
Carbon monoxide	mgCO/m <sup>3</sup>	-	50	125	20

Maximum allowable certified ranges are based on a multiple of 2.5 times the daily average ELV.

Factors for the peripheral measurement of oxygen are based on M20, 3.5.17.

## 2.2 Operational information and site monitoring provisions

The installation is an 800MW natural gas fired combined cycle gas turbine (CCGT) plant comprising two generators, a waste heat recovery boiler and a steam turbine.

Exhaust gases from the system are passed to two exhaust stacks (denoted emission points A1 and A2) for release to atmosphere.

### 2.2.1 Process type and variation in emissions

Is the process continuous or batch?	Process is continuous when required.
Were there any variations in emissions during the BS EN 14181 test (e.g. load changes)?	Load is dependent on demand, although load was reasonably stable over the period of the QAL 2.
Will these variations affect the representativeness of the data collected?	No.
Are there any factors that may affect the collected data (e.g. auto-calibrations, start up, shutdown)?	Periods of auto calibration and start up and shutdown have been excluded from the assessment.
Based on historical plant information were low emissions expected for any determinand, and if so were any special provisions made?	Low concentrations, relative to the ELV, were expected for carbon monoxide, although no special provisions were considered necessary for the assessment.
Was the CEM reading zero for any determinands and if so was this investigated to ensure proper operation?	No persistent zero readings were encountered. The CEM's response for all parameters was checked during the linearity assessment and found to be compliant with acceptance requirements.

### 2.2.2 Type of fuel

Type of fuel used during the QAL2?	Natural gas.
Is the fuel use typical of that during a normal operating year?	Yes.

### 2.2.3 Abatement

What abatement systems are applied to the exhaust gases?	Dry low NO <sub>x</sub> burners
What impact do these measures have on emissions?	Controls the formation of nitrogen oxides.

## 2.3 Monitoring provisions at the installation for periodic monitoring

### 2.3.1 Stack and sampling ports

The sampling locations associated with the exhaust of the gas turbines are illustrated in Figure 1. The sampling platform for each stack (see Figure 1) is located just above the roof exit and is accessed via stairs and a short hooped ladder. Each of the exhaust stacks has a circular cross section of diameter 8.0 m providing a sampling plane area of around 50.5 m<sup>2</sup>. Four off 5" (125 mm) sampling sockets (denoted A to D) are available positioned at 90° to each other on each stack which provide access to each sampling plane along four radii.

The sampling of determinands in accordance with the requirements of BS EN 13284-1 for this geometry of flue requires sampling at a total of at 20 points, located at the centres of equal areas on two sampling lines. This is most conveniently achieved in this case by sampling at five points on each of the radii accessible via sockets A to D.

In this case all manual extractive sampling of gaseous parameters was undertaken at a single representative point within each stack. The suitability of this approach was confirmed by an assessment of the stack gas conditions which confirmed homogeneity in accordance with the requirements of BS EN 15259, Clause 8.3.

The sampling heads for the CEM systems are also present on each platform.

In each case all measurements were made downstream of all inlets to the stack and represent the final emission to atmosphere of the process.

### 2.3.2 Monitoring platform and site provisions

The platform around the sampling area for each stack also houses the sampling head for the analysers. The analyser is located in a cabinet at ground level. Both the sampling head and analyser cabinet are protected from the weather. The working area available is adequate both at the sampling platform and around the analyser cabinet.

The CEM systems are covered by an external service contract with Siemens Limited. Materials are provided under this arrangement and as such the site holds a limited supply of tools and spares.

An adequate stock of reference materials is held on site (see Table 2.2). All materials held were within their certification expiry dates at the time of this assessment.

The analysers have facilities for introducing reference materials both at the inlet of the sampling line and the inlet of the analyser.

In view of the size of the stack and restricted access, it was not possible to measure the average flow conditions at the stack or determine whether these met the flow stability requirements of BS EN 13284-1, 5.2.

The manual extractive sampling positions have been assessed to determine homogeneity. Compliance with the requirements of BS EN 15259 (and MID 15259) has been confirmed for all determinands where appropriate (report reference NEL 2011/93, 23 March 2011).

Table 2.2

Reference material audit – 7 June 2016

Gas	Certified concentration	Cylinder No.	Expiry date
Unit 10 CO	101.2 ppm	163264	27.10.2020
Unit 10 NO	94.6 ppm		
Unit 20 CO	100.6 ppm	108632	27.10.2020
Unit 20 NO	94.5 ppm		

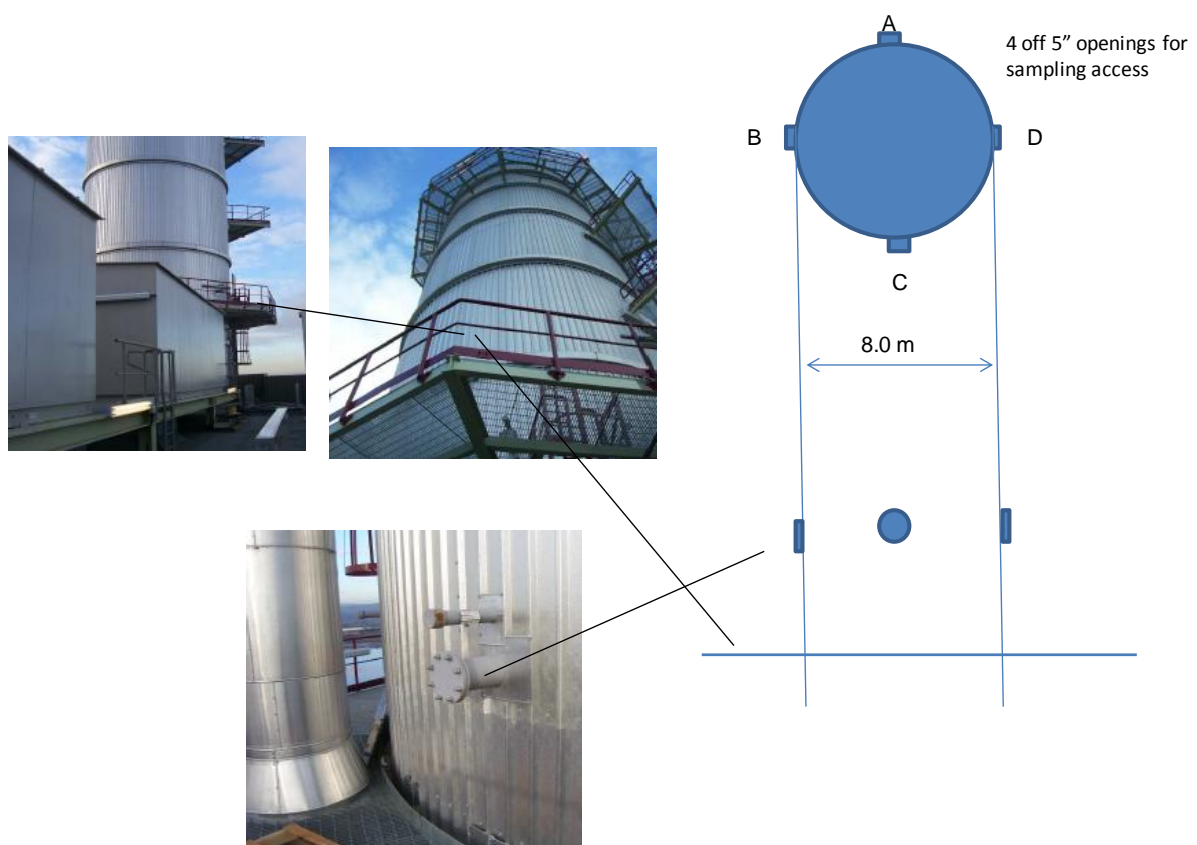


Figure 1 Typical exhaust stack and sampling platform

## 2.4 Continuous emissions monitoring systems at the installation

Table 2.3

Continuous Emissions Monitoring System Description

Determinand	Certified Range	Measurement basis	Operating principle
Manufacturer	Siemens Production Automatisation S.A.S		
Model	Ultramat 23 Multi gas analyser		
MCERTS certification	MCERTS: MC 040033/05		
Nitrogen monoxide	0-100/250/400/750 mgNO/m <sup>3</sup>	dry	Non dispersive infra red
Oxygen	0-10/25 %O <sub>2</sub>	dry	Paramagnetic
Carbon monoxide	0-150/250 mgCO/m <sup>3</sup>	dry	Non dispersive infra red

The sampling positions for the CEMs are located at the same level as the manual sampling positions.

All equipment associated with the CEM systems has MCERTS certification. The certified ranges are within the maximum allowable based on a 2.5 multiple of the daily average ELV, with the exception of carbon monoxide which has a lower certified range in excess of the maximum.

The CEM system assessed meets the relevant MCERTS specification and is QAL 1 compliant.

Water vapour is not measured.

Neither temperature nor pressure are recorded.

All analysers operate on an extractive basis.

## Section 3 Information about the monitoring campaign

### 3.1 Test laboratory staff

Table 3.1 summarises the qualifications of the test laboratory staff involved in the execution of this assessment. All staff were suitably qualified under the MCERTs scheme for the tasks undertaken.

Table 3.1

#### Staff Competency

Function	Name	MCERTs					
		Reg. No. MM	Level Expiry	Certification expiry			
				TE1	TE2	TE3	TE4
Manager	N Ford	02084	2 (09/17)	01/19	10/19	10/19	10/19
Team leader	M Davies	02087	2 (09/17)	03/18	06/18	06/18	08/18
Team leader	O May	101072	2 (09/16)	09/16	07/21	02/18	03/17
Technician	A Holmes	131218	1 (03/18)	01/19			

### 3.2 Standard reference methods

The standard reference methods employed are summarised in Table 3.2. All methods are UKAS accredited to the MCERTs performance standard under certificate 1015.

Table 3.2

#### Standard reference methods

Determinand	Sampling method	ESG Procedure No.	UKAS No.
NO <sub>x</sub>	BS EN 14792 (Chemiluminescent analyser)	AE102	1015
CO	BS EN 15058 (Infra red analyser)	AE102	1015
O <sub>2</sub>	BS EN 14789 (Zirconium cell analyser)	AE102	1015

There are no separate analytical tasks associated with these measurements.

Table 3.3 summarises the operational details of the direct reading analysers employed in the standard reference methods.

**Table 3.3**

**Direct reading analysers**

Determinand	Certified Range	Operating range	Measurement basis
<b>Manufacturer</b>	Horiba		
<b>Model</b>	PG 250		
<b>Identifier</b>	P1865		
<b>MCERTS certification</b>	MC050056/04 (valid for products manufactured before 10.2.10)		
Oxygen	25%	25%	dry
Carbon monoxide	95 mgCO/m <sup>3</sup>	200	dry
Nitrogen monoxide	125 mgCO/m <sup>3</sup>	250 ppm	dry

All direct reading analysers used in the standard reference methods have MCERTs certification. The certified ranges are within the maximum allowable based on a 2.5 multiple of the daily average ELV.

The uncertainty associated with the standard reference methods employed in this assessment is no more than the maximum allowable for the corresponding CEM. Table 3.4 summarises the measurement uncertainties.

**Table 3.4**

**Standard reference method uncertainty**

Determinand	Allowable uncertainty	Measurement uncertainty
NO <sub>x</sub> mg/m <sup>3</sup>	10	4
CO mg/m <sup>3</sup>	10	5
O <sub>2</sub> %	2.1	0.6

## Section 4A Data & calculations QAL 2

Annex E and Sections 6.3 to 6.7 of BS EN 14181:2014 specify the requirements for undertaking parallel SRM and CEM measurements and subsequently determining the calibration function. It is required to determine the following properties for each determinand based on at least 15 parallel measurements from the CEM system and corresponding SRM:

- The calibration function
- The calibration range
- A comparison of variability with the allowable measurement uncertainty

In addition to the use of parallel measurements the assessments for carbon monoxide employ additional data based on the CEM's response to reference materials in accordance with guidance for the treatment of low level clusters.

The reporting forms contain:

- The measurement pairs employed
- The methodology for calculation of calibration function
- The determination of calibration range
- The determination of variability
- The acceptability of the calibration function in comparison with the permitted uncertainty

## 4.1 HRSG 10 (A1) Duty CEM

### 4.1.1 Oxygen

Sample point HRSG 10 exhaust flue (A1)

Determinand Oxygen

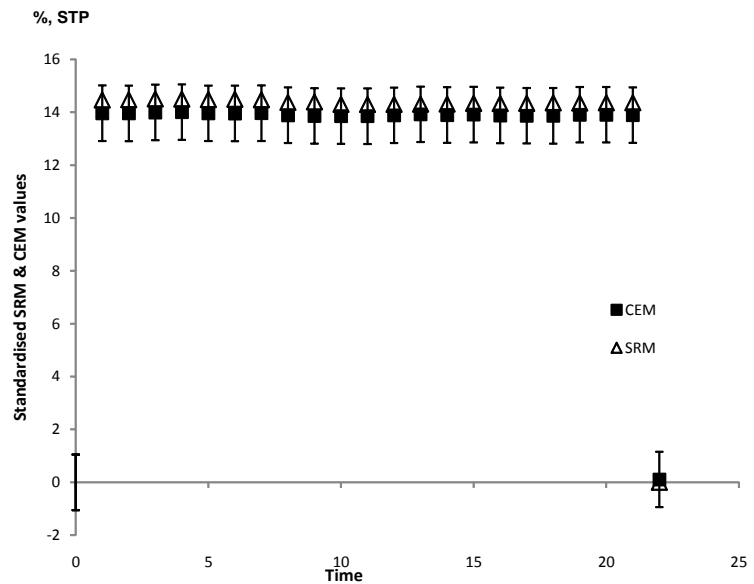
A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	CEM basis
				%	%, dry	%	%	%, dry	%	%
1	31.5.16	1530	1630	13.97	13.97	0.00	14.47	14.47	0.00	14.47
2	31.5.16	1630	1730	13.96	13.96	0.00	14.48	14.48	0.00	14.48
3	31.5.16	1730	1830	14.00	14.00	0.00	14.51	14.51	0.00	14.51
4	31.5.16	1830	1930	14.01	14.01	0.00	14.50	14.50	0.00	14.50
5	31.5.16	1930	2030	13.96	13.96	0.00	14.49	14.49	0.00	14.49
6	31.5.16	2030	2130	13.96	13.96	0.00	14.50	14.50	0.00	14.50
7	31.5.16	2130	2230	13.97	13.97	0.00	14.48	14.48	0.00	14.48
8	1.6.16	1100	1200	13.89	13.89	0.00	14.38	14.38	0.00	14.38
9	1.6.16	1200	1300	13.86	13.86	0.00	14.40	14.40	0.00	14.40
10	1.6.16	1300	1400	13.86	13.86	0.00	14.31	14.31	0.00	14.31
11	1.6.16	1400	1500	13.86	13.86	0.00	14.30	14.30	0.00	14.30
12	1.6.16	1500	1600	13.89	13.89	0.00	14.31	14.31	0.00	14.31
13	1.6.16	1600	1700	13.93	13.93	0.00	14.31	14.31	0.00	14.31
14	1.6.16	1700	1800	13.90	13.90	0.00	14.32	14.32	0.00	14.32
15	2.6.16	1100	1200	13.92	13.92	0.00	14.34	14.34	0.00	14.34
16	2.6.16	1200	1300	13.88	13.88	0.00	14.34	14.34	0.00	14.34
17	2.6.16	1300	1400	13.87	13.87	0.00	14.34	14.34	0.00	14.34
18	2.6.16	1400	1500	13.87	13.87	0.00	14.36	14.36	0.00	14.36
19	2.6.16	1500	1600	13.91	13.91	0.00	14.36	14.36	0.00	14.36
20	2.6.16	1600	1700	13.91	13.91	0.00	14.37	14.37	0.00	14.37
21	2.6.16	1700	1800	13.90	13.90	0.00	14.37	14.37	0.00	14.37
22	7.5.16	-	-	0.11	0.11	0.00	0.00	0.00	0.00	0.00

A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	%	%
1	13.97	14.47
2	13.96	14.48
3	14.00	14.51
4	14.01	14.50
5	13.96	14.49
6	13.96	14.50
7	13.97	14.48
8	13.89	14.38
9	13.86	14.40
10	13.86	14.31
11	13.86	14.30
12	13.89	14.31
13	13.93	14.31
14	13.90	14.32
15	13.92	14.34
16	13.88	14.34
17	13.87	14.34
18	13.87	14.36
19	13.91	14.36
20	13.91	14.37
21	13.90	14.37
22	0.11	0

A4.3 Plot 1 - Standardised CEM & SRM values versus time



100 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)

Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM		SRM		Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$			
	%	%							
i	x	y							
1	13.97	14.47	0.51	0.03	0.00	0.76	include		
2	13.96	14.48	0.52	0.04	0.00	1.06	include		
3	14.00	14.51	0.51	0.04	0.00	0.92	include		
4	14.01	14.50	0.50	0.02	0.00	0.52	include		
5	13.96	14.49	0.52	0.05	0.00	1.14	include		
6	13.96	14.50	0.54	0.06	0.00	1.53	include		
7	13.97	14.48	0.51	0.04	0.00	0.83	include		
8	13.89	14.38	0.49	0.01	0.00	0.33	include		
9	13.86	14.40	0.53	0.06	0.00	1.40	include		
10	13.86	14.31	0.45	0.03	0.00	0.64	include		
11	13.86	14.30	0.45	0.03	0.00	0.64	include		
12	13.89	14.31	0.42	0.05	0.00	1.29	include		
13	13.93	14.31	0.39	0.09	0.01	2.04	exclude		
14	13.90	14.32	0.42	0.06	0.00	1.32	include		
15	13.92	14.34	0.43	0.05	0.00	1.13	include		
16	13.88	14.34	0.45	0.02	0.00	0.53	include		
17	13.87	14.34	0.47	0.01	0.00	0.13	include		
18	13.87	14.36	0.49	0.02	0.00	0.41	include		
19	13.91	14.36	0.45	0.03	0.00	0.67	include		
20	13.91	14.37	0.46	0.02	0.00	0.47	include		
21	13.90	14.37	0.47	0.00	0.00	0.05	include		

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum_{s=1}^n (y_s - \hat{y}_s)}{n}$

where n is the number of samples = 20  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.04 given by

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2}$$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 14.51$       Smallest SRM value  $y_{s \min} = 14.3$

Data span = 1 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$       Minimum value = 68 % of ELV  
(Procedure a if greater than 10 % of ELV)

Select Procedure b for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM		SRM		Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$		
	%	%						
i	x	y						
1	13.97	14.47	0.7	0.8	0.5	0.6		
2	13.96	14.48	0.7	0.8	0.5	0.6		
3	14.00	14.51	0.7	0.8	0.5	0.6		
4	14.01	14.50	0.7	0.8	0.6	0.6		
5	13.96	14.49	0.7	0.8	0.5	0.6		
6	13.96	14.50	0.7	0.8	0.5	0.6		
7	13.97	14.48	0.7	0.8	0.5	0.6		
8	13.89	14.38	0.6	0.7	0.4	0.4		
9	13.86	14.40	0.6	0.7	0.4	0.5		
10	13.86	14.31	0.6	0.6	0.4	0.4		
11	13.86	14.30	0.6	0.6	0.4	0.4		
12	13.89	14.31	0.6	0.6	0.4	0.4		
13								
14	13.90	14.32	0.6	0.6	0.4	0.4		
15	13.92	14.34	0.7	0.6	0.4	0.4		
16	13.88	14.34	0.6	0.6	0.4	0.4		
17	13.87	14.34	0.6	0.6	0.4	0.4		
18	13.87	14.36	0.6	0.7	0.4	0.4		
19	13.91	14.36	0.6	0.6	0.4	0.4		
20	13.91	14.37	0.7	0.7	0.4	0.4		
21	13.90	14.37	0.6	0.7	0.4	0.4		
22	0.11	0.00	-13.1	-13.7	172.9	188.0		

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 1.034 x$$

Procedure b

$$y = bx$$

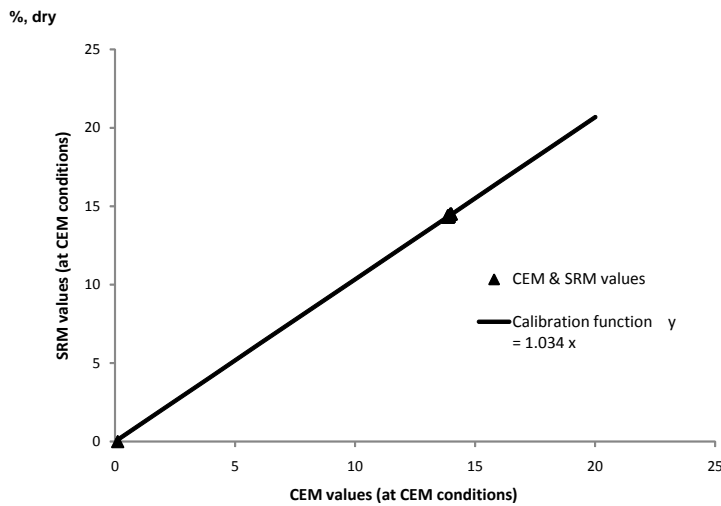
where

$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions			Stack	O <sub>2</sub>	H <sub>2</sub> O	
	%	%	%	%	%	%	
1	13.97	14.47	14.44	14.47	13.97	0.00	14.44
2	13.96	14.48	14.44	14.48	13.96	0.00	14.44
3	14.00	14.51	14.47	14.51	14.00	0.00	14.47
4	14.01	14.50	14.48	14.50	14.01	0.00	14.48
5	13.96	14.49	14.44	14.49	13.96	0.00	14.44
6	13.96	14.50	14.43	14.50	13.96	0.00	14.43
7	13.97	14.48	14.44	14.48	13.97	0.00	14.44
8	13.89	14.38	14.36	14.38	13.89	0.00	14.36
9	13.86	14.40	14.34	14.40	13.86	0.00	14.34
10	13.86	14.31	14.33	14.31	13.86	0.00	14.33
11	13.86	14.30	14.33	14.30	13.86	0.00	14.33
12	13.89	14.31	14.36	14.31	13.89	0.00	14.36
13							
14	13.90	14.32	14.37	14.32	13.90	0.00	14.37
15	13.92	14.34	14.39	14.34	13.92	0.00	14.39
16	13.88	14.34	14.36	14.34	13.88	0.00	14.36
17	13.87	14.34	14.35	14.34	13.87	0.00	14.35
18	13.87	14.36	14.34	14.36	13.87	0.00	14.34
19	13.91	14.36	14.38	14.36	13.91	0.00	14.38
20	13.91	14.37	14.38	14.37	13.91	0.00	14.38
21	13.90	14.37	14.37	14.37	13.90	0.00	14.37
22	0.11	0.00	0.11		0.11	0.00	0.11

**Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)**



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 0.9999$

$$R^2 = 0.9999$$

A4.10 Data used for the variability test (Table 4.5)

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	D - $\bar{D}$	$(D - \bar{D})^2$
	%	%			
i	$\hat{y}_i$	$y_i$			
1	14.44	14.47	0.03	0.03	0.00
2	14.44	14.48	0.04	0.04	0.00
3	14.47	14.51	0.04	0.04	0.00
4	14.48	14.50	0.02	0.02	0.00
5	14.44	14.49	0.05	0.05	0.00
6	14.43	14.50	0.06	0.06	0.00
7	14.44	14.48	0.03	0.03	0.00
8	14.36	14.38	0.02	0.02	0.00
9	14.34	14.40	0.06	0.06	0.00
10	14.33	14.31	-0.02	-0.02	0.00
11	14.33	14.30	-0.02	-0.02	0.00
12	14.36	14.31	-0.05	-0.05	0.00
14	14.37	14.32	-0.05	-0.05	0.00
15	14.39	14.34	-0.05	-0.05	0.00
16	14.36	14.34	-0.02	-0.02	0.00
17	14.35	14.34	0.00	0.00	0.00
18	14.34	14.36	0.02	0.02	0.00
19	14.38	14.36	-0.03	-0.03	0.00
20	14.38	14.37	-0.02	-0.02	0.00
21	14.37	14.37	0.00	0.00	0.00

A4.11 The variability test

The variability test is passed when  $\sigma_D \leq \sigma_D k$   
 based on parallel measurements only  
 where

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 0.0377$$

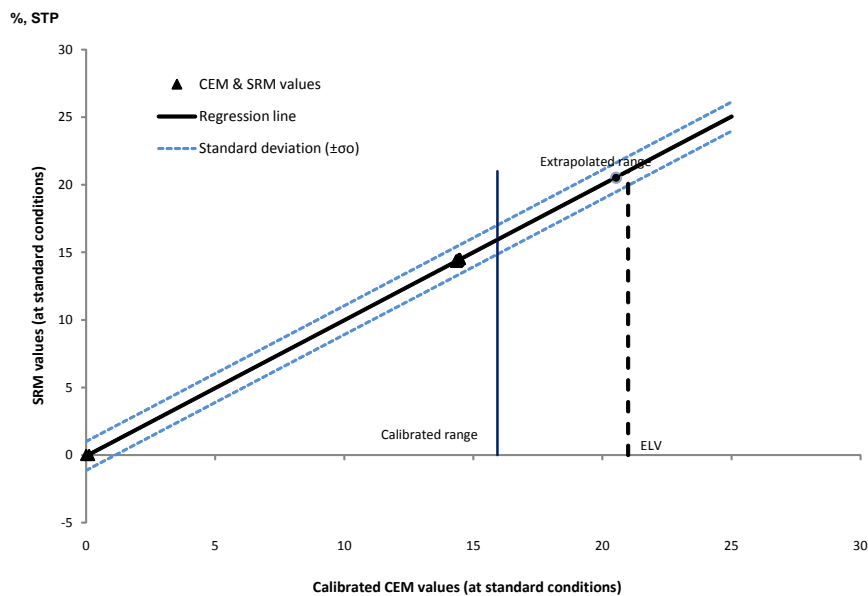
$$\sigma_D = \frac{pELV}{f} = 1.0714$$

$$k = 0.9824 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_D k = 1.0526$$

**Variability test is passed (4% of limit)**

A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_m$  plus an extension of 10% or 20% of the ELV, whichever is the greater.  
 The range may also be extrapolated to the ELV using reference materials  
 if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 16 % (75% of ELV)**

**CEM response of 21 to reference material of 20 %  
 Range extrapolated to 21 % (98% of ELV)**

## 4.1.2 Nitrogen monoxide

Sample point HRSG 10 exhaust flue (A1)

Determinand Nitrogen monoxide

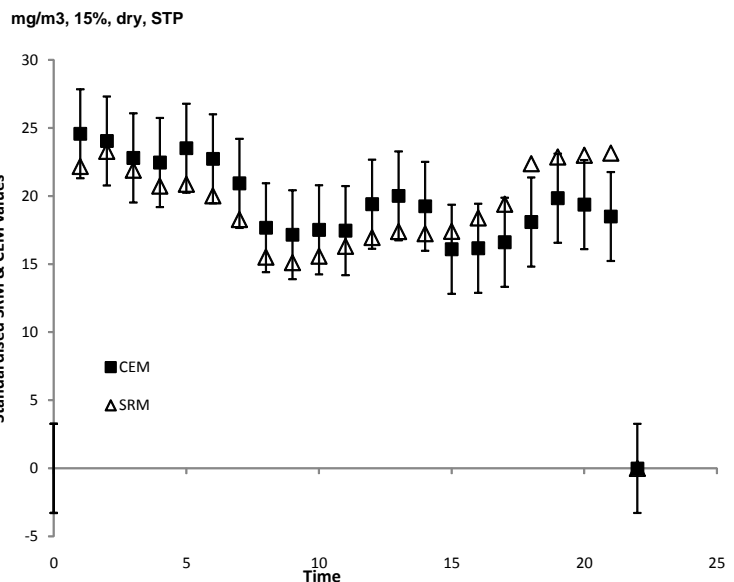
### A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			CEM basis
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	
				mg/m3	%, dry	%	ppm	%, dry	%	
1	31.5.16	1530	1630	28.88	13.97	0.00	18.05	14.47	0.00	24.15
2	31.5.16	1630	1730	28.27	13.96	0.00	18.92	14.48	0.00	25.33
3	31.5.16	1730	1830	26.68	14.00	0.00	17.71	14.51	0.00	23.71
4	31.5.16	1830	1930	26.24	14.01	0.00	16.79	14.50	0.00	22.47
5	31.5.16	1930	2030	27.65	13.96	0.00	16.94	14.49	0.00	22.68
6	31.5.16	2030	2130	26.75	13.96	0.00	16.22	14.50	0.00	21.72
7	31.5.16	2130	2230	24.59	13.97	0.00	14.86	14.48	0.00	19.89
8	1.6.16	1100	1200	21.00	13.89	0.00	12.81	14.38	0.00	17.15
9	1.6.16	1200	1300	20.46	13.86	0.00	12.44	14.40	0.00	16.65
10	1.6.16	1300	1400	20.91	13.86	0.00	13.01	14.31	0.00	17.42
11	1.6.16	1400	1500	20.85	13.86	0.00	13.62	14.30	0.00	18.23
12	1.6.16	1500	1600	23.07	13.89	0.00	14.15	14.31	0.00	18.95
13	1.6.16	1600	1700	23.66	13.93	0.00	14.50	14.31	0.00	19.41
14	1.6.16	1700	1800	22.84	13.90	0.00	14.36	14.32	0.00	19.22
15	2.6.16	1100	1200	19.05	13.92	0.00	14.45	14.34	0.00	19.34
16	2.6.16	1200	1300	19.23	13.88	0.00	15.29	14.34	0.00	20.46
17	2.6.16	1300	1400	19.78	13.87	0.00	16.11	14.34	0.00	21.56
18	2.6.16	1400	1500	21.56	13.87	0.00	18.52	14.36	0.00	24.79
19	2.6.16	1500	1600	23.52	13.91	0.00	18.95	14.36	0.00	25.36
20	2.6.16	1600	1700	22.95	13.91	0.00	19.03	14.37	0.00	25.47
21	2.6.16	1700	1800	21.96	13.90	0.00	19.15	14.37	0.00	25.63
22	7.5.16	-	-	0.00	0.11	0.00	0.00	0.00	0.00	0.00

### A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	mg/m3	mg/m3
1	24.57	22.17
2	24.05	23.28
3	22.81	21.90
4	22.47	20.73
5	23.52	20.87
6	22.73	20.01
7	20.94	18.28
8	17.68	15.51
9	17.16	15.11
10	17.52	15.59
11	17.46	16.31
12	19.40	16.96
13	20.02	17.39
14	19.25	17.23
15	16.09	17.41
16	16.17	18.39
17	16.61	19.40
18	18.10	22.37
19	19.85	22.87
20	19.38	23.00
21	18.50	23.15
22	0	0

### A4.3 Plot 1 - Standardised CEM & SRM values versus time



85 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)

Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM		SRM		Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$			
	mg/m3	mg/m3							
i	x	y							
1	28.88	24.15	4.72	1.42	2.01	1.13	include		
2	28.27	25.33	2.94	0.36	0.13	0.29	include		
3	26.68	23.71	2.97	0.34	0.12	0.27	include		
4	26.24	22.47	3.77	0.46	0.22	0.37	include		
5	27.65	22.68	4.97	1.66	2.76	1.32	include		
6	26.75	21.72	5.03	1.72	2.97	1.37	include		
7	24.59	19.89	4.71	1.40	1.96	1.12	include		
8	21.00	17.15	3.86	0.55	0.30	0.44	include		
9	20.46	16.65	3.81	0.51	0.26	0.40	include		
10	20.91	17.42	3.50	0.19	0.04	0.15	include		
11	20.85	18.23	2.61	0.69	0.48	0.55	include		
12	23.07	18.95	4.12	0.81	0.66	0.65	include		
13	23.66	19.41	4.25	0.94	0.89	0.75	include		
14	22.84	19.22	3.62	0.31	0.10	0.25	include		
15	19.05	19.34	0.29	3.01	9.09	2.40	exclude		
16	19.23	20.46	1.23	2.07	4.29	1.65	include		
17	19.78	21.56	1.78	1.53	2.33	1.22	include		
18	21.56	24.79	3.23	0.08	0.01	0.06	include		
19	23.52	25.36	1.85	1.46	2.13	1.16	include		
20	22.95	25.47	2.51	0.79	0.63	0.63	include		
21	21.96	25.63	3.67	0.36	0.13	0.29	include		

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum_{i=1}^n (y_{si} - \hat{y}_{si})}{n}$

where  $n$  is the number of samples = 20  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 1.25 given by

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2}$$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 23.28$       Smallest SRM value  $y_{s \min} = 15.11$

Data span = 25 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$       Minimum value = 46 % of ELV  
(Procedure a if greater than 20 % of ELV)      (Procedure b if greater than 15% of ELV)

Select Procedure a for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM		SRM		Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$		
	mg/m3	mg/m3						
i	x	y						
1	28.88	24.15	6.5	3.7	41.7	13.4		
2	28.27	25.33	5.9	4.8	34.2	23.5		
3	26.68	23.71	4.3	3.2	18.1	10.4		
4	26.24	22.47	3.8	2.0	14.6	3.9		
5	27.65	22.68	5.2	2.2	27.3	4.8		
6	26.75	21.72	4.3	1.2	18.7	1.5		
7	24.59	19.89	2.2	-0.6	4.7	0.4		
8	21.00	17.15	-1.4	-3.3	2.0	11.2		
9	20.46	16.65	-2.0	-3.8	3.8	14.7		
10	20.91	17.42	-1.5	-3.1	2.3	9.4		
11	20.85	18.23	-1.6	-2.3	2.5	5.1		
12	23.07	18.95	0.6	-1.5	0.4	2.4		
13	23.66	19.41	1.2	-1.1	1.5	1.2		
14	22.84	19.22	0.4	-1.3	0.2	1.6		
15								
16	19.23	20.46	-3.2	0.0	10.2	0.0		
17	19.78	21.56	-2.6	1.1	7.0	1.1		
18	21.56	24.79	-0.9	4.3	0.7	18.5		
19	23.52	25.36	1.1	4.9	1.2	23.8		
20	22.95	25.47	0.5	5.0	0.3	24.8		
21	21.96	25.63	-0.5	5.1	0.2	26.4		
22	0.00	0.00	-22.4	-20.5	502.8	419.8		

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 0.8135 x + 2.25$$

Procedure b

$$y = bx$$

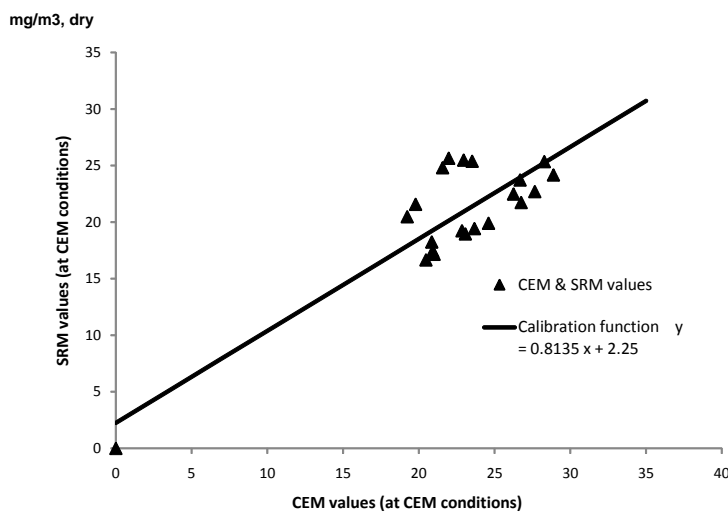
where

$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions				O <sub>2</sub>	H <sub>2</sub> O	
	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>			
1	28.88	24.15	25.74	24.15	13.97	0.00	21.90
2	28.27	25.33	25.25	25.33	13.96	0.00	21.47
3	26.68	23.71	23.95	23.71	14.00	0.00	20.47
4	26.24	22.47	23.60	22.47	14.01	0.00	20.20
5	27.65	22.68	24.74	22.68	13.96	0.00	21.05
6	26.75	21.72	24.01	21.72	13.96	0.00	20.41
7	24.59	19.89	22.26	19.89	13.97	0.00	18.95
8	21.00	17.15	19.33	17.15	13.89	0.00	16.27
9	20.46	16.65	18.90	16.65	13.86	0.00	15.85
10	20.91	17.42	19.26	17.42	13.86	0.00	16.14
11	20.85	18.23	19.21	18.23	13.86	0.00	16.09
12	23.07	18.95	21.01	18.95	13.89	0.00	17.68
13	23.66	19.41	21.50	19.41	13.93	0.00	18.19
14	22.84	19.22	20.83	19.22	13.90	0.00	17.56
15							
16	19.23	20.46	17.89	20.46	13.88	0.00	15.04
17	19.78	21.56	18.34	21.56	13.87	0.00	15.40
18	21.56	24.79	19.79	24.79	13.87	0.00	16.61
19	23.52	25.36	21.38	25.36	13.91	0.00	18.04
20	22.95	25.47	20.92	23.00	13.91	0.00	17.66
21	21.96	25.63	20.12	23.15	13.90	0.00	16.95
22	0.00	0.00	2.25		0.11	0.00	2.25

**Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)**



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 0.8624$

$R^2 = 0.7438$

**A4.10 Data used for the variability test (Table 4.5)**

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$
	mg/m3	mg/m3			
$i$	$\hat{y}_i$	$y_i$			
1	21.90	22.17	0.27	-0.98	0.97
2	21.47	23.28	1.81	0.56	0.31
3	20.47	21.90	1.43	0.17	0.03
4	20.20	20.73	0.53	-0.72	0.52
5	21.05	20.87	-0.18	-1.43	2.06
6	20.41	20.01	-0.39	-1.65	2.71
7	18.95	18.28	-0.67	-1.93	3.71
8	16.27	15.51	-0.76	-2.02	4.06
9	15.85	15.11	-0.74	-1.99	3.97
10	16.14	15.59	-0.55	-1.81	3.27
11	16.09	16.31	0.22	-1.03	1.07
12	17.68	16.96	-0.72	-1.98	3.90
13	18.19	17.39	-0.79	-2.05	4.19
14	17.56	17.23	-0.32	-1.58	2.49
16	15.04	18.39	3.35	2.09	4.39
17	15.40	19.40	4.00	2.74	7.53
18	16.61	22.37	5.76	4.51	20.32
19	18.04	22.87	4.83	3.57	12.75
20	17.66	23.00	5.34	4.08	16.65
21	16.95	23.15	6.21	4.95	24.53

**A4.11 The variability test**

The variability test is passed when  $\sigma_D \leq \sigma_D k$   
 based on parallel measurements only  
 where

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 2.5073$$

$$\sigma_D = \frac{pELV}{f} = 3.3367$$

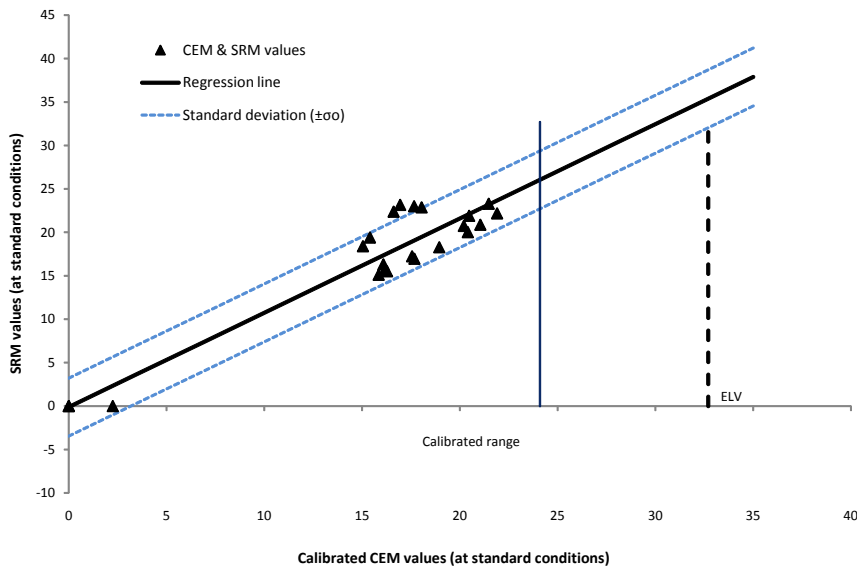
$$k = 0.9824 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_D k = 3.278$$

**Variability test is passed (76% of limit)**

**A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions**

mg/m3, 15%, dry, STP



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_{ELV}$  plus an extension of 10% or 20% of the ELV, whichever is the greater.  
 The range may also be extrapolated to the ELV using reference materials if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 24 mg/m3 (73% of ELV)**

**Range is not extrapolated**

### 4.1.3 Carbon monoxide

**Sample point** HRSG 10 exhaust flue (A1)  
**Determinand** Carbon monoxide

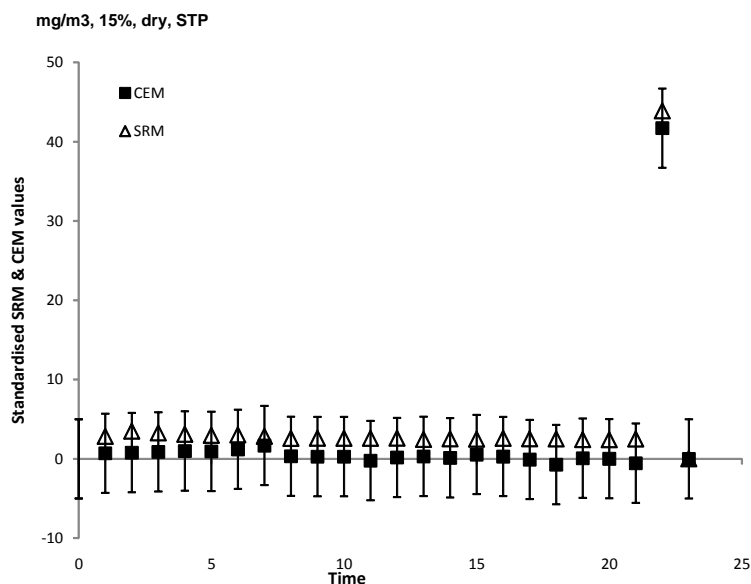
#### A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			CEM basis
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	
				mg/m3	%, dry	%	ppm	%, dry	%	
1	31.5.16	1530	1630	0.83	13.97	0.00	2.47	14.47	0.00	3.09
2	31.5.16	1630	1730	0.92	13.96	0.00	3.04	14.48	0.00	3.80
3	31.5.16	1730	1830	1.03	14.00	0.00	2.83	14.51	0.00	3.54
4	31.5.16	1830	1930	1.15	14.01	0.00	2.69	14.50	0.00	3.36
5	31.5.16	1930	2030	1.10	13.96	0.00	2.58	14.49	0.00	3.22
6	31.5.16	2030	2130	1.42	13.96	0.00	2.62	14.50	0.00	3.27
7	31.5.16	2130	2230	1.98	13.97	0.00	2.48	14.48	0.00	3.09
8	1.6.16	1100	1200	0.39	13.89	0.00	2.28	14.38	0.00	2.85
9	1.6.16	1200	1300	0.34	13.86	0.00	2.30	14.40	0.00	2.87
10	1.6.16	1300	1400	0.34	13.86	0.00	2.32	14.31	0.00	2.90
11	1.6.16	1400	1500	-0.26	13.86	0.00	2.32	14.30	0.00	2.90
12	1.6.16	1500	1600	0.21	13.89	0.00	2.33	14.31	0.00	2.91
13	1.6.16	1600	1700	0.36	13.93	0.00	2.19	14.31	0.00	2.74
14	1.6.16	1700	1800	0.16	13.90	0.00	2.25	14.32	0.00	2.81
15	2.6.16	1100	1200	0.65	13.92	0.00	2.21	14.34	0.00	2.76
16	2.6.16	1200	1300	0.35	13.88	0.00	2.30	14.34	0.00	2.88
17	2.6.16	1300	1400	-0.10	13.87	0.00	2.25	14.34	0.00	2.81
18	2.6.16	1400	1500	-0.86	13.87	0.00	2.23	14.36	0.00	2.78
19	2.6.16	1500	1600	0.10	13.91	0.00	2.15	14.36	0.00	2.69
20	2.6.16	1600	1700	0.02	13.91	0.00	2.14	14.37	0.00	2.67
21	2.6.16	1700	1800	-0.65	13.90	0.00	2.21	14.37	0.00	2.77
22	7.5.16	-	-	49.36	13.92	0.00	51.95	13.92	0.00	51.95
23	7.5.16	-	-	0.00	13.92	0.00	0.00	13.92	0.00	0.00

#### A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	mg/m3	mg/m3
1	0.70	2.84
2	0.78	3.49
3	0.88	3.27
4	0.98	3.10
5	0.94	2.96
6	1.21	3.02
7	1.68	2.84
8	0.33	2.58
9	0.29	2.60
10	0.28	2.59
11	-0.22	2.59
12	0.17	2.61
13	0.30	2.45
14	0.13	2.52
15	0.55	2.48
16	0.29	2.59
17	-0.09	2.52
18	-0.72	2.51
19	0.08	2.42
20	0.01	2.41
21	-0.54	2.50
22	41.71	43.91
23	0	0

#### A4.3 Plot 1 - Standardised CEM & SRM values versus time



100 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)  
Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM	SRM	Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$	
	mg/m3	mg/m3					
i	x	y				$\sigma_D$	
1	0.83	3.09	2.26	0.27	0.07	0.51	include
2	0.92	3.80	2.87	0.34	0.11	0.63	include
3	1.03	3.54	2.51	0.02	0.00	0.04	include
4	1.15	3.36	2.21	0.33	0.11	0.61	include
5	1.10	3.22	2.11	0.42	0.18	0.78	include
6	1.42	3.27	1.86	0.68	0.46	1.27	include
7	1.98	3.09	1.12	1.42	2.01	2.65	exclude
8	0.39	2.85	2.46	0.07	0.01	0.14	include
9	0.34	2.87	2.53	0.01	0.00	0.02	include
10	0.34	2.90	2.56	0.02	0.00	0.04	include
11	-0.26	2.90	3.16	0.62	0.39	1.16	include
12	0.21	2.91	2.70	0.17	0.03	0.31	include
13	0.36	2.74	2.38	0.16	0.02	0.29	include
14	0.16	2.81	2.65	0.12	0.01	0.22	include
15	0.65	2.76	2.11	0.42	0.18	0.79	include
16	0.35	2.88	2.53	0.00	0.00	0.01	include
17	-0.10	2.81	2.91	0.38	0.14	0.70	include
18	-0.86	2.78	3.64	1.11	1.23	2.07	exclude
19	0.10	2.69	2.59	0.06	0.00	0.10	include
20	0.02	2.67	2.65	0.12	0.01	0.22	include
21	-0.65	2.77	3.41	0.88	0.77	1.64	include

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum (y_s - \hat{y}_s)}{n}$

where n is the number of samples = 19  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.54 given by

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum (D_i - \bar{D})^2}$$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 3.49$       Smallest SRM value  $y_{s \min} = 2.42$

Data span = 2 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$       Minimum value = 5 % of ELV  
(Procedure a if greater than 20 % of ELV)

Select Procedure c for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM	SRM	Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$
	mg/m3	mg/m3				
i	x	y				
1	0.83	3.09	-1.9	-2.1	3.7	4.4
2	0.92	3.80	-1.8	-1.4	3.3	1.9
3	1.03	3.54	-1.7	-1.6	3.0	2.7
4	1.15	3.36	-1.6	-1.8	2.6	3.3
5	1.10	3.22	-1.6	-2.0	2.7	3.8
6	1.42	3.27	-1.3	-1.9	1.8	3.6
7						
8	0.39	2.85	-2.4	-2.3	5.6	5.4
9	0.34	2.87	-2.4	-2.3	5.8	5.3
10	0.34	2.90	-2.4	-2.3	5.8	5.2
11	-0.26	2.90	-3.0	-2.3	9.1	5.2
12	0.21	2.91	-2.5	-2.3	6.5	5.1
13	0.36	2.74	-2.4	-2.4	5.7	6.0
14	0.16	2.81	-2.6	-2.4	6.7	5.6
15	0.65	2.76	-2.1	-2.4	4.4	5.8
16	0.35	2.88	-2.4	-2.3	5.8	5.3
17	-0.10	2.81	-2.9	-2.4	8.1	5.6
18						
19	0.10	2.69	-2.6	-2.5	7.0	6.2
20	0.02	2.67	-2.7	-2.5	7.5	6.3
21	-0.65	2.77	-3.4	-2.4	11.5	5.8
22	49.36	51.95	46.6	46.8	2172.3	2187.8
23	0.00	0.00	-2.7	-5.2	7.5	26.8

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 1.0027x + 2.42$$

Procedure b

$$y = bx$$

where

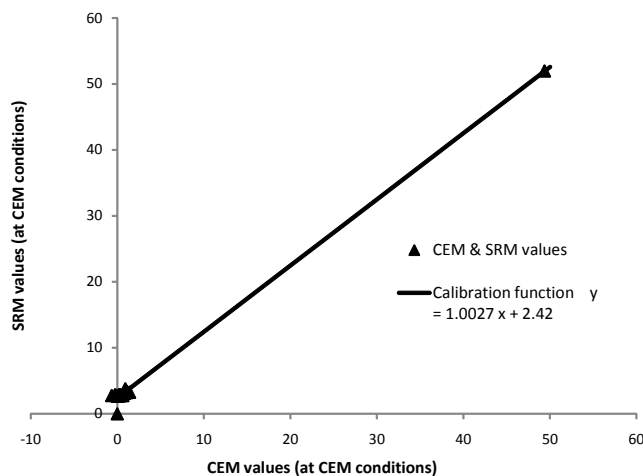
$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions				O <sub>2</sub>	H <sub>2</sub> O	
	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>			
1	0.83	3.09	3.25	3.09	13.97	0.00	2.77
2	0.92	3.80	3.35	3.80	13.96	0.00	2.85
3	1.03	3.54	3.45	3.54	14.00	0.00	2.95
4	1.15	3.36	3.58	3.36	14.01	0.00	3.06
5	1.10	3.22	3.53	3.22	13.96	0.00	3.00
6	1.42	3.27	3.85	3.27	13.96	0.00	3.27
7							
8	0.39	2.85	2.81	2.85	13.89	0.00	2.37
9	0.34	2.87	2.77	2.87	13.86	0.00	2.32
10	0.34	2.90	2.77	2.90	13.86	0.00	2.32
11	-0.26	2.90	2.16	2.90	13.86	0.00	1.81
12	0.21	2.91	2.63	2.91	13.89	0.00	2.21
13	0.36	2.74	2.78	2.74	13.93	0.00	2.36
14	0.16	2.81	2.58	2.81	13.90	0.00	2.17
15	0.65	2.76	3.07	2.76	13.92	0.00	2.60
16	0.35	2.88	2.77	2.88	13.88	0.00	2.33
17	-0.10	2.81	2.32	2.81	13.87	0.00	1.95
18							
19	0.10	2.69	2.52	2.69	13.91	0.00	2.13
20	0.02	2.67	2.44	2.41	13.91	0.00	2.06
21	-0.65	2.77	1.78	2.50	13.90	0.00	1.50
22	49.36	51.95	51.91		13.92	0.00	43.87
23	0.00	0.00	2.42	0.00	13.92	0.00	2.42

**Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)**

mg/m<sup>3</sup>, dry



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 0.9981$

$R^2 = 0.9962$

**A4.10 Data used for the variability test (Table 4.5)**

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	D - $\bar{D}$	$(D - \bar{D})^2$
i	mg/m3	mg/m3			
	$\hat{y}_i$	$y_i$			
1	2.77	2.84	0.07	-0.08	0.01
2	2.85	3.49	0.64	0.49	0.24
3	2.95	3.27	0.31	0.17	0.03
4	3.06	3.10	0.03	-0.11	0.01
5	3.00	2.96	-0.04	-0.19	0.04
6	3.27	3.02	-0.25	-0.40	0.16
8	2.37	2.58	0.21	0.06	0.00
9	2.32	2.60	0.28	0.13	0.02
10	2.32	2.59	0.28	0.13	0.02
11	1.81	2.59	0.78	0.63	0.40
12	2.21	2.61	0.39	0.24	0.06
13	2.36	2.45	0.10	-0.05	0.00
14	2.17	2.52	0.34	0.20	0.04
15	2.60	2.48	-0.11	-0.26	0.07
16	2.33	2.59	0.26	0.11	0.01
17	1.95	2.52	0.58	0.43	0.18
19	2.13	2.42	0.29	0.15	0.02
20	2.06	2.41	0.35	0.20	0.04
21	1.50	2.50	1.00	0.86	0.73

**A4.11 The variability test**

The variability test is passed when  $\sigma_o \leq \sigma_o k$   
based on parallel measurements only  
where

$$\sigma_o = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 0.34$$

$$\sigma_o = \frac{pELV}{f} = 5.102$$

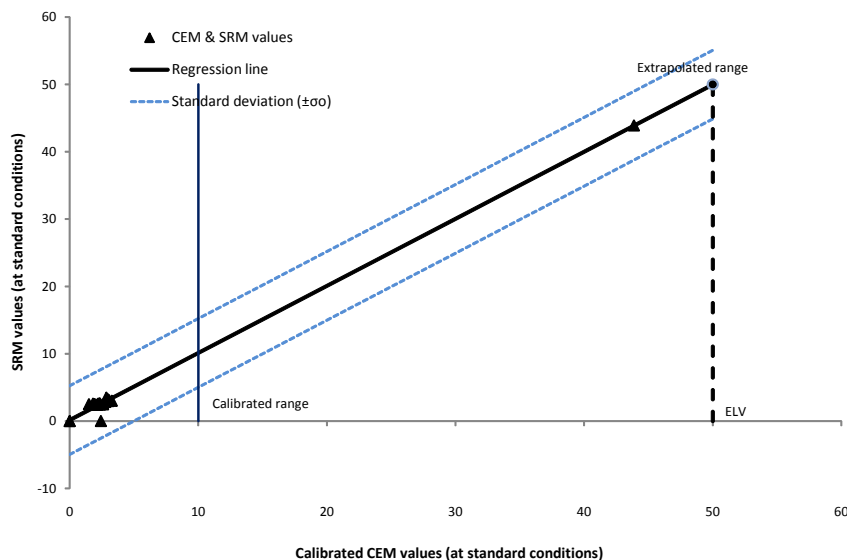
$$k = 0.9814 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_o k = 5.0071$$

**Variability test is passed (7% of limit)**

**A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions**

mg/m3, 15%, dry, STP



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_{s-max}$  plus an extension of 10% or 20% of the ELV, whichever is the greater.  
The range may also be extrapolated to the ELV using reference materials  
if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 10 mg/m3 (20% of ELV)**

**CEM response of 60 to reference material of 60 mg/m3  
Range extrapolated to 50 mg/m3 (100% of ELV)**

## 4.2 HRSG 20 (A2) Duty CEM

### 4.2.1 Oxygen

Sample point HRSG 20 exhaust flue (A2)

Determinand Oxygen

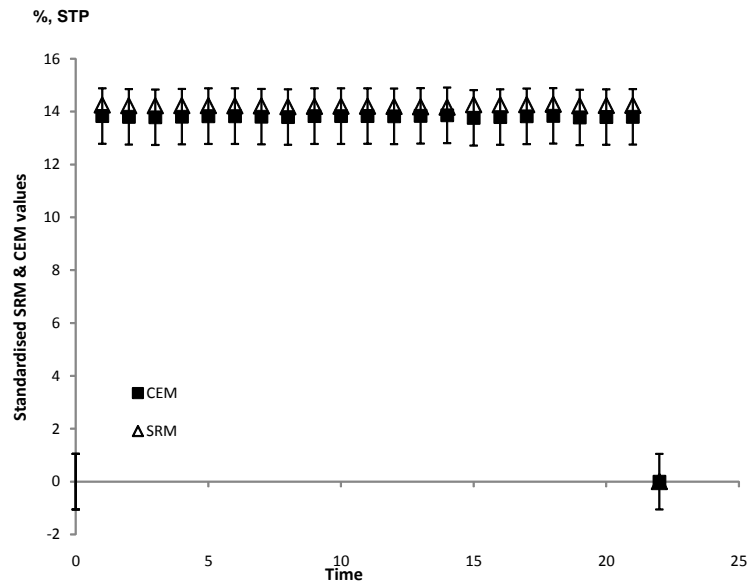
#### A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	CEM basis
				%	%, dry	%	%	%, dry	%	%
1	3.6.16	1300	1400	13.84	13.84	0.00	14.25	14.25	0.00	14.25
2	3.6.16	1400	1500	13.81	13.81	0.00	14.23	14.23	0.00	14.23
3	3.6.16	1500	1600	13.79	13.79	0.00	14.23	14.23	0.00	14.23
4	3.6.16	1600	1700	13.81	13.81	0.00	14.23	14.23	0.00	14.23
5	3.6.16	1700	1800	13.83	13.83	0.00	14.23	14.23	0.00	14.23
6	3.6.16	1800	1900	13.83	13.83	0.00	14.22	14.22	0.00	14.22
7	3.6.16	1900	2000	13.81	13.81	0.00	14.22	14.22	0.00	14.22
8	6.6.16	1100	1200	13.80	13.80	0.00	14.19	14.19	0.00	14.19
9	6.6.16	1200	1300	13.83	13.83	0.00	14.20	14.20	0.00	14.20
10	6.6.16	1300	1400	13.83	13.83	0.00	14.21	14.21	0.00	14.21
11	6.6.16	1400	1500	13.84	13.84	0.00	14.21	14.21	0.00	14.21
12	6.6.16	1500	1600	13.82	13.82	0.00	14.20	14.20	0.00	14.20
13	6.6.16	1600	1700	13.84	13.84	0.00	14.18	14.18	0.00	14.18
14	6.6.16	1700	1800	13.86	13.86	0.00	14.17	14.17	0.00	14.17
15	7.6.16	1100	1200	13.77	13.77	0.00	14.26	14.26	0.00	14.26
16	7.6.16	1200	1300	13.80	13.80	0.00	14.26	14.26	0.00	14.26
17	7.6.16	1300	1400	13.83	13.83	0.00	14.27	14.27	0.00	14.27
18	7.6.16	1400	1500	13.84	13.84	0.00	14.28	14.28	0.00	14.28
19	7.6.16	1500	1600	13.78	13.78	0.00	14.22	14.22	0.00	14.22
20	7.6.16	1600	1700	13.80	13.80	0.00	14.24	14.24	0.00	14.24
21	7.6.16	1700	1800	13.81	13.81	0.00	14.24	14.24	0.00	14.24
22	7.6.16	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00

#### A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	%	%
1	13.84	14.25
2	13.81	14.23
3	13.79	14.23
4	13.81	14.23
5	13.83	14.23
6	13.83	14.22
7	13.81	14.22
8	13.80	14.19
9	13.83	14.20
10	13.83	14.21
11	13.84	14.21
12	13.82	14.20
13	13.84	14.18
14	13.86	14.17
15	13.77	14.26
16	13.80	14.26
17	13.83	14.27
18	13.84	14.28
19	13.78	14.22
20	13.80	14.24
21	13.81	14.24
22	0	0

#### A4.3 Plot 1 - Standardised CEM & SRM values versus time



100 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)

Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM		SRM		Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$			
	%	%							
i	x	y							
1	13.84	14.25	0.42	0.01	0.00	0.22	include		
2	13.81	14.23	0.42	0.01	0.00	0.32	include		
3	13.79	14.23	0.44	0.03	0.00	0.68	include		
4	13.81	14.23	0.42	0.01	0.00	0.21	include		
5	13.83	14.23	0.40	0.01	0.00	0.23	include		
6	13.83	14.22	0.39	0.02	0.00	0.39	include		
7	13.81	14.22	0.41	0.00	0.00	0.07	include		
8	13.80	14.19	0.39	0.02	0.00	0.41	include		
9	13.83	14.20	0.37	0.04	0.00	0.86	include		
10	13.83	14.21	0.38	0.03	0.00	0.75	include		
11	13.84	14.21	0.37	0.04	0.00	0.87	include		
12	13.82	14.20	0.37	0.03	0.00	0.79	include		
13	13.84	14.18	0.34	0.07	0.00	1.59	include		
14	13.86	14.17	0.31	0.10	0.01	2.32	exclude		
15	13.77	14.26	0.50	0.09	0.01	2.07	exclude		
16	13.80	14.26	0.46	0.05	0.00	1.27	include		
17	13.83	14.27	0.44	0.03	0.00	0.77	include		
18	13.84	14.28	0.44	0.03	0.00	0.70	include		
19	13.78	14.22	0.44	0.03	0.00	0.67	include		
20	13.80	14.24	0.44	0.03	0.00	0.70	include		
21	13.81	14.24	0.44	0.03	0.00	0.66	include		

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum (y_{si} - \hat{y}_{si})}{n}$

where n is the number of samples = 19  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.04 given by

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum (D_i - \bar{D})^2}$$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 14.28$       Smallest SRM value  $y_{s \min} = 14.18$

Data span = 0 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$       Minimum value = 68 % of ELV  
(Procedure a if greater than 10 % of ELV)

Select Procedure b for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM		SRM		Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$		
	%	%						
i	x	y						
1	13.84	14.25	0.7	0.7	0.5	0.5		
2	13.81	14.23	0.7	0.7	0.5	0.5		
3	13.79	14.23	0.7	0.7	0.4	0.5		
4	13.81	14.23	0.7	0.7	0.5	0.5		
5	13.83	14.23	0.7	0.7	0.5	0.5		
6	13.83	14.22	0.7	0.7	0.5	0.5		
7	13.81	14.22	0.7	0.7	0.5	0.5		
8	13.80	14.19	0.7	0.7	0.4	0.5		
9	13.83	14.20	0.7	0.7	0.5	0.5		
10	13.83	14.21	0.7	0.7	0.5	0.5		
11	13.84	14.21	0.7	0.7	0.5	0.5		
12	13.82	14.20	0.7	0.7	0.5	0.5		
13	13.84	14.18	0.7	0.7	0.5	0.4		
14								
15								
16	13.80	14.26	0.7	0.7	0.4	0.6		
17	13.83	14.27	0.7	0.8	0.5	0.6		
18	13.84	14.28	0.7	0.8	0.5	0.6		
19	13.78	14.22	0.7	0.7	0.4	0.5		
20	13.80	14.24	0.7	0.7	0.5	0.5		
21	13.81	14.24	0.7	0.7	0.5	0.5		
22	0.00	0.00	-13.1	-13.5	172.3	182.7		

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 1.0296 x$$

Procedure b

$$y = bx$$

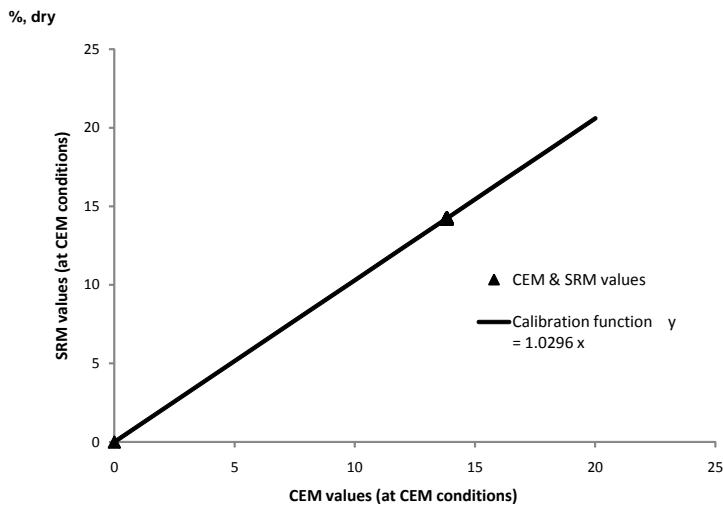
where

$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions			Stack	O <sub>2</sub>	H <sub>2</sub> O	
	%	%	%	%	%, dry	%	
1	13.84	14.25	14.25	14.25	13.84	0.00	14.25
2	13.81	14.23	14.21	14.23	13.81	0.00	14.21
3	13.79	14.23	14.20	14.23	13.79	0.00	14.20
4	13.81	14.23	14.22	14.23	13.81	0.00	14.22
5	13.83	14.23	14.24	14.23	13.83	0.00	14.24
6	13.83	14.22	14.24	14.22	13.83	0.00	14.24
7	13.81	14.22	14.22	14.22	13.81	0.00	14.22
8	13.80	14.19	14.21	14.19	13.80	0.00	14.21
9	13.83	14.20	14.24	14.20	13.83	0.00	14.24
10	13.83	14.21	14.24	14.21	13.83	0.00	14.24
11	13.84	14.21	14.24	14.21	13.84	0.00	14.24
12	13.82	14.20	14.23	14.20	13.82	0.00	14.23
13	13.84	14.18	14.25	14.18	13.84	0.00	14.25
14							
15							
16	13.80	14.26	14.21	14.26	13.80	0.00	14.21
17	13.83	14.27	14.23	14.27	13.83	0.00	14.23
18	13.84	14.28	14.25	14.28	13.84	0.00	14.25
19	13.78	14.22	14.19	14.22	13.78	0.00	14.19
20	13.80	14.24	14.21	14.24	13.80	0.00	14.21
21	13.81	14.24	14.22	14.24	13.81	0.00	14.22
22	0.00	0.00	0.00		0.00	0.00	0.00

**Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)**



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 1$

**R<sup>2</sup> = 0.9999**

A4.10 Data used for the variability test (Table 4.5)

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	D - $\bar{D}$	$(D - \bar{D})^2$
	%	%			
i	$\hat{y}_i$	$y_i$			
1	14.25	14.25	0.01	0.01	0.00
2	14.21	14.23	0.01	0.01	0.00
3	14.20	14.23	0.03	0.03	0.00
4	14.22	14.23	0.01	0.01	0.00
5	14.24	14.23	-0.01	-0.01	0.00
6	14.24	14.22	-0.02	-0.02	0.00
7	14.22	14.22	0.00	0.00	0.00
8	14.21	14.19	-0.02	-0.02	0.00
9	14.24	14.20	-0.04	-0.04	0.00
10	14.24	14.21	-0.03	-0.03	0.00
11	14.24	14.21	-0.04	-0.04	0.00
12	14.23	14.20	-0.03	-0.03	0.00
13	14.25	14.18	-0.07	-0.07	0.00
16	14.21	14.26	0.05	0.05	0.00
17	14.23	14.27	0.03	0.03	0.00
18	14.25	14.28	0.03	0.03	0.00
19	14.19	14.22	0.03	0.03	0.00
20	14.21	14.24	0.03	0.03	0.00
21	14.22	14.24	0.03	0.03	0.00

A4.11 The variability test

The variability test is passed when  $\sigma_o \leq \sigma_o k$   
based on parallel measurements only  
where

$$\sigma_o = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 0.0325$$

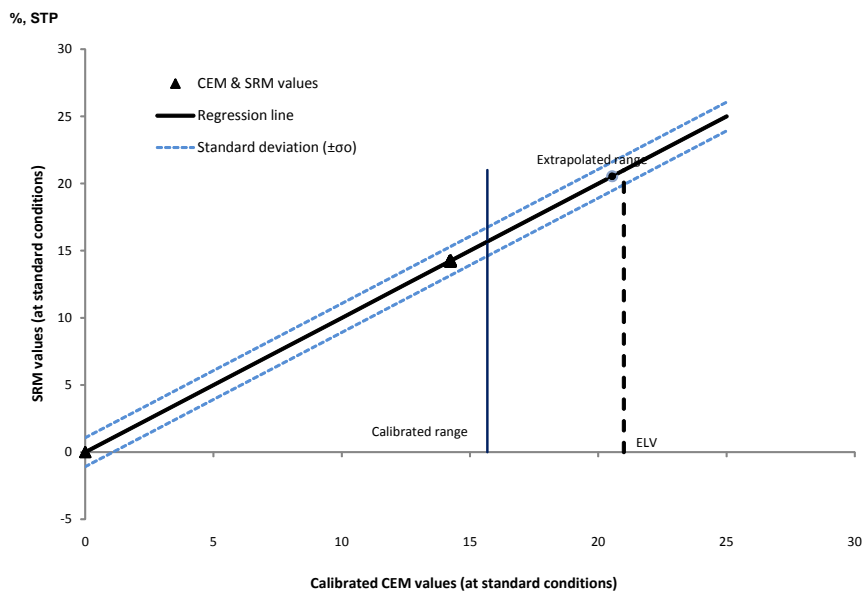
$$\sigma_o = \frac{pELV}{f} = 1.0714$$

$$k = 0.9814 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_o k = 1.0515$$

**Variability test is passed (3% of limit)**

A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_{o,max}$  plus an extension of 10% or 20% of the ELV, whichever is the greater.  
The range may also be extrapolated to the ELV using reference materials  
if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 16 % (74% of ELV)**

**CEM response of 21 to reference material of 20 %  
Range extrapolated to 21 % (98% of ELV)**

## 4.2.2 Nitrogen monoxide

Sample point HRSG 20 exhaust flue (A2)

Determinand Nitrogen monoxide

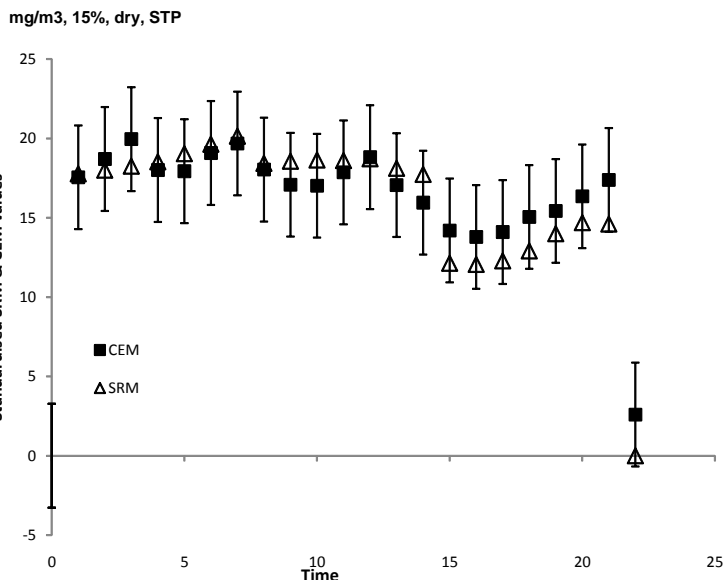
### A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			CEM basis
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	
				mg/m3	%, dry	%	ppm	%, dry	%	
1	3.6.16	1300	1400	21.01	13.84	0.00	14.95	14.25	0.00	20.01
2	3.6.16	1400	1500	22.49	13.81	0.00	15.21	14.23	0.00	20.36
3	3.6.16	1500	1600	24.05	13.79	0.00	15.43	14.23	0.00	20.65
4	3.6.16	1600	1700	21.64	13.81	0.00	15.65	14.23	0.00	20.95
5	3.6.16	1700	1800	21.49	13.83	0.00	16.08	14.23	0.00	21.53
6	3.6.16	1800	1900	22.87	13.83	0.00	16.61	14.22	0.00	22.23
7	3.6.16	1900	2000	23.65	13.81	0.00	17.04	14.22	0.00	22.81
8	6.6.16	1100	1200	21.72	13.80	0.00	15.66	14.19	0.00	20.96
9	6.6.16	1200	1300	20.47	13.83	0.00	15.74	14.20	0.00	21.07
10	6.6.16	1300	1400	20.39	13.83	0.00	15.79	14.21	0.00	21.14
11	6.6.16	1400	1500	21.39	13.84	0.00	15.77	14.21	0.00	21.11
12	6.6.16	1500	1600	22.57	13.82	0.00	15.88	14.20	0.00	21.26
13	6.6.16	1600	1700	20.40	13.84	0.00	15.41	14.18	0.00	20.63
14	6.6.16	1700	1800	19.03	13.86	0.00	15.11	14.17	0.00	20.22
15	7.6.16	1100	1200	17.17	13.77	0.00	10.20	14.26	0.00	13.65
16	7.6.16	1200	1300	16.61	13.80	0.00	10.14	14.26	0.00	13.57
17	7.6.16	1300	1400	16.91	13.83	0.00	10.32	14.27	0.00	13.81
18	7.6.16	1400	1500	18.01	13.84	0.00	10.82	14.28	0.00	14.48
19	7.6.16	1500	1600	18.62	13.78	0.00	11.84	14.22	0.00	15.84
20	7.6.16	1600	1700	19.69	13.80	0.00	12.39	14.24	0.00	16.59
21	7.6.16	1700	1800	20.91	13.81	0.00	12.31	14.24	0.00	16.48
22	7.6.16	-	-	2.60	0.00	0.00	0.00	0.00	0.00	0.00

### A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	mg/m3	mg/m3
1	17.55	17.77
2	18.70	18.00
3	19.96	18.25
4	18.01	18.53
5	17.94	19.04
6	19.08	19.64
7	19.68	20.14
8	18.04	18.43
9	17.09	18.56
10	17.02	18.64
11	17.86	18.61
12	18.82	18.72
13	17.06	18.12
14	15.96	17.73
15	14.20	12.13
16	13.79	12.06
17	14.10	12.28
18	15.05	12.91
19	15.44	14.00
20	16.35	14.69
21	17.39	14.61
22	2.6	0

### A4.3 Plot 1 - Standardised CEM & SRM values versus time



100 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)  
Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM		SRM		Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$			
	mg/m3	mg/m3							
i	x	y							
1	21.01	20.01	1.00	0.78	0.61	0.57	include		
2	22.49	20.36	2.13	0.36	0.13	0.26	include		
3	24.05	20.65	3.41	1.63	2.65	1.19	include		
4	21.64	20.95	0.69	1.08	1.18	0.79	include		
5	21.49	21.53	0.04	1.74	3.03	1.27	include		
6	22.87	22.23	0.64	1.14	1.29	0.83	include		
7	23.65	22.81	0.84	0.94	0.89	0.69	include		
8	21.72	20.96	0.75	1.02	1.05	0.75	include		
9	20.47	21.07	0.60	1.18	1.38	0.86	include		
10	20.39	21.14	0.75	1.03	1.06	0.75	include		
11	21.39	21.11	0.28	1.49	2.23	1.09	include		
12	22.57	21.26	1.31	0.47	0.22	0.34	include		
13	20.40	20.63	0.22	1.55	2.42	1.13	include		
14	19.03	20.22	1.19	0.59	0.35	0.43	include		
15	17.17	13.65	3.52	1.74	3.04	1.27	include		
16	16.61	13.57	3.03	1.25	1.57	0.91	include		
17	16.91	13.81	3.10	1.32	1.75	0.96	include		
18	18.01	14.48	3.52	1.75	3.05	1.27	include		
19	18.62	15.84	2.77	1.00	0.99	0.73	include		
20	19.69	16.59	3.09	1.32	1.73	0.96	include		
21	20.91	16.48	4.43	2.65	7.02	1.93	include		

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum_{i=1}^n (y_{si} - \hat{y}_{si})}{n}$

where  $n$  is the number of samples = 21  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 1.37 given by  $\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2}$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 20.14$       Smallest SRM value  $y_{s \min} = 12.06$

Data span = 25 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$       Minimum value = 37 % of ELV  
(Procedure a if greater than 20 % of ELV)      (Procedure b if greater than 15% of ELV)

Select Procedure a for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM		SRM		Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$		
	mg/m3	mg/m3						
i	x	y						
1	21.01	20.01	1.3	1.9	1.7	3.5		
2	22.49	20.36	2.8	2.2	7.7	4.9		
3	24.05	20.65	4.3	2.5	18.8	6.2		
4	21.64	20.95	1.9	2.8	3.7	7.8		
5	21.49	21.53	1.8	3.4	3.2	11.4		
6	22.87	22.23	3.2	4.1	10.0	16.6		
7	23.65	22.81	3.9	4.7	15.5	21.7		
8	21.72	20.96	2.0	2.8	4.0	7.9		
9	20.47	21.07	0.8	2.9	0.6	8.5		
10	20.39	21.14	0.7	3.0	0.5	8.9		
11	21.39	21.11	1.7	3.0	2.8	8.7		
12	22.57	21.26	2.9	3.1	8.2	9.6		
13	20.40	20.63	0.7	2.5	0.5	6.1		
14	19.03	20.22	-0.7	2.1	0.5	4.3		
15	17.17	13.65	-2.5	-4.5	6.5	20.3		
16	16.61	13.57	-3.1	-4.6	9.7	21.0		
17	16.91	13.81	-2.8	-4.3	7.9	18.9		
18	18.01	14.48	-1.7	-3.7	2.9	13.5		
19	18.62	15.84	-1.1	-2.3	1.2	5.3		
20	19.69	16.59	0.0	-1.6	0.0	2.4		
21	20.91	16.48	1.2	-1.7	1.4	2.8		
22	2.60	0.00	-17.1	-18.2	292.8	329.5		

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 1.1036 x - 3.6$$

Procedure b

$$y = bx$$

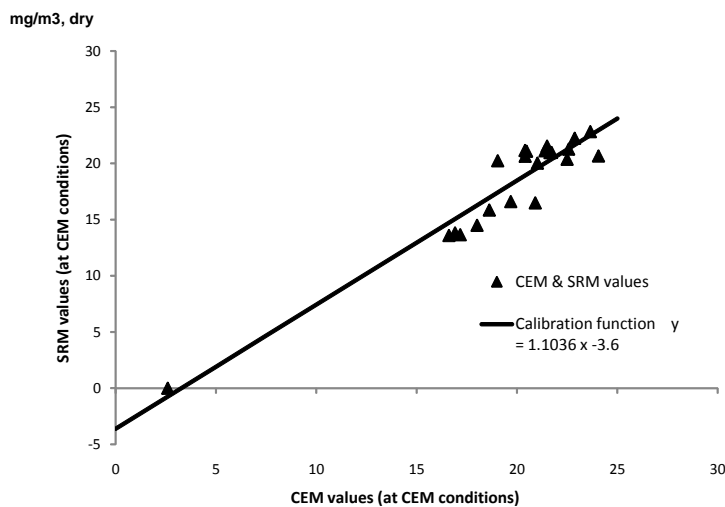
where

$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions			Stack	O <sub>2</sub>	H <sub>2</sub> O	
	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	%, dry	%	
1	21.01	20.01	19.59	20.01	13.84	0.00	16.36
2	22.49	20.36	21.22	20.36	13.81	0.00	17.65
3	24.05	20.65	22.94	20.65	13.79	0.00	19.04
4	21.64	20.95	20.28	20.95	13.81	0.00	16.88
5	21.49	21.53	20.12	21.53	13.83	0.00	16.79
6	22.87	22.23	21.63	22.23	13.83	0.00	18.05
7	23.65	22.81	22.49	22.81	13.81	0.00	18.72
8	21.72	20.96	20.36	20.96	13.80	0.00	16.92
9	20.47	21.07	18.99	21.07	13.83	0.00	15.85
10	20.39	21.14	18.90	21.14	13.83	0.00	15.78
11	21.39	21.11	20.00	21.11	13.84	0.00	16.71
12	22.57	21.26	21.30	21.26	13.82	0.00	17.76
13	20.40	20.63	18.91	20.63	13.84	0.00	15.81
14	19.03	20.22	17.40	20.22	13.86	0.00	14.59
15	17.17	13.65	15.34	13.65	13.77	0.00	12.69
16	16.61	13.57	14.72	13.57	13.80	0.00	12.23
17	16.91	13.81	15.06	13.81	13.83	0.00	12.56
18	18.01	14.48	16.27	14.48	13.84	0.00	13.60
19	18.62	15.84	16.94	15.84	13.78	0.00	14.05
20	19.69	16.59	18.12	16.59	13.80	0.00	15.06
21	20.91	16.48	19.47	16.48	13.81	0.00	16.19
22	2.60	0.00	-0.73		0.00	0.00	-0.73

**Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)**



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 0.9498$

**R<sup>2</sup> = 0.9021**

**A4.10 Data used for the variability test (Table 4.5)**

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	D - $\bar{D}$	$(D - \bar{D})^2$
	mg/m3	mg/m3			
i	$\hat{y}_i$	$y_i$			
1	16.36	17.77	1.41	0.48	0.24
2	17.65	18.00	0.35	-0.57	0.32
3	19.04	18.25	-0.78	-1.70	2.90
4	16.88	18.53	1.65	0.72	0.52
5	16.79	19.04	2.25	1.33	1.77
6	18.05	19.64	1.58	0.66	0.44
7	18.72	20.14	1.42	0.49	0.24
8	16.92	18.43	1.51	0.59	0.35
9	15.85	18.56	2.72	1.79	3.21
10	15.78	18.64	2.86	1.94	3.75
11	16.71	18.61	1.90	0.98	0.95
12	17.76	18.72	0.95	0.03	0.00
13	15.81	18.12	2.31	1.38	1.91
14	14.59	17.73	3.14	2.22	4.94
15	12.69	12.13	-0.56	-1.48	2.20
16	12.23	12.06	-0.17	-1.09	1.19
17	12.56	12.28	-0.28	-1.20	1.44
18	13.60	12.91	-0.69	-1.61	2.61
19	14.05	14.00	-0.05	-0.98	0.95
20	15.06	14.69	-0.37	-1.29	1.66
21	16.19	14.61	-1.59	-2.51	6.30

**A4.11 The variability test**

The variability test is passed when  $\sigma_o \leq \sigma_o k$   
 based on parallel measurements only  
 where

$$\sigma_o = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 1.3766$$

$$\sigma_o = \frac{\rho ELV}{f} = 3.3367$$

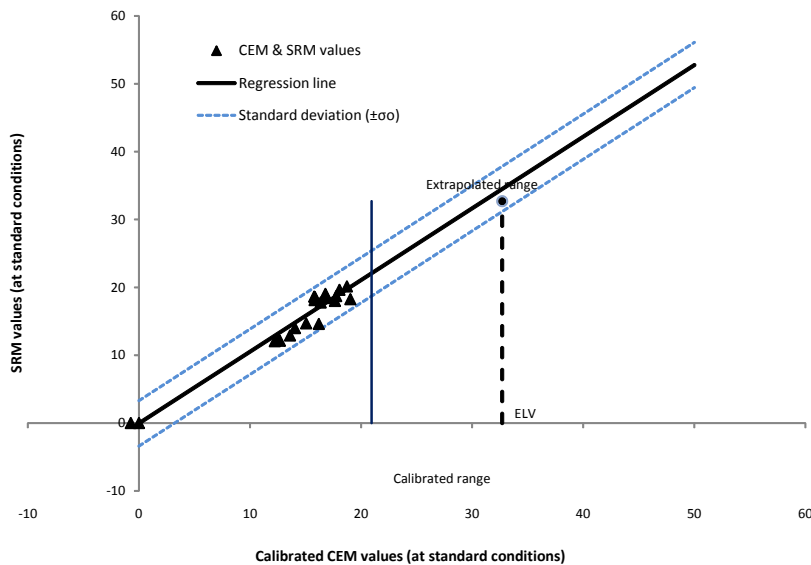
$$k = 0.9839 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_o k = 3.283$$

**Variability test is passed (42% of limit)**

**A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions**

mg/m3, 15%, dry, STP



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_o$  plus an extension of 10% or 20% of the ELV, whichever is the greater. The range may also be extrapolated to the ELV using reference materials if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 21 mg/m3 (64% of ELV)**

**CEM response of 56 to reference material of 53 mg/m3  
 Range extrapolated to 33 mg/m3 (100% of ELV)**

## 4.2.3 Carbon monoxide

Sample point HRSG 20 exhaust flue (A2)

Determinand Carbon monoxide

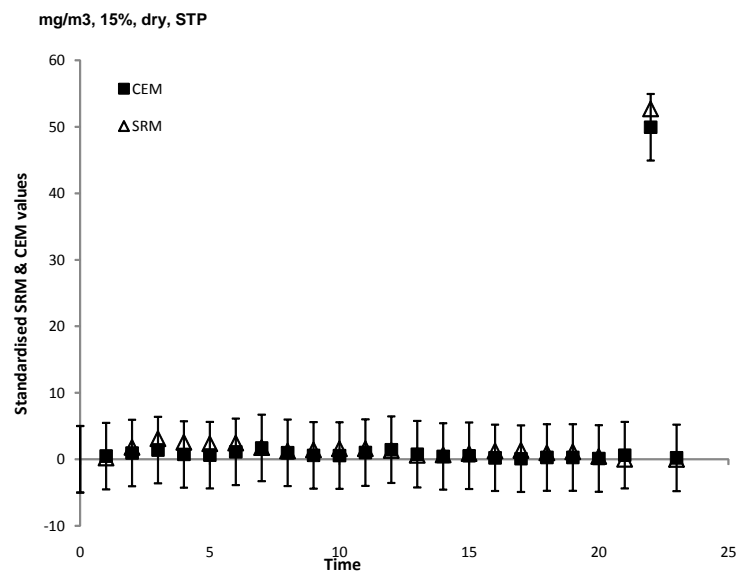
### A4.1 Raw monitoring data (Table 4.1)

Sample No.	Date	Start time	End time	CEM measurements			SRM measurements			CEM basis
				CEM	O <sub>2</sub>	H <sub>2</sub> O	SRM	O <sub>2</sub>	H <sub>2</sub> O	
				mg/m <sup>3</sup>	%, dry	%	ppm	%, dry	%	
1	3.6.16	1300	1400	0.58	13.84	0.00	0.19	14.25	0.00	0.24
2	3.6.16	1400	1500	1.14	13.81	0.00	1.64	14.23	0.00	2.05
3	3.6.16	1500	1600	1.69	13.79	0.00	2.82	14.23	0.00	3.52
4	3.6.16	1600	1700	0.88	13.81	0.00	2.32	14.23	0.00	2.90
5	3.6.16	1700	1800	0.76	13.83	0.00	2.13	14.23	0.00	2.67
6	3.6.16	1800	1900	1.36	13.83	0.00	2.22	14.22	0.00	2.78
7	3.6.16	1900	2000	2.06	13.81	0.00	1.61	14.22	0.00	2.01
8	6.6.16	1100	1200	1.19	13.80	0.00	1.14	14.19	0.00	1.43
9	6.6.16	1200	1300	0.71	13.83	0.00	1.29	14.20	0.00	1.61
10	6.6.16	1300	1400	0.67	13.83	0.00	1.45	14.21	0.00	1.81
11	6.6.16	1400	1500	1.22	13.84	0.00	1.47	14.21	0.00	1.83
12	6.6.16	1500	1600	1.75	13.82	0.00	1.23	14.20	0.00	1.53
13	6.6.16	1600	1700	0.93	13.84	0.00	0.57	14.18	0.00	0.71
14	6.6.16	1700	1800	0.52	13.86	0.00	0.62	14.17	0.00	0.77
15	7.6.16	1100	1200	0.65	13.77	0.00	0.79	14.26	0.00	0.99
16	7.6.16	1200	1300	0.28	13.80	0.00	1.14	14.26	0.00	1.43
17	7.6.16	1300	1400	0.12	13.83	0.00	1.22	14.27	0.00	1.52
18	7.6.16	1400	1500	0.34	13.84	0.00	0.88	14.28	0.00	1.10
19	7.6.16	1500	1600	0.34	13.78	0.00	1.03	14.22	0.00	1.29
20	7.6.16	1600	1700	0.14	13.80	0.00	0.40	14.24	0.00	0.50
21	7.6.16	1700	1800	0.75	13.81	0.00	0.02	14.24	0.00	0.02
22	7.6.16	-	-	49.94	13.82	0.00	52.70	13.82	0.00	52.70
23	7.6.16	-	-	0.27	13.82	0.00	0.00	13.82	0.00	0.00

### A4.2 Standardised monitoring data (Table 4.2)

Sample No.	CEM	SRM
	Standard conditions <sup>1</sup>	
	mg/m <sup>3</sup>	mg/m <sup>3</sup>
1	0.49	0.21
2	0.95	1.81
3	1.40	3.11
4	0.74	2.57
5	0.64	2.36
6	1.13	2.46
7	1.72	1.77
8	0.99	1.25
9	0.60	1.42
10	0.56	1.60
11	1.02	1.62
12	1.46	1.35
13	0.78	0.62
14	0.44	0.68
15	0.54	0.88
16	0.23	1.27
17	0.10	1.35
18	0.29	0.98
19	0.28	1.14
20	0.12	0.44
21	0.62	0.02
22	49.94	52.70
23	0.23	0.00

### A4.3 Plot 1 - Standardised CEM & SRM values versus time



100 % of all SRM and CEM pairs deviated by less than half of the confidence interval of the ELV (see error bars above)

Average of the CEM and SRM results does not differ by more than the confidence interval of the ELV

<sup>1</sup> Raw CEM and SRM values from Table 4.1 corrected to standard conditions using peripheral measurements in Table 4.1.

**A4.4 Test for outliers**

Sample No.	CEM		SRM	Difference			Outlier condition	Data point used
	CEM conditions		$y_i - x_i = D_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$	$\frac{D_i - \bar{D}}{\sigma_D}$		
	mg/m3	mg/m3						
i	x	y						
1	0.58	0.24	0.34	0.50	0.25	0.83	include	
2	1.14	2.05	0.91	0.07	0.00	0.11	include	
3	1.69	3.52	1.83	0.98	0.97	1.63	include	
4	0.88	2.90	2.02	1.18	1.38	1.95	include	
5	0.76	2.67	1.90	1.06	1.12	1.76	include	
6	1.36	2.78	1.42	0.58	0.33	0.96	include	
7	2.06	2.01	0.06	0.79	0.62	1.31	include	
8	1.19	1.43	0.23	0.61	0.37	1.01	include	
9	0.71	1.61	0.90	0.05	0.00	0.09	include	
10	0.67	1.81	1.14	0.29	0.09	0.48	include	
11	1.22	1.83	0.61	0.24	0.06	0.39	include	
12	1.75	1.53	0.22	0.63	0.39	1.04	include	
13	0.93	0.71	0.23	0.62	0.38	1.03	include	
14	0.52	0.77	0.25	0.60	0.36	0.99	include	
15	0.65	0.99	0.34	0.50	0.25	0.83	include	
16	0.28	1.43	1.15	0.30	0.09	0.50	include	
17	0.12	1.52	1.40	0.55	0.31	0.92	include	
18	0.34	1.10	0.76	0.09	0.01	0.14	include	
19	0.34	1.29	0.95	0.10	0.01	0.17	include	
20	0.14	0.50	0.36	0.49	0.24	0.81	include	
21	0.75	0.02	0.73	0.12	0.01	0.19	include	

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$   
(parallel measurements only considered in outlier test)

where  $D = y_s - \hat{y}_s$  and  $\bar{D} = \frac{\sum_{i=1}^n (y_i - \hat{y}_i)}{n}$

where  $n$  is the number of samples = 21  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.6 given by

$$\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2}$$

**A4.5 Determination of the calculation procedure**

The selection of calculation method depends on the span of available data (excluding near zero points)

Largest SRM value  $y_{s \max} = 3.11$  Smallest SRM value  $y_{s \min} = 0.21$

Data span = 6 % of ELV e.g.  $\frac{y_{s \max} - y_{s \min}}{ELV}$  Minimum value = 0 % of ELV  
(Procedure a if greater than 20 % of ELV)

Select Procedure c for calculation of calibration function

**A4.6 Data used to determine the calibration function (Table 4.3)**

Sample No.	CEM		SRM	Calculation parameters			
	CEM conditions		$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$	
	mg/m3	mg/m3					
i	x	y					
1	0.58	0.24	-2.4	-3.5	5.7	12.1	
2	1.14	2.05	-1.8	-1.7	3.4	2.8	
3	1.69	3.52	-1.3	-0.2	1.6	0.0	
4	0.88	2.90	-2.1	-0.8	4.4	0.7	
5	0.76	2.67	-2.2	-1.0	4.9	1.1	
6	1.36	2.78	-1.6	-0.9	2.6	0.9	
7	2.06	2.01	-0.9	-1.7	0.8	2.9	
8	1.19	1.43	-1.8	-2.3	3.2	5.2	
9	0.71	1.61	-2.3	-2.1	5.1	4.4	
10	0.67	1.81	-2.3	-1.9	5.3	3.6	
11	1.22	1.83	-1.7	-1.9	3.1	3.5	
12	1.75	1.53	-1.2	-2.2	1.5	4.8	
13	0.93	0.71	-2.0	-3.0	4.2	9.0	
14	0.52	0.77	-2.4	-2.9	6.0	8.7	
15	0.65	0.99	-2.3	-2.7	5.4	7.4	
16	0.28	1.43	-2.7	-2.3	7.2	5.2	
17	0.12	1.52	-2.8	-2.2	8.1	4.8	
18	0.34	1.10	-2.6	-2.6	6.9	6.8	
19	0.34	1.29	-2.6	-2.4	6.9	5.9	
20	0.14	0.50	-2.8	-3.2	8.0	10.3	
21	0.75	0.02	-2.2	-3.7	4.9	13.6	
22	49.94	52.70	47.0	49.0	2205.9	2400.1	
23	0.27	0.00	-2.7	-3.7	7.3	13.8	

**A4.7 Determination of calibration function**

Procedure a

$$y = bx + a$$

where

$$b = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

and

$$a = \bar{y} - b\bar{x}$$

from values in Table 4.3 above calibration function is

$$y = 1.0429x + 0.62$$

Procedure b

$$y = bx$$

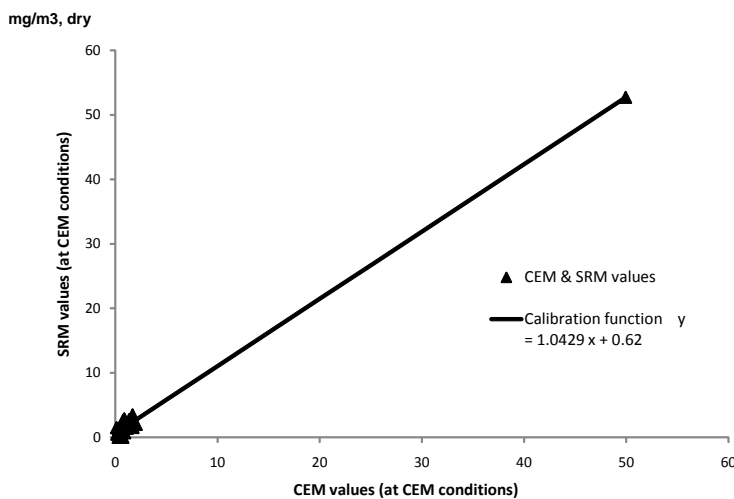
where

$$b = \frac{\bar{y}}{\bar{x}}$$

**A4.8 Calculation of calibrated CEM values**

Sample No.	CEM	SRM	Calibrated CEM	SRM	CEM measurements		Standardised Calibrated CEM
	CEM conditions		Stack	mg/m3	O <sub>2</sub>	H <sub>2</sub> O	
	mg/m3	mg/m3	mg/m3		% dry	%	
1	0.58	0.24	1.23	0.24	13.84	0.00	1.02
2	1.14	2.05	1.80	2.05	13.81	0.00	1.50
3	1.69	3.52	2.38	3.52	13.79	0.00	1.97
4	0.88	2.90	1.54	2.90	13.81	0.00	1.28
5	0.76	2.67	1.41	2.67	13.83	0.00	1.18
6	1.36	2.78	2.03	2.78	13.83	0.00	1.69
7	2.06	2.01	2.77	2.01	13.81	0.00	2.31
8	1.19	1.43	1.86	1.43	13.80	0.00	1.54
9	0.71	1.61	1.36	1.61	13.83	0.00	1.14
10	0.67	1.81	1.32	1.81	13.83	0.00	1.10
11	1.22	1.83	1.89	1.83	13.84	0.00	1.58
12	1.75	1.53	2.44	1.53	13.82	0.00	2.03
13	0.93	0.71	1.59	0.71	13.84	0.00	1.33
14	0.52	0.77	1.16	0.77	13.86	0.00	0.97
15	0.65	0.99	1.29	0.99	13.77	0.00	1.07
16	0.28	1.43	0.91	1.43	13.80	0.00	0.75
17	0.12	1.52	0.74	1.52	13.83	0.00	0.62
18	0.34	1.10	0.97	1.10	13.84	0.00	0.81
19	0.34	1.29	0.97	1.29	13.78	0.00	0.81
20	0.14	0.50	0.77	0.44	13.80	0.00	0.64
21	0.75	0.02	1.40	0.02	13.81	0.00	1.16
22	49.94	52.70	52.69		13.82	0.00	52.69
23	0.27	0.00	0.90	0.00	13.82	0.00	0.75

Plot 2 - CEM values versus SRM values expressed at CEM conditions (A4.9)



Regression coefficient  $r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\left[ \sum_{i=1}^n (y_i - \bar{y})^2 \right]^{1/2} \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}} = 0.9974$

$$R^2 = 0.9948$$

**A4.10 Data used for the variability test (Table 4.5)**

Sample No.	Calibrated CEM	SRM	Difference		
	Standard conditions		$y_i - \hat{y}_i$	$D_i - \bar{D}$	$(D_i - \bar{D})^2$
	mg/m <sup>3</sup>	mg/m <sup>3</sup>			
<i>i</i>	$\hat{y}_i$	$y_i$			
1	1.02	0.21	-0.81	-0.88	0.78
2	1.50	1.81	0.31	0.24	0.06
3	1.97	3.11	1.14	1.06	1.13
4	1.28	2.57	1.29	1.22	1.48
5	1.18	2.36	1.18	1.11	1.23
6	1.69	2.46	0.76	0.69	0.47
7	2.31	1.77	-0.53	-0.60	0.36
8	1.54	1.25	-0.29	-0.36	0.13
9	1.14	1.42	0.29	0.21	0.05
10	1.10	1.60	0.50	0.42	0.18
11	1.58	1.62	0.04	-0.04	0.00
12	2.03	1.35	-0.69	-0.76	0.58
13	1.33	0.62	-0.71	-0.78	0.61
14	0.97	0.68	-0.30	-0.37	0.14
15	1.07	0.88	-0.19	-0.26	0.07
16	0.75	1.27	0.51	0.44	0.20
17	0.62	1.35	0.73	0.66	0.44
18	0.81	0.98	0.17	0.10	0.01
19	0.81	1.14	0.33	0.26	0.07
20	0.64	0.44	-0.19	-0.27	0.07
21	1.16	0.02	-1.14	-1.22	1.48

**A4.11 The variability test**

The variability test is passed when  $\sigma_o \leq \sigma_o k$   
 based on parallel measurements only  
 where

$$\sigma_o = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2} = 0.6901$$

$$\sigma_o = \frac{pELV}{f} = 5.102$$

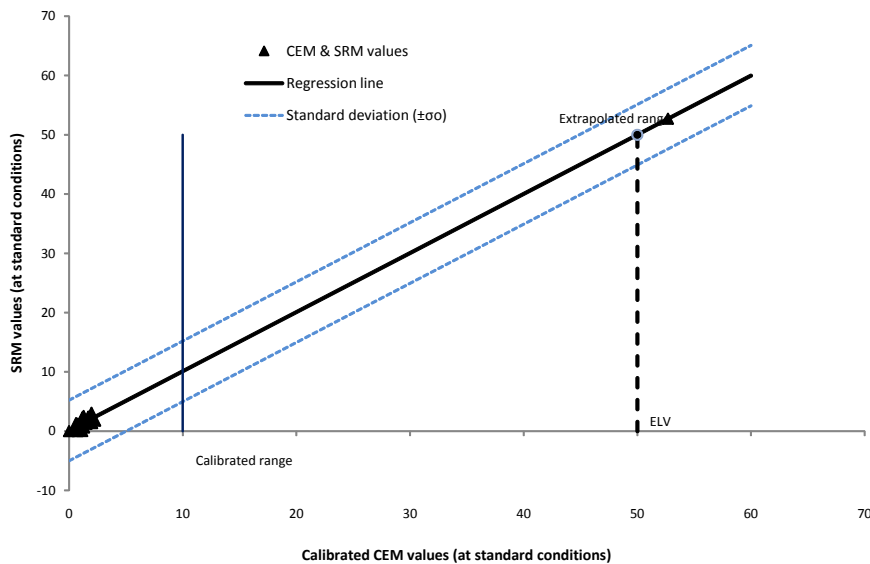
$$k_v = 0.9839 \text{ value from a } \chi^2 \text{ test with a } \beta \text{ value of 50\%}$$

$$\sigma_o k = 5.0199$$

**Variability test is passed (14% of limit)**

**A4.12 Plot 3 - Calibrated CEM values versus SRM values expressed at standard conditions**

mg/m<sup>3</sup>, 15%, dry, STP



The valid calibrated range of the analyser is defined as zero to  $\hat{y}_{ELV}$  plus an extension of 10% or 20% of the ELV, whichever is the greater.  
 The range may also be extrapolated to the ELV using reference materials  
 if the corresponding CEM response is within the confidence interval of the ELV

**Valid calibration range is 0 to 10 mg/m<sup>3</sup> (20% of ELV)**

**CEM response of 53 to reference material of 53 mg/m<sup>3</sup>  
 Range extrapolated to 50 mg/m<sup>3</sup> (100% of ELV)**

## Section 5 Results of the functional test

The functional test in accordance with BS EN 14181 Annex A was undertaken by ESG with certain parts, which require manipulation of the CEM system, undertaken by Siemens on the 24 May 2016 as part of their fortnightly system check. ESG undertook linearity testing of the CEM systems on the 7 June 2016. A copy of the report detailing the work undertaken is presented in Annex 1. A summary of the findings of the functional test covering the prescribed elements is provided below.

<b>1</b>	<b>Alignment &amp; cleanliness</b>		
A visual inspection, with reference to the CEM's manuals shall be carried out on the following when applicable:			
1.1	Internal check of CEM	n.a.	
1.2	Cleanliness of optical components	n.a.	
1.3	Flushing air supply	n.a.	
1.4	Obstructions in the optical path	n.a.	
1.5	After re-assembly check of alignment	n.a.	
1.6	Contamination control (internal check of optical surfaces)	n.a.	
<b>2</b>	<b>Sampling systems</b>		
A visual inspection of the sampling system shall be performed, noting the condition of the following components, when fitted:			
2.1	Sampling probe	✓	The CEM was inspected by Siemens during their most recent service and again, by ESG, prior to the commencement of parallel testing. Both inspections indicated that the system was in satisfactory condition. The NO <sub>x</sub> converter efficiency check was undertaken by ESG on the 8 June 2016 (see Annex 3).
2.2	Gas conditioning systems	✓	
2.3	Pumps	✓	
2.4	All connections	✓	
2.5	Sample lines	✓	
2.6	Power supplies	✓	
2.7	Filters	✓	
2.8	NO <sub>x</sub> converters – if the sampling system contains a NO <sub>x</sub> converter, then the test laboratory shall record when the last efficiency test was performed, and the result of this test.	n.a.	
2.9	The sampling system shall be in good condition and free of any visible faults, which may decrease the quality of data.	✓	
Siemens Limited      24 May 2016			
<b>3</b>	<b>Leak testing</b>		
	Leak testing shall be performed according to the CEM's manuals. The test shall cover the entire sampling system.	✓	A leak check was undertaken as part of the service by Siemens on the 24 May and as part of the linearity assessment on the 7 June 2016. No significant leakage was detected in either case.
Siemens Limited      24 May 2016			

4	<b>Zero &amp; span check</b>		
4.1	Reference zero and span materials shall be used to verify the corresponding readings of the CEM.	✓	Zero and span checks were undertaken by ESG as part of the linearity assessment on the 7 June 2016 and by Siemens during the service check on the 24 May 2016. In both cases responses were determined to be satisfactory.
4.2	In the case of non-extractive CEMs, zero and span checks shall be performed using a reference path free of flue gas before and after re-adjustment and after re-assembly of the CEM at the measurement location.	n.a.	
Siemens Limited                      24 May 2016			
5	<b>Linearity</b>		
5.1	During the calibration/linearity tests the applied concentrations should be logged onto the DAHS to prove the complete system i.e. concentration applied to the instrument is represented by the instrument output and identical to the value logged on the DAHS. DAHS logged values should be included in the instrument service report.	✓	The DCS logged values corresponding to the period of the linearity test are not reproduced in the service report, but are available from the Operator.
5.2	The linearity of the CEM's response shall be checked using five different reference materials including a zero concentration.	✓	ESG undertook linearity assessments of the analysers measuring oxygen, nitrogen monoxide and carbon monoxide. The ranges and concentrations tested met the requirements of EN 14181, Annex A8 – see report in Annex 1.
5.3	The reference material with zero concentration, as well as the reference materials with four different concentrations, shall have a verifiable quantity and quality.	✓	
5.4	In the case of gaseous reference materials, these four reference materials can be obtained from different gas cylinders or can be prepared by means of a calibrated dilution system from one single gas concentration.	✓	Values logged by the DCS during the linearity test period are presented in Annex 1.
5.5	The reference material concentrations shall be selected such that the measured values are at approximately 20%, 40%, 60% and 80% of a range that is at least the short term emission limit value. It is necessary to know the values of the ratios of their concentrations precisely enough so that an incorrect failure of the linearity test does not occur. The dry test reference materials shall be applied at the inlet of the CEM.	✓	The assessment made demonstrated acceptable linearity, in accordance with criteria specified in BS EN 14181, for all analysers.
The individual CEMs are tested using the following concentrations applied in a randomised sequence:			
5.6	Reference material with zero concentration	✓	
5.7	Reference material approx. 20% of the range		
5.8	Reference material approx. 40% of the range		
5.9	Reference material approx. 60% of the range		
5.10	Reference material approx. 80% of the range		
5.11	Reference material with zero concentration		
The linearity assessment for all analysers met the linearity acceptance criteria in EN 14181, Annex B. Details of all testing and subsequent data evaluation are provided in Annex 1.			
ESG    7 June 2016			

6	<b>Interferences</b>		
6.1	A test shall be undertaken if the process gases to be monitored contain components that are known interferences, as identified during QAL 1, and there is a failure of the QAL 2 or AST which could be due to interferences.	✓	An assessment of interferences has not been undertaken, although this assessment is not required where there is compliance with acceptance criteria.
-			
7	<b>Zero &amp; span drift (Audit)</b>		
7.1	The test laboratory shall assess whether the operator has a QAL 3 procedure in place, and whether the operator has applied this procedure. The evidence would comprise: i) a documented procedure ii) zero & span data iii) control charts	✓	The CEM is checked on a regular basis (15 day intervals) by DR. An example is provided in Annex 2 for May and June 2016. Records are maintained electronically on the BFS. There is no record of an assessment of data using control charts, although since autocalibration is undertaken prior to checking this would not be meaningful. Acceptance criteria for checks after autocalibration are specified.
ESG		1 May 2016	
8	<b>Response time</b>		
8.1	The response time of the CEM shall be checked. This can be performed, if appropriate, by feeding of the reference material at the end of the sampling probe. The response time shall not exceed the performance requirement applied during the QAL 1 tests.	✓	ESG assessed response time during the linearity assessment. All measured response times met the requirements of the MCERTs specification for the analysers (<200s for all parameters). These results compare reasonably with those determined for the SRMs (140 seconds). No adjustment for differences in response times was considered necessary
ESG		7 June 2016	
9	<b>Service report</b>		
As a minimum requirement the service report should include the following: All items are covered in the main report			
9.1	Document reference for work instruction for the type of work being undertaken	✓	
9.2	Instrument manufacturer	✓	
9.3	Instrument type	✓	
9.4	Instrument model	✓	
9.5	Instrument serial number	✓	
9.6	Operating principle	✓	
9.7	Operating range	✓	
9.8	Certification details	✓	
9.9	Compliance with MCERTs (including certificate number)	✓	
9.10	Location	✓	
9.11	Date and time work was undertaken	✓	
9.12	Equipment used – type, serial nos, calibration dates	✓	
9.13	Gases used – certificate nos, expiry dates,	✓	

	binary/mix		
9.14	NO <sub>x</sub> converter efficiency test, if applicable	n.a.	
9.15	Calibration & linearity data as required by EN 14181	✓	Provided, see comments in 5.
9.16	Logged data for period of calibration and linearity	✓	Not provided, but available from operator.
9.17	Name & signature of service engineer	✓	
ESG		7 June 2016	
10	<b>Documentation &amp; records</b>		
The following documentation shall be controlled readily accessible and up to date			
10.1	A plan of the CEM	✓	Site plan and permit
10.2	All manuals (maintenance, users etc.)	✓	In office and CEM's cabinet
10.3	Log books to document malfunctions and remedial actions	✓	Electronic - BFS/T3000
10.4	Service reports	✓	Electronic - BFS
10.5	Management system procedures for maintenance, calibration & training	✓	Calibrations and checks are undertaken by DR, and records maintained on the BFS.
10.6	Training records	✓	Records for D Rowland and team.
10.7	Maintenance schedules	✓	Electronic - BFS
10.8	Auditing plans and records	✓	Electronic - BFS
ESG		7 June 2016	

The following items are considered to be outside of the requirements of the BS EN 14181 specification for a functional test (BS EN 14181, Annex A):

Item	Comment
9	The service report provided by Siemens does not cover fully the requirements of MID 14181. It may be noted that the report does not claim to meet the full functional test requirements of BS EN 14181 and tends to be more of an analyser check record. All omissions are covered elsewhere within the main report and as such this is not considered significant.

The functional test was undertaken on the 7 June 2016 by O May of ESG. Selected elements, requiring manipulation of the CEM system, were undertaken by Siemens as part of their regular analyser checks on the 24 May 2016. It is recognised that the functional test was undertaken just after the main parallel testing. This was due to plant availability considerations. This is not considered significant since an inspection and check was undertaken by Siemens both before (24 May) and after (8 June) the parallel testing which determined that the analysers were in satisfactory order. A visual assessment was undertaken prior to parallel testing by ESG and a full linearity assessment was undertaken on the 7 June, again showing satisfactory performance.

Annexes 1 and 2 provide details of the linearity assessment and NO<sub>x</sub> converter efficiency checks undertaken by ESG. Reports for the analyser checks undertaken before and after parallel testing by Siemens are presented in Annex 3.

# Annex 1 Linearity assessment

ESG attended the Nash site on the 7 June 2016 to undertake a linearity check on the CEM systems. The work undertaken on the analysers measuring oxygen, nitrogen monoxide and carbon monoxide is documented below.

HRSG 10

### Linearity check of a direct reading analyser (BS EN 14181:2014, Annex B)

Determination		Carbon monoxide	
Analyser Type	Siemens Ultramat 23 multi-gas analyser		
Analyser No.	-		
Full scale	150	mg/m <sup>3</sup> CO	
RMI Conc.	496.25	mg/m <sup>3</sup> CO	RMI Reference DA 13
Certified Range	150	mg/m <sup>3</sup> CO	
ELV (ppm)	50	mg/m <sup>3</sup> CO	

Company	Severn Power Limited
Site	Newport
Sample point	HRSG III exhaust (A3)
Test carried out by	O May

Date	07-Jun-16
Test Ref	ESG/HA/16/CO
Time Start	-
Time End	-

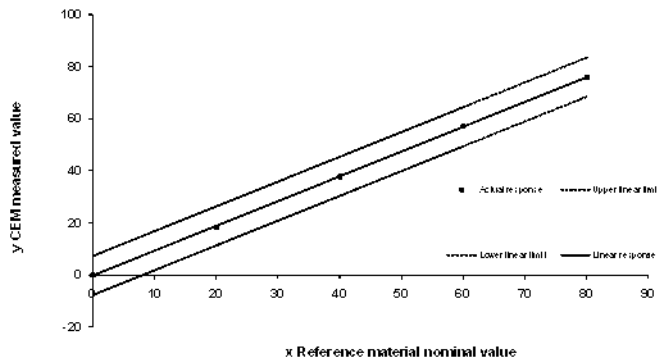
**Measurements for Linearity test**

Sample Number	Proportion of RMI concentration (%)	RMI value (mg/m <sup>3</sup> , x)	Analyser measured signal (mg/m <sup>3</sup> , y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	16	80.00	76.00	76.00	76.00	76.00	0.0	0.0	152.0
2	0	0.00	0.00	0.00	0.00	0.00	0.1	0.1	0.0
3	12	60.00	57.20	57.20	57.20	57.20	0.2	0.2	114.4
4	0	0.00	0.00	0.00	0.00	0.00	0.1	0.1	0.0
5	8	40.00	37.80	37.80	37.80	37.80	0.1	0.1	75.6
6	4	20.00	18.40	18.40	18.40	18.40	0.3	0.3	36.8

**Allowable residual** 5.0 % of range  
**Maximum residual** 0.3 % of operating range  
**Minimum residual** 0.3 % of certified range

**Analysers measured signals (y) versus RMI nominal values (x)**

**Regression line**  $y = 0.952x + 8.175$   
**Regression coefficient**  $R^2 = 1$



**Analysers passes test of linearity in accordance with BS EN 14181, Annex B**

**Linearity check of a direct reading analyser  
 (BS EN 14181:2014, Annex B)**

Determinand	Nitrogen monoxide		
Analysar Type	Siemens Ultramat 23 multiple analyser		
Analysar No.	-		
Full scale	100	mg/m <sup>3</sup> NO	
RM Conc.	962.5	mg/m <sup>3</sup> NO	RM Reference: DA ES
Certified Range	100	mg/m <sup>3</sup> NO	
ELV (stability)	32.7	mg/m <sup>3</sup> NO	

Company	Severn Power Limited
Site	Stratford
Sample point	SESC: W exhaust (A1)
Test carried out by	O May

Date	07-Jan-16
Test Ref	SESC/DA/16/00
Time Start	-
Time End	-

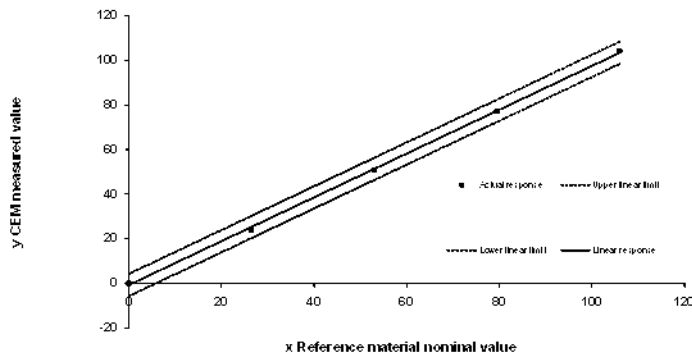
**Measurements for Linearity test**

Sample Number	Proportion of RM concentration (%)	RM value (mg/m <sup>3</sup> , x)	Analyser measured signal (mg/m <sup>3</sup> , y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	19	105.96	104.20	104.20	104.20	104.20	0.9	0.9	318.7
2	0	0.00	0.00	0.00	0.00	0.00	0.8	0.8	0.0
3	14	79.47	77.00	77.00	77.00	77.00	0.3	0.3	235.5
4	0	0.00	0.00	0.00	0.00	0.00	0.8	0.8	0.0
5	9	62.98	50.80	50.80	50.80	50.80	0.5	0.5	155.4
6	5	28.49	23.60	23.60	23.60	23.60	1.6	1.6	72.2

Allowable residual: 5.0 % of range  
 Maximum residual: 1.6 % of operating range  
 Minimum residual: 1.6 % of certified range

**Analysar measured signals (y) versus RM nominal values (x)**

Regression line:  $y = 0.982x + 0.775$   
 Regression coefficient:  $R^2 = 0.999$



**Analysar passes test of linearity in accordance with BS EN 14181, Annex B**

**Linearity check of a direct reading analyser  
 (BS EN 14181:2014, Annex B)**

Determinand	Oxygen	
Analyser Type	Siemens Ultramat 23 multiplex analyser	
Analyser No.	-	
Full scale	25	% O2
RM Conc.	20.6	% O2 RM Reference: DXS
Certified Range	25	% O2
ELV (stability)	21	% O2

Company	Severn Power Limited
Site	Sturport
Sample point	WGC in exhaust(A1)
Test carried out by	O May

Date	07-Jun-16
Test Ref	MS16A1102
Time Start	-
Time End	-

**Measurements for Linearity test**

Sample Number	Proportion of RM concentration (%)	RM value (% x)	Analyser measured signal (% y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	95	19.67	19.85	19.85	19.85	19.85	1.1	1.1	94.5
2	0	0.00	0.11	0.11	0.11	0.11	0.6	0.6	0.5
3	72	14.75	14.54	14.54	14.54	14.54	0.5	0.5	89.2
4	0	0.00	0.11	0.11	0.11	0.11	0.6	0.6	0.5
5	48	9.83	9.51	9.51	9.51	9.51	1.0	1.0	45.3
6	24	4.92	4.69	4.69	4.69	4.69	0.7	0.7	22.3

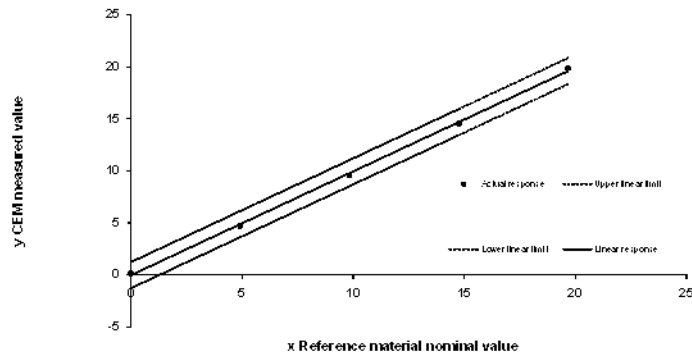
Allowable residual  
 Maximum residual  
 Maximum residual

5.0 % of range  
 1.1 % of operating range  
 1.1 % of certified range

**Analysers measured signals (y) versus RM nominal values (x)**

Regression line  
 Regression coefficient

$y = 0.957x + 0.037$   
 $R^2 = 0.999$



**Analysers passes test of linearity in accordance with BS EN 14181, Annex B**

HRSO 20

**Linearity check of a direct reading analyser  
 (BS EN 14181:2014, Annex B)**

Determinand	Carbon monoxide		
Analysar Type	Siemens Ultramat 23 multigas analyser		
Analysar No.	-		
Full scale	150	mg/m <sup>3</sup> CO	
RMI Conc.	496.25	mg/m <sup>3</sup> CO	RMI Reference DA .B
Certified Range	150	mg/m <sup>3</sup> CO	
ELV (study)	50	mg/m <sup>3</sup> CO	

Company	Severn Power Limited
Site	Burport
Sample point	HRSG 20 exhaust (A2)
Test carried out by	O May

Date	07-Jun-16
Test Ref	160518/20
Time Start	-
Time End	-

Measurements for Linearity test:

Sample Number	Proportion of RMI concentration (%)	RMI value (mg/m <sup>3</sup> , x)	Analysar measured signal (mg/m <sup>3</sup> , y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	10	50.00	75.80	75.80	75.80	75.80	0.3	0.3	151.6
2	0	0.00	0.80	0.80	0.80	0.80	0.2	0.2	1.6
3	12	60.00	50.40	50.40	50.40	50.40	0.1	0.1	112.8
4	0	0.00	0.80	0.80	0.80	0.80	0.2	0.2	1.6
5	8	40.00	37.40	37.40	37.40	37.40	0.3	0.3	74.8
6	4	20.00	18.70	18.70	18.70	18.70	0.3	0.3	37.4

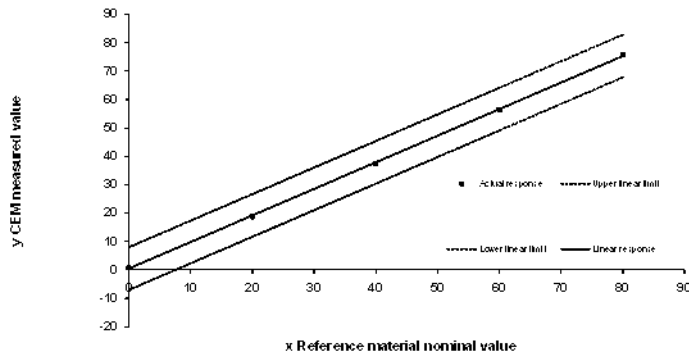
Allowable residual  
 Maximum residual  
 Maximum residual

5.0 % of range  
 0.3 % of operating range  
 0.3 % of certified range

Analysar measured signals (y) versus RMI nominal values (x)

Regression line  
 Regression coefficient

$y = 0.335x + 0.475$   
 $R^2 = 1$



Analysar passes test of linearity in accordance with BS EN 14181, Annex B

**Linearity check of a direct reading analyser  
 (BS EN 14181:2014, Annex B)**

Determinand	Nitrogen monoxide		
Analysar Type	Siemens Ultramat 23 multi-gas analyser		
Analysar No.	-		
Full scale	100	mg/m <sup>3</sup> NO	
RM Conc.	962.5	mg/m <sup>3</sup> NO	RM Reference: DA ES
Certified Range	100	mg/m <sup>3</sup> NO	
ELV (%abv)	32.7	mg/m <sup>3</sup> NO	

Company	Severn Power Limited
Site	Stratford
Sample point	SEC 28 exhaust(A2)
Test carried out by	O May

Date	07-Jan-16
Test Ref	160518-2016
Time Start	-
Time End	-

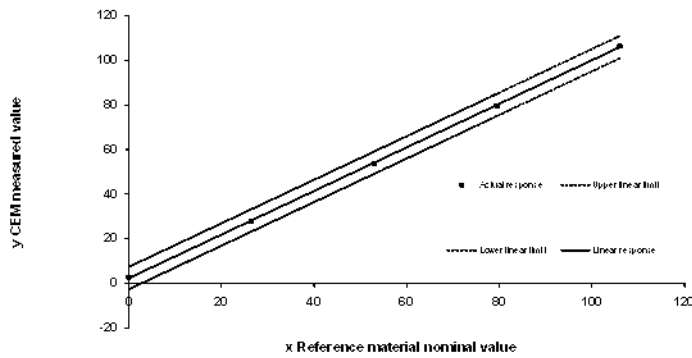
**Measurements for Linearity test**

Sample Number	Proportion of RM concentration (%)	RM value (mg/m <sup>3</sup> , x)	Analyser measured signal (mg/m <sup>3</sup> , y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	19	106.596	106.40	106.40	106.40	106.40	0.5	0.5	32.4
2	0	0.00	2.00	2.00	2.00	2.00	0.3	0.3	8.0
3	14	79.47	79.00	79.00	79.00	79.00	0.4	0.4	243.4
4	0	0.00	2.00	2.00	2.00	2.00	0.3	0.3	8.0
5	9	62.98	63.80	63.80	63.80	63.80	0.3	0.3	194.5
6	5	28.49	27.80	27.80	27.80	27.80	0.4	0.4	85.0

Allowable residual: 5.0 % of range  
 Maximum residual: 0.5 % of operating range  
 Minimum residual: 0.5 % of certified range

**Analysar measured signals (y) versus RM nominal values (x)**

Regression line:  $y = 0.977x + 2.325$   
 Regression coefficient:  $R^2 = 1$



**Analysar passes test of linearity in accordance with BS EN 14181, Annex B**

**Linearity check of a direct reading analyser  
 (BS EN 14181:2014, Annex B)**

Determinand	Oxygen	
Analyser Type	Siemens Ultramat 23 multiplex analyser	
Analyser No.	-	
Full scale	25	% O2
RM Conc.	20.6	% O2 RM Reference: DXS
Certified Range	25	% O2
ELV (stability)	21	% O2

Company	Severn Power Limited
Site	Sturport
Sample point	MS2C 28 exhaust (A2)
Test carried out by	O May

Date	07-Jun-16
Test Ref	MS2C28A2102
Time Start	-
Time End	-

**Measurements for Linearity test**

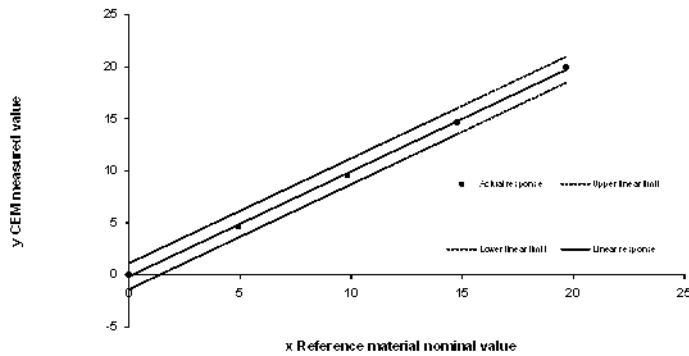
Sample Number	Proportion of RM concentration (%)	RM value (% x)	Analyser measured signal (% y)				Residual % certified range	Residual % range	Measured value % ELV
			1	2	3	Mean			
1	95	19.67	19.95	19.95	19.95	19.95	1.0	1.0	95.0
2	0	0.00	0.00	0.00	0.00	0.00	0.6	0.6	0.0
3	72	14.75	14.64	14.64	14.64	14.64	0.4	0.4	69.7
4	0	0.00	0.00	0.00	0.00	0.00	0.6	0.6	0.0
5	48	9.83	9.54	9.54	9.54	9.54	0.9	0.9	46.4
6	24	4.92	4.59	4.59	4.59	4.59	0.9	0.9	21.9

Allowable residual  
 Maximum residual  
 Maximum residual

5.0 % of range  
 1.0 % of operating range  
 1.0 % of certified range

**Analysed measured signals (y) versus RM nominal values (x)**

Regression line  
 Regression coefficient  
 $y = 1.01x + 0.154$   
 $R^2 = 0.999$



**Analysed passes test of linearity in accordance with BS EN 14181, Annex B**

ESG hold all one minute readings of the CEM systems as recorded on the DCS for the period of the linearity assessment. Examples for these from the 7 July 2016 are provided below.

## SPPA-T3000

### Analog Interval Report

Name:  
 Comment:  
 Created at: 2016/06/30 13:50:40.965  
 Time: From 2016/06/07 08:00:00.000 To 2016/06/07 18:00:00.000  
 Time Interval : 0:00:30  
 Aggregate: average values per time period  
 Note:

Tag	Name	Designation	EngUnit	Time	Avg	QF
Tag1	10HNE10CQ001 XQ01	FLUGAS STACK O2	%-Vol		13.454463	1.0
Tag2	10HNE10CQ002 227147 OUT	Output Value	mg/Nm3		-1.0096121	1.0
Tag3	10HNE10CQ003 227093 OUT	Output Value	mg/Nm3		18.01986	1.0
Tag4	10MBY10CE90 XQ01	ACTIVE POWER	MW		391.66217	1.0

### Analog Interval Report

Name:  
 Created at: 2016/06/30 13:49:24.572  
 Time: From 2016/06/07 08:00:00.000 To 2016/06/07 18:00:00.000

Time	Tag1	Tag2	Tag3	Tag4
2016/06/07 10:22:00.000 - 2016/06/07 10:23:00.000	13.840964	-1.1555989	14.4477	392.459
2016/06/07 10:23:00.000 - 2016/06/07 10:24:00.000	13.840964	-1.1555989	14.744516	392.2381
2016/06/07 10:24:00.000 - 2016/06/07 10:25:00.000	13.840964	-1.1555989	14.946831	392.53696
2016/06/07 10:25:00.000 - 2016/06/07 10:26:00.000	13.840964	-1.1555989	14.727082	392.58658
2016/06/07 10:26:00.000 - 2016/06/07 10:27:00.000	13.836798	-1.5174623	13.996701	392.34183
2016/06/07 10:27:00.000 - 2016/06/07 10:28:00.000	13.808413	-1.5570745	14.843749	392.5556
2016/06/07 10:28:00.000 - 2016/06/07 10:29:00.000	13.808413	-1.5570745	14.843749	392.64874
2016/06/07 10:29:00.000 - 2016/06/07 10:30:00.000	13.808413	-1.5570745	14.843749	392.6076
2016/06/07 10:30:00.000 - 2016/06/07 10:31:00.000	14.551574	-1.5570745	24.061815	392.8497
2016/06/07 10:31:00.000 - 2016/06/07 10:32:00.000	12.1716	-2.1086652	39.883987	392.77972
2016/06/07 10:32:00.000 - 2016/06/07 10:33:00.000	7.250674	-2.34375	64.71846	392.45502
2016/06/07 10:33:00.000 - 2016/06/07 10:34:00.000	0.21972656	-2.34375	100.77457	392.3507
2016/06/07 10:34:00.000 - 2016/06/07 10:35:00.000	0.16480759	-2.34375	102.56699	392.37845
2016/06/07 10:35:00.000 - 2016/06/07 10:36:00.000	0.10398582	-2.34375	103.65668	392.49292
2016/06/07 10:36:00.000 - 2016/06/07 10:37:00.000	0.10398582	-2.34375	104.41274	392.4161
2016/06/07 10:37:00.000 - 2016/06/07 10:38:00.000	0.10398582	-2.2190583	98.43447	392.39862
2016/06/07 10:38:00.000 - 2016/06/07 10:39:00.000	0.10398582	-2.143012	53.18652	392.3153
2016/06/07 10:39:00.000 - 2016/06/07 10:40:00.000	0.10398582	-2.143012	50.699867	392.36084
2016/06/07 10:40:00.000 - 2016/06/07 10:41:00.000	0.10060116	-2.143012	70.53362	392.63184
2016/06/07 10:41:00.000 - 2016/06/07 10:42:00.000	0.07052951	-1.7906901	71.22233	392.4082
2016/06/07 10:42:00.000 - 2016/06/07 10:43:00.000	0.07052951	-1.4919704	27.40327	392.44904
2016/06/07 10:43:00.000 - 2016/06/07 10:44:00.000	0.07052951	-1.4919704	24.560547	392.44296
2016/06/07 10:44:00.000 - 2016/06/07 10:45:00.000	0.07052951	-1.4919704	23.670723	392.4968
2016/06/07 10:45:00.000 - 2016/06/07 10:46:00.000	0.07052951	-1.4919704	15.682172	392.43594
2016/06/07 10:46:00.000 - 2016/06/07 10:47:00.000	0.07052951	-1.4919704	-1.6680284	392.27985
2016/06/07 10:47:00.000 - 2016/06/07 10:48:00.000	0.07052951	-1.4919704	-2.6101198	392.26813
2016/06/07 10:48:00.000 - 2016/06/07 10:49:00.000	0.07052951	-1.4919704	-2.9947915	392.33664
2016/06/07 10:49:00.000 - 2016/06/07 10:50:00.000	0.07052951	-1.4919704	-2.9947915	392.53073
2016/06/07 10:50:00.000 - 2016/06/07 10:51:00.000	1.1660717	-1.4919704	-2.9947915	392.39743
2016/06/07 10:51:00.000 - 2016/06/07 10:52:00.000	20.207165	-1.4919704	-3.936335	392.41733
2016/06/07 10:52:00.000 - 2016/06/07 10:53:00.000	20.737156	-1.4919704	-4.578993	392.45584
2016/06/07 10:53:00.000 - 2016/06/07 10:54:00.000	20.758282	-1.4919704	-4.5994825	392.45694

# SPPA-T3000

## Analog Interval Report

Name:  
 Comment:  
 Created at: 2016/06/09 14:02:34.629  
 Time: From 2016/06/03 11:00:00.343 To 2016/06/08 10:30:00.343  
 Time Interval : 0:01:00  
 Aggregate: average values per time period  
 Note:

Name	Designation	EngUnit	Time	Avg	QF
Tag1 20HNE10CQ001 XQ01	FLUGAS STACK O2	%-Vol		13.996006	1.0
Tag2 20HNE10CQ002 227147 OUT	Output Value	mg/Nm3		2.290095	1.0
Tag3 20HNE10CQ003 227093 OUT	Output Value	mg/Nm3		17.244871	1.0
Tag4 20MBY10CE901 XQ01	ACTIVE POWER	MW		348.13596	1.0

## Analog Interval Report

Name:  
 Created at: 2016/06/09 14:02:34.629  
 Time: From 2016/06/03 11:00:00.343 To 2016/06/08 10:30:00.343

Time	Tag1	Tag2	Tag3	Tag4
2016/06/07 14:58:00.343 - 2016/06/07 14:59:00.343	13.8436775	0.4394531	17.836895	389.92792
2016/06/07 14:59:00.343 - 2016/06/07 15:00:00.343	13.8436775	0.4394531	17.773438	389.715
2016/06/07 15:00:00.343 - 2016/06/07 15:01:00.343	13.8436775	0.4394531	17.773438	390.43408
2016/06/07 15:01:00.343 - 2016/06/07 15:02:00.343	13.8436775	0.4394531	17.773438	391.47427
2016/06/07 15:02:00.343 - 2016/06/07 15:03:00.343	13.8436775	0.4394531	17.773438	391.95908
2016/06/07 15:03:00.343 - 2016/06/07 15:04:00.343	13.8436775	0.4394531	18.849937	392.41986
2016/06/07 15:04:00.343 - 2016/06/07 15:05:00.343	13.8436775	0.4394531	18.863932	392.56824
2016/06/07 15:05:00.343 - 2016/06/07 15:06:00.343	13.8436775	0.4394531	18.863932	392.5877
2016/06/07 15:06:00.343 - 2016/06/07 15:07:00.343	13.781157	0.4394531	19.190374	392.7094
2016/06/07 15:07:00.343 - 2016/06/07 15:08:00.343	13.777669	0.4394531	19.46072	392.6833
2016/06/07 15:08:00.343 - 2016/06/07 15:09:00.343	13.777669	0.4394531	19.46072	392.72906
2016/06/07 15:09:00.343 - 2016/06/07 15:10:00.343	13.777669	0.4394531	19.46072	392.72296
2016/06/07 15:10:00.343 - 2016/06/07 15:11:00.343	13.777669	0.4394531	19.46072	392.6362
2016/06/07 15:11:00.343 - 2016/06/07 15:12:00.343	13.777669	0.4394531	19.73736	392.44168
2016/06/07 15:12:00.343 - 2016/06/07 15:13:00.343	13.777669	0.4394531	19.954426	392.6171
2016/06/07 15:13:00.343 - 2016/06/07 15:14:00.343	13.751622	0.4394531	19.447218	392.2818
2016/06/07 15:14:00.343 - 2016/06/07 15:15:00.343	13.745117	0.56460774	16.945045	392.23584
2016/06/07 15:15:00.343 - 2016/06/07 15:16:00.343	13.745117	0.9331597	16.775173	391.81497
2016/06/07 15:16:00.343 - 2016/06/07 15:17:00.343	13.745117	0.9331597	16.728298	392.0749
2016/06/07 15:17:00.343 - 2016/06/07 15:18:00.343	13.745117	1.1400462	16.382088	392.02377
2016/06/07 15:18:00.343 - 2016/06/07 15:19:00.343	13.745117	1.5299479	22.649088	392.16815
2016/06/07 15:19:00.343 - 2016/06/07 15:20:00.343	13.768072	1.5299479	20.263672	392.3351
2016/06/07 15:20:00.343 - 2016/06/07 15:21:00.343	13.7957535	1.5299479	20.073496	392.02426
2016/06/07 15:21:00.343 - 2016/06/07 15:22:00.343	13.7957535	1.5299479	18.938114	392.74823
2016/06/07 15:22:00.343 - 2016/06/07 15:23:00.343	13.801391	1.5299479	17.876518	392.62122
2016/06/07 15:23:00.343 - 2016/06/07 15:24:00.343	13.828305	0.95713073	17.876518	392.5093
2016/06/07 15:24:00.343 - 2016/06/07 15:25:00.343	13.828305	0.9331597	17.876518	392.14136
2016/06/07 15:25:00.343 - 2016/06/07 15:26:00.343	13.828305	0.66527236	17.613981	392.23688
2016/06/07 15:26:00.343 - 2016/06/07 15:27:00.343	13.828305	0.34179688	17.578125	391.68378
2016/06/07 15:27:00.343 - 2016/06/07 15:28:00.343	13.80404	0.34179688	17.578125	392.2983
2016/06/07 15:28:00.343 - 2016/06/07 15:29:00.343	13.780382	0.34179688	17.578125	392.4057
2016/06/07 15:29:00.343 - 2016/06/07 15:30:00.343	13.780382	0.08845667	17.620173	392.01822

## Annex 2 NO<sub>x</sub> converter checks

ESG attended the Nash site on the 7 June 2016 to undertake an efficiency check on the NO<sub>x</sub> converters associated with both CEM systems. The work undertaken is documented in the attached report.

HRSO 10

### NO<sub>2</sub> converter efficiency check BS EN 14792:2005 (Annex B)

Operator	Svern Power Limited
Date	8 June 2016
Analysar Type	Siemens Ultramat 23
Analysar No.	serving GT10
Analysar Range	0-1000/750 mg/m <sup>3</sup> NO <sub>2</sub>
Converter ref (if applicable)	Gas Converter CG-2M ser no. 1329/9202677

NO<sub>2</sub> ref gas cylinder XA 6  
 NO<sub>2</sub> ref gas certification expiry 1 November 2018 filed Nov 2015  
 NO<sub>2</sub> ref gas concentration 169.25 mg/m<sup>3</sup> NO<sub>2</sub>

Reading	Analysar response (mg/m <sup>3</sup> )		Converter efficiency (%)
	NO	NO <sub>x</sub>	
1	106.8	0	96.5
2	107.2	0	96.9
3	107.2	0	96.9
Mean	107.1	0	96.8

Required minimum efficiency 95 %

#### Converter passes efficiency test

For analysers with two reaction chambers note both the nitrogen monoxide and nitrogen oxides readings.  
 For analyser with a single reaction chamber the nitrogen oxides value should be set to zero

#### 5 Converter efficiency check

- 5.1 The converter efficiency check is only applicable to nitrogen oxides analysers and check the efficiency of conversion of NO<sub>2</sub> to NO in the catalytic converter.
- 5.2 Select a gas containing nitrogen dioxide (preferably in the range 50-100 ppm).
- 5.3 Span and zero the analyser accordingly.
- 5.4 For a dual reaction chamber system (e.g. Ecophysics), both channels (NO and NO<sub>x</sub>) should undergo span and zero and be adjusted to give the same value.
- 5.5 Pass NO<sub>2</sub> into the analyser and note the readings (NO and NO<sub>x</sub> as appropriate) after a stabilisation period of at least three time the response time. Undertake three determinations and note on the attached spreadsheet.
- 5.6 For a single channel system the analyser should be set to measure NO and the NO readings should be noted on the spreadsheet. The corresponding NO<sub>x</sub> reading should be entered as zero.
- 5.7 Using the spreadsheet determine the converter efficiency and its compliance with the standard performance requirement.

HRSO 20

**NO<sub>2</sub> converter efficiency check  
 BS EN 14792:2005 (Annex B)**

Operator	Severn Power Limited
Date	8 June 2016

Analysar Type	Siemens Ultramat 23
Analysar No.	serving GT20
Analysar Range	0-100/750 mg/m <sup>3</sup> NO
Converter ref (if applicable)	Gas Konverter CG-2M ser no. 1325/9202677

NO<sub>2</sub> ref gas cylinder XA 6  
 NO<sub>2</sub> ref gas certification expiry 1 November 2018 filled Nov 2015  
 NO<sub>2</sub> ref gas concentration 169.25 mg/m<sup>3</sup> NO<sub>2</sub>

Reading	Analysar response (mg/m <sup>3</sup> )		Converter efficiency (%)
	NO	NO <sub>x</sub>	
1	105.2	0	95.1
2	105.4	0	95.3
3	105.2	0	95.1
Mean	105.3	0	95.2

Required minimum efficiency 95 %

**Converter passes efficiency test**

For analysers with two reaction chambers note both the nitrogen monoxide and nitrogen oxides readings.  
 For analyser with a single reaction chamber the nitrogen oxides value should be set to zero

**5 Converter efficiency check**

- 5.1 The converter efficiency check is only applicable to nitrogen oxides analysers and check the efficiency of conversion of NO<sub>2</sub> to NO in the catalytic converter.
- 5.2 Select a gas containing nitrogen dioxide (preferably in the range 50–100 ppm.
- 5.3 Span and zero the analyser accordingly.
- 5.4 For a dual reaction chamber system (e.g. Ecophysics), both channels (NO and NO<sub>x</sub>) should undergo span and zero and be adjusted to give the same value.
- 5.5 Pass NO<sub>2</sub> into the analyser and note the readings (NO and NO<sub>x</sub> as appropriate) after a stabilisation period of at least three time the response time. Undertake three determinations and note on the attached spreadsheet.
- 5.6 For a single channel system the analyser should be set to measure NO and the NO readings should be noted on the spreadsheet. The corresponding NO<sub>x</sub> reading should be entered as zero.
- 5.7 Using the spreadsheet determine the converter efficiency and its compliance with the standard performance requirement.

## Annex 3 Routine analyser checking

Siemens undertake checking of the analyser performance every 15 days. The analyser undergoes an auto calibration and is then checked with reference gases. Acceptance criteria are specified. This is not entirely consistent with QAL 3 as auto calibration prior to checking does not permit a meaningful assessment of the system measurement bias. An example of checks on each CEM system is provided below and refers to the system checks undertaken on the 24 May and 8 June 2016.

HRSG 10

# SIEMENS

**SEVERN POWER**  
**O&M Form No: EF-08.007-01**  
**Rev. 0**

### 15 day CEMS Maintenance Checklist

<b>Work Order:</b>	648	<b>Unit:</b>	10	<b>Date:</b>	24/05/2016
<b>Gas Calibration Bottle Information:</b>					
			<b>Gas Calibration Data</b>	<b>Test Gas Certified Values</b>	
<b>Cylinder ID Number</b>	163264		<b>Gas</b>	<b>ppm</b>	<b>mg/m<sup>3</sup></b>
<b>Certification Type</b>			<b>CO</b>	101.2	126.5
<b>Certification Date</b>	28-Oct-2015		<b>NO</b>	94.6	126.764
<b>Certification Expiry</b>	27-Oct-2020				
<b>Analyser Information:</b>					
<b>Manufacturer</b>	<b>Model</b>	<b>Meas Components</b>		<b>Serial Number</b>	
Siemens	Ultramat 23	CO/NO/O2		7MB2337-4AU10-PT1-Z	
<b>Calibration Information:</b>					
<b>Component</b>	<b>ZERO (after AUTOCAL)</b>	<b>MEAS VALUE (before CAL)</b>	<b>MEAS VALUE (after CAL) (A)</b>	<b>Test Gas Certified Value (B)</b>	<b>Span Error (%) (C)</b> <small>See Notes 1&amp;2</small>
CO (mg/m <sup>3</sup> )	-0.8	126.6	126.6	126.5	0.079051383
NO (mg/m <sup>3</sup> )	-0.8	127	127	126.764	0.18617273
<b>System General Check</b>					
<b>Cabinet Visual Inspection:</b>	OK		<b>Cabinet Fans/Filter/Heater Status:</b>	OK	
<b>Line 1 Flow (l/h):</b>	OK		<b>Filter Status (B4 and KT2):</b>	OK	
<b>Line 2 Flow (l/h):</b>	OK		<b>O<sup>2</sup> Sensor Voltage (mV):</b>	11.98	

- Notes:**  
 (1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.  
 (2) C = (A-B) \* 100/B  
 (3) 1ppm CO = 1.25mg/m<sup>3</sup>  
 (4) 1ppm NO = 1.34mg/m<sup>3</sup>

**Remarks: Ultramat HMI screen characters corrupting? Monitor same.**

Non-Conformance reported with FN No. \_\_\_\_\_ / \_\_\_\_\_ (year)

Inspector/Date: WJ/AE 24/05/2016



SEVERN POWER  
 O&M Form No: EF-08.007-01  
 Rev. 0

15 day CEMS Maintenance Checklist

Work Order:	741	Unit:	10	Date:	08/06/2016
<b>Gas Calibration Bottle Information:</b>					
	<b>Gas Calibration Data</b>		<b>Test Gas Certified Values</b>		
Cylinder ID Number	163264		Gas	ppm	mg/m <sup>3</sup>
Certification Type			CO	101.2	126.5
Certification Date	28-Oct-2015		NO	94.6	126.764
Certification Expiry	27-Oct-2020				
<b>Analyzer Information:</b>					
Manufacturer	Model	Meas Components		Serial Number	
Siemens	Ultramat 23	CO/NO/O2		7MB2337-4AU10-PT1-Z	
<b>Calibration Information:</b>					
Component	ZERO (after AUTO CAL)	MEAS VALUE (before CAL)	MEAS VALUE (after CAL) (A)	Test Gas Certified Value (B)	Span Error (%) (C) <small>See Notes 1&amp;2</small>
CO (mg/m <sup>3</sup> )	-0.8	126.6	126.6	126.5	0.079051383
NO (mg/m <sup>3</sup> )	-0.8	127	127	126.764	0.18617273
<b>System General Check</b>					
Cabinet Visual Inspection:	OK		Cabinet Fans/Filter/Heater Status:	OK	
Line 1 Flow (l/h):	OK		Filter Status (B4 and KT2):	OK	
Line 2 Flow (l/h):	OK		O <sup>2</sup> Sensor Voltage (mV):	11.98	
Notes:					
(1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.					
(2) C = (A-B) * 100/B					
(3) 1ppm CO = 1.25mg/m <sup>3</sup>					
(4) 1ppm NO = 1.34mg/m <sup>3</sup>					
Remarks: Ultramat HMI screen characters corrupting? Monitor same.					

Non-Conformance reported with FN No. \_\_\_\_\_ / \_\_\_\_\_ (year)

Inspector/Date: WJ/AE 08/06/2016

HRSO 20

# SIEMENS

SEVERN POWER  
 O&M Form No: EF-08.007-01  
 Rev. 0

## 15 day CEMS Maintenance Checklist

Work Order: 647 Unit: 20 Date: 24/05/2016

Gas Calibration Bottle Information:					
Gas Calibration Data			Test Gas Certified Values		
Cylinder ID Number	219842		Gas	ppm	mg/m <sup>3</sup>
Certification Type	BOC HiQ		CO	100.6	125.75
Certification Date	04-Oct-2010		NO	94.5	126.63
Certification Expiry	04-Oct-2015				
Analyzer Information:					
Manufacturer	Model	Meas Components		Serial Number	
Siemens	Ultramat 23	CO/NO/O2		7MB2337-4AU10-3PT1-Z	
Calibration Information:					
Component	ZERO (after AUTOCAL)	MEAS VALUE (before CAL)	MEAS VALUE (after CAL) (A)	Test Gas Certified Value (B)	Span Error (%) (C) <small>See Notes 1&amp;2</small>
CO (mg/m <sup>3</sup> )	0.3	124.8	124.8	125.75	-0.755467197
NO (mg/m <sup>3</sup> )	0.6	126	126	126.63	-0.497512438
System General Check					
Cabinet Visual Inspection:	OK		Cabinet Fans/Filter/Heater Status:	OK	
Line 1 Flow (l/h):	OK		Filter Status (B4 and KT2):	OK	
Line 2 Flow (l/h):	OK		O <sup>2</sup> Sensor Voltage (mV):	12.05	

**Notes:**

- (1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.
- (2)  $C = (A-B) * 100/B$
- (3) 1ppm CO = 1.25mg/m<sup>3</sup>
- (4) 1ppm NO = 1.34mg/m<sup>3</sup>

**Remarks:**

Non-Conformance reported with FN No. \_\_\_\_\_ / \_\_\_\_\_ (year)

Inspector/Date: WJ/AE 24/05/16



SEVERN POWER  
 O&M Form No: EF-08.007-01  
 Rev. 0

**15 day CEMS Maintenance Checklist**

Work Order:	740	Unit:	20	Date:	08/06/2016
<b>Gas Calibration Bottle Information:</b>					
	<b>Gas Calibration Data</b>		<b>Test Gas Certified Values</b>		
Cylinder ID Number	219842	Gas	ppm	mg/m <sup>3</sup>	
Certification Type	BOC HiQ	CO	100.6	125.75	
Certification Date	04-Oct-2010	NO	94.5	126.63	
Certification Expiry	04-Oct-2015				
<b>Analyzer Information:</b>					
Manufacturer	Model	Meas Components	Serial Number		
Siemens	Ultramat 23	CO/NO/O2	7MB2337-4AU10-3PT1-Z		
<b>Calibration Information:</b>					
Component	ZERO (after AUTO CAL)	MEAS VALUE (before CAL)	MEAS VALUE (after CAL) (A)	Test Gas Certified Value (B)	Span Error (%) (C) <small>See Notes 1&amp;2</small>
CO (mg/m <sup>3</sup> )	0.3	124.8	124.8	125.75	-0.755467197
NO (mg/m <sup>3</sup> )	0.6	126	126	126.63	-0.497512438
<b>System General Check</b>					
Cabinet Visual Inspection:	OK	Cabinet Fans/Filter/Heater Status:	OK		
Line 1 Flow (l/h):	OK	Filter Status (B4 and KT2):	OK		
Line 2 Flow (l/h):	OK	O <sup>2</sup> Sensor Voltage (mV):	12.05		

**Notes:**

- (1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.
- (2)  $C = (A-B) * 100/B$
- (3) 1ppm CO = 1.25mg/m<sup>3</sup>
- (4) 1ppm NO = 1.34mg/m<sup>3</sup>

**Remarks:**

Non-Conformance reported with FN No. \_\_\_\_\_ / \_\_\_\_\_ (year)

Inspector/Date: DW 08/06/16

END OF REPORT

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