

# Severn Power Limited

## Annual surveillance test of continuous emissions monitoring systems serving two gas turbines

|          |                 |
|----------|-----------------|
| Report   | 150613-2015/AST |
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## ANNUAL SURVEILLANCE TEST OF CONTINUOUS EMISSIONS MONITORING SYSTEMS SERVING TWO GAS TURBINES

Permit No. **HP3737UE**

Operator **Severn Power Limited**

Installation **West Nash Road  
Nash  
Newport  
Gwent NP1822BZ**

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Test date **22 & 23 June 2015**

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## CONTENTS

|                                                               | Page No. |
|---------------------------------------------------------------|----------|
| <b>Part 1 – Executive Summary</b>                             |          |
| 1.A Cover                                                     | 1        |
| Contents                                                      | 2        |
| 1.B Summary of results                                        | 3        |
| 1.C Deviations and discussion                                 | 5        |
| 1.C.1 Compliance with standard reference methods              | 5        |
| 1.C.2 Compliance with BS EN 14181                             | 5        |
| 1.C.3 Impact on results                                       | 5        |
| 1.C.4 Required actions                                        | 6        |
| <b>Part 2 – Information about the Regulated Installation</b>  |          |
| 2.1 Regulatory information                                    | 7        |
| 2.2 Operational information and site monitoring provisions    | 7        |
| 2.3 Monitoring provisions for periodic monitoring             | 7        |
| 2.3.1 Manual sampling positions                               | 7        |
| 2.3.2 Monitoring platform and site provisions                 | 8        |
| 2.4 Continuous emissions monitoring (CEM) system              | 9        |
| <b>Part 3 – Information about the monitoring campaign</b>     |          |
| 3.1 Laboratory staff                                          | 10       |
| 3.2 Standard reference methods (SRMs)                         | 10       |
| <b>Part 4 – Data and Calculations</b>                         |          |
| 4.1 Gas turbine exhaust (A1) CEM – Annual Surveillance Test   |          |
| 4.1.1 Nitrogen oxides                                         | 13       |
| 4.1.2 Carbon monoxide (parallel measurements)                 | 15       |
| 4.1.3 Carbon monoxide (CEM's response to reference materials) | 17       |
| 4.2 Gas turbine exhaust (A2) CEM – Annual Surveillance Test   |          |
| 4.2.1 Nitrogen oxides                                         | 19       |
| 4.2.2 Carbon monoxide (parallel measurements)                 | 21       |
| 4.2.3 Carbon monoxide (CEM's response to reference materials) | 23       |
| <b>Part 5 – Results of the functional test</b>                |          |
| 5 Functional test summary                                     | 25       |
| Annex 1 Linearity test report                                 | 29       |
| Annex 2 Service reports                                       | 54       |
| Annex 3 NO <sub>x</sub> converter efficiency check            | 60       |
| Annex 4 Routine analyser checking                             | 62       |

## Part 1 Executive Summary

### 1.B Summary of results

Severn Power Limited contracted Environmental Scientifics Group Limited (ESG) to undertake an annual surveillance test (AST) on the continuous emissions monitoring (CEM) system serving the exhausts of two gas turbines (emission points A1 and A2) at their Nash site. This testing is undertaken to confirm that the system performance continues to meet permit requirements.

The assessment was undertaken in accordance with the requirements of BS EN 14181:2004, amended according to MID 14181 and TGN M20.

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

The CEM system has already undergone a QAL 2 assessment and subsequent ASTs:

|     |                     |                               |
|-----|---------------------|-------------------------------|
| 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   |

An AST assessment was undertaken. This assessment comprised the following activities:

- Installation and management of the CEM system - undertaking of a functional test.
- Acceptance of variability and verification of the calibration functions – by means of parallel measurements with standard reference methods (SRMs) and their subsequent comparison with acceptance criteria.
- Determination of the revised calibration range – assessment to determine whether the existing valid calibration range may be extended.

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.

The following tables summarise the main results of the assessment.

**Table 1.1**  
**Summary of Results (HRSG10 – A1)**

|                                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------|----------------------|--------------|-----------------------------------|---------------------|---------------------|
| BS EN 14181 AST                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
| HRSG10 exhaust (A1)                                                                                                   |                                      |       |                      |              |                                   |                     |                     |
| Duty CEM                                                                                                              |                                      |       |                      |              |                                   |                     |                     |
| 23 June 2015                                                                                                          |                                      |       |                      |              |                                   |                     |                     |
| Determinand                                                                                                           | Calibration function<br>(y = bx + a) |       | Valid<br>calibration | Extrapolated | Units                             | Variability<br>Test | Calibration<br>Test |
|                                                                                                                       | a                                    | b     | Range 0-             |              |                                   |                     |                     |
| Nitrogen oxides <sup>1</sup>                                                                                          | 0.533                                | 0.931 | 43                   | -            | mgNO <sub>2</sub> /m <sup>3</sup> | Pass                | Pass                |
| Carbon monoxide                                                                                                       | 0                                    | 1.0   | 3↑                   | -            | mgCO/m <sup>3</sup>               | Pass                | Pass                |
|                                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
| The above calibration functions, once applied, only remain valid so long as there are no adjustments made to the CEM. |                                      |       |                      |              |                                   |                     |                     |

**Table 1.2**  
**Summary of Results (HRSG20 – A2)**

|                                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------|----------------------|--------------|-----------------------------------|---------------------|---------------------|
| BS EN 14181 AST                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
| HRSG20 exhaust (A2)                                                                                                   |                                      |       |                      |              |                                   |                     |                     |
| Duty CEM                                                                                                              |                                      |       |                      |              |                                   |                     |                     |
| 22 & 23 June 2015                                                                                                     |                                      |       |                      |              |                                   |                     |                     |
| Determinand                                                                                                           | Calibration function<br>(y = bx + a) |       | Valid<br>calibration | Extrapolated | Units                             | Variability<br>Test | Calibration<br>Test |
|                                                                                                                       | a                                    | b     | Range 0-             |              |                                   |                     |                     |
| Nitrogen oxides <sup>1</sup>                                                                                          | 0.509                                | 0.833 | 37                   | -            | mgNO <sub>2</sub> /m <sup>3</sup> | Pass                | Pass                |
| Carbon monoxide                                                                                                       | 0                                    | 1.0   | 3↑                   | -            | mgCO/m <sup>3</sup>               | Pass                | Pass                |
|                                                                                                                       |                                      |       |                      |              |                                   |                     |                     |
| The above calibration functions, once applied, only remain valid so long as there are no adjustments made to the CEM. |                                      |       |                      |              |                                   |                     |                     |

**Notes**

- 1 The CEM system measures total nitrogen oxides. Following the latest guidance the calibration function for total nitrogen oxides is assessed based on an SRM measurement for total nitrogen oxides (NO + NO<sub>2</sub>).

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 calibration functions 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 value achieved in the corresponding parallel testing plus 10%.

The valid calibration ranges for carbon monoxide on both units may be extended as shown in Tables 1.1 and 1.2. For nitrogen oxides the calibration ranges remain unchanged on this occasion.

## 1.C 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.C.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.C.2 Compliance with BS EN 14181

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.

Due to restrictions on plant operation it was necessary to spread the measurements required to perform the AST over a period of two days on HRSG20 (A2).

The initial check of the efficiency of the nitrogen oxides catalytic converter associated with the HRSG 20 CEM failed to meet minimum requirements. Following a change of converter cartridge and adjustment of operating temperature converter efficiency exceeded minimum requirements.

The assessments undertaken for all analysers complied fully with the requirements of BS EN 14181:2004.

### 1.C.3 Impact on results

For both carbon monoxide and nitrogen oxides the existing calibration functions for both CEM systems passed the required variability test and are valid and suitable for continued use.

The valid calibration range for carbon monoxide on both systems may be extended (see Tables 1.1 and 1.2), whilst for nitrogen oxides the ranges remain unchanged.

On both systems the measured carbon monoxide concentration was below the confidence interval (CI) of the applicable emission limit value (ELV). In these cases the assessment undertaken using parallel measurements has been repeated using the CEMs' response to reference materials in order to provide confidence in the performance of the analyser at higher concentrations. In the case of the CEM serving HRSG 10 the response to reference materials failed to meet AST acceptance requirements, largely due to a substantial zero offset. This offset was not present during the subsequent parallel testing. The confirmatory check with reference materials on the CEM serving HRSG 20 met AST requirements.

It is understood that some major measurement components within each system have been renewed or swapped since the 2014 annual surveillance test. In accordance with guidance (M20, 3.5.19 - *If the operator replaces a CEM with an identical one, then the operator may use the same calibration function as the original CEM, and then verify the performance using an AST. If needed, then the AST may be extended to become a full QAL2*) an annual surveillance test was initially undertaken. As compliance with test requirements was confirmed for all parameters on both units it is considered that the existing calibration functions are applicable to the amended systems and that further detailed assessment in the form of a QAL 2 is not required. It is noted that within the 5-year assessment cycle a QAL 2 is due in 2016.

#### 1.C.4 Required actions

The following actions are recommended:

##### HRSG 10 (A1) duty CEM

| Parameter       | Comment                      | Action              |
|-----------------|------------------------------|---------------------|
| NO <sub>x</sub> | Met AST acceptance criteria. | No action required. |
| CO              | Met AST acceptance criteria. | No action required. |

##### HRSG 20 (A2) duty CEM

| Parameter       | Comment                      | Action              |
|-----------------|------------------------------|---------------------|
| NO <sub>x</sub> | Met AST acceptance criteria. | No action required. |
| CO              | Met AST acceptance criteria. | No action required. |

It is recommended that the catalytic converter associated with the CEM system serving HRSG 20 be assessed at the next routine service to confirm acceptable operating settings and then assessed as part of the following monthly check to ensure satisfactory conversion efficiency.

## Part 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<br>Nash, Newport<br>Gwent, NP18 2BZ |                |                   |                                       |                             |
| Industry sector                                                             | Power generation                                   |                |                   |                                       |                             |
| Permit No.                                                                  | HP3737UE                                           |                |                   |                                       |                             |
| Date of last QAL 2                                                          | February 2011 and May 2012                         |                |                   |                                       |                             |
|                                                                             |                                                    |                |                   |                                       |                             |
| Regulated determinands and emission limit values (STP, 15% oxygen, dry gas) |                                                    |                |                   |                                       |                             |
|                                                                             |                                                    |                |                   |                                       |                             |
| HRSG exhaust stacks (A1 & A2)                                               |                                                    |                |                   |                                       |                             |
|                                                                             |                                                    |                |                   |                                       |                             |
| Determinand                                                                 |                                                    | Short term ELV | Daily average ELV | Maximum allowable certified CEM range | Uncertainty requirement (%) |
| 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.

### 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.

### 2.3 Monitoring provisions for periodic monitoring

#### 2.3.1 Manual sampling positions

The sampling locations associated with the exhaust of the gas turbines are illustrated in Figure 1. 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>. All sampling was undertaken through the available opening at a position around 1.5 m into the stack.

The sampling heads for the CEM system are also present on this platform.

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

A compliant homogeneity test in accordance with the requirements of BS EN 15259, 8.3 has been undertaken on each exhaust stack.

### 2.3.2 Monitoring platform and site provisions

The platform around the sampling area 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 analyser is 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. It is noted that the certification for two of the cylinders expires in October 2015.

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.

Table 2.2

Reference material audit – 22 June 2015

| Gas                     | Certified concentration | Cylinder No. | Expiry date |
|-------------------------|-------------------------|--------------|-------------|
| Unit 10 CO              | 100.1 ppm               | 219847       | 04/10/15    |
| Unit 10 NO              | 96.5 ppm                | 219847       | 04/10/15    |
| Unit 20 CO              | 102.2 ppm               | 219842       | 04/10/15    |
| Unit 20 NO              | 93.4 ppm                | 219842       | 04/10/15    |
| Unit 10 NO <sub>2</sub> | 80.8 ppm                | 95890        | 20/02/16    |
| Unit 20 NO <sub>2</sub> | 78.8ppm                 | 95533        | 20/02/16    |



Figure 1 Typical exhaust stack and sampling platform

## 2.4 Continuous emissions monitoring systems

The exhaust stacks (A1 and A2) are each served by identical duty CEM systems. There is no stand by CEM capacity. Table 2.3 summarises the main properties of the systems.

Table 2.3

Continuous Emissions Monitoring System Description

| Determinand          | Certified Range                          | Measurement basis | Operating principle      |
|----------------------|------------------------------------------|-------------------|--------------------------|
| Manufacturer         | Siemens Production Automatisations 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.

Neither temperature nor pressure are recorded.

All analysers operate on an extractive basis.

## Part 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.<br>MM | Level | Certification expiry |       |       |       |
|             |           |                |       | TE1                  | TE2   | TE3   | TE4   |
| Manager     | N Ford    | 02084          | 2     | 10/19                | 10/19 | 10/19 | 10/19 |
| Team leader | M Davies  | 02087          | 2     | 03/18                | 06/18 | 06/18 | 08/18 |
| Team leader | O May     | 06752          | 2     | 06/16                | 09/16 | 02/18 | 03/17 |
| Team leader | D May     | 07862          | 2     | 12/19                | 09/20 | 03/20 | 09/19 |
| Technician  | O Redfern | 131248         | 1     | 10/19                | -     | -     | -     |

### 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             | 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 were no separate analytical tasks associated with this work.

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 |
|--------------------------------------------------------------|---------------------------------------|-----------------|-------------------|
| Manufacturer                                                 |                                       |                 |                   |
| Horiba                                                       |                                       |                 |                   |
| Model                                                        |                                       |                 |                   |
| PG 250                                                       |                                       |                 |                   |
| Identifier                                                   |                                       |                 |                   |
| P1985                                                        |                                       |                 |                   |
| MCERTS certification                                         |                                       |                 |                   |
| 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 mgNO <sub>2</sub> /m <sup>3</sup> | 250             | 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.

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**

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

## Part 4 Data & calculations

Annex G and Sections 8.2 to 8.5 of BS EN 14181:2004 specify the requirements for undertaking parallel SRM and CEM measurements and evaluating the subsequent data to determine the acceptability of variability and the validity of the existing calibration function for an annual surveillance tests. Based on at least 5 parallel measurements from the CEM system and corresponding SRM, it is required to determine the following properties for each determinand:

- SRM signals at reference conditions
- CEM signals at reference conditions
- A comparison of variability with the allowable measurement uncertainty
- Determination of the validity of the calibration function by comparison with defined limits
- Determination of the revised calibration range, if applicable

This approach has been employed for the assessment of all gaseous parameters. In addition, for carbon monoxide, where normal operating concentrations were relatively low, the assessment has been repeated using the CEM's response to reference materials. This provides an assessment over a much wider range providing some confidence in the performance of the analyser at higher concentrations.

These calculations are presented in the attached reporting forms for each determinand. The reporting forms contain:

- Details of the SRM and CEM systems
- The measurement pairs employed
- The methodology for calculation of variability and its acceptability
- The methodology for determination of the validity of the existing calibration function
- The determination of the revised calibration range

## 4.1 Gas Turbine Exhaust (A1) CEM – Annual Surveillance Test

### 4.1.1 Nitrogen oxides

Sample point HRS 10 exhaust stack

Determinand Nitrogen oxides

Raw monitoring data (1)

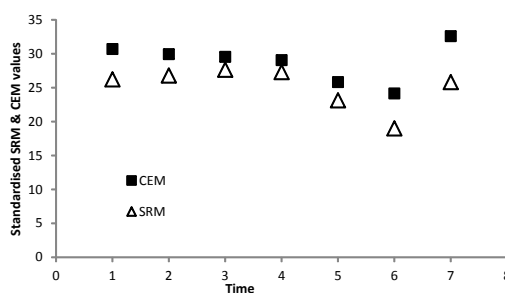
| Sample No. | Date    | Start time | End time | CEM measurements |                |                  | SRM measurements |                |                  |           |
|------------|---------|------------|----------|------------------|----------------|------------------|------------------|----------------|------------------|-----------|
|            |         |            |          | CEM              | O <sub>2</sub> | H <sub>2</sub> O | SRM              | O <sub>2</sub> | H <sub>2</sub> O | CEM basis |
| 1          | 23.6.15 | 1600       | 1700     | 30.56            | 15.03          | 0.00             | 14.72            | 14.11          | 0.00             | 30.20     |
| 2          | 23.6.15 | 1700       | 1800     | 30.20            | 14.95          | 0.00             | 15.08            | 14.09          | 0.00             | 30.94     |
| 3          | 23.6.15 | 1800       | 1900     | 29.86            | 14.94          | 0.00             | 15.52            | 14.10          | 0.00             | 31.86     |
| 4          | 23.6.15 | 1900       | 2000     | 29.31            | 14.95          | 0.00             | 15.29            | 14.12          | 0.00             | 31.37     |
| 5          | 23.6.15 | 2000       | 2100     | 25.46            | 15.08          | 0.00             | 12.75            | 14.23          | 0.00             | 26.17     |
| 6          | 23.6.15 | 2100       | 2200     | 23.02            | 15.28          | 0.00             | 10.14            | 14.44          | 0.00             | 20.81     |
| 7          | 23.6.15 | 2200       | 2300     | 29.94            | 15.48          | 0.00             | 13.13            | 14.74          | 0.00             | 26.95     |

Standardised monitoring data (2)

Plot 1 - Nitrogen oxides

| Sample No. | CEM               | SRM               |
|------------|-------------------|-------------------|
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> |
| 1          | 30.70             | 26.23             |
| 2          | 29.94             | 26.80             |
| 3          | 29.55             | 27.65             |
| 4          | 29.06             | 27.30             |
| 5          | 25.83             | 23.14             |
| 6          | 24.16             | 19.01             |
| 7          | 32.60             | 25.82             |

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



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

Test for outliers (3)

| Sample No. | CEM               | SRM               | Difference        |                 |                     | Outlier condition                | Data point used |
|------------|-------------------|-------------------|-------------------|-----------------|---------------------|----------------------------------|-----------------|
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> | $y_i - x_i = D_i$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ | $\frac{D_i - \bar{D}}{\sigma_D}$ |                 |
| i          | x                 | y                 |                   |                 |                     |                                  |                 |
| 1          | 30.56             | 30.20             | 0.35              | -1.23           | 1.52                | 1.26                             | include         |
| 2          | 30.20             | 30.94             | 0.75              | -0.84           | 0.70                | 0.85                             | include         |
| 3          | 29.86             | 31.86             | 2.00              | 0.42            | 0.17                | 0.43                             | include         |
| 4          | 29.31             | 31.37             | 2.07              | 0.48            | 0.23                | 0.49                             | include         |
| 5          | 25.46             | 26.17             | 0.71              | -0.88           | 0.77                | 0.89                             | include         |
| 6          | 23.02             | 20.81             | 2.21              | 0.63            | 0.40                | 0.65                             | include         |
| 7          | 29.94             | 26.95             | 2.99              | 1.41            | 1.98                | 1.44                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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 = 7

and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.98 given by

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

Calculation of calibrated values (4)

Original calibration function  $y = 0.553 + 0.931 x$

| Sample No. | Raw               | Calibrated        |                     | SRM <sup>4</sup> |
|------------|-------------------|-------------------|---------------------|------------------|
|            | CEM               | CEM <sup>2</sup>  | CEM <sup>3</sup>    |                  |
|            | Stack conditions  |                   | Standard conditions |                  |
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> | mg/m <sup>3</sup>   |                  |
| 1          | 30.56             | 29.00             | 29.14               | 26.23            |
| 2          | 30.20             | 28.67             | 28.43               | 26.80            |
| 3          | 29.86             | 28.35             | 28.06               | 27.65            |
| 4          | 29.31             | 27.84             | 27.61               | 27.30            |
| 5          | 25.46             | 24.26             | 24.61               | 23.14            |
| 6          | 23.02             | 21.99             | 23.07               | 19.01            |
| 7          | 29.94             | 28.42             | 30.95               | 25.82            |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_s$         | $y_s$ | $y_s - \hat{y}_s$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 29.14               | 26.23 | -2.91             | -0.63           | 0.40                |
| 2          | 28.43               | 26.80 | -1.63             | 0.65            | 0.42                |
| 3          | 28.06               | 27.65 | -0.40             | 1.87            | 3.49                |
| 4          | 27.61               | 27.30 | -0.31             | 1.97            | 3.86                |
| 5          | 24.61               | 23.14 | -1.47             | 0.80            | 0.64                |
| 6          | 23.07               | 19.01 | -4.06             | -1.79           | 3.20                |
| 7          | 30.95               | 25.82 | -5.13             | -2.86           | 8.16                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_0k_v = 7.23$

where  $\sigma_0 = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9441

The variability test is passed when  $\sigma_D \leq 1.5\sigma_0k_v$   
 $\sigma_D = 1.83$   
 $1.5\sigma_0k_v = 7.23$

**Variability test passed - 25% of limit**

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.02  
 $|\bar{D}|$  is the absolute value of the average difference = 2.27

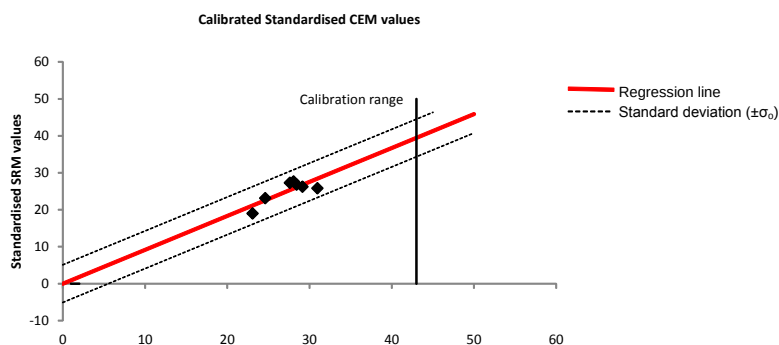
$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 6.50$$

**Calibration is acceptable - 35% of limit**

#### Valid calibration range (8)

Plot 2 - Nitrogen oxides

mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

Extrapolated range

$\hat{y}_{s, \max c}$  43 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  68 is the maximum allowable data value  
 $y_{s, \max}$  31.00 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (64.5)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max c}$  then no extension is possible and the upper calibration range remains as previously (43)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (64.5)  
 otherwise the extension is to  $\hat{y}_{s, \max}$

No extension to range

Calibration range 0 to 43 mg/m3 (86 %ELV)

## 4.1.2 Carbon monoxide (parallel measurements)

Sample point HRSO 10 exhaust stack

Determinand Carbon monoxide

Raw monitoring data (1)

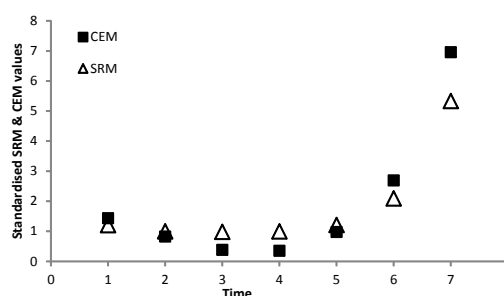
| Sample No. | Date    | Start time | End time | CEM measurements |                |                  | SRM measurements |                |                  |           |
|------------|---------|------------|----------|------------------|----------------|------------------|------------------|----------------|------------------|-----------|
|            |         |            |          | CEM              | O <sub>2</sub> | H <sub>2</sub> O | SRM              | O <sub>2</sub> | H <sub>2</sub> O | CEM basis |
|            |         |            |          | mg/m3            | %, dry         | %                | ppm              | %, dry         | %                | mg/m3     |
| 1          | 23.6.15 | 1600       | 1700     | 1.43             | 15.03          | 0.00             | 1.11             | 14.11          | 0.00             | 1.39      |
| 2          | 23.6.15 | 1700       | 1800     | 0.83             | 14.95          | 0.00             | 0.92             | 14.09          | 0.00             | 1.15      |
| 3          | 23.6.15 | 1800       | 1900     | 0.39             | 14.94          | 0.00             | 0.91             | 14.10          | 0.00             | 1.13      |
| 4          | 23.6.15 | 1900       | 2000     | 0.36             | 14.95          | 0.00             | 0.92             | 14.12          | 0.00             | 1.15      |
| 5          | 23.6.15 | 2000       | 2100     | 0.96             | 15.08          | 0.00             | 1.10             | 14.23          | 0.00             | 1.37      |
| 6          | 23.6.15 | 2100       | 2200     | 2.57             | 15.28          | 0.00             | 1.84             | 14.44          | 0.00             | 2.29      |
| 7          | 23.6.15 | 2200       | 2300     | 6.39             | 15.48          | 0.00             | 4.45             | 14.74          | 0.00             | 5.57      |

Standardised monitoring data (2)

Plot 1 - Carbon monoxide

| Sample No. | CEM                              | SRM   |
|------------|----------------------------------|-------|
|            | Standard conditions <sup>1</sup> |       |
|            | mg/m3                            | mg/m3 |
| 1          | 1.44                             | 1.20  |
| 2          | 0.83                             | 1.00  |
| 3          | 0.38                             | 0.98  |
| 4          | 0.35                             | 1.00  |
| 5          | 0.98                             | 1.21  |
| 6          | 2.69                             | 2.10  |
| 7          | 6.96                             | 5.33  |

mg/m3, 15%, dry, STP



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

Test for outliers (3)

| 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          | 1.43           | 1.39  | 0.04              | -0.44           | 0.20                | 1.46                             | include         |
| 2          | 0.83           | 1.15  | 0.32              | -0.17           | 0.03                | 0.55                             | include         |
| 3          | 0.39           | 1.13  | 0.74              | 0.26            | 0.07                | 0.85                             | include         |
| 4          | 0.36           | 1.15  | 0.79              | 0.30            | 0.09                | 1.00                             | include         |
| 5          | 0.96           | 1.37  | 0.40              | -0.08           | 0.01                | 0.27                             | include         |
| 6          | 2.57           | 2.29  | 0.27              | -0.21           | 0.05                | 0.70                             | include         |
| 7          | 6.39           | 5.57  | 0.83              | 0.34            | 0.12                | 1.12                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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 = 7

and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.3 given by

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

Calculation of calibrated values (4)

Original calibration function  $y = 0 + 1 \cdot x$

| Sample No. | Raw              | Calibrated          |                     | SRM <sup>4</sup> |
|------------|------------------|---------------------|---------------------|------------------|
|            | CEM              | CEM <sup>2</sup>    | CEM <sup>3</sup>    |                  |
|            | Stack conditions | Standard conditions | Standard conditions |                  |
|            | mg/m3            | mg/m3               | mg/m3               | mg/m3            |
| 1          | 1.43             | 1.43                | 1.44                | 1.20             |
| 2          | 0.83             | 0.83                | 0.83                | 1.00             |
| 3          | 0.39             | 0.39                | 0.38                | 0.98             |
| 4          | 0.36             | 0.36                | 0.35                | 1.00             |
| 5          | 0.96             | 0.96                | 0.98                | 1.21             |
| 6          | 2.57             | 2.57                | 2.69                | 2.10             |
| 7          | 6.39             | 6.39                | 6.96                | 5.33             |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_i$         | $y_i$ | $y_i - \hat{y}_i$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 1.44                | 1.20  | -0.23             | -0.12           | 0.01                |
| 2          | 0.83                | 1.00  | 0.17              | 0.29            | 0.08                |
| 3          | 0.38                | 0.98  | 0.60              | 0.71            | 0.51                |
| 4          | 0.35                | 1.00  | 0.64              | 0.76            | 0.58                |
| 5          | 0.98                | 1.21  | 0.23              | 0.35            | 0.12                |
| 6          | 2.69                | 2.10  | -0.60             | -0.48           | 0.23                |
| 7          | 6.96                | 5.33  | -1.63             | -1.51           | 2.28                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_D k_v = 7.23$

where  $\sigma_D = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9441

The variability test is passed when  $\sigma_D \leq 1.5\sigma_D k_v$

|                   |      |
|-------------------|------|
| $\sigma_D$        | 0.80 |
| $1.5\sigma_D k_v$ | 7.23 |

Variability test passed - 11% of limit

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

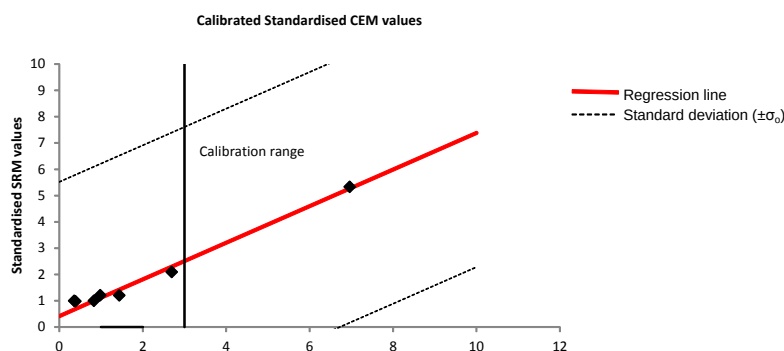
where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.02  
 $|\bar{D}|$  is the absolute value of the average difference = 0.12

$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 5.71$$

Calibration is acceptable - 2% of limit

#### Valid calibration range (8)

Plot 2 - Carbon monoxide  
mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

Extrapolated rang

$\hat{y}_{s, \max c}$  2 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  27 is the maximum allowable data value  
 $y_{s, \max}$  7.00 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (3)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max c}$  then no extension is possible and the upper calibration range remains as previously (2)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (3)  
otherwise the extension is to  $y_{s, \max}$

Range may be extended  
Calibration range 0 to 3 mg/m3 (6 %ELV)

### 4.1.3 Carbon monoxide (CEM's response to reference materials)

Sample point HRSO 10 exhaust stack

Determinand Carbon monoxide

Raw monitoring data (1)

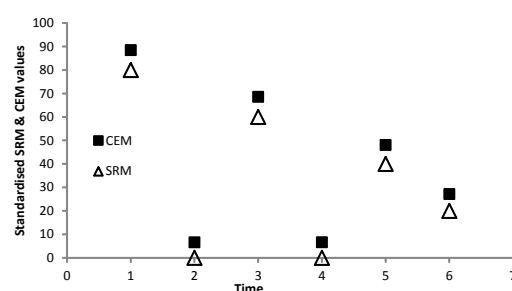
| Sample No. | Date    | Start time | End time | CEM measurements  |                |                  | SRM measurements  |                |                  |                   |
|------------|---------|------------|----------|-------------------|----------------|------------------|-------------------|----------------|------------------|-------------------|
|            |         |            |          | CEM               | O <sub>2</sub> | H <sub>2</sub> O | SRM               | O <sub>2</sub> | H <sub>2</sub> O | CEM basis         |
|            |         |            |          | mg/m <sup>3</sup> | % dry          | %                | mg/m <sup>3</sup> | % dry          | %                | mg/m <sup>3</sup> |
| 1          | 22.6.15 | -          | -        | 88.47             | 15.00          | 0.00             | 80.00             | 15.00          | 0.00             | 80.00             |
| 2          | 22.6.15 | -          | -        | 6.60              | 15.00          | 0.00             | 0.00              | 15.00          | 0.00             | 0.00              |
| 3          | 22.6.15 | -          | -        | 68.60             | 15.00          | 0.00             | 60.00             | 15.00          | 0.00             | 60.00             |
| 4          | 22.6.15 | -          | -        | 6.63              | 15.00          | 0.00             | 0.00              | 15.00          | 0.00             | 0.00              |
| 5          | 22.6.15 | -          | -        | 48.10             | 15.00          | 0.00             | 40.00             | 15.00          | 0.00             | 40.00             |
| 6          | 22.6.15 | -          | -        | 27.17             | 15.00          | 0.00             | 20.00             | 15.00          | 0.00             | 20.00             |

Standardised monitoring data (2)

Plot 1 - Carbon monoxide

| Sample No. | CEM                                                   | SRM               |
|------------|-------------------------------------------------------|-------------------|
|            | Standard conditions <sup>1</sup><br>mg/m <sup>3</sup> | mg/m <sup>3</sup> |
| 1          | 88.47                                                 | 80.00             |
| 2          | 6.60                                                  | 0.00              |
| 3          | 68.60                                                 | 60.00             |
| 4          | 6.63                                                  | 0.00              |
| 5          | 48.10                                                 | 40.00             |
| 6          | 27.17                                                 | 20.00             |

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



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

Test for outliers (3)

| Sample No. | CEM               | SRM               | Difference        |                 |                     | Outlier condition                | Data point used |
|------------|-------------------|-------------------|-------------------|-----------------|---------------------|----------------------------------|-----------------|
|            | CEM conditions    | SRM conditions    |                   |                 |                     |                                  |                 |
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> | $y_i - x_i = D_i$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ | $\frac{D_i - \bar{D}}{\sigma_D}$ |                 |
| i          | x                 | y                 |                   |                 |                     | $\sigma_D$                       |                 |
| 1          | 88.47             | 80.00             | 8.47              | 0.87            | 0.76                | 0.96                             | include         |
| 2          | 6.60              | 0.00              | 6.60              | -0.99           | 0.99                | 1.10                             | include         |
| 3          | 68.60             | 60.00             | 8.60              | 1.01            | 1.01                | 1.11                             | include         |
| 4          | 6.63              | 0.00              | 6.63              | -0.96           | 0.92                | 1.06                             | include         |
| 5          | 48.10             | 40.00             | 8.10              | 0.51            | 0.26                | 0.56                             | include         |
| 6          | 27.17             | 20.00             | 7.17              | -0.43           | 0.18                | 0.47                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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 = 6

and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.91 given by

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

Calculation of calibrated values (4)

Original calibration function  $y = 0 + 1x$

| Sample No. | Raw               | Calibrated          |                     | SRM <sup>4</sup>  |
|------------|-------------------|---------------------|---------------------|-------------------|
|            | CEM               | CEM <sup>2</sup>    | CEM <sup>3</sup>    |                   |
|            | Stack conditions  | Standard conditions | Standard conditions |                   |
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup>   | mg/m <sup>3</sup>   | mg/m <sup>3</sup> |
| 1          | 88.47             | 88.47               | 88.47               | 80.00             |
| 2          | 6.60              | 6.60                | 6.60                | 0.00              |
| 3          | 68.60             | 68.60               | 68.60               | 60.00             |
| 4          | 6.63              | 6.63                | 6.63                | 0.00              |
| 5          | 48.10             | 48.10               | 48.10               | 40.00             |
| 6          | 27.17             | 27.17               | 27.17               | 20.00             |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_s$         | $y_s$ | $y_s - \hat{y}_s$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 88.47               | 80.00 | -8.47             | -0.87           | 0.76                |
| 2          | 6.60                | 0.00  | -6.60             | 0.99            | 0.99                |
| 3          | 68.60               | 60.00 | -8.60             | -1.01           | 1.01                |
| 4          | 6.63                | 0.00  | -6.63             | 0.96            | 0.92                |
| 5          | 48.10               | 40.00 | -8.10             | -0.51           | 0.26                |
| 6          | 27.17               | 20.00 | -7.17             | 0.43            | 0.18                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_0 k_v = 7.14$

where  $\sigma_0 = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9329

The variability test is passed when  $\sigma_D \leq 1.5\sigma_0 k_v$

|                   |      |
|-------------------|------|
| $\sigma_D$        | 0.91 |
| $1.5\sigma_0 k_v$ | 7.14 |

Variability test passed - 13% of limit

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

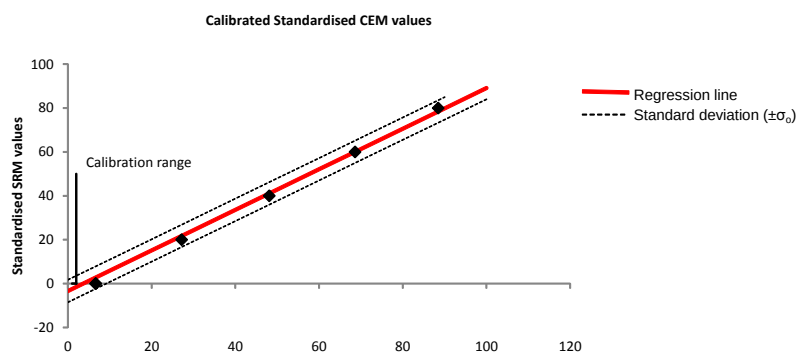
where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.13  
 $|\bar{D}|$  is the absolute value of the average difference = 7.59

$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 5.89$$

Calibration is not acceptable - 129% of limit

#### Valid calibration range (8)

Plot 2 - Carbon monoxide  
mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

Extrapolated range

$\hat{y}_{s, \max c}$  2 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  27 is the maximum allowable data value  
 $y_{s, \max}$  88.50 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (3)

If  $\hat{y}_{s, \max} > \hat{y}_{s, \max a}$  then no extension is possible and the upper calibration range remains as previously (2)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (3)  
otherwise the extension is to  $\hat{y}_{s, \max}$

No extension to range  
Calibration range 0 to 2 mg/m3 (4 %ELV)

## 4.2 Gas Turbine Exhaust (A2) CEM – Annual Surveillance Test

### 4.2.1 Nitrogen oxides

Sample point HRSO 20 exhaust stack

Determinand Nitrogen oxides

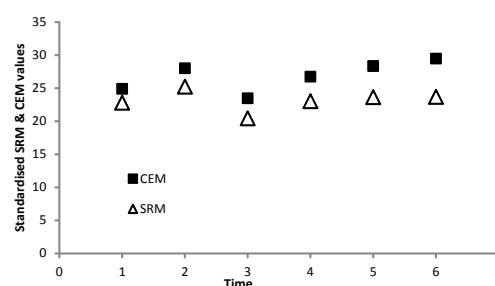
Raw monitoring data (1)

| 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         |
|            |         |            |          | mg/m <sup>3</sup> | % dry          | %                | ppm              | % dry          | %                | mg/m <sup>3</sup> |
| 1          | 22.6.15 | 1700       | 1800     | 27.50             | 14.39          | 0.00             | 11.41            | 14.85          | 0.00             | 23.41             |
| 2          | 22.6.15 | 1800       | 1900     | 30.80             | 14.42          | 0.00             | 12.49            | 14.91          | 0.00             | 25.64             |
| 3          | 23.6.15 | 0845       | 0945     | 27.69             | 13.94          | 0.00             | 10.90            | 14.45          | 0.00             | 22.36             |
| 4          | 23.6.15 | 0945       | 1045     | 32.32             | 13.78          | 0.00             | 12.52            | 14.32          | 0.00             | 25.69             |
| 5          | 23.6.15 | 1045       | 1145     | 34.36             | 13.75          | 0.00             | 12.85            | 14.32          | 0.00             | 26.37             |
| 6          | 23.6.15 | 1145       | 1245     | 35.92             | 13.72          | 0.00             | 12.90            | 14.31          | 0.00             | 26.48             |

Standardised monitoring data (2)  
Plot 1 - Nitrogen oxides

| Sample No. | CEM               | SRM               |
|------------|-------------------|-------------------|
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> |
| 1          | 24.92             | 22.82             |
| 2          | 28.03             | 25.25             |
| 3          | 23.48             | 20.45             |
| 4          | 26.76             | 23.05             |
| 5          | 28.37             | 23.66             |
| 6          | 29.50             | 23.71             |

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



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

Test for outliers (3)

| Sample No. | CEM               | SRM               | Difference      |                 |                     | Outlier condition                | Data point used |
|------------|-------------------|-------------------|-----------------|-----------------|---------------------|----------------------------------|-----------------|
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup> | $y_i - \bar{y}$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ | $\frac{D_i - \bar{D}}{\sigma_D}$ |                 |
| i          | x                 | y                 |                 |                 |                     |                                  |                 |
| 1          | 27.50             | 23.41             | 4.09            | -2.35           | 5.53                | 1.18                             | include         |
| 2          | 30.80             | 25.64             | 5.15            | -1.28           | 1.65                | 0.64                             | include         |
| 3          | 27.69             | 22.36             | 5.33            | -1.11           | 1.23                | 0.56                             | include         |
| 4          | 32.32             | 25.69             | 6.63            | 0.19            | 0.04                | 0.10                             | include         |
| 5          | 34.36             | 26.37             | 7.99            | 1.55            | 2.41                | 0.78                             | include         |
| 6          | 35.92             | 26.48             | 9.44            | 3.00            | 9.01                | 1.51                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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 = 6

and  $\sigma_D$  is the standard deviation or variability of the CEM = 1.99 given by

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

Calculation of calibrated values (4)

Original calibration function  $y = 0.509 + 0.833 x$

| Sample No. | Raw               | Calibrated          |                   | SRM <sup>4</sup>  |
|------------|-------------------|---------------------|-------------------|-------------------|
|            | CEM               | CEM <sup>2</sup>    | CEM <sup>3</sup>  |                   |
|            | Stack conditions  | Standard conditions |                   |                   |
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup>   | mg/m <sup>3</sup> | mg/m <sup>3</sup> |
| 1          | 27.50             | 23.41               | 21.22             | 22.82             |
| 2          | 30.80             | 26.16               | 23.81             | 25.25             |
| 3          | 27.69             | 23.58               | 19.99             | 20.45             |
| 4          | 32.32             | 27.43               | 22.71             | 23.05             |
| 5          | 34.36             | 29.13               | 24.05             | 23.66             |
| 6          | 35.92             | 30.43               | 24.99             | 23.71             |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_s$         | $y_s$ | $y_s - \hat{y}_s$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 21.22               | 22.82 | 1.59              | 1.24            | 1.53                |
| 2          | 23.81               | 25.25 | 1.44              | 1.08            | 1.17                |
| 3          | 19.99               | 20.45 | 0.46              | 0.10            | 0.01                |
| 4          | 22.71               | 23.05 | 0.33              | -0.02           | 0.00                |
| 5          | 24.05               | 23.66 | -0.40             | -0.75           | 0.57                |
| 6          | 24.99               | 23.71 | -1.29             | -1.64           | 2.70                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_0 k_v = 7.14$

where  $\sigma_0 = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9329

The variability test is passed when  $\sigma_0 \leq 1.5\sigma_0 k_v$   
 $\sigma_0 = 1.09$   
 $1.5\sigma_0 k_v = 7.14$

Variability test passed - 15% of limit

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.13  
 $|\bar{D}|$  is the absolute value of the average difference = 0.36

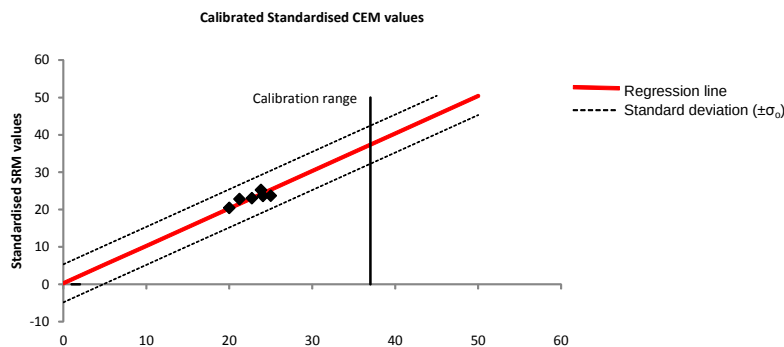
$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 6.05$$

Calibration is acceptable - 6% of limit

#### Valid calibration range (8)

Plot 2 - Nitrogen oxides

mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

Extrapolated range

$\hat{y}_{s, \max c}$  37 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  62 is the maximum allowable data value  
 $y_{s, \max}$  25.00 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (55.5)

If  $\hat{y}_{s, \max} > \hat{y}_{s, \max c}$  then no extension is possible and the upper calibration range remains as previously (37)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (55.5) otherwise the extension is to  $y_{s, \max}$

No extension to range

Calibration range 0 to 37 mg/m3 (74 %ELV)

## 4.2.2 Carbon monoxide (parallel measurements)

Sample point HRSO 20 exhaust stack

Determinand Carbon monoxide

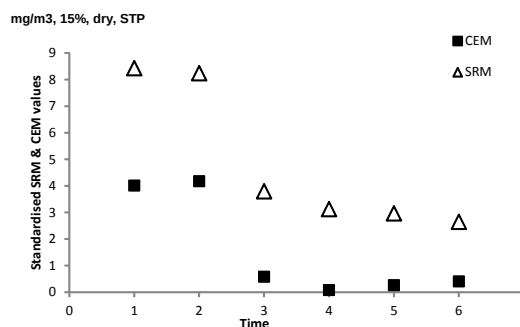
Raw monitoring data (1)

| 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         |
|            |         |            |          | mg/m <sup>3</sup> | %, dry         | %                | ppm              | %, dry         | %                | mg/m <sup>3</sup> |
| 1          | 22.6.15 | 1700       | 1800     | 4.43              | 14.39          | 0.00             | 6.92             | 14.85          | 0.00             | 8.65              |
| 2          | 22.6.15 | 1800       | 1900     | 4.59              | 14.42          | 0.00             | 6.70             | 14.91          | 0.00             | 8.37              |
| 3          | 23.6.15 | 0845       | 0945     | 0.69              | 13.94          | 0.00             | 3.32             | 14.45          | 0.00             | 4.15              |
| 4          | 23.6.15 | 0945       | 1045     | 0.10              | 13.78          | 0.00             | 2.79             | 14.32          | 0.00             | 3.48              |
| 5          | 23.6.15 | 1045       | 1145     | 0.32              | 13.75          | 0.00             | 2.65             | 14.32          | 0.00             | 3.31              |
| 6          | 23.6.15 | 1145       | 1245     | 0.50              | 13.72          | 0.00             | 2.37             | 14.31          | 0.00             | 2.96              |

Standardised monitoring data (2)

Plot 1 - Carbon monoxide

| Sample No. | CEM                              | SRM               |
|------------|----------------------------------|-------------------|
|            | Standard conditions <sup>1</sup> |                   |
|            | mg/m <sup>3</sup>                | mg/m <sup>3</sup> |
| 1          | 4.01                             | 8.43              |
| 2          | 4.18                             | 8.24              |
| 3          | 0.58                             | 3.80              |
| 4          | 0.08                             | 3.13              |
| 5          | 0.26                             | 2.97              |
| 6          | 0.41                             | 2.65              |



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

Test for outliers (3)

| 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          | 4.43           | 8.65  | 4.22              | 0.84            | 0.70                | 1.37                             | include         |
| 2          | 4.59           | 8.37  | 3.78              | 0.40            | 0.16                | 0.65                             | include         |
| 3          | 0.69           | 4.15  | 3.46              | 0.08            | 0.01                | 0.13                             | include         |
| 4          | 0.10           | 3.48  | 3.39              | 0.00            | 0.00                | 0.00                             | include         |
| 5          | 0.32           | 3.31  | 2.99              | -0.40           | 0.16                | 0.65                             | include         |
| 6          | 0.50           | 2.96  | 2.46              | -0.92           | 0.85                | 1.51                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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 = 6

and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.61 given by

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

Calculation of calibrated values (4)

Original calibration function  $y = 0 + 1x$

| Sample No. | Raw               | Calibrated          |                     | SRM <sup>4</sup>  |
|------------|-------------------|---------------------|---------------------|-------------------|
|            | CEM               | CEM <sup>2</sup>    | CEM <sup>3</sup>    |                   |
|            | Stack conditions  | Standard conditions | Standard conditions |                   |
|            | mg/m <sup>3</sup> | mg/m <sup>3</sup>   | mg/m <sup>3</sup>   | mg/m <sup>3</sup> |
| 1          | 4.43              | 4.43                | 4.01                | 8.43              |
| 2          | 4.59              | 4.59                | 4.18                | 8.24              |
| 3          | 0.69              | 0.69                | 0.58                | 3.80              |
| 4          | 0.10              | 0.10                | 0.08                | 3.13              |
| 5          | 0.32              | 0.32                | 0.26                | 2.97              |
| 6          | 0.50              | 0.50                | 0.41                | 2.65              |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_s$         | $y_s$ | $y_s - \hat{y}_s$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 4.01                | 8.43  | 4.42              | 1.14            | 1.29                |
| 2          | 4.18                | 8.24  | 4.06              | 0.78            | 0.61                |
| 3          | 0.58                | 3.80  | 3.21              | -0.07           | 0.00                |
| 4          | 0.08                | 3.13  | 3.04              | -0.24           | 0.06                |
| 5          | 0.26                | 2.97  | 2.70              | -0.58           | 0.33                |
| 6          | 0.41                | 2.65  | 2.24              | -1.04           | 1.08                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_0 k_v = 7.14$

where  $\sigma_0 = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9329

The variability test is passed when  $\sigma_D \leq 1.5\sigma_0 k_v$   
 $\sigma_D = 0.82$   
 $1.5\sigma_0 k_v = 7.14$

**Variability test passed - 12% of limit**

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.13  
 $|\bar{D}|$  is the absolute value of the average difference = 3.28

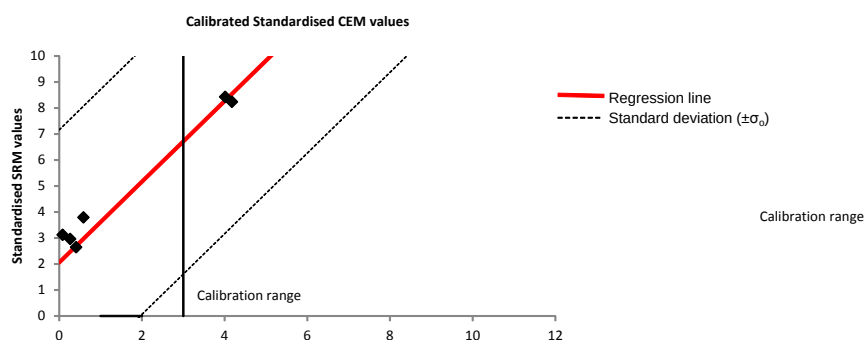
$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 5.82$$

**Calibration is acceptable - 56% of limit**

#### Valid calibration range (8)

##### Plot 2 - Carbon monoxide

mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

$\hat{y}_{s, \max c}$  2 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  27 is the maximum allowable data value  
 $y_{s, \max}$  4.20 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (3)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max c}$  then no extension is possible and the upper calibration range remains as previously (2)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (3)  
otherwise the extension is to  $\hat{y}_{s, \max}$

**Range may be extended**

Calibration range 0 to 3 mg/m3 (6 %ELV)

## 4.2.3 Carbon monoxide (CEM's response to reference materials)

Sample point HRSG 20 exhaust stack

Determinand Carbon monoxide

Raw monitoring data (1)

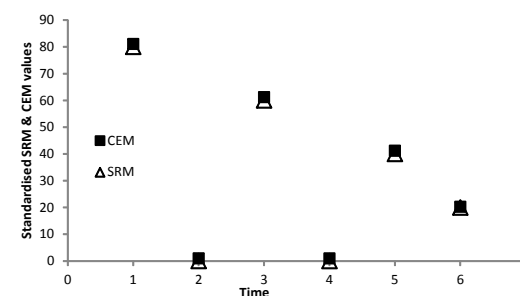
| Sample No. | Date    | Start time | End time | CEM measurements |                |                  | SRM measurements |                |                  |           |
|------------|---------|------------|----------|------------------|----------------|------------------|------------------|----------------|------------------|-----------|
|            |         |            |          | CEM              | O <sub>2</sub> | H <sub>2</sub> O | SRM              | O <sub>2</sub> | H <sub>2</sub> O | CEM basis |
|            |         |            |          | mg/m3            | %, dry         | %                | mg/m3            | %, dry         | %                | mg/m3     |
| 1          | 22.6.15 | -          | -        | 81.10            | 15.00          | 0.00             | 80.00            | 15.00          | 0.00             | 80.00     |
| 2          | 22.6.15 | -          | -        | 1.00             | 15.00          | 0.00             | 0.00             | 15.00          | 0.00             | 0.00      |
| 3          | 22.6.15 | -          | -        | 61.23            | 15.00          | 0.00             | 60.00            | 15.00          | 0.00             | 60.00     |
| 4          | 22.6.15 | -          | -        | 1.00             | 15.00          | 0.00             | 0.00             | 15.00          | 0.00             | 0.00      |
| 5          | 22.6.15 | -          | -        | 41.23            | 15.00          | 0.00             | 40.00            | 15.00          | 0.00             | 40.00     |
| 6          | 22.6.15 | -          | -        | 20.30            | 15.00          | 0.00             | 20.00            | 15.00          | 0.00             | 20.00     |

Standardised monitoring data (2)

Plot 1 - Carbon monoxide

| Sample No. | CEM                                       | SRM   |
|------------|-------------------------------------------|-------|
|            | Standard conditions <sup>1</sup><br>mg/m3 | mg/m3 |
| 1          | 81.10                                     | 80.00 |
| 2          | 1.00                                      | 0.00  |
| 3          | 61.23                                     | 60.00 |
| 4          | 1.00                                      | 0.00  |
| 5          | 41.23                                     | 40.00 |
| 6          | 20.30                                     | 20.00 |

mg/m3, 15%, dry, STP



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

Test for outliers (3)

| 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          | 81.10          | 80.00 | 1.10              | 0.12            | 0.01                | 0.35                             | include         |
| 2          | 1.00           | 0.00  | 1.00              | 0.02            | 0.00                | 0.06                             | include         |
| 3          | 61.23          | 60.00 | 1.23              | 0.26            | 0.07                | 0.73                             | include         |
| 4          | 1.00           | 0.00  | 1.00              | 0.02            | 0.00                | 0.06                             | include         |
| 5          | 41.23          | 40.00 | 1.23              | 0.26            | 0.07                | 0.73                             | include         |
| 6          | 20.30          | 20.00 | 0.30              | -0.68           | 0.46                | 1.95                             | include         |

A data point will be considered an outlier and excluded from the assessment if:  $D_i - \bar{D} > 2\sigma_D$

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

where  $n$  is the number of samples = 6  
and  $\sigma_D$  is the standard deviation or variability of the CEM = 0.35 given by  $\sigma_D = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (D_i - \bar{D})^2}$

Calculation of calibrated values (4)

Original calibration function  $y = 0 + 1x$

| Sample No. | Raw                       | Calibrated                   |                              | SRM <sup>4</sup> |
|------------|---------------------------|------------------------------|------------------------------|------------------|
|            | CEM                       | CEM <sup>2</sup>             | CEM <sup>3</sup>             |                  |
|            | Stack conditions<br>mg/m3 | Standard conditions<br>mg/m3 | Standard conditions<br>mg/m3 |                  |
| 1          | 81.10                     | 81.10                        | 81.10                        | 80.00            |
| 2          | 1.00                      | 1.00                         | 1.00                         | 0.00             |
| 3          | 61.23                     | 61.23                        | 61.23                        | 60.00            |
| 4          | 1.00                      | 1.00                         | 1.00                         | 0.00             |
| 5          | 41.23                     | 41.23                        | 41.23                        | 40.00            |
| 6          | 20.30                     | 20.30                        | 20.30                        | 20.00            |

<sup>2</sup> Raw CEM data at stack conditions calibrated using existing calibration function

<sup>3</sup> Calibrated stack CEM values corrected to standard conditions using peripheral measurements in Table 1.

<sup>4</sup> Raw SRM values in Table 1 corrected to standard conditions using peripheral measurements in Table 1.

Data used for variability test (5)  
(excludes outliers - see 3)

| Sample No. | Calibrated CEM      | SRM   | Difference        |                 |                     |
|------------|---------------------|-------|-------------------|-----------------|---------------------|
|            | Standard conditions |       |                   |                 |                     |
|            | mg/m3               | mg/m3 |                   |                 |                     |
| i          | $\hat{y}_i$         | $y_i$ | $y_i - \hat{y}_i$ | $D_i - \bar{D}$ | $(D_i - \bar{D})^2$ |
| 1          | 81.10               | 80.00 | -1.10             | -0.12           | 0.01                |
| 2          | 1.00                | 0.00  | -1.00             | -0.02           | 0.00                |
| 3          | 61.23               | 60.00 | -1.23             | -0.26           | 0.07                |
| 4          | 1.00                | 0.00  | -1.00             | -0.02           | 0.00                |
| 5          | 41.23               | 40.00 | -1.23             | -0.26           | 0.07                |
| 6          | 20.30               | 20.00 | -0.30             | 0.68            | 0.46                |

See Table 3 for determination of above parameters.

#### Variability test (6)

The limit for variability is specified as  $1.5\sigma_D k_v = 7.14$

where  $\sigma_D = \frac{pELV}{f}$   
 $p$  is the allowable uncertainty = 20%  
 $f$  is the coverage factor = 1.96  
 $ELV$  is the daily average emission limit value = 50mg/m3  
 $k_v$  is the value from a  $\chi^2$  test with a  $\beta$  value of 50% = 0.9329

The variability test is passed when  $\sigma_D \leq 1.5\sigma_D k_v$

|                   |      |
|-------------------|------|
| $\sigma_D$        | 0.35 |
| $1.5\sigma_D k_v$ | 7.14 |

Variability test passed - 5% of limit

#### Acceptance test (7)

The existing calibration function is considered to be valid if the variability test is passed and:

$$|\bar{D}| \leq t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0$$

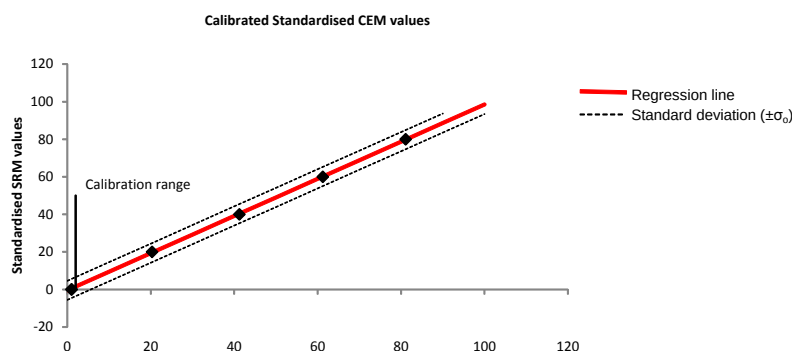
where  $t_{0.95(n-1)}$  is the Student-t value for n-1 degrees of freedom and a 95% confidence interval = 2.13  
 $|\bar{D}|$  is the absolute value of the average difference = 0.98

$$t_{0.95(n-1)} \frac{\sigma_D}{\sqrt{n}} + \sigma_0 = 5.41$$

Calibration is acceptable - 18% of limit

#### Valid calibration range (8)

Plot 2 - Carbon monoxide  
mg/m3, 15%, dry, STP



The data employed in this assessment is only valid if it does not exceed the existing upper calibration range extended by 50% of the ELV i.e.

$$\hat{y}_{s, \max a} = \hat{y}_{s, \max c} + 0.5ELV$$

Extrapolated range

$\hat{y}_{s, \max c}$  2 is the existing calibration range upper value  
 $\hat{y}_{s, \max a}$  27 is the maximum allowable data value  
 $y_{s, \max}$  81.10 is the maximum value of the CEM data (at standard conditions)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max a}$  then the data are valid and the existing calibration range may be extended by the lower of the maximum CEM value in the tests or the existing calibration range plus 50% (3)

If  $\hat{y}_{s, \max} < \hat{y}_{s, \max c}$  then no extension is possible and the upper calibration range remains as previously (2)

If  $\hat{y}_{s, \max} > 1.5\hat{y}_{s, \max c}$  then the extension is to the maximum allowable (3)  
 otherwise the extension is to  $y_{s, \max}$

No extension to range

Calibration range 0 to 2 mg/m3 (4 %ELV)

## Part 5 Results of the functional test

The functional test in accordance with BS EN 14181 Annex A was undertaken by ESG with certain parts also undertaken by Siemens during their biannual service visit on the 14 May 2015 and monthly visit on the 12 June 2015. A copy of the report detailing the work undertaken during the linearity test of the CEM systems by ESG is presented in Annex 1. A copy of the report on the service visit by Siemens is reproduced in Annex 2. A summary of the findings of the functional test covering the prescribed elements is provided below.

|                                                                                                                               |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                                                                                                                             | <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. |                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                               |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                               |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
| 2                                                                                                                             | <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 24 June 2015 (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. | ✓    |                                                                                                                                                                                                                                                                                                                      |
| 2.9                                                                                                                           | The sampling system shall be in good condition and free of any visible faults, which may decrease the quality of data.                                                                                    | ✓    |                                                                                                                                                                                                                                                                                                                      |
| Siemens 14 May 2015                                                                                                           |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                               |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
| 3                                                                                                                             | <b>Leak testing</b>                                                                                                                                                                                       |      |                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                               | Leak testing shall be performed according to the CEM's manuals. The test shall cover the entire sampling system.                                                                                          | ✓    | Leak checking of the CEM was undertaken by ESG during the linearity assessment. No significant leakage was detected.                                                                                                                                                                                                 |
| ESG 22 June 2015                                                                                                              |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |
|                                                                                                                               |                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                      |

|                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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. Responses were determined to be satisfactory with the exception of the CO analyser serving HRSG10. The zero offset identified was remedied ahead of parallel testing.                                                                                                      |
| 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. |                                                                                                                                                                                                                                                                                                                                                             |
| ESG 22 June 2015                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5                                                                                                   | <b>Linearity</b>                                                                                                                                                                                                                                                                                                                                                                                                             |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5.1                                                                                                 | During the calibration/linearity tests the applied concentrations should be logged onto the DCS 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 DCS. DCS logged values should be included in the instrument service report.                                                                                       | ✗    | ESG undertook linearity assessments of the analysers measuring oxygen, nitrogen oxides and carbon monoxide. The ranges and concentrations tested met the requirements of EN 14181, Annex A8 – see report in Annex 1.<br><br>The assessment made demonstrated acceptable linearity, in accordance with criteria specified in BS EN 14181, for all analysers. |
| 5.2                                                                                                 | The linearity of the CEM's response shall be checked using five different reference materials including a zero concentration.                                                                                                                                                                                                                                                                                                | ✗    |                                                                                                                                                                                                                                                                                                                                                             |
| 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.                                                                                                                                                                                                       | ✓    |                                                                                                                                                                                                                                                                                                                                                             |
| 5.5                                                                                                 | The reference material concentrations shall be selected such that the measured values are at approximately 20%, 40%, 60% and 80% of the range of two times the 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 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 2 x ELV                                                                                                                                                                                                                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5.8                                                                                                 | Reference material approx. 40% of 2 x ELV                                                                                                                                                                                                                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5.9                                                                                                 | Reference material approx. 60% of 2 x ELV                                                                                                                                                                                                                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5.10                                                                                                | Reference material approx. 80% of 2 x ELV                                                                                                                                                                                                                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                             |
| 5.11                                                                                                | Reference material with zero concentration                                                                                                                                                                                                                                                                                                                                                                                   |      |                                                                                                                                                                                                                                                                                                                                                             |
| ESG 22 June 2015                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                                                                                                                                                                                                                                                                                                                                                             |

|                                                                                                                            |                                                                                                                                                                                                                                                             |              |                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 been not been undertaken, although this is not required where AST acceptance criteria are met.                                                                                                                                                                                                                                                                     |
| - -                                                                                                                        |                                                                                                                                                                                                                                                             |              |                                                                                                                                                                                                                                                                                                                                                                                                       |
| 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:<br>i) a documented procedure<br>ii) zero & span data<br>iii) control charts         | ✓            | The CEM is checked on a regular basis (15 day intervals) by DR. An example is provided in Annex 4 for June 2015. 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                                                                                                                        |                                                                                                                                                                                                                                                             | 22 June 2015 |                                                                                                                                                                                                                                                                                                                                                                                                       |
| 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 (150 seconds). No adjustment for differences in response times was considered necessary.                                                   |
| ESG                                                                                                                        |                                                                                                                                                                                                                                                             | 22 June 2015 |                                                                                                                                                                                                                                                                                                                                                                                                       |
| 9                                                                                                                          | <b>Service report</b>                                                                                                                                                                                                                                       |              |                                                                                                                                                                                                                                                                                                                                                                                                       |
| As a minimum requirement the service report should include the following:<br>All items are covered within 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 | ✓            |  |
| 9.15 | Calibration & linearity data as required by EN 14181     | ✓            |  |
| 9.16 | Logged data for period of calibration and linearity      | ✗            |  |
| 9.17 | Name & signature of service engineer                     | ✓            |  |
| ESG  |                                                          | 22 June 2014 |  |
|      |                                                          |              |  |

|                                                                                   |                                                                      |              |                                                                                  |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------|--------------|----------------------------------------------------------------------------------|
| 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                                                                               |                                                                      | 22 June 2014 |                                                                                  |

It is considered that the requirements of the BS EN 14181 specification for a functional test (BS EN 14181, Annex A) have been met.

The functional test was undertaken on the 22 June 2015 by O May of ESG and included a full linearity check. A copy of the report on this test is presented in Annex 1. Copies of the most recent bi annual and monthly service visits by Siemens are reproduced in Annex 2. Annex 3 provides details of the check on the NO<sub>x</sub> converter efficiency.

## Annex 1 Linearity test report

ESG attended the Nash site on the 22 June 2015 to undertake a linearity check on the CEM systems. The work undertaken is documented in the attached reports.



### AIR & EMISSIONS TESTING GROUP

Unit D  
Bankside Trade Park  
Cirencester  
Gloucestershire  
GL7 1YT  
Tel: 01285 770 593

#### Your contact at ESG:

Nick Ford  
Divisional Projects Manager  
Tel: 01285 770 593  
Email: [nick.ford@esg.co.uk](mailto:nick.ford@esg.co.uk)

#### BS EN 14181:2004 - Linearity

#### Calibration Report

Nitrogen Monoxide  
Carbon Monoxide  
Oxygen

|                         |                             |
|-------------------------|-----------------------------|
| Report Date / Version:  | 6th July 2015<br>Version 1  |
| Report By:              | Owen May                    |
| MCERTS Number:          | MM 10 1072                  |
| MCERTS Level:           | Level 2                     |
| Technical Endorsements: | TE1, TE2, TE3 & TE4         |
| Report Approved By:     | Nick Ford                   |
| MCERTS Number:          | MM 02 084                   |
| Business Title:         | Divisional Projects Manager |
| Technical Endorsements: | TE1, TE2, TE3 & TE4         |
| Signature:              |                             |

#### Severn Power Limited

#### Newport

#### HRSG Unit 10

**Sampling Date/s:**  
22nd June 2015

**Job Number:**  
LSO 150613

## CONTENTS

|                                                | Page Number |
|------------------------------------------------|-------------|
| TITLE PAGE                                     | 1           |
| CONTENTS                                       | 2           |
| EXECUTIVE SUMMARY                              | 3           |
| Monitoring Objectives                          | 3           |
| - Plant                                        |             |
| - Operator                                     |             |
| - Stack Emissions Test House                   |             |
| Linearity / Calibration Summary                | 4           |
| Calibration Gases Used During Linearity Checks | 4           |
| Linearity Performed By                         | 4           |
| APPENDICES                                     | 5           |

## EXECUTIVE SUMMARY (Page 1 of 2)

### Monitoring Objectives

Environmental Scientifics Group Limited were commissioned by Severn Power Limited to carry out a linearity check under BS EN 14181 as part of a calibration and validation exercise on the CEM system serving HRSG Unit 10 at their Newport site.

#### Plant

HRSG Unit 10

#### Operator

Severn Power Limited  
West Nash Road  
Nash  
Newport  
Gwent  
NP18 2BZ

HP 3737UE

#### Stack Emissions Test House

Environmental Scientifics Group Ltd - Cirencester Office  
Unit D  
Bankside Trade Park  
Cirencester  
Gloucestershire  
GL7 1YT  
UKAS and MCERTS Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

This test report shall not be reproduced, except in full, without written approval of ESG.

## EXECUTIVE SUMMARY (Page 2 of 2)

### Linearity / Calibration Summary

Severn Power Limited, Newport  
HRSG Unit 10  
22nd June 2015

| Parameter         | Calibration Function    | Emission Limit Value<br>(mg/m <sup>3</sup> ) | Valid Calibration Range<br>(mg/m <sup>3</sup> ) |
|-------------------|-------------------------|----------------------------------------------|-------------------------------------------------|
| Oxygen            | $Y = 1.0345x + -0.1137$ | 25                                           | 0 to 20                                         |
| Nitrogen Monoxide | $Y = 1.0425x -13.1315$  | 66.2                                         | 0 to 106                                        |
| Carbon Monoxide   | $Y = 0.974x -6.5319$    | 50                                           | 0 to 80                                         |

### Calibration Gases Used During Linearity Checks

| Determinand | Supplier    | Concentration<br>ppm | Standard | Quality<br>Checked<br>to ISO 17025 | ESG<br>HPC<br>Number |
|-------------|-------------|----------------------|----------|------------------------------------|----------------------|
| Oxygen      | N/A         | 20.61                | N/A      | N/A                                | 244018               |
| NO          | BOC         | 215.5                | Gold 2%  | Yes                                | DA E2                |
| CO          | Cryoservice | 163                  | Gold 2%  | Yes                                | 187525               |

### Linearity Performed By

Environmental Team Leader      Owen May  
MCERTS Level 2, Technical Endorsements 1, 2, 3, & 4  
MM 10 1072  
LLB Law Degree

Environmental Technician      Owain Redfern  
Level 1  
MM 13 1248

APPENDICES

**CONTENTS**

CONTENTS

APPENDIX 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data  
Oxygen - Calibration Data - CEM Stability Chart  
Oxygen - Calibration Data - Regression Analysis  
Oxygen - Calibration Data - X - Y Plot  
Oxygen - Calibration Data - Test of Residuals  
Oxygen - Calibration Data - Test of Residuals Chart  
  
Nitrogen Monoxide - Calibration Data  
Nitrogen Monoxide - Calibration Data - CEM Stability Chart  
Nitrogen Monoxide - Calibration Data - Regression Analysis  
Nitrogen Monoxide - Calibration Data - X - Y Plot  
Nitrogen Monoxide - Calibration Data - Test of Residuals  
Nitrogen Monoxide - Calibration Data - Test of Residuals Chart  
  
Carbon Monoxide - Calibration Data  
Carbon Monoxide - Calibration Data - CEM Stability Chart  
Carbon Monoxide - Calibration Data - Regression Analysis  
Carbon Monoxide - Calibration Data - X - Y Plot  
Carbon Monoxide - Calibration Data - Test of Residuals  
Carbon Monoxide - Calibration Data - Test of Residuals Chart

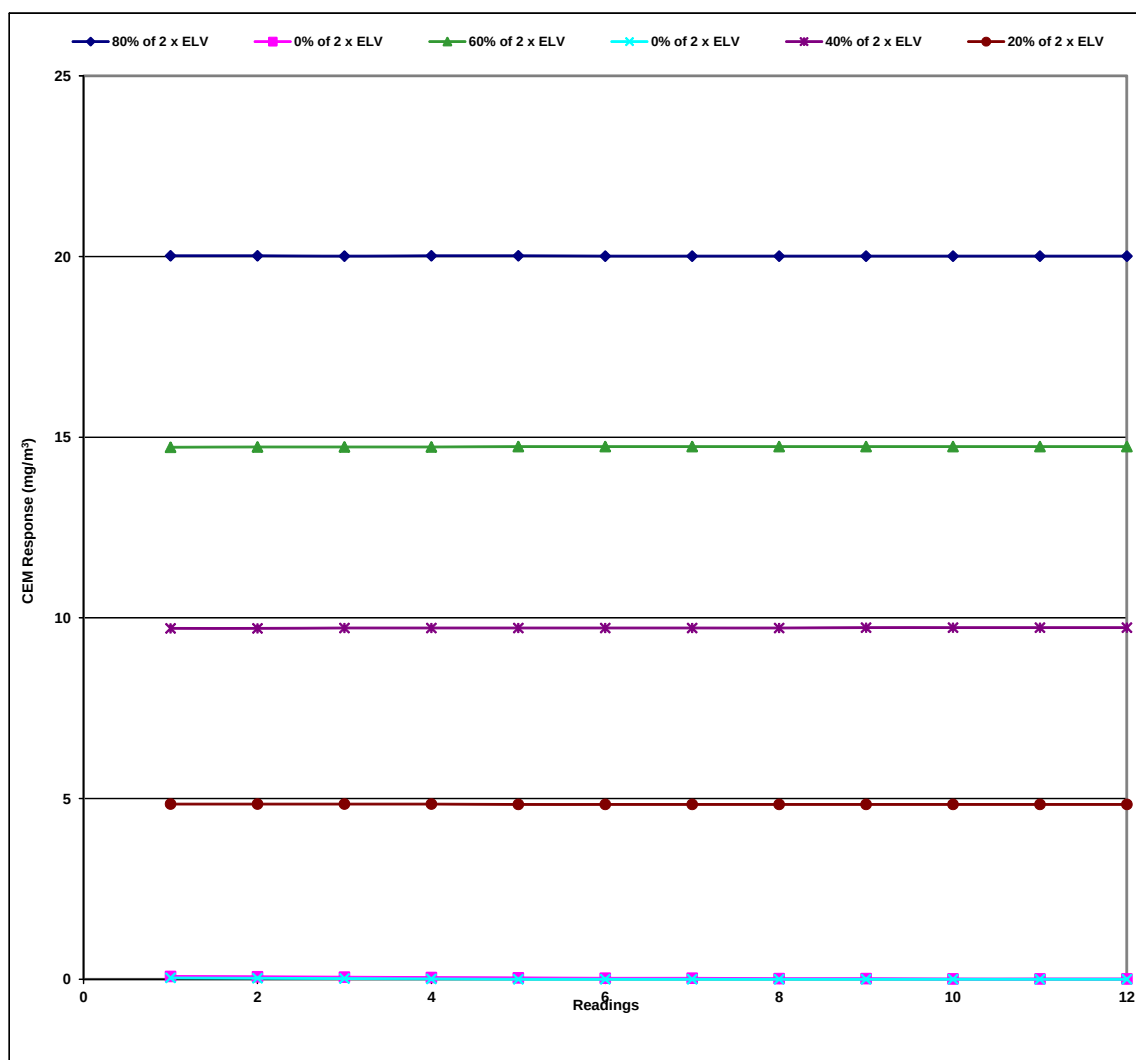
Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>20<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>15<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>10<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>5<br>mg/m <sup>3</sup> |
|----------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------|
| 1              | 20.02                                                   | 0.08                                                  | 14.72                                                   | 0.04                                                  | 9.71                                                    | 4.85                                                   |
| 2              | 20.02                                                   | 0.07                                                  | 14.73                                                   | 0.03                                                  | 9.71                                                    | 4.85                                                   |
| 3              | 20.01                                                   | 0.06                                                  | 14.73                                                   | 0.02                                                  | 9.72                                                    | 4.85                                                   |
| 4              | 20.02                                                   | 0.05                                                  | 14.73                                                   | 0.01                                                  | 9.72                                                    | 4.85                                                   |
| 5              | 20.02                                                   | 0.04                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 6              | 20.01                                                   | 0.03                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 7              | 20.01                                                   | 0.03                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 8              | 20.01                                                   | 0.02                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 9              | 20.01                                                   | 0.02                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 10             | 20.01                                                   | 0.01                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 11             | 20.01                                                   | 0.01                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 12             | 20.01                                                   | 0.01                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Regression Analysis

| Cal Gas<br>$y_i$ | CEM Response<br>$x_i$ | $x - x_z$  | $(x - x_z)^2$ | $y_i(x - x_z)$ | Average<br>$x_c$ |
|------------------|-----------------------|------------|---------------|----------------|------------------|
| 20               | 19.42                 | 11.255     | 126.675       | 225.100        | 19.427           |
| 20               | 19.43                 | 11.265     | 126.900       | 225.300        |                  |
| 20               | 19.43                 | 11.265     | 126.900       | 225.300        |                  |
| 0.0              | 0.07                  | -8.095     | 65.529        | 0.000          | 0.063            |
| 0.0              | 0.06                  | -8.105     | 65.691        | 0.000          |                  |
| 0.0              | 0.06                  | -8.105     | 65.691        | 0.000          |                  |
| 15               | 14.58                 | 6.415      | 41.152        | 96.225         | 14.567           |
| 15               | 14.56                 | 6.395      | 40.896        | 95.925         |                  |
| 15               | 14.56                 | 6.395      | 40.896        | 95.925         |                  |
| 0.0              | 0.06                  | -8.105     | 65.691        | 0.000          | 0.063            |
| 0.0              | 0.07                  | -8.095     | 65.529        | 0.000          |                  |
| 0.0              | 0.06                  | -8.105     | 65.691        | 0.000          |                  |
| 10               | 9.81                  | 1.645      | 2.706         | 16.450         | 9.810            |
| 10               | 9.81                  | 1.645      | 2.706         | 16.450         |                  |
| 10               | 9.81                  | 1.645      | 2.706         | 16.450         |                  |
| 5                | 5.06                  | -3.105     | 9.641         | -15.525        | 5.060            |
| 5                | 5.06                  | -3.105     | 9.641         | -15.525        |                  |
| 5                | 5.06                  | -3.105     | 9.641         | -15.525        |                  |
| Sum              | 150                   | 146.97     | -             | 934.283        | 966.550          |
| n                | 18                    | 18         | -             | 18             | -                |
| Average          | yz = 8.333            | xz = 8.165 | -             | 51.905         | 53.697           |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where a = average  $Y_i$  reading or  $yz = 8.333$

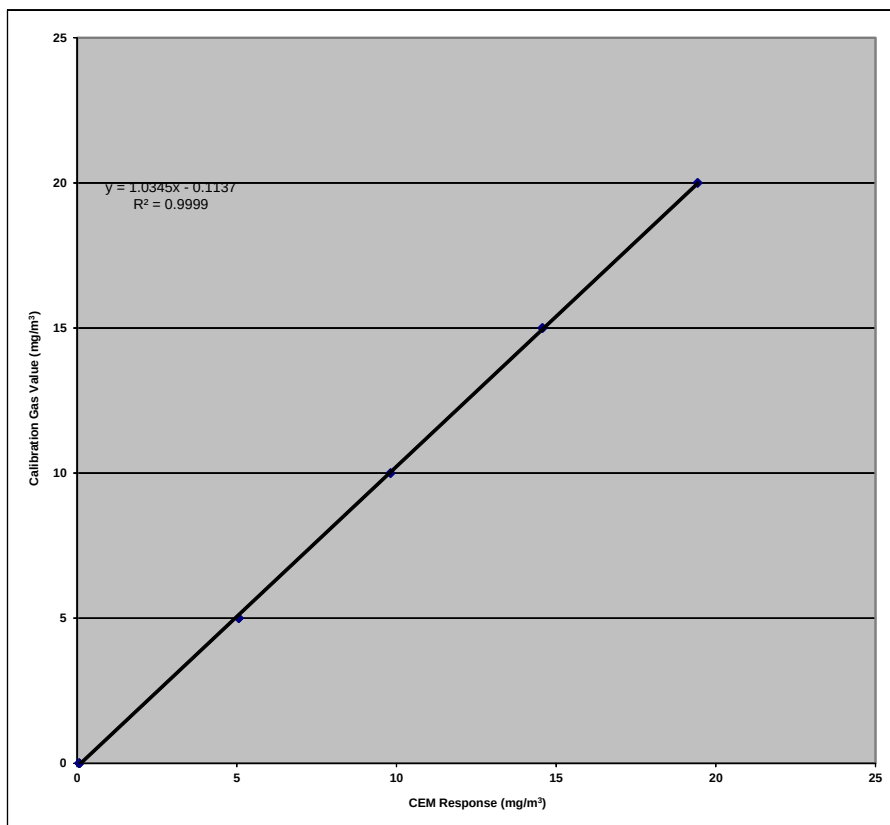
$$\text{where } B = \frac{\text{average } Y_i(x - x_z)}{\text{average}(x - x_z)^2} = \frac{53.697}{51.905} = 1.0345$$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

$$\text{where } A = a - (Bx_z) = 8.333 - (1.0345 \times 8.165) = -0.1134$$

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average<br>$x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|------------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 20               | 19.427           | 0.016  | 0.080            | 0.080                | 0.605                    | 5     | Pass    |
| 0.0              | 0.063            | 0.048  | 0.241            | 0.241                |                          |       |         |
| 15               | 14.567           | 0.044  | 0.220            | 0.220                |                          |       |         |
| 0.0              | 0.063            | 0.048  | 0.241            | 0.241                |                          |       |         |
| 10               | 9.810            | -0.035 | -0.176           | 0.176                |                          |       |         |
| 5                | 5.060            | -0.121 | -0.605           | 0.605                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 20 - (-0.1134 + 1.0345 \times 19.427)$

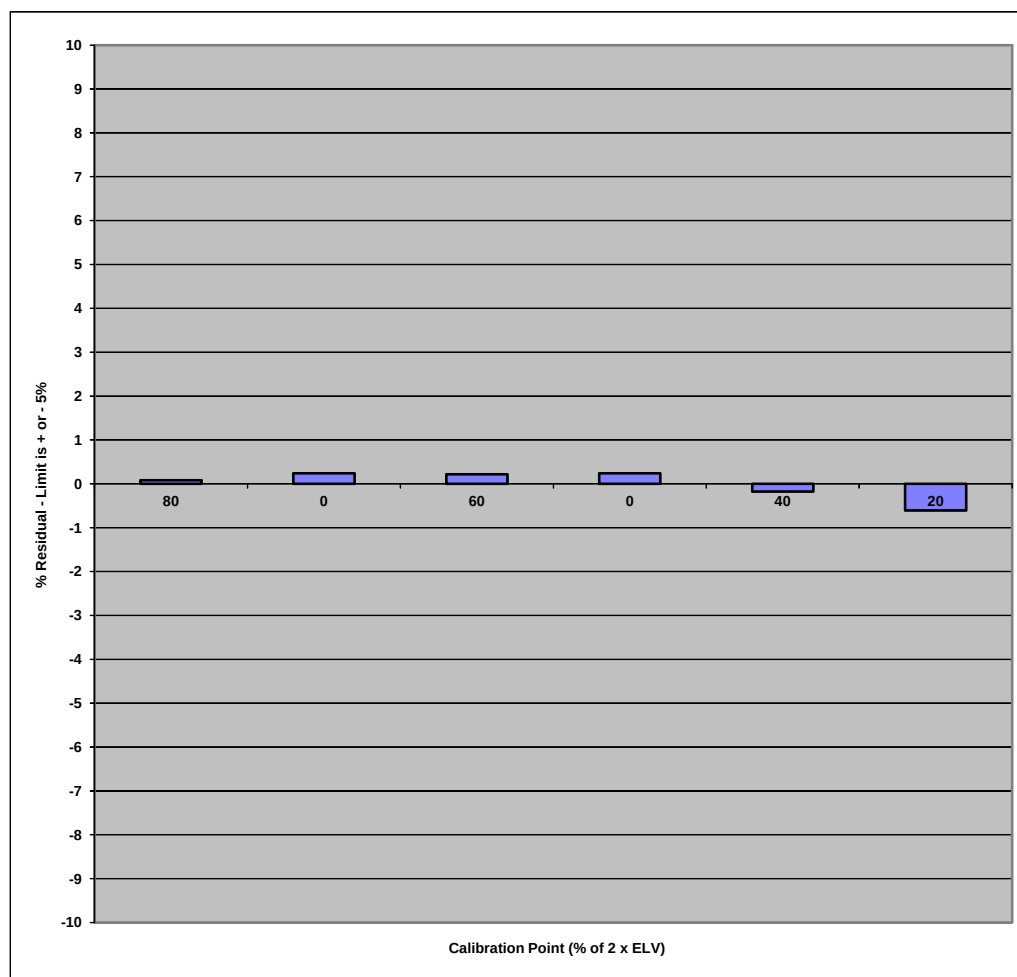
and  $d_{c,rel} = \frac{d_c}{y_{i \max}} \times 100$

e.g.  $d_{c,rel} = (0.016/20) \times 100 = 0.08$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Test of Residuals Chart



Appendix 1 - Raw Data, Calculations & Graphs

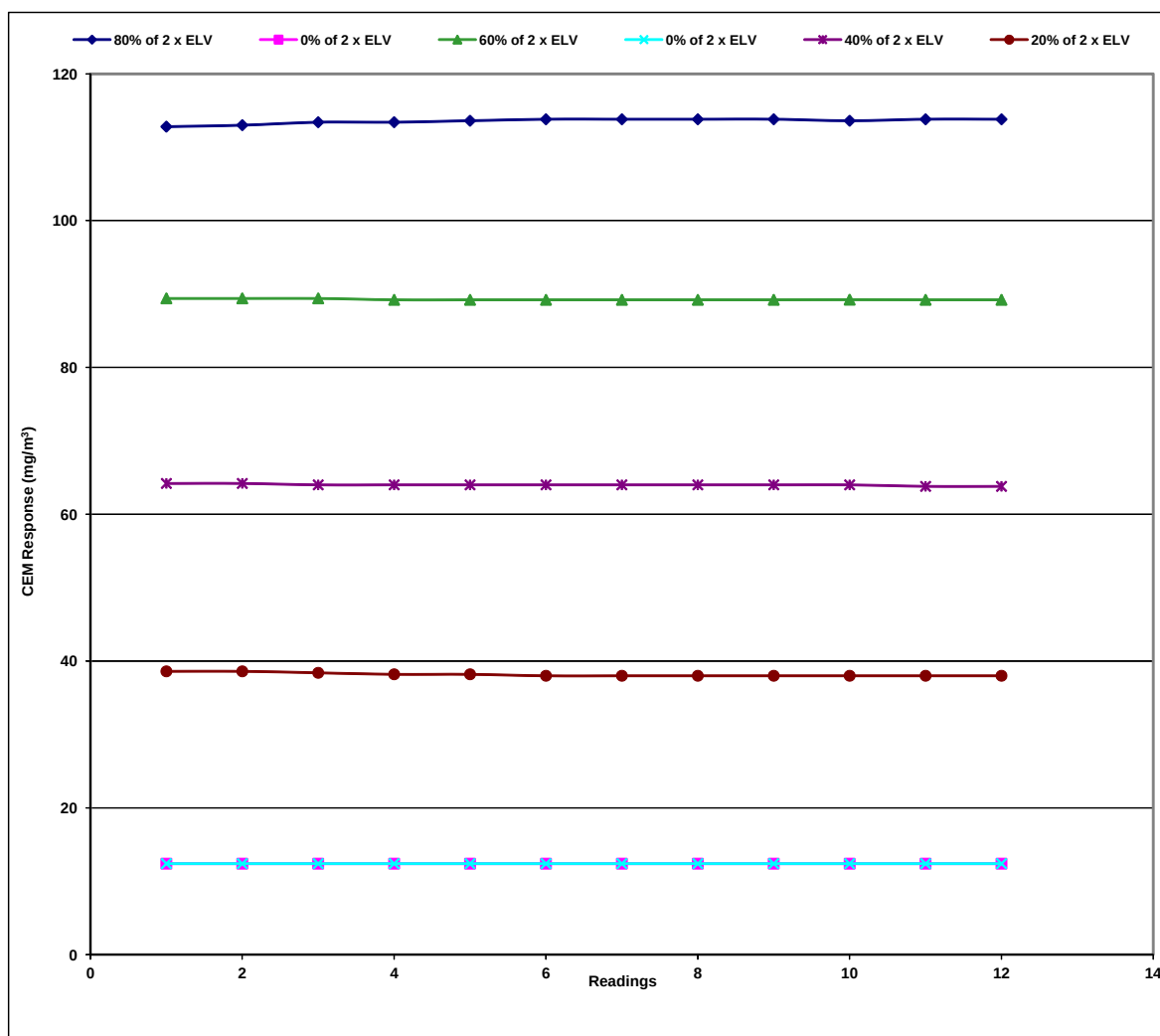
Nitrogen Monoxide - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>105.96<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0.00<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>79.47<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0.00<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>52.98<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>26.49<br>mg/m <sup>3</sup> |
|----------------|-------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|
| 1              | 112.8                                                       | 12.4                                                     | 89.4                                                       | 12.4                                                     | 64.2                                                       | 38.6                                                       |
| 2              | 113.0                                                       | 12.4                                                     | 89.4                                                       | 12.4                                                     | 64.2                                                       | 38.6                                                       |
| 3              | 113.4                                                       | 12.4                                                     | 89.4                                                       | 12.4                                                     | 64.0                                                       | 38.4                                                       |
| 4              | 113.4                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.2                                                       |
| 5              | 113.6                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.2                                                       |
| 6              | 113.8                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.0                                                       |
| 7              | 113.8                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.0                                                       |
| 8              | <b>113.8</b>                                                | <b>12.4</b>                                              | <b>89.2</b>                                                | <b>12.4</b>                                              | <b>64.0</b>                                                | <b>38.0</b>                                                |
| 9              | 113.8                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.0                                                       |
| 10             | 113.6                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 64.0                                                       | 38.0                                                       |
| 11             | 113.8                                                       | 12.4                                                     | 89.2                                                       | 12.4                                                     | 63.8                                                       | 38.0                                                       |
| 12             | <b>113.8</b>                                                | <b>12.4</b>                                              | <b>89.2</b>                                                | <b>12.4</b>                                              | <b>63.8</b>                                                | <b>38.0</b>                                                |

Readings 8, 12 and 16 are those selected for regression analysis.

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Regression Analysis

|         | Cal Gas<br>$y_i$ | CEM Response<br>$x_i$ | $x - x_z$ | $(x - x_z)^2$ | $y_i(x - x_z)$ | Average<br>$x_c$ |
|---------|------------------|-----------------------|-----------|---------------|----------------|------------------|
|         | 105.96           | 113.80                | 58.856    | 3463.976      | 6236.350       | 113.667          |
|         | 105.96           | 113.80                | 58.856    | 3463.976      | 6236.350       |                  |
|         | 105.96           | 113.40                | 58.456    | 3417.052      | 6193.966       |                  |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          | 12.400           |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          |                  |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          |                  |
|         | 79.47            | 89.20                 | 34.256    | 1173.443      | 2722.296       | 89.200           |
|         | 79.47            | 89.20                 | 34.256    | 1173.443      | 2722.296       |                  |
|         | 79.47            | 89.20                 | 34.256    | 1173.443      | 2722.296       |                  |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          | 12.400           |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          |                  |
|         | 0.00             | 12.40                 | -42.544   | 1810.030      | 0.000          |                  |
|         | 52.98            | 64.00                 | 9.056     | 82.003        | 479.765        | 63.933           |
|         | 52.98            | 63.80                 | 8.856     | 78.421        | 469.169        |                  |
|         | 52.98            | 64.00                 | 9.056     | 82.003        | 479.765        |                  |
|         | 26.49            | 38.00                 | -16.944   | 287.114       | -448.859       | 38.067           |
|         | 26.49            | 38.00                 | -16.944   | 287.114       | -448.859       |                  |
|         | 26.49            | 38.20                 | -16.744   | 280.376       | -443.561       |                  |
| Sum     | 794.701987       | 989.000               | -         | 25822.544     | 26920.971      | -                |
| n       | 18               | 18                    | -         | 18            | 18             | -                |
| Average | vz = 44.15       | xz = 54.944           | -         | 1434.585802   | 1496           | -                |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where  $a =$  average  $Y_i$  reading or  $yz = 44.15$

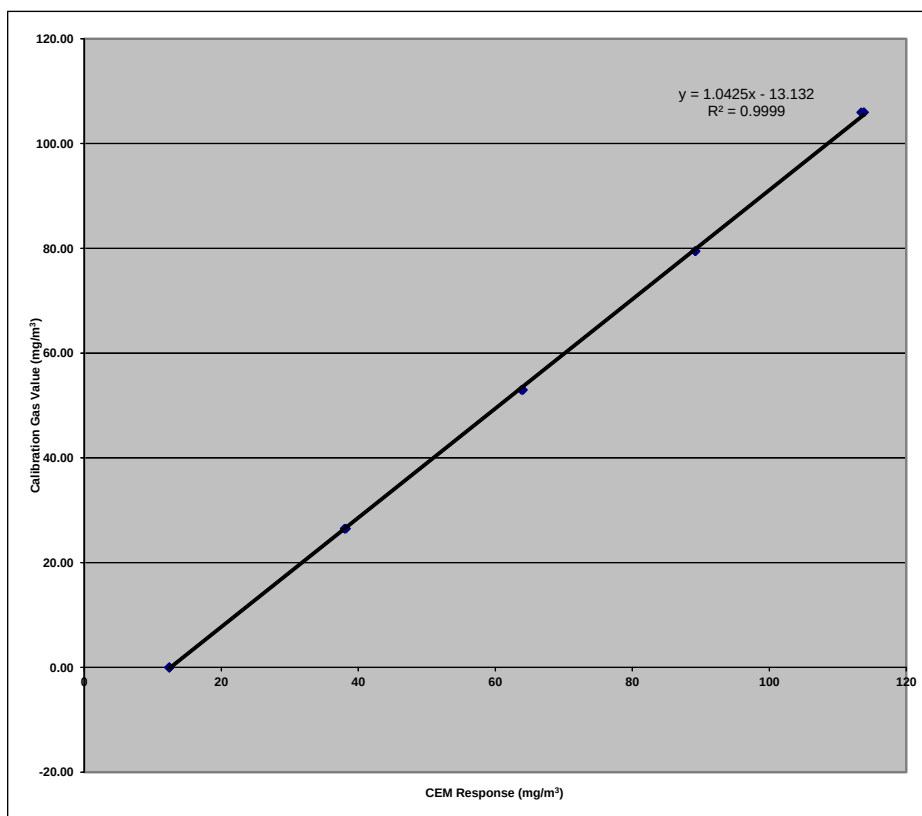
$$\text{where } B = \frac{\text{average } Y_i(x - x_z)}{\text{average}(x - x_z)^2} = \frac{1495.610}{1434.586} = 1.0425$$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

$$\text{where } A = a - (Bx_z) = 44.15 - (1.0425 \times 54.944) = -13.1295$$

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average $x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|---------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 105.96           | 113.67        | 0.590  | 0.557            | 0.557                | 0.557                    | 5     | Pass    |
| 0.00             | 12.40         | 0.204  | 0.193            | 0.193                |                          |       |         |
| 79.47            | 89.20         | -0.393 | -0.371           | 0.371                |                          |       |         |
| 0.00             | 12.40         | 0.204  | 0.193            | 0.193                |                          |       |         |
| 52.98            | 63.93         | -0.541 | -0.511           | 0.511                |                          |       |         |
| 26.49            | 38.07         | -0.064 | -0.061           | 0.061                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 105.960264900662 - (-13.1295 + 1.0425 \times 113.667)$

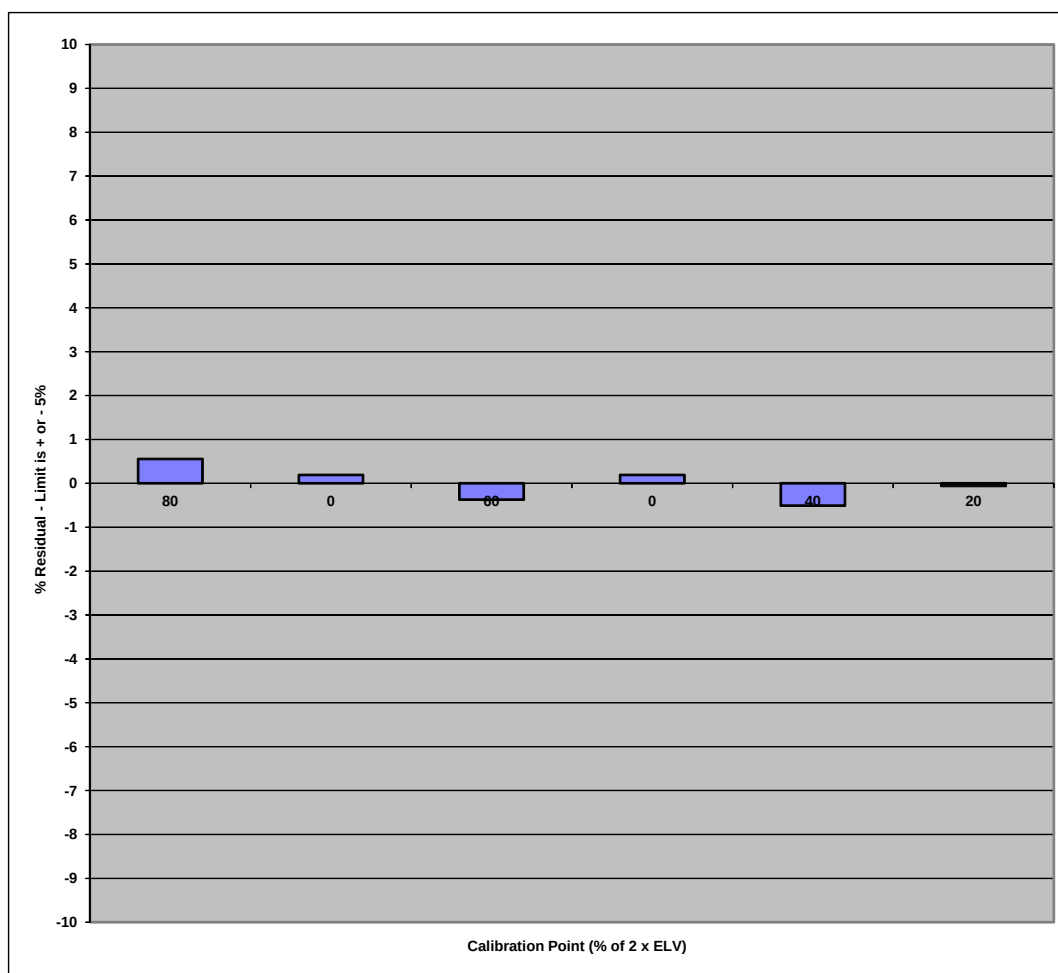
and  $d_{c,rel} = \frac{d_c}{y_{i,max}} \times 100$

e.g.  $d_{c,rel} = (0.59/105.960264900662) \times 100 = 0.557$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Test of Residuals Chart



Appendix 1 - Raw Data, Calculations & Graphs

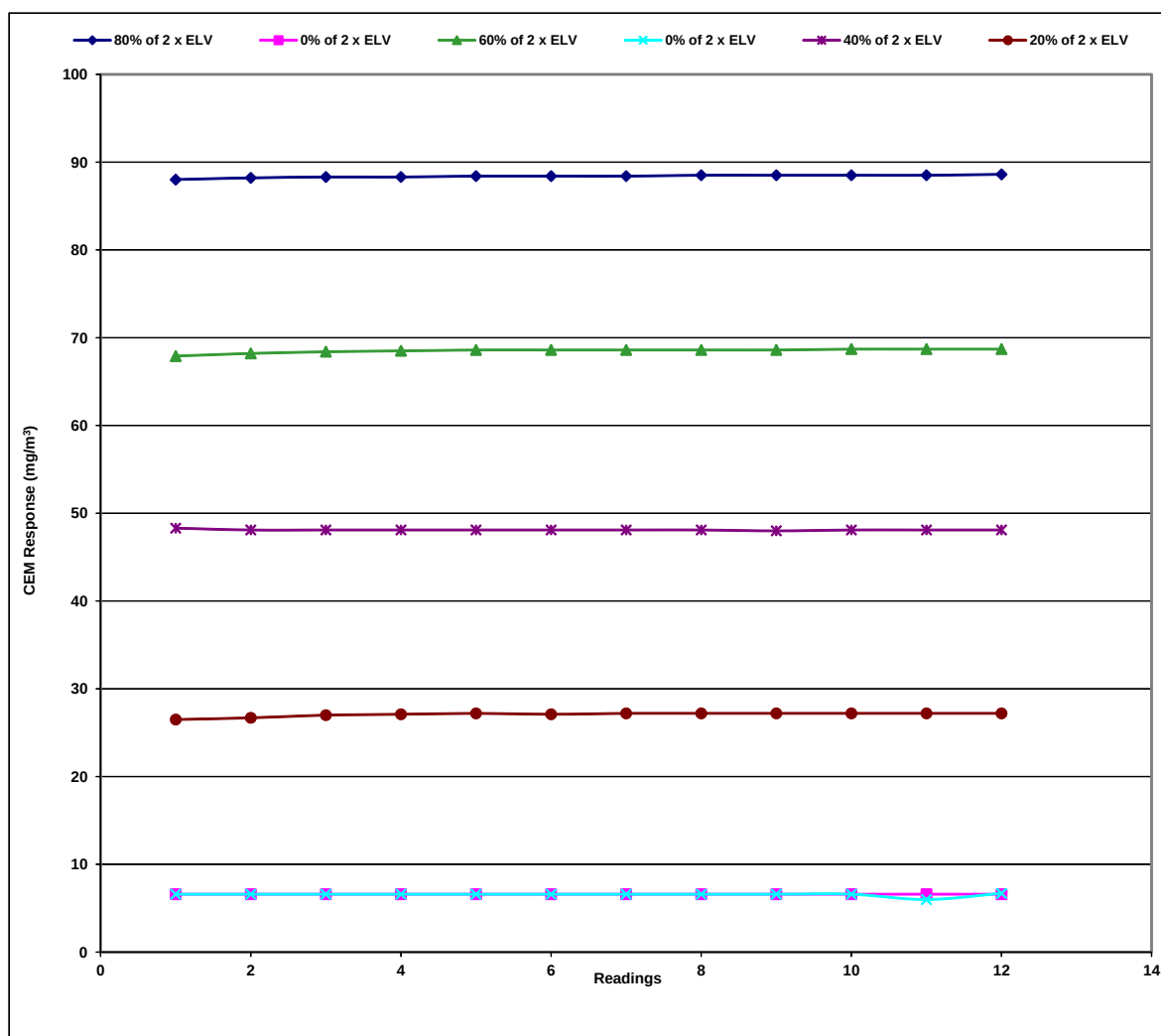
Carbon Monoxide - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>80<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0.0<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>60<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0.0<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>40<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>20<br>mg/m <sup>3</sup> |
|----------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|
| 1              | 88.0                                                    | 6.6                                                     | 67.9                                                    | 6.6                                                     | 48.3                                                    | 26.5                                                    |
| 2              | 88.2                                                    | 6.6                                                     | 68.2                                                    | 6.6                                                     | 48.1                                                    | 26.7                                                    |
| 3              | 88.3                                                    | 6.6                                                     | 68.4                                                    | 6.6                                                     | 48.1                                                    | 27.0                                                    |
| 4              | <b>88.3</b>                                             | <b>6.6</b>                                              | <b>68.5</b>                                             | <b>6.6</b>                                              | <b>48.1</b>                                             | <b>27.1</b>                                             |
| 5              | 88.4                                                    | 6.6                                                     | 68.6                                                    | 6.6                                                     | 48.1                                                    | 27.2                                                    |
| 6              | 88.4                                                    | 6.6                                                     | 68.6                                                    | 6.6                                                     | 48.1                                                    | 27.1                                                    |
| 7              | 88.4                                                    | 6.6                                                     | 68.6                                                    | 6.6                                                     | 48.1                                                    | 27.2                                                    |
| 8              | <b>88.5</b>                                             | <b>6.6</b>                                              | <b>68.6</b>                                             | <b>6.6</b>                                              | <b>48.1</b>                                             | <b>27.2</b>                                             |
| 9              | 88.5                                                    | 6.6                                                     | 68.6                                                    | 6.6                                                     | 48.0                                                    | 27.2                                                    |
| 10             | 88.5                                                    | 6.6                                                     | 68.7                                                    | 6.6                                                     | 48.1                                                    | 27.2                                                    |
| 11             | 88.5                                                    | 6.6                                                     | 68.7                                                    | 6.0                                                     | 48.1                                                    | 27.2                                                    |
| 12             | <b>88.6</b>                                             | <b>6.6</b>                                              | <b>68.7</b>                                             | <b>6.7</b>                                              | <b>48.1</b>                                             | <b>27.2</b>                                             |

Readings 4, 8, and 12 are those selected for regression analysis.

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Regression Analysis

| Cal Gas<br>$y_i$ | CEM Response<br>$x_i$ | $x - x_z$     | $(x - x_z)^2$ | $y_i(x - x_z)$ | Average<br>$x_c$ |
|------------------|-----------------------|---------------|---------------|----------------|------------------|
| 80.0             | 88.3                  | 47.372        | 2244.127      | 3790           | 88.467           |
| 80.0             | 88.5                  | 47.572        | 2263.116      | 3806           |                  |
| 80.0             | 88.6                  | 47.672        | 2272.641      | 3814           |                  |
| 0.0              | 6.60                  | -34.328       | 1178.396      | 0.000          | 6.600            |
| 0.0              | 6.60                  | -34.328       | 1178.396      | 0.000          |                  |
| 0.0              | 6.60                  | -34.328       | 1178.396      | 0.000          |                  |
| 60.0             | 68.5                  | 27.572        | 760.227       | 1654           | 68.600           |
| 60.0             | 68.6                  | 27.672        | 765.752       | 1660           |                  |
| 60.0             | 68.7                  | 27.772        | 771.296       | 1666           |                  |
| 0.0              | 6.60                  | -34.328       | 1178.396      | 0.000          | 6.633            |
| 0.0              | 6.60                  | -34.328       | 1178.396      | 0.000          |                  |
| 0.0              | 6.70                  | -34.228       | 1171.541      | 0.000          |                  |
| 40.0             | 48.1                  | 7.172         | 51.441        | 287            | 48.100           |
| 40.0             | 48.1                  | 7.172         | 51.441        | 287            |                  |
| 40.0             | 48.1                  | 7.172         | 51.441        | 287            |                  |
| 20.0             | 27.1                  | -13.828       | 191.207       | -277           | 27.167           |
| 20.0             | 27.2                  | -13.728       | 188.452       | -275           |                  |
| 20.0             | 27.2                  | -13.728       | 188.452       | -275           |                  |
| <b>Sum</b>       | 600                   | 736.7         | -             | 16863.11611    | 16425            |
| <b>n</b>         | 18                    | 18            | -             | 18             | -                |
| <b>Average</b>   | $yz = 33.333$         | $xz = 40.928$ | -             | 936.839784     | 912.5185185      |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where  $a =$  average  $Y_i$  reading or  $yz = 33.333$

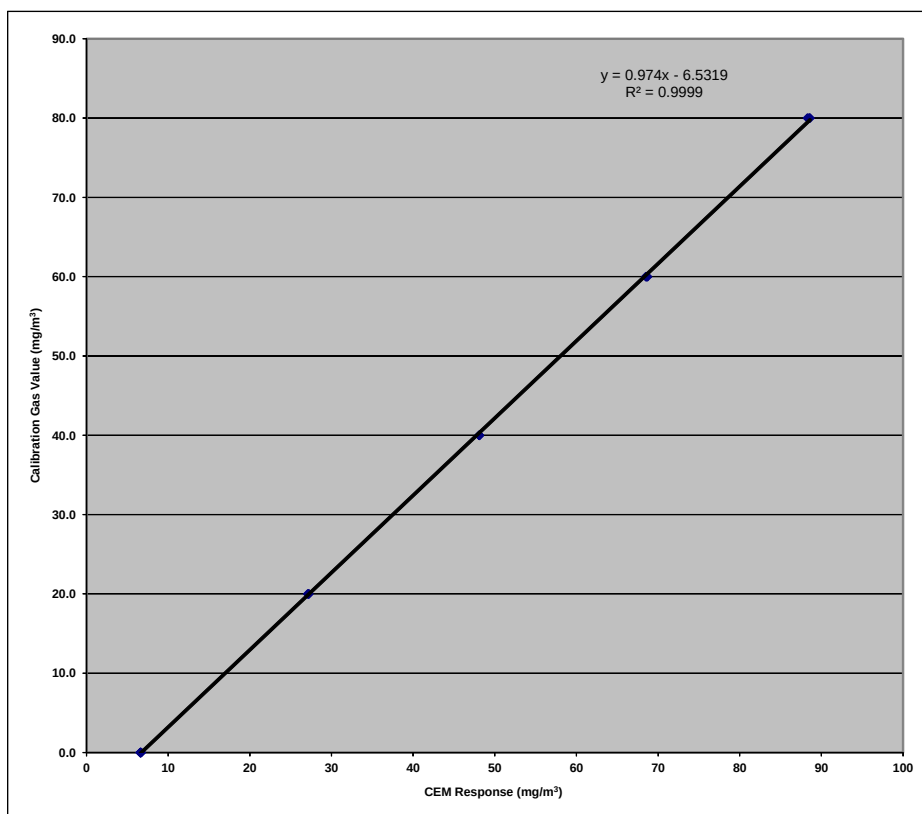
$$\text{where } B = \frac{\text{average } Y_i(x - x_z)}{\text{average}(x - x_z)^2} = \frac{912.519}{936.840} = 0.974$$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

$$\text{where } A = a - (Bx_z) = 33.333 - (0.974 \times 40.928) = -6.5303$$

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average $x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|---------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 80.00            | 88.47         | 0.362  | 0.452            | 0.452                | 0.452                    | 5     | Pass    |
| 0.00             | 6.60          | 0.103  | 0.129            | 0.129                |                          |       |         |
| 60.00            | 68.60         | -0.287 | -0.359           | 0.359                |                          |       |         |
| 0.00             | 6.63          | 0.071  | 0.088            | 0.088                |                          |       |         |
| 40.00            | 48.10         | -0.319 | -0.399           | 0.399                |                          |       |         |
| 20.00            | 27.17         | 0.071  | 0.088            | 0.088                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 80 - (-6.5303 + 0.974 \times 88.467)$

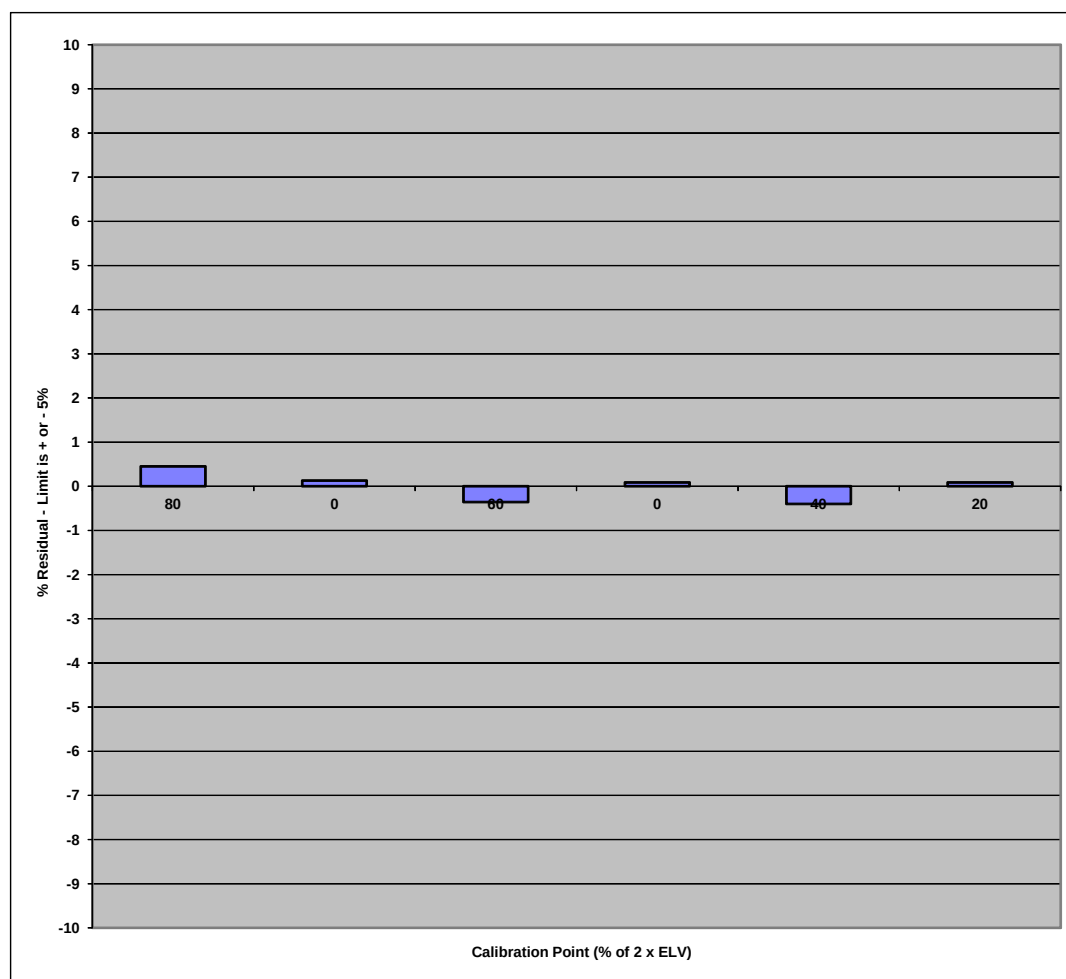
and  $d_{c,rel} = \frac{d_c}{y_{i,max}} \times 100$

e.g.  $d_{c,rel} = (0.362/80) \times 100 = 0.452$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Test of Residuals Chart





## AIR & EMISSIONS TESTING GROUP

Unit D  
Bankside Trade Park  
Cirencester  
Gloucestershire  
GL7 1YT  
Tel: 01285 770 593

### Your contact at ESG:

Nick Ford  
Divisional Projects Manager  
Tel: 01285 770 593  
Email: [nick.ford@esg.co.uk](mailto:nick.ford@esg.co.uk)

### BS EN 14181:2004 - Linearity

#### Calibration Report

Nitrogen Monoxide  
Carbon Monoxide  
Oxygen

|                         |                             |
|-------------------------|-----------------------------|
| Report Date / Version:  | 6th July 2105               |
| Report By:              | Owen May                    |
| MCERTS Number:          | MM 10 1072                  |
| MCERTS Level:           | Level 2                     |
| Technical Endorsements: | TE1, TE2, TE3 & TE4         |
| Report Approved By:     | Nick Ford                   |
| MCERTS Number:          | MM 02 084                   |
| Business Title:         | Divisional Projects Manager |
| Technical Endorsements: | TE1, TE2, TE3 & TE4         |
| Signature:              | <i>N Ford</i>               |

### Severn Power Limited

### Newport

### HRSG Unit 20

**Sampling Date/s:**  
22nd June 2015

**Job Number:**  
LSO 150613

## CONTENTS

|                                                | Page Number |
|------------------------------------------------|-------------|
| TITLE PAGE                                     | 1           |
| CONTENTS                                       | 2           |
| EXECUTIVE SUMMARY                              | 3           |
| Monitoring Objectives                          | 3           |
| - Plant                                        |             |
| - Operator                                     |             |
| - Stack Emissions Test House                   |             |
| Linearity / Calibration Summary                | 4           |
| Calibration Gases Used During Linearity Checks | 4           |
| Linearity Performed By                         | 4           |
| APPENDICES                                     | 5           |

## EXECUTIVE SUMMARY (Page 1 of 2)

### Monitoring Objectives

Environmental Scientifics Group Limited were commissioned by Severn Power Limited to carry out a linearity check under BS EN 14181 as part of a calibration and validation exercise on the the CEM system serving HRSG Unit 20 at their Newport site.

### Plant

HRSG Unit 20

### Operator

Severn Power Limited  
West Nash Road  
Nash  
Newport  
Gwent  
NP18 22BZ  
HP 3737UE

### Stack Emissions Test House

Environmental Scientifics Group Ltd - Cirencester Office  
Unit D  
Bankside Trade Park  
Cirencester  
Gloucestershire  
GL7 1YT  
UKAS and MCERTS Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

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## EXECUTIVE SUMMARY (Page 2 of 2)

### Linearity / Calibration Summary

Severn Power Limited, Newport  
HRSG Unit 20  
22nd June 2015

| Parameter         | Calibration Function    | Emission Limit Value<br>(mg/m <sup>3</sup> ) | Valid Calibration Range<br>(mg/m <sup>3</sup> ) |
|-------------------|-------------------------|----------------------------------------------|-------------------------------------------------|
| Oxygen            | $Y = 1.0206x + -0.0036$ | 25                                           | 0 to 20                                         |
| Nitrogen Monoxide | $Y = 1.047x -0.7317$    | 66.2                                         | 0 to 106                                        |
| Carbon Monoxide   | $Y = 0.9958x -0.8349$   | 50                                           | 0 to 80                                         |

### Calibration Gases Used During Linearity Checks

| Determinand | Supplier    | Concentration<br>ppm | Standard | Quality<br>Checked<br>to ISO 17025 | ESG<br>HPC<br>Number |
|-------------|-------------|----------------------|----------|------------------------------------|----------------------|
| Oxygen      | N/A         | 20.61                | N/A      | N/A                                | 244018               |
| NO          | BOC         | 215.5                | Gold 2%  | Yes                                | DA E2                |
| CO          | Cryoservice | 163                  | Gold 2%  | Yes                                | 187525               |

### Linearity Performed By

Environmental Team Leader

Owen May  
MCERTS Level 2, Technical Endorsements 1, 2, 3, & 4  
MM 10 1072  
LLB Law Degree

Environmental Technician



Owain Redfern  
Level 1  
MM 13 1248

Severn Power Limited  
Nash, Newport

APPENDICES

**CONTENTS**

CONTENTS

APPENDIX 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data  
Oxygen - Calibration Data - CEM Stability Chart  
Oxygen - Calibration Data - Regression Analysis  
Oxygen - Calibration Data - X - Y Plot  
Oxygen - Calibration Data - Test of Residuals  
Oxygen - Calibration Data - Test of Residuals Chart

Nitrogen Monoxide - Calibration Data  
Nitrogen Monoxide - Calibration Data - CEM Stability Chart  
Nitrogen Monoxide - Calibration Data - Regression Analysis  
Nitrogen Monoxide - Calibration Data - X - Y Plot  
Nitrogen Monoxide - Calibration Data - Test of Residuals  
Nitrogen Monoxide - Calibration Data - Test of Residuals Chart

Carbon Monoxide - Calibration Data  
Carbon Monoxide - Calibration Data - CEM Stability Chart  
Carbon Monoxide - Calibration Data - Regression Analysis  
Carbon Monoxide - Calibration Data - X - Y Plot  
Carbon Monoxide - Calibration Data - Test of Residuals  
Carbon Monoxide - Calibration Data - Test of Residuals Chart

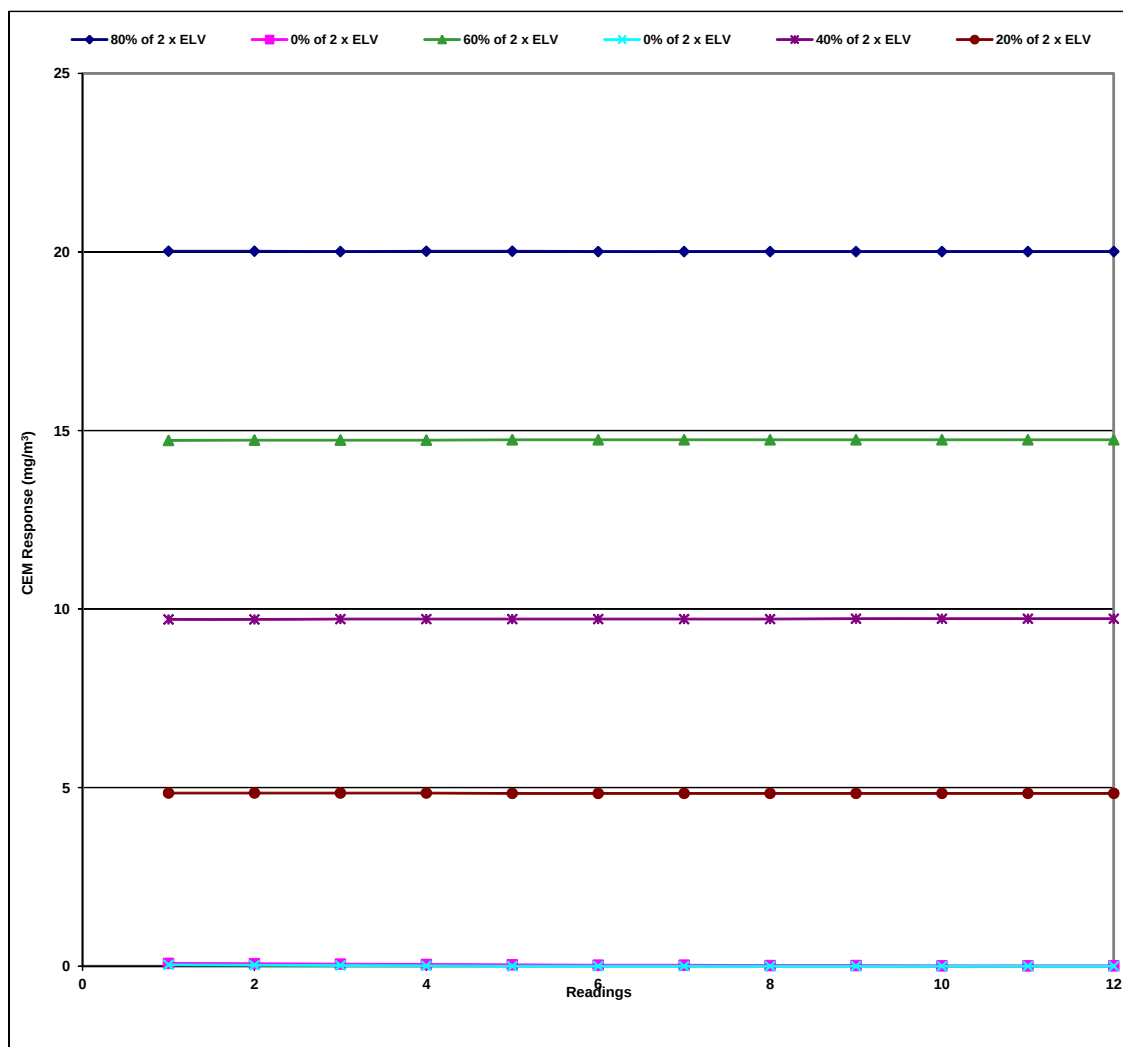
Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>20<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>15<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>10<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>5<br>mg/m <sup>3</sup> |
|----------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------|
| 1              | 20.02                                                   | 0.08                                                  | 14.72                                                   | 0.04                                                  | 9.71                                                    | 4.85                                                   |
| 2              | 20.02                                                   | 0.07                                                  | 14.73                                                   | 0.03                                                  | 9.71                                                    | 4.85                                                   |
| 3              | 20.01                                                   | 0.06                                                  | 14.73                                                   | 0.02                                                  | 9.72                                                    | 4.85                                                   |
| 4              | <b>20.02</b>                                            | <b>0.05</b>                                           | <b>14.73</b>                                            | <b>0.01</b>                                           | <b>9.72</b>                                             | <b>4.85</b>                                            |
| 5              | 20.02                                                   | 0.04                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 6              | 20.01                                                   | 0.03                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 7              | 20.01                                                   | 0.03                                                  | 14.74                                                   | 0.00                                                  | 9.72                                                    | 4.84                                                   |
| 8              | <b>20.01</b>                                            | <b>0.02</b>                                           | <b>14.74</b>                                            | <b>0.00</b>                                           | <b>9.72</b>                                             | <b>4.84</b>                                            |
| 9              | 20.01                                                   | 0.02                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 10             | 20.01                                                   | 0.01                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 11             | 20.01                                                   | 0.01                                                  | 14.74                                                   | 0.00                                                  | 9.73                                                    | 4.84                                                   |
| 12             | <b>20.01</b>                                            | <b>0.01</b>                                           | <b>14.74</b>                                            | <b>0.00</b>                                           | <b>9.73</b>                                             | <b>4.84</b>                                            |

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Regression Analysis

| Cal Gas<br>$y_i$ | CEM Response<br>$x_i$ | $x - x_z$    | $(x - x_z)^2$ | $y(x - x_z)$ | Average<br>$x_z$ |
|------------------|-----------------------|--------------|---------------|--------------|------------------|
| 20               | 19.64                 | 11.472       | 131.599       | 229.433      | 19.640           |
| 20               | 19.64                 | 11.472       | 131.599       | 229.433      |                  |
| 20               | 19.64                 | 11.472       | 131.599       | 229.433      |                  |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        | 0.000            |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        |                  |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        |                  |
| 15               | 14.64                 | 6.472        | 41.882        | 97.075       | 14.640           |
| 15               | 14.64                 | 6.472        | 41.882        | 97.075       |                  |
| 15               | 14.64                 | 6.472        | 41.882        | 97.075       |                  |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        | 0.000            |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        |                  |
| 0.0              | 0                     | -8.168       | 66.722        | 0.000        |                  |
| 10               | 9.79                  | 1.622        | 2.630         | 16.217       | 9.790            |
| 10               | 9.79                  | 1.622        | 2.630         | 16.217       |                  |
| 10               | 9.79                  | 1.622        | 2.630         | 16.217       |                  |
| 5                | 4.94                  | -3.228       | 10.422        | -16.142      | 4.940            |
| 5                | 4.94                  | -3.228       | 10.422        | -16.142      |                  |
| 5                | 4.94                  | -3.228       | 10.422        | -16.142      |                  |
| Sum              | 150                   | 147.03       | -             | 959.931      | -                |
| n                | 18                    | 18           | -             | 18           | -                |
| Average          | $yz = 8.333$          | $xz = 8.168$ | -             | 53.329       | -                |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where  $a =$  average  $Y_i$  reading or  $yz = 8.333$

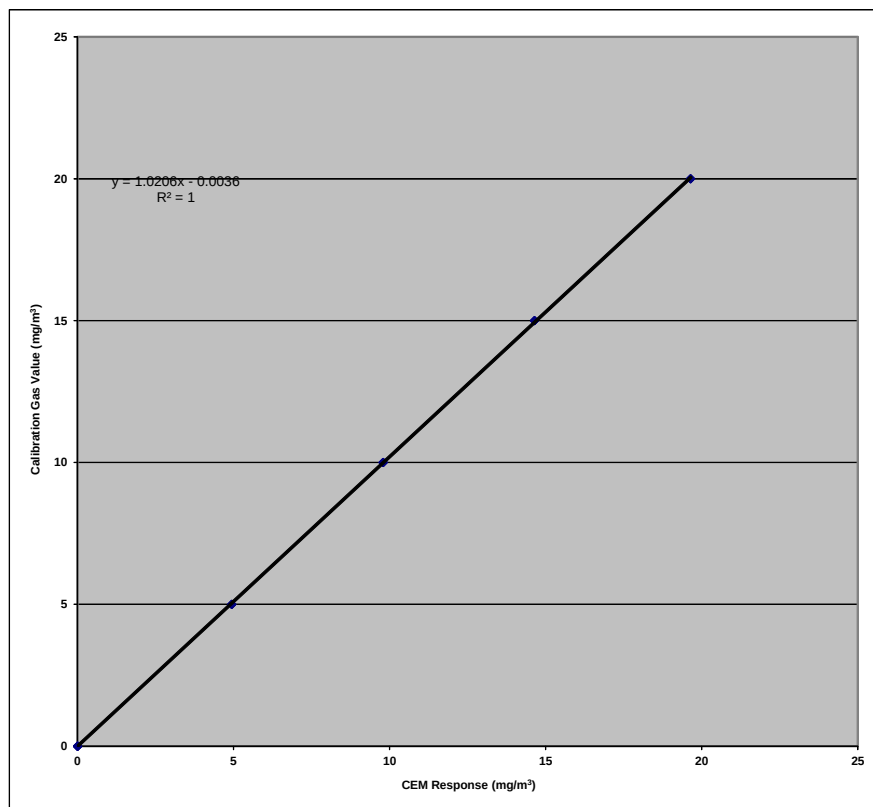
where  $B = \frac{\text{average } Y_i(x_i - x_z)}{\text{average}(x_i - x_z)^2} = \frac{54.431}{53.329} = 1.0206$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

where  $A = a - (Bx_z) = 8.333 - (1.0206 \times 8.168) = -0.0033$

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average<br>$x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|------------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 20               | 19.640           | -0.042 | -0.209           | 0.209                | 0.307                    | 5     | Pass    |
| 0.0              | 0.000            | 0.004  | 0.018            | 0.018                |                          |       |         |
| 15               | 14.640           | 0.061  | 0.307            | 0.307                |                          |       |         |
| 0.0              | 0.000            | 0.004  | 0.018            | 0.018                |                          |       |         |
| 10               | 9.790            | 0.012  | 0.058            | 0.058                |                          |       |         |
| 5                | 4.940            | -0.038 | -0.192           | 0.192                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 20 - (-0.0033 + 1.0206 \times 19.64)$

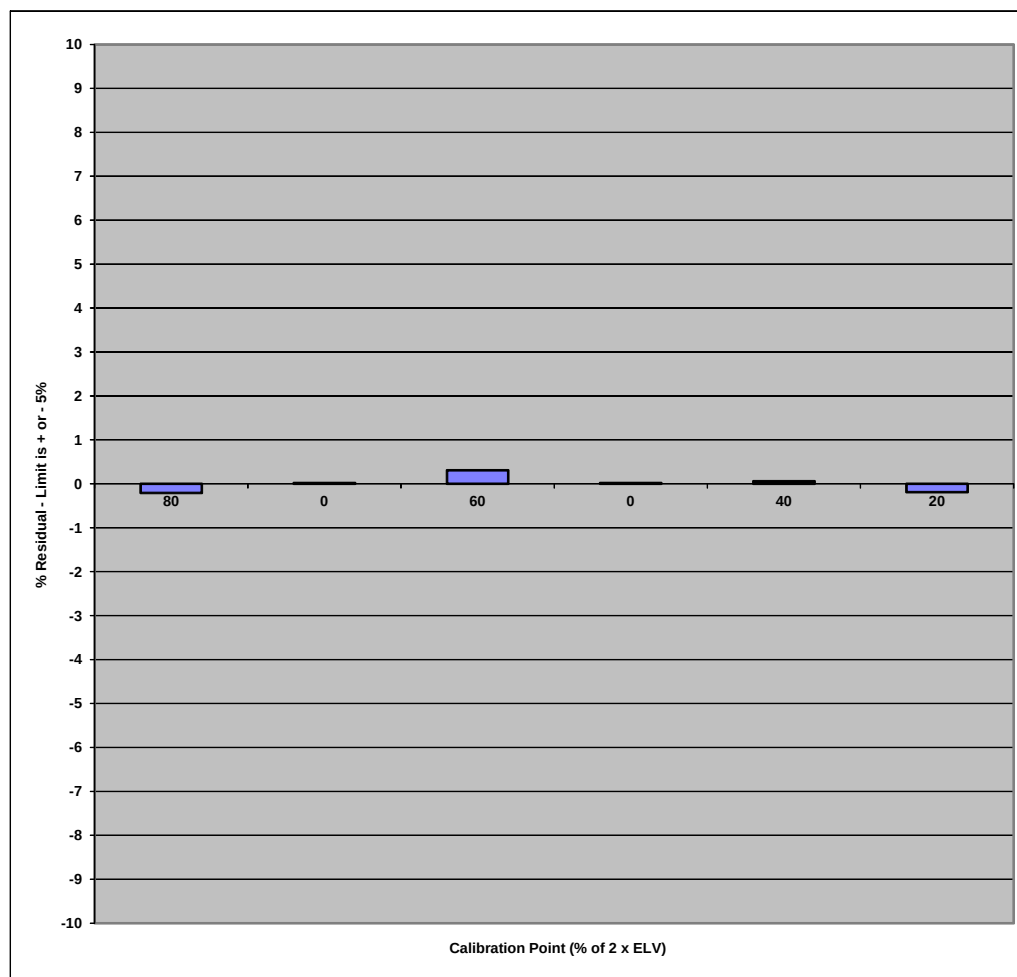
and  $d_{c,rel} = \frac{d_c}{y_{i \max}} \times 100$

e.g.  $d_{c,rel} = (-0.042/20) \times 100 = -0.209$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Oxygen - Calibration Data - Test of Residuals Chart



Appendix 1 - Raw Data, Calculations & Graphs

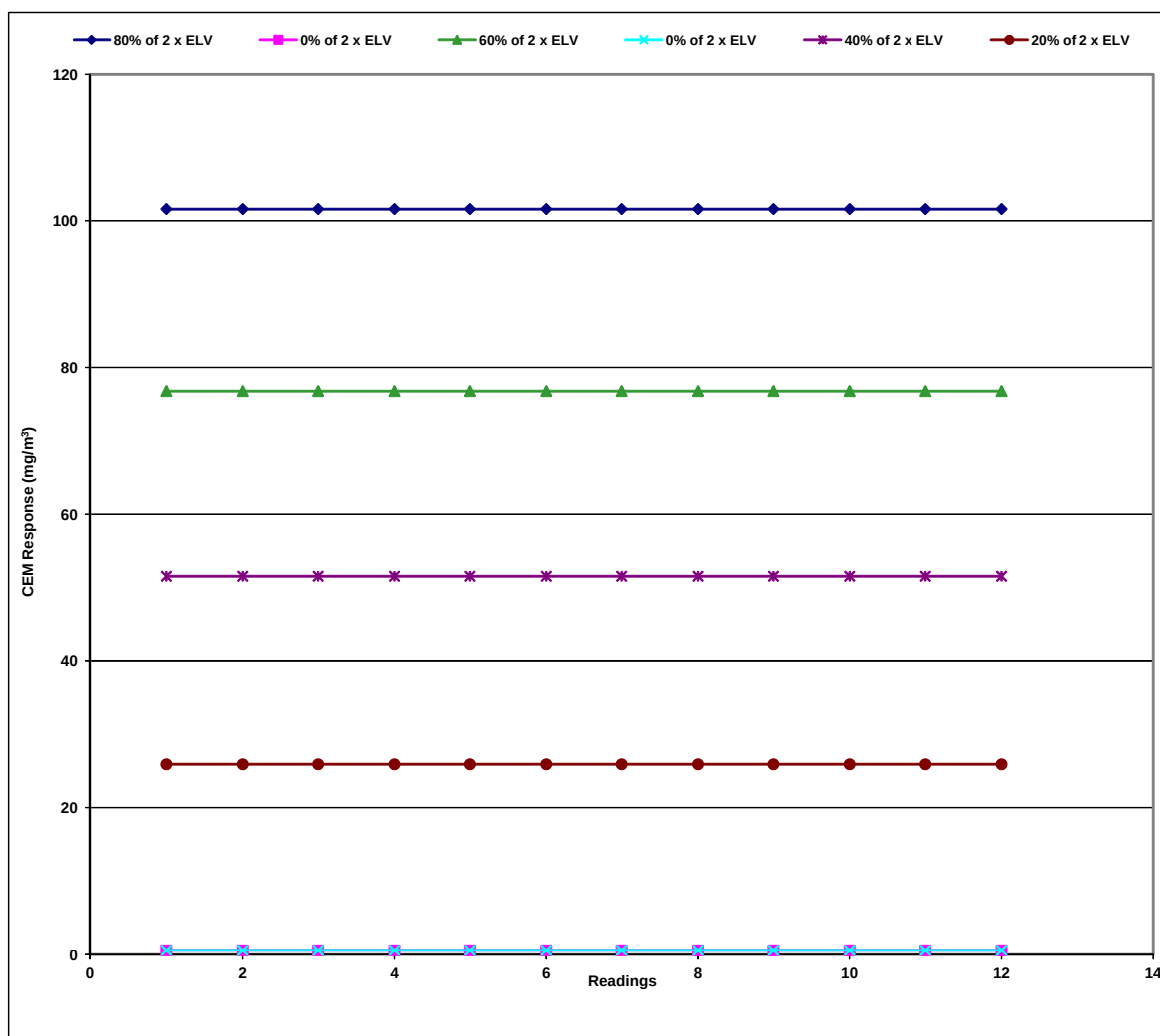
Nitrogen Monoxide - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>105.96<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0.00<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>79.47<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0.00<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>52.98<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>26.49<br>mg/m <sup>3</sup> |
|----------------|-------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|
| 1              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 2              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 3              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 4              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 5              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 6              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 7              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 8              | <b>101.6</b>                                                | <b>0.6</b>                                               | <b>76.8</b>                                                | <b>0.6</b>                                               | <b>51.6</b>                                                | <b>26.0</b>                                                |
| 9              | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 10             | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 11             | 101.6                                                       | 0.6                                                      | 76.8                                                       | 0.6                                                      | 51.6                                                       | 26.0                                                       |
| 12             | <b>101.6</b>                                                | <b>0.6</b>                                               | <b>76.8</b>                                                | <b>0.6</b>                                               | <b>51.6</b>                                                | <b>26.0</b>                                                |

Readings 8, 12 and 16 are those selected for regression analysis.

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Regression Analysis

|         | Cal Gas    | CEM Response |           |               |                | Average |
|---------|------------|--------------|-----------|---------------|----------------|---------|
|         | $y_i$      | $x_i$        | $x - x_z$ | $(x - x_z)^2$ | $y_i(x - x_z)$ | $x_c$   |
|         | 105.96     | 101.60       | 58.733    | 3449.604      | 6223.400       | 101.600 |
|         | 105.96     | 101.60       | 58.733    | 3449.604      | 6223.400       |         |
|         | 105.96     | 101.60       | 58.733    | 3449.604      | 6223.400       |         |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          | 0.600   |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          |         |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          |         |
|         | 79.47      | 76.80        | 33.933    | 1151.471      | 2696.689       | 76.800  |
|         | 79.47      | 76.80        | 33.933    | 1151.471      | 2696.689       |         |
|         | 79.47      | 76.80        | 33.933    | 1151.471      | 2696.689       |         |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          | 0.600   |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          |         |
|         | 0.00       | 0.60         | -42.267   | 1786.471      | 0.000          |         |
|         | 52.98      | 51.60        | 8.733     | 76.271        | 462.693        | 51.600  |
|         | 52.98      | 51.60        | 8.733     | 76.271        | 462.693        |         |
|         | 52.98      | 51.60        | 8.733     | 76.271        | 462.693        |         |
|         | 26.49      | 26.00        | -16.867   | 284.484       | -446.799       | 26.000  |
|         | 26.49      | 26.00        | -16.867   | 284.484       | -446.799       |         |
|         | 26.49      | 26.00        | -16.867   | 284.484       | -446.799       |         |
| Sum     | 794.701987 | 771.600      | -         | 25604.320     | 26807.947      | -       |
| n       | 18         | 18           | -         | 18            | 18             | -       |
| Average | vz = 44.15 | xz = 42.867  | -         | 1422.462222   | 1489           | -       |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where  $a =$  average  $Y_i$  reading or  $yz = 44.15$

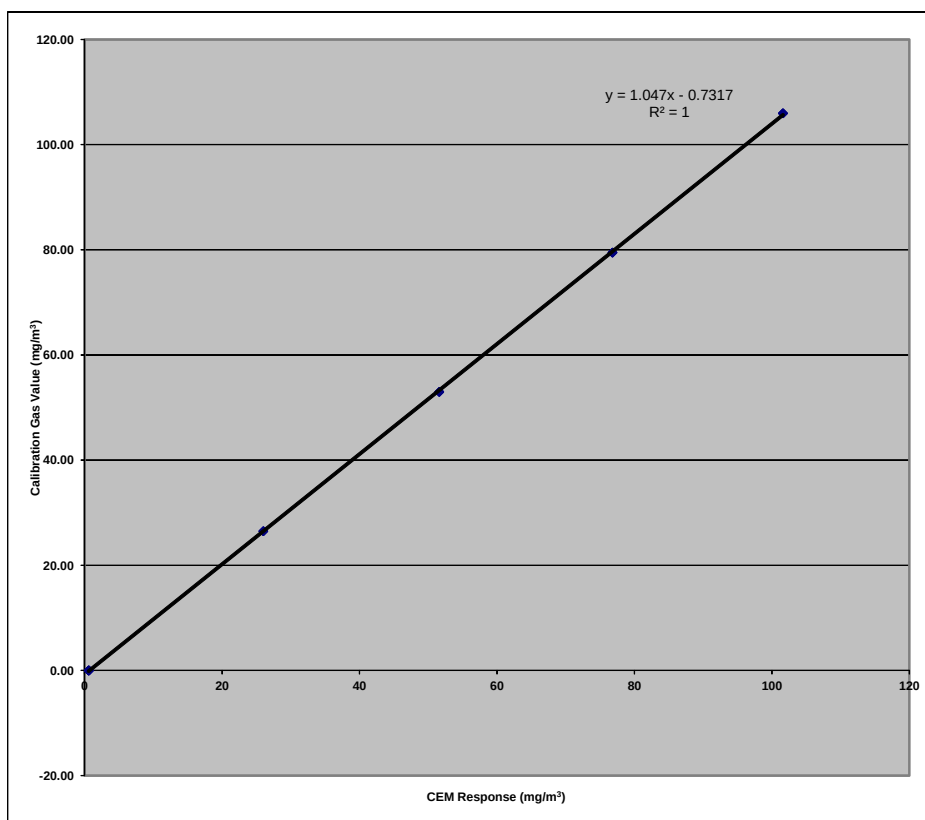
$$\text{where } B = \frac{\text{average } Y_i(x_i - x_z)}{\text{average}(x_i - x_z)^2} = \frac{1489.330}{1422.462} = 1.047$$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

$$\text{where } A = a - (Bx_z) = 44.15 - (1.047 \times 42.867) = -0.7313$$

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average $x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|---------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 105.96           | 101.60        | 0.316  | 0.298            | 0.298                | 0.298                    | 5     | Pass    |
| 0.00             | 0.60          | 0.103  | 0.098            | 0.098                |                          |       |         |
| 79.47            | 76.80         | -0.208 | -0.197           | 0.197                |                          |       |         |
| 0.00             | 0.60          | 0.103  | 0.098            | 0.098                |                          |       |         |
| 52.98            | 51.60         | -0.314 | -0.296           | 0.296                |                          |       |         |
| 26.49            | 26.00         | 0.000  | 0.000            | 0.000                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 105.960264900662 - (-0.7313 + 1.047 \times 101.6)$

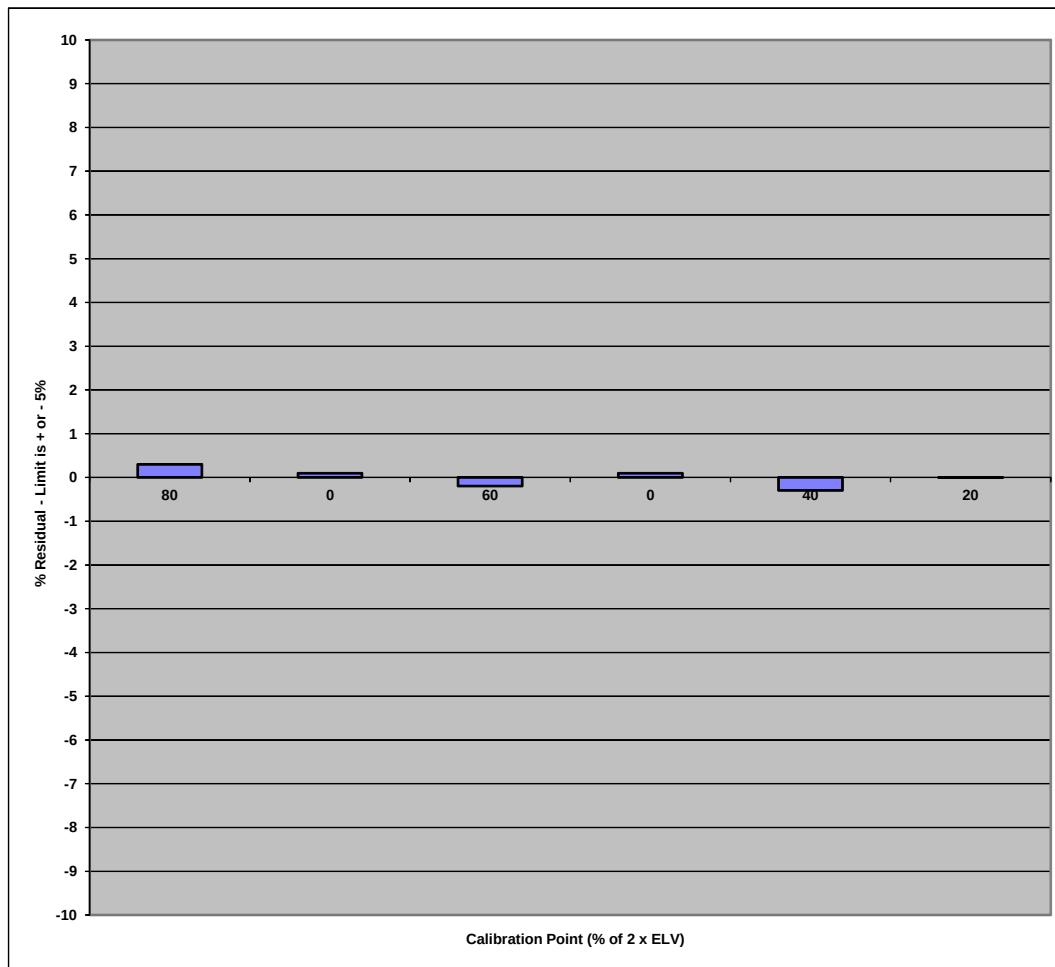
and  $d_{c,rel} = \frac{d_c}{y_{i \max}} \times 100$

e.g.  $d_{c,rel} = (0.316/105.960264900662) \times 100 = 0.298$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Nitrogen Monoxide - Calibration Data - Test of Residuals Chart



Appendix 1 - Raw Data, Calculations & Graphs

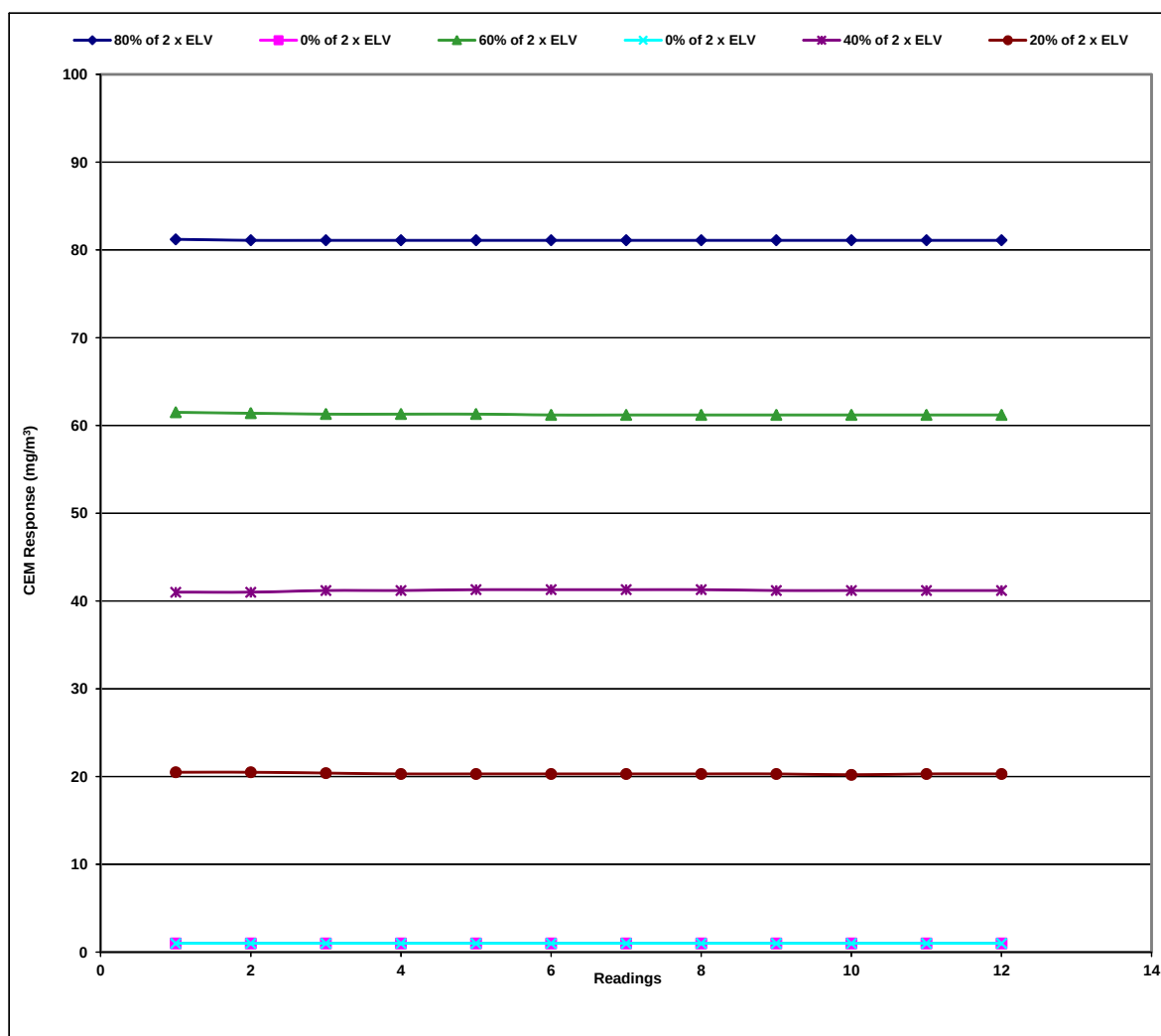
Carbon Monoxide - Calibration Data

| Response Times | Level 1<br>80% of<br>2 x ELV<br>80<br>mg/m <sup>3</sup> | Level 2<br>0% of<br>2 x ELV<br>0.0<br>mg/m <sup>3</sup> | Level 3<br>60% of<br>2 x ELV<br>60<br>mg/m <sup>3</sup> | Level 4<br>0% of<br>2 x ELV<br>0.0<br>mg/m <sup>3</sup> | Level 5<br>40% of<br>2 x ELV<br>40<br>mg/m <sup>3</sup> | Level 6<br>20% of<br>2 x ELV<br>20<br>mg/m <sup>3</sup> |
|----------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|
| 1              | 81.2                                                    | 1.0                                                     | 61.5                                                    | 1.0                                                     | 41.0                                                    | 20.5                                                    |
| 2              | 81.1                                                    | 1.0                                                     | 61.4                                                    | 1.0                                                     | 41.0                                                    | 20.5                                                    |
| 3              | 81.1                                                    | 1.0                                                     | 61.3                                                    | 1.0                                                     | 41.2                                                    | 20.4                                                    |
| 4              | <b>81.1</b>                                             | <b>1.0</b>                                              | <b>61.3</b>                                             | <b>1.0</b>                                              | <b>41.2</b>                                             | <b>20.3</b>                                             |
| 5              | 81.1                                                    | 1.0                                                     | 61.3                                                    | 1.0                                                     | 41.3                                                    | 20.3                                                    |
| 6              | 81.1                                                    | 1.0                                                     | 61.2                                                    | 1.0                                                     | 41.3                                                    | 20.3                                                    |
| 7              | 81.1                                                    | 1.0                                                     | 61.2                                                    | 1.0                                                     | 41.3                                                    | 20.3                                                    |
| 8              | <b>81.1</b>                                             | <b>1.0</b>                                              | <b>61.2</b>                                             | <b>1.0</b>                                              | <b>41.3</b>                                             | <b>20.3</b>                                             |
| 9              | 81.1                                                    | 1.0                                                     | 61.2                                                    | 1.0                                                     | 41.2                                                    | 20.3                                                    |
| 10             | 81.1                                                    | 1.0                                                     | 61.2                                                    | 1.0                                                     | 41.2                                                    | 20.2                                                    |
| 11             | 81.1                                                    | 1.0                                                     | 61.2                                                    | 1.0                                                     | 41.2                                                    | 20.3                                                    |
| 12             | <b>81.1</b>                                             | <b>1.0</b>                                              | <b>61.2</b>                                             | <b>1.0</b>                                              | <b>41.2</b>                                             | <b>20.3</b>                                             |

Readings 4, 8, and 12 are those selected for regression analysis.

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - CEM Stability Chart



Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Regression Analysis

| Cal Gas<br>$y_i$ | CEM Response<br>$x_i$ | $x - x_z$     | $(x - x_z)^2$ | $y_i(x - x_z)$ | Average<br>$x_c$ |
|------------------|-----------------------|---------------|---------------|----------------|------------------|
| 80.0             | 81.1                  | 46.789        | 2189.200      | 3743           | 81.100           |
| 80.0             | 81.1                  | 46.789        | 2189.200      | 3743           |                  |
| 80.0             | 81.1                  | 46.789        | 2189.200      | 3743           |                  |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          | 1.000            |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          |                  |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          |                  |
| 60.0             | 61.3                  | 26.989        | 728.400       | 1619           | 61.233           |
| 60.0             | 61.2                  | 26.889        | 723.012       | 1613           |                  |
| 60.0             | 61.2                  | 26.889        | 723.012       | 1613           |                  |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          | 1.000            |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          |                  |
| 0.0              | 1.00                  | -33.311       | 1109.630      | 0.000          |                  |
| 40.0             | 41.2                  | 6.889         | 47.457        | 276            | 41.233           |
| 40.0             | 41.3                  | 6.989         | 48.845        | 280            |                  |
| 40.0             | 41.2                  | 6.889         | 47.457        | 276            |                  |
| 20.0             | 20.3                  | -14.011       | 196.311       | -280           | 20.300           |
| 20.0             | 20.3                  | -14.011       | 196.311       | -280           |                  |
| 20.0             | 20.3                  | -14.011       | 196.311       | -280           |                  |
| Sum              | 600                   | 617.6         | -             | 16132.49778    | 16065            |
| n                | 18                    | 18            | -             | 18             | -                |
| Average          | $yz = 33.333$         | $xz = 34.311$ | -             | 896.2498765    | 892.5185185      |

The linear regression for the function of  $Y_i = a + B(x_i - x_z)$

where  $a =$  average  $Y_i$  reading or  $yz = 33.333$

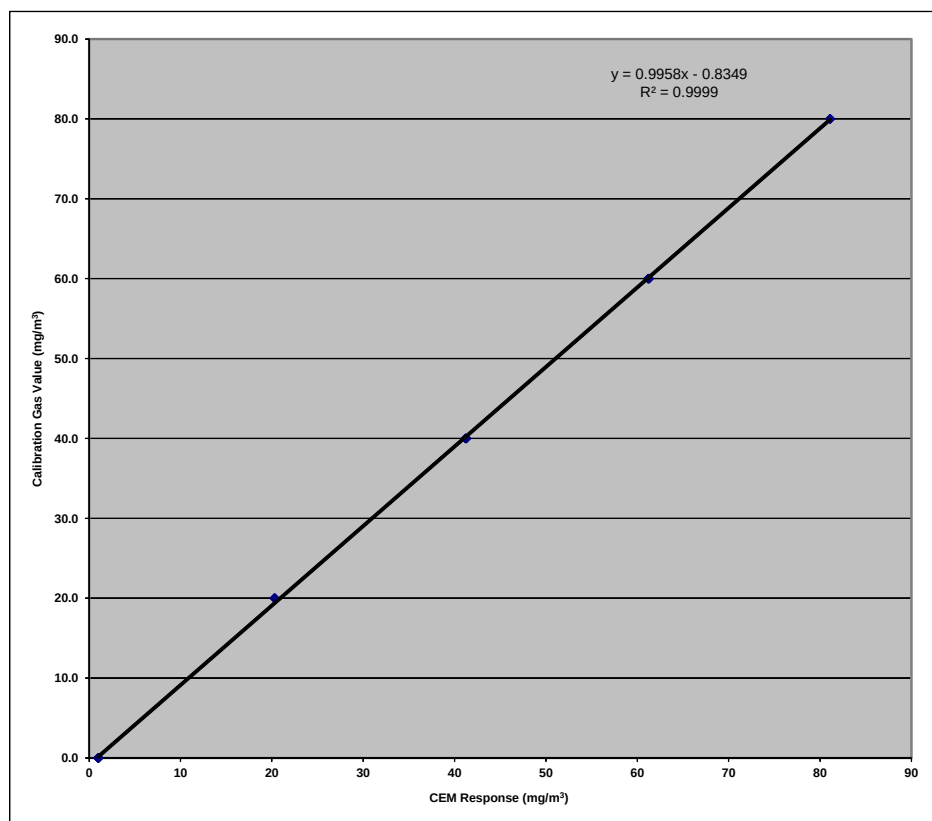
$$\text{where } B = \frac{\text{average } Y_i(x - x_z)}{\text{average}(x - x_z)^2} = \frac{892.519}{896.250} = 0.9958$$

The function  $Y_i = a + B(x_i - x_z)$  is then converted to  $Y_i = A + Bx_i$

$$\text{where } A = a - (Bx_z) = 33.333 - (0.9958 \times 34.311) = -0.8337$$

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - X - Y Plot



Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Test of Residuals

| Cal gas<br>$y_i$ | Average $x_c$ | $d_c$  | %<br>$d_{c,rel}$ | ABS %<br>$d_{c,rel}$ | Max ABS %<br>$d_{c,rel}$ | Limit | Outcome |
|------------------|---------------|--------|------------------|----------------------|--------------------------|-------|---------|
| 80.00            | 81.10         | 0.073  | 0.091            | 0.091                | 0.774                    | 5     | Pass    |
| 0.00             | 1.00          | -0.161 | -0.201           | 0.201                |                          |       |         |
| 60.00            | 61.23         | -0.143 | -0.179           | 0.179                |                          |       |         |
| 0.00             | 1.00          | -0.161 | -0.201           | 0.201                |                          |       |         |
| 40.00            | 41.23         | -0.227 | -0.283           | 0.283                |                          |       |         |
| 20.00            | 20.30         | 0.619  | 0.774            | 0.774                |                          |       |         |

Where  $d_c = y_i - (A + B x_c)$

e.g.  $d_c = 80 - (-0.8337 + 0.9958 \times 81.1)$

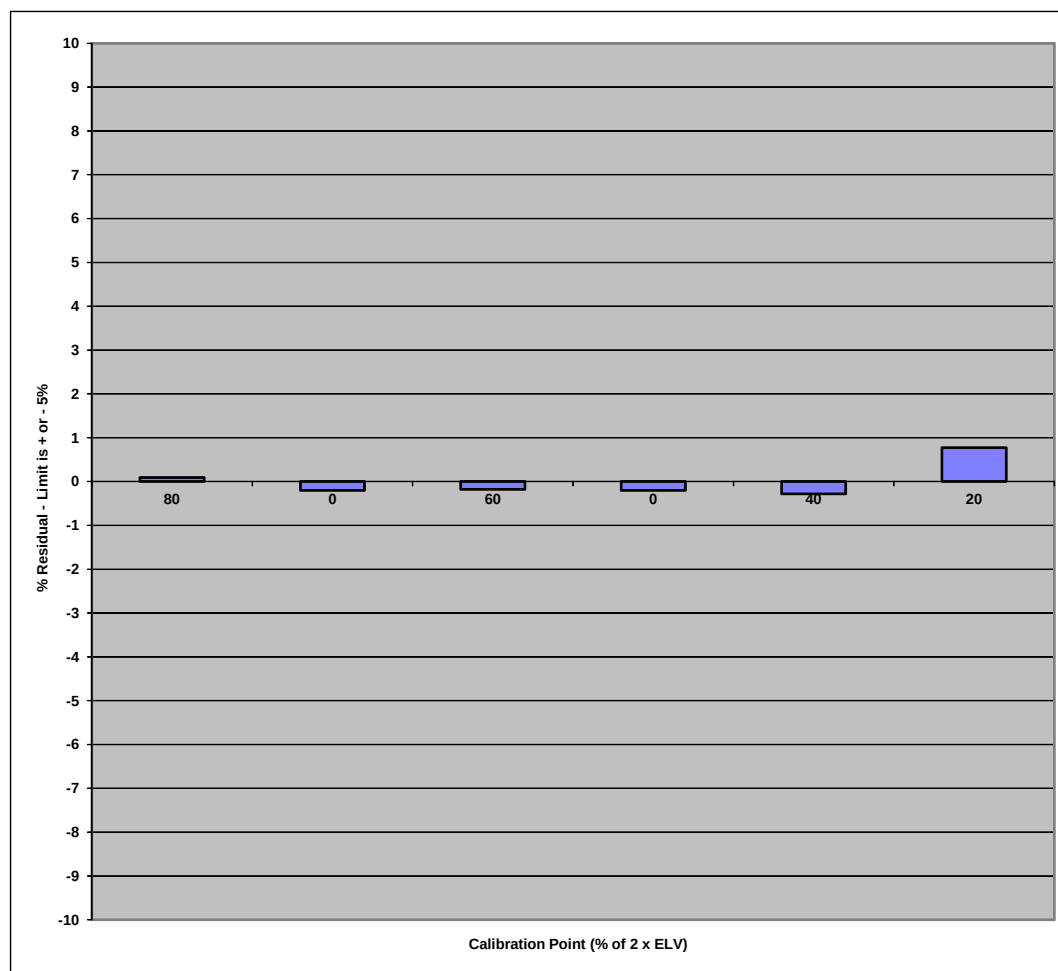
and  $d_{c,rel} = \frac{d_c}{y_{i \max}} \times 100$

e.g.  $d_{c,rel} = (0.073/80) \times 100 = 0.091$

$d_{c,rel}$  is then converted to an absolute figure and then the maximum  $d_{c,rel}$  is selected. This figure has to be less than 5% for the residuals to pass the test.

Appendix 1 - Raw Data, Calculations & Graphs

Carbon Monoxide - Calibration Data - Test of Residuals Chart



## Annex 2 Service reports

Siemens undertake routine maintenance on the CEM systems on a 6 monthly basis. The work undertaken at the service on the 14 May 2015 prior to the current annual surveillance test is detailed in the reports below

# SIEMENS

Severn Power  
O&M Form No: EF-08.007-02

### Biannual / Annual CEMS Maintenance Checklist

| Biannual CEMS Maintenance                      |      |           |            |
|------------------------------------------------|------|-----------|------------|
| Unit                                           | : 10 | Date/Time | : 14/05/15 |
| <b>Emission PC</b>                             |      |           |            |
|                                                | OK   | NOT OK    | Remarks    |
| Automatic backup system running properly       |      |           |            |
| Copying files backup to an external hard drive |      |           |            |
| Cleaning status of PC, monitor, keyboard, etc. |      |           |            |
| <b>NO2 Catalytic converter</b>                 |      |           |            |
|                                                | OK   | NOT OK    | Remarks    |
| Replacing catalyst cartridge and o-rings seals | X    |           | REPLACED   |

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

Inspector/Date: \_\_\_\_\_ D WAGG, C JONES 14/05/15

| Annual CEMS Maintenance                      |    |           |         |
|----------------------------------------------|----|-----------|---------|
|                                              |    | Date/Time |         |
| <b>Gas coolers and condensate pumps</b>      |    |           |         |
|                                              | OK | NOT OK    | Remarks |
| Water exuding in condensate extraction pump? | X  |           |         |
| Air suction filter status                    | X  |           |         |
| Silicon tubes of condensate pumps status     | X  |           |         |
| Checking/Cleaning heat exchanger surfaces    | X  |           |         |
| <b>Gas pump</b>                              |    |           |         |
|                                              | OK | NOT OK    | Remarks |
| Gas pump membrane (type K) status            | X  |           |         |
| Silicon tubing status                        | X  |           |         |

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

Inspector/Date:

# SIEMENS

Severn Power  
O&M Form No: EF-08.007-02

## Biannual / Annual CEMS Maintenance Checklist

| Biannual CEMS Maintenance                      |      |           |            |
|------------------------------------------------|------|-----------|------------|
| Unit                                           | : 20 | Date/Time | : 14/05/15 |
| Emission PC                                    |      |           |            |
|                                                | OK   | NOT OK    | Remarks    |
| Automatic backup system running properly       |      |           |            |
| Copying files backup to an external hard drive |      |           |            |
| Cleaning status of PC, monitor, keyboard, etc. |      |           |            |
| NO2 Catalytic converter                        |      |           |            |
|                                                | OK   | NOT OK    | Remarks    |
| Replacing catalyst cartridge and o-rings seals | X    |           | CHANGED    |

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

Inspector/Date: \_\_\_\_\_ D WAGG, C JONES 14/05/15

| Annual CEMS Maintenance                       |      |           |            |
|-----------------------------------------------|------|-----------|------------|
| Unit                                          | : 20 | Date/Time | : 21/10/14 |
| Gas coolers and condensate pumps              |      |           |            |
|                                               | OK   | NOT OK    | Remarks    |
| Water existing in condensate extraction pump? | X    |           |            |
| Air suction filter status                     | X    |           |            |
| Silicon tubes of condensate pumps status      | X    |           |            |
| Checking/Cleaning heat exchanger surfaces     | X    |           |            |
| Gas pump                                      |      |           |            |
|                                               | OK   | NOT OK    | Remarks    |
| Gas pump membrane (type K) status             | X    |           |            |
| Silicon tubing status                         | X    |           |            |

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

Inspector/Date: \_\_\_\_\_ DW/WJ/CJ 21/10/14

In addition monthly service checks are undertaken. The reports on the monthly check undertaken on the 12 June 2015 are provided below.

| <h1>SIEMENS</h1>                                                 |                                | <b>SEVERN POWER</b><br>O&M Form No: EF-08.007-03<br>Rev. 0 |                      |
|------------------------------------------------------------------|--------------------------------|------------------------------------------------------------|----------------------|
| <b>Monthly CEMS Maintenance</b>                                  |                                |                                                            |                      |
| <b>NO2 Converter Efficiency Check</b>                            |                                |                                                            |                      |
| WO:                                                              | 688                            |                                                            | UNIT: 10             |
| Analyser Type                                                    | Siemens Ultramat 23            |                                                            |                      |
| Analser No.                                                      | KKS -10CFE01GH001              |                                                            |                      |
| Analyser Range                                                   | 0-100/750 mg/m <sup>3</sup> NO |                                                            |                      |
| NO2 ref gas cylinder                                             | 95890                          |                                                            |                      |
| NO2 ref gas certification expiry                                 | 20/02/2016                     |                                                            |                      |
| NO2 ref gas concentration                                        | 162                            | mg/m <sup>3</sup> NO <sup>3</sup>                          |                      |
| NO expected at 100% converter efficiency                         | 105.6521739                    | mg/m <sup>3</sup> NO <sup>3</sup>                          |                      |
| <b>Cartridge as found:</b>                                       |                                |                                                            |                      |
| READING                                                          | ANALYSER RESPONSE (MG/M3)      |                                                            | CONVERTER EFFICIENCY |
|                                                                  | NO                             | NOX                                                        |                      |
| 1                                                                | 100.0                          |                                                            | 95%                  |
| 2                                                                | 100.1                          |                                                            | 95%                  |
| 3                                                                | 100                            |                                                            | 95%                  |
| MEAN                                                             |                                |                                                            | 95%                  |
| Required minimum efficiency      95%<br>PASS OR FAIL <b>FAIL</b> |                                |                                                            |                      |
| <b>After cartridge is changed:</b>                               |                                |                                                            |                      |
| READING                                                          | ANALYSER RESPONSE (MG/M3)      |                                                            | CONVERTER EFFICIENCY |
|                                                                  | NO                             | NOX                                                        |                      |
| 1                                                                |                                |                                                            | 0%                   |
| 2                                                                |                                |                                                            | 0%                   |
| 3                                                                |                                |                                                            | 0%                   |
| MEAN                                                             |                                |                                                            | 0%                   |
| Required minimum efficiency      95%<br>PASS OR FAIL <b>FAIL</b> |                                |                                                            |                      |

|                                                   |    |                                                            |           |
|---------------------------------------------------|----|------------------------------------------------------------|-----------|
| <h1 style="margin: 0;">SIEMENS</h1>               |    | <b>SEVERN POWER</b><br>O&M Form No: EF-08.007-03<br>Rev. 0 |           |
| <b>Sampling System</b>                            |    |                                                            |           |
|                                                   | OK | NOT OK                                                     | Remarks   |
| Operation probe heater                            | OK |                                                            |           |
| Operation of sampling line heater                 | OK |                                                            | 135 deg C |
| Condition of ceramic probe filter (60 µm)         | OK |                                                            |           |
| Cleaning conditions of probe tube                 | OK |                                                            |           |
| Status of bolts, flanges and heated sampling tube | OK |                                                            |           |
| Non-conformance was : _____ / _____ (year)        |    |                                                            |           |
| <b>Remarks</b>                                    |    | <b>Inspector / Date</b>                                    |           |
|                                                   |    | Signed: WJ 12/06/15                                        |           |
| <b>Corrective actions</b>                         |    | <b>Engineer/ Date</b>                                      |           |
|                                                   |    | Signed:                                                    |           |

| <h1 style="margin: 0;">SIEMENS</h1>                                                                                        |                                | <b>SEVERN POWER</b><br>O&M Form No: EF-08.007-03<br>Rev. 0 |                      |
|----------------------------------------------------------------------------------------------------------------------------|--------------------------------|------------------------------------------------------------|----------------------|
| <b>Monthly CEMS Maintenance</b>                                                                                            |                                |                                                            |                      |
| <b>NO2 Converter Efficiency Check</b>                                                                                      |                                |                                                            |                      |
| WO:                                                                                                                        | 689                            |                                                            | UNIT: 20             |
| Analysers Type                                                                                                             | Siemens Ultramat 23            |                                                            |                      |
| Analysers No.                                                                                                              | KKS - 20CFE01GH001             |                                                            |                      |
| Analysers Range                                                                                                            | 0-100/750 mg/m <sup>3</sup> NO |                                                            |                      |
| NO2 ref gas cylinder                                                                                                       | 95533                          |                                                            |                      |
| NO2 ref gas certification expiry                                                                                           | 20/02/2016                     |                                                            |                      |
| NO2 ref gas concentration                                                                                                  | 160                            | mg/m <sup>3</sup> NO <sup>3</sup>                          |                      |
| NO expected at 100% converter efficiency                                                                                   | 104.3478261                    | mg/m <sup>3</sup> NO <sup>3</sup>                          |                      |
| <b>Cartridge as found:</b>                                                                                                 |                                |                                                            |                      |
| READING                                                                                                                    | ANALYSER RESPONSE (MG/M3)      |                                                            | CONVERTER EFFICIENCY |
|                                                                                                                            | NO                             | NOX                                                        |                      |
| 1                                                                                                                          | 99.6                           |                                                            | 95%                  |
| 2                                                                                                                          | 99.8                           |                                                            | 96%                  |
| 3                                                                                                                          | 100.2                          |                                                            | 96%                  |
| MEAN                                                                                                                       |                                |                                                            | 96%                  |
| Required minimum efficiency      95%<br>PASS OR FAIL <span style="border: 1px solid black; padding: 2px 10px;">PASS</span> |                                |                                                            |                      |
| <b>After cartridge is changed:</b>                                                                                         |                                |                                                            |                      |
| READING                                                                                                                    | ANALYSER RESPONSE (MG/M3)      |                                                            | CONVERTER EFFICIENCY |
|                                                                                                                            | NO                             | NOX                                                        |                      |
| 1                                                                                                                          |                                |                                                            | 0%                   |
| 2                                                                                                                          |                                |                                                            | 0%                   |
| 3                                                                                                                          |                                |                                                            | 0%                   |
| MEAN                                                                                                                       |                                |                                                            | 0%                   |
| Required minimum efficiency      95%<br>PASS OR FAIL <span style="border: 1px solid black; padding: 2px 10px;">FAIL</span> |                                |                                                            |                      |

| <div style="display: inline-block; width: 60%; font-size: 24px; font-weight: bold; margin: 0;">SIEMENS</div> <div style="display: inline-block; width: 40%; font-size: 12px; margin: 0;"> SEVERN POWER<br/>O&amp;M Form No: EF-08.007-03<br/>Rev. 0 </div> |                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sampling System</b>                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                               |
|                                                                                                                                                                                                                                                            | <div style="display: flex; justify-content: space-around;"> <div style="width: 20%; text-align: center;">OK</div> <div style="width: 20%; text-align: center;">NOT OK</div> <div style="width: 60%; text-align: center;">Remarks</div> </div> |
| Operation probe heater                                                                                                                                                                                                                                     | OK                                                                                                                                                                                                                                            |
| Operation of sampling line heater                                                                                                                                                                                                                          | OK <span style="float: right;">134</span>                                                                                                                                                                                                     |
| Condition of ceramic probe filter (60 µm)                                                                                                                                                                                                                  | OK                                                                                                                                                                                                                                            |
| Cleaning conditions of probe tube                                                                                                                                                                                                                          | OK                                                                                                                                                                                                                                            |
| Status of bolts, flanges and heated sampling tube                                                                                                                                                                                                          | OK                                                                                                                                                                                                                                            |
| Non-conformance was : _____ / _____ (year)                                                                                                                                                                                                                 |                                                                                                                                                                                                                                               |
| <div style="background-color: #cccccc; padding: 2px; font-weight: bold; margin-bottom: 5px;">Remarks</div> <div style="height: 100px; border: 1px solid black;"></div>                                                                                     | <div style="background-color: #cccccc; padding: 2px; font-weight: bold; margin-bottom: 5px;">Inspector / Date</div> <div style="height: 100px; border: 1px solid black; padding: 5px;"> Signed: WJ 12/06/15 </div>                            |
| <div style="background-color: #cccccc; padding: 2px; font-weight: bold; margin-bottom: 5px;">Corrective actions</div> <div style="height: 100px; border: 1px solid black;"></div>                                                                          | <div style="background-color: #cccccc; padding: 2px; font-weight: bold; margin-bottom: 5px;">Engineer/ Date</div> <div style="height: 100px; border: 1px solid black; padding: 5px;"> Signed: </div>                                          |

## Annex 3 NO<sub>x</sub> converter efficiency check

ESG attended the Nash site on the 24 June 2015 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.

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

|                               |                                          |
|-------------------------------|------------------------------------------|
| Operator                      | Siemens                                  |
| Date                          | 22/06/2015                               |
| Analysers                     | Siemens Ultramat 23                      |
| Analysers No.                 | Serving GT10                             |
| Analysers Range               | 0-100/750                                |
| Converter ref (if applicable) | Gas Converter CG-2M ser no. 1325/9202677 |

NO<sub>2</sub> ref gas cylinder CY6  
NO<sub>2</sub> ref gas certification expiry 01/04/2016 filled April 2012  
NO<sub>2</sub> ref gas concentration 176.65 mg/m<sup>3</sup> NO<sub>2</sub>

| Reading | Analyser response (mg/m <sup>3</sup> ) |                 | Converter efficiency (%) |
|---------|----------------------------------------|-----------------|--------------------------|
|         | NO                                     | NO <sub>x</sub> |                          |
| 1       | 113.8                                  | 0               | 98.6                     |
| 2       | 113.6                                  | 0               | 98.4                     |
| 3       | 113.6                                  | 0               | 98.4                     |
| Mean    | 113.7                                  | 0               | 98.4                     |

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

### Converter efficiency check

- 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.
- Select a gas containing nitrogen dioxide (preferably in the range 50-100 ppm).
- Span and zero the analyser accordingly.
- 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.
- 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 times the response time.
- Undertake three determinations and note on the attached spreadsheet.
- 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.
- Using the spreadsheet determine the converter efficiency and its compliance with the standard performance requirement.

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

|          |            |
|----------|------------|
| Operator | Siemens    |
| Date     | 24/06/2015 |

|                               |                                          |
|-------------------------------|------------------------------------------|
| Analyser Type                 | Siemens Ultramat 23                      |
| Analysar No.                  | serving HRSG 20                          |
| 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 CY6  
NO<sub>2</sub> ref gas certification expiry 01/04/2016 filled April 2012  
NO<sub>2</sub> ref gas concentration 176.65 mg/m<sup>3</sup> NO<sub>2</sub>

| Reading | Analyser response (mg/m <sup>3</sup> ) |                 | Converter efficiency (%) |
|---------|----------------------------------------|-----------------|--------------------------|
|         | NO                                     | NO <sub>x</sub> |                          |
| 1       | 122.8                                  | 0               | 106.3                    |
| 2       | 122.8                                  | 0               | 106.3                    |
| 3       | 122.8                                  | 0               | 106.3                    |
| Mean    | 122.8                                  | 0               | 106.3                    |

Temp change on catalyst 375

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

### Converter efficiency check

- 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.
- Select a gas containing nitrogen dioxide (preferably in the range 50-100 ppm).
- Span and zero the analyser accordingly.
- 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.
- 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 times the response time.
- Undertake three determinations and note on the attached spreadsheet.
- 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.

Using the spreadsheet determine the converter efficiency and its compliance with the standard performance requirement.

## Annex 4 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 a check on each CEM system is provided below and refers to the system check undertaken on the 12 June 2015.

# SIEMENS

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

### 15 day CEMS Maintenance Checklist

|                                            |                       |                         |                                           |                              |                                                        |
|--------------------------------------------|-----------------------|-------------------------|-------------------------------------------|------------------------------|--------------------------------------------------------|
| Work Order:                                | 692                   | Unit:                   | 10                                        | Date:                        | 12/06/2015                                             |
| <b>Gas Calibration Bottle Information:</b> |                       |                         |                                           |                              |                                                        |
|                                            | Gas Calibration Data  |                         | Test Gas Certified Values                 |                              |                                                        |
| Cylinder ID Number                         | 219847                |                         | Gas                                       | ppm                          | mg/m <sup>3</sup>                                      |
| Certification Type                         |                       |                         | CO                                        | 100.1                        | 125.125                                                |
| Certification Date                         | 04-Oct-2010           |                         | NO                                        | 96.5                         | 129.31                                                 |
| Certification Expiry                       | 04-Oct-2015           |                         |                                           |                              |                                                        |
| <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)<br><small>See Notes 1&amp;2</small> |
| CO (mg/m <sup>3</sup> )                    | 0                     | 124.2                   | 124.2                                     | 125.125                      | -0.739260739                                           |
| NO (mg/m <sup>3</sup> )                    | 0                     | 128.6                   | 128.6                                     | 129.31                       | -0.549068131                                           |
| <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 <sub>2</sub> Sensor Voltage (mV): 12.63 |                              |                                                        |

**Notes:**

- (1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.
- (2)  $C = (A-B) \times 100/B$
- (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 12/06/2015

# SIEMENS

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

## 15 day CEMS Maintenance Checklist

|                                                                                                                                                                                                                                                                |                       |                                     |                            |                              |                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------|----------------------------|------------------------------|--------------------------------------------------------|
| Work Order:                                                                                                                                                                                                                                                    | 691                   | Unit:                               | 20                         | Date:                        | 12/06/2015                                             |
| <b>Gas Calibration Bottle Information:</b>                                                                                                                                                                                                                     |                       |                                     |                            |                              |                                                        |
|                                                                                                                                                                                                                                                                | Gas Calibration Data  |                                     | Test Gas Certified Values  |                              |                                                        |
| Cylinder ID Number                                                                                                                                                                                                                                             | 219842                | Gas                                 | ppm                        | mg/m <sup>3</sup>            |                                                        |
| Certification Type                                                                                                                                                                                                                                             | BOC HiQ               | CO                                  | 102.2                      | 127.75                       |                                                        |
| Certification Date                                                                                                                                                                                                                                             | 04-Oct-2010           | NO                                  | 93.4                       | 125.156                      |                                                        |
| 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)<br><small>See Notes 1&amp;2</small> |
| CO (mg/m <sup>3</sup> )                                                                                                                                                                                                                                        | 0.6                   | 126.7                               | 127.8                      | 127.75                       | 0.039138943                                            |
| NO (mg/m <sup>3</sup> )                                                                                                                                                                                                                                        | 0.6                   | 122.6                               | 125.2                      | 125.156                      | 0.035156125                                            |
| <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 <sub>2</sub> Sensor Voltage (mV): |                            | 12.8                         |                                                        |
| <b>Notes:</b><br>(1) If span error is greater than 2% following calibration then calibration should be considered failed and should be repeated.<br>(2) $C = (A-B) \times 100/B$<br>(3) 1ppm CO = 1.25mg/m <sup>3</sup><br>(4) 1ppm NO = 1.34mg/m <sup>3</sup> |                       |                                     |                            |                              |                                                        |
| <b>Remarks:</b><br><div style="border: 1px solid black; height: 100px; width: 100%;"></div>                                                                                                                                                                    |                       |                                     |                            |                              |                                                        |

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

Inspector/Date: WJ 12/06/2015

END OF REPORT

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