Dow Corning CHP Plant
AST SURVEY

Prepared for:

Cofely (GDF Suez)
Cofely CHP Site
Dow Corning Gate 7
Wimborne Road
Dock No.2, Barry
CF63 3DH

Permit Number	**JP3632ZH**
Job Number	**P2099**
Report Number	**R001**
Report Issue Date	**21st October 2014**
Survey Dates	**2nd to 4th September 2014**

Prepared by:

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Main Avenue
Treforest Industrial Estate
Pontypridd
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DOCUMENT CONTROL SHEET

Report Issue:		Final	
Report Prepared by:		Report Reviewed & Approved by MCERTS Level Two	
Name:	**Sam Brookes**	***Name:***	**David Boles**
Signature:		***Signature:***	
Date:	2nd October 2014	***Date:***	21st October 2014

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1.0 EXECUTIVE SUMMARY

Monitoring was carried out at the request of **Paul Gardner** as part of an AST calibration validation procedure in accordance with BS EN 14181, the Environment Agency's Technical Guidance Note M20 & MID. The survey was carried out between the **2nd to 4th September 2014** at **Cofely (GDF Suez)** , **Cofely CHP Site**, **Dow Corning Gate 7**, **Wimborne Road**, **Dock No.2, Barry**, **CF63 3DH.**

The substances requested for monitoring at each emissions point are listed below:

Substances to be monitored	**Emission Point Identification**
	A1, A2, A3
Oxides of Nitrogen as Nitrogen Monoxide	• u
Carbon Monoxide	• u
Oxygen	• u

- • Denotes the substances to be monitored.
- u Denotes UKAS accreditation is held for monitoring[1] that substance.

Special Requirements: *Conduct parallel monitoring under normal operating conditions. Aim for as large a spread of data as possible within normal operating parameters.*

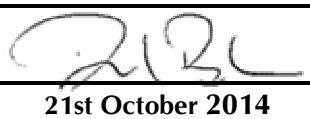
mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

UKAS TESTING 2499

1 UKAS / MCERTS accreditation is held by ECL for the sampling method and data analysis in accordance with the requirements of BS EN 14181:2004 for the specific determinand(s) indicated above. Where applicable the sub-contract laboratory will be UKAS accredited for analysis of samples.

1A EN14181 compliance report

Table 1A – EN14181 compliance report

<table>
<tr><td colspan="3">Process Operator: Cofely (GDF Suez)</td></tr>
<tr><td colspan="2" rowspan="5">Address: Cofely CHP Site
Dow Corning Gate 7
Wimborne Road
Dock No.2, Barry
CF63 3DH</td><td>EPR Permit No.: JP3632ZH</td></tr>
<tr><td>Contact: Paul Gardner</td></tr>
<tr><td>Tel. No.: 01446 723002</td></tr>
<tr><td>Email: paul.gardner@cofely-gdfsuez.com</td></tr>
<tr><td>Process Type: CHP Plant</td></tr>
<tr><td>Test carried out:</td><td>AST</td><td>Date tests carried out:
2nd to 4th September 2014</td></tr>
<tr><td colspan="3">Test laboratory: Environmental Compliance Limited</td></tr>
<tr><td colspan="2" rowspan="5">Address: Environmental Compliance Ltd.
Unit G1 Treforest Industrial Estate
Main Avenue
Pontypridd
CF37 5YL</td><td>UKAS Accreditation No.: 2499</td></tr>
<tr><td>Contact: Sam Brookes</td></tr>
<tr><td>Tel. No.: 01443 841760</td></tr>
<tr><td>Email: s.brookes@envirocompli.com</td></tr>
<tr><td>Quote Ref.: MM/P2099/Q001</td></tr>
<tr><td colspan="2">Report reference number:</td><td>R001</td></tr>
<tr><td colspan="2">Report version:</td><td>1</td></tr>
<tr><td colspan="2">Report status:</td><td>Final</td></tr>
<tr><td colspan="2">Summary report submitted by:</td><td>Sam Brookes</td></tr>
<tr><td colspan="2">Report approved by:</td><td>David Boles</td></tr>
<tr><td colspan="2">Signature:</td><td>  </td></tr>
<tr><td colspan="2">Date:</td><td>21st October 2014</td></tr>
</table>

1B Calibration Function Summary

BS EN 14181 Test Designation	AST	Stack Designation:	A1 HR-001A

Substance to be Calibrated	Calibration Coefficients		Units of Calibration Function	Conditions of Calibration Function	Valid (Extended?) Calibration Range[2]	Extrapolated Calibration Range (From Previous QAL 2) [3]	PASS BS EN 14181	
	a	*b*					Variability	Calibration Validation
Oxides of Nitrogen as (NO)	- 0.9335	1.0056	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 57.88 mg/m^3	…	PASS	PASS
Carbon Monoxide	0.3218	1.0096	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 31.01 mg/m^3	…	PASS	PASS
Oxygen (Dry)	- 0.4262	1.0249	%Vol	273K, 101.3 kPa, Dry Gas	0 – 17.47 %Vol	0 – 21.01 %Vol	PASS	PASS

Note:
The QAL2 calibration function only remains valid so long as there are no adjustments made to the CEM

[2] Data from the AST may be used to extend the valid calibration range to a value no more than 1.5x the maximum value of the calibration range from the original QAL 2. (See MID 14181, section 8.3)
[3] MID 14181 states that the calibration range may be extrapolated "to the ELV" (section 6.5 MID 14181). During the QAL2 an extrapolated calibration range was included for NO and CO on A1 that exceeded the ELV. This has since been removed for this AST.

BS EN 14181 Test Designation	AST	Stack Designation:	A2 FB-001

Substance to be Calibrated	Calibration Coefficients		Units of Calibration Function	Conditions of Calibration Function	Valid (Extended?) Calibration Range[4]	Extrapolated Calibration Range (From Previous QAL 2) [5]	PASS BS EN 14181	
	a	*b*					Variability	Calibration Validation
Oxides of Nitrogen as (NO)	0.0091	0.9141	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 51.32 mg/m^3	…	PASS	PASS
Carbon Monoxide	0.1111	1.0552	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 22.59 mg/m^3	0 – 87.50 mg/m^3	PASS	PASS
Oxygen (Dry)	0.0098	0.9788	%Vol	273K, 101.3 kPa, Dry Gas	0 – 10.07 %Vol	0 – 20.49 %Vol	PASS	PASS

BS EN 14181 Test Designation	AST	Stack Designation:	A3 HR-001B

Substance to be Calibrated	Calibration Coefficients		Units of Calibration Function	Conditions of Calibration Function	Valid (Extended?) Calibration Range[6]	Extrapolated Calibration Range (From Previous QAL 2) [7]	PASS BS EN 14181	
	a	*b*					Variability	Calibration Validation
Oxides of Nitrogen as (NO)	- 1.5148	0.9849	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 51.22 mg/m^3	…	PASS	PASS
Carbon Monoxide	1.2686	0.8611	ppm	273K, 101.3 kPa, Dry Gas, 15% O_2	0 – 15.95 mg/m^3	0 – 72.42 mg/m^3	PASS	PASS
Oxygen (Dry)	- 0.1857	1.0149	%Vol	273K, 101.3 kPa, Dry Gas	0 – 17.86 %Vol	0 – 21.10 %Vol	PASS	PASS

Note:
The QAL2 calibration function only remains valid so long as there are no adjustments made to the CEM

[4] Data from the AST may be used to extend the valid calibration range to a value no more than 1.5x the maximum value of the calibration range from the original QAL 2. (See MID 14181, section 8.3)
[5] MID 14181 states that the calibration range may be extrapolated "to the ELV" (section 6.5 MID 14181). During the QAL2 an extrapolated calibration range was included for NO on A2 that exceeded the ELV. This has since been removed for this AST.
[6] Data from the AST may be used to extend the valid calibration range to a value no more than 1.5x the maximum value of the calibration range from the original QAL 2. (See MID 14181, section 8.3)
[7] MID 14181 states that the calibration range may be extrapolated "to the ELV" (section 6.5 MID 14181). During the QAL2 an extrapolated calibration range for NO on A3 was included that exceeded the ELV. This has since been removed for this AST.

1C Details of Any Deviations from SRMs & EN 14181

Functional tests audit carried out by: (If elements of the tests were carried out by a third party)	Name: **Mike Mullett**	MCERTS No.: **MM 05 683**
Were there any deviations from SRMs?	**NO**	
Were there any deviations from EN14181?	**YES**	
Were there any corrective actions required?	**NO**	

There were no samples which deviated from the SRM's.

Details of any Deviations from BS EN 14181

Deviation	Reason for Deviation	Impact on Final Result?	Actions Required as a Result of Deviation?
Conditions of raw CEMs data is Dry, 15% O2. BS EN 14181states that it is a requirement to record data in an uncorrected format.	CEMs have oxygen correction selected at the analyzer on the sampling platform, calculations done automatically by analyzer.	None, however ensure that SRM data has been corrected to correspond with the CEMs data prior to calculations.	If possible / practical select oxygen correction off at the analyzer so that raw data reaches the Envirosoft software, oxygen corrections can then be implemented from within the software.
Functional tests do not comply with requirements of Annex A, EN 14181	CEM supplier service report contains does not contain all the necessary details for the functional tests. There is limited or no information on the sampling system, serviceability, leak test, zero and span check, interferences and response time.	Functional tests are a mandatory requirement of EN 14181 (Section 6.2, MID 14181). Please note that ECL carried out the linearity tests and comply with EN 14181. In addition, a QAL3 audit was carried out and is in compliance with EN 14181.	Operator to investigate with CEM supplier to make sure that the service report meets the requirements outlined in Annex A of EN 14181.

2.0 INSTALLATION INFORMATION

2.1 Regulatory Information

2.1.1 Operator
Cofely (GDF Suez)

2.1.2 Installation
Cofely CHP Site

2.1.3 Address
Cofely CHP Site, Dow Corning Gate 7, Wimborne Road, Dock No.2, Barry, CF63 3DH

2.1.4 Sector
LCPD

2.1.5 Permit Number
JP3632ZH

2.1.6 Date of Previous QAL2
28th October 2012

2.1.7 Regulated determinands

Determinand	Emission Point	Short Term ELV	Daily ELV	Allowable Uncertainty
Oxides of Nitrogen as (NO)	A1, A2, A3	125 mg/m^3	[8] 125 mg/m^3	20%
Carbon Monoxide		80 mg/m^3	80 mg/m^3	10% [9]

[8] Please note that no individual limits exist for NO, only for total NOx (expressed as NO_2). ELV quoted above is for NOx (as NO_2) as detailed in the site permit but an NO equivalent ELV of 81.5mg/m^3 will be used for calculation purposes in this report.
[9] A 95% Confidence Interval of 20% can be used for CO for the variability test (Section 8.5, MID 14181)

2.2 Operating Information and site monitoring-provisions

2.2.1.1 Process Details

Emission Point Reference	Date(s)	Process Type	Process[10] Duration	Fuel	Abatement	Load
A1	02/09/2014	Gas Turbine	Continuous	Gas	None	8 to 45 tones/hour
A2	03/09/2014	HP Boiler	Continuous	Gas	None	15 to 35 tones/hour
A3	04/09/2014	Gas Turbine	Continuous	Gas	None	8 to 45 tones/hour

Substance to be Monitored	CEM Zero & Span						
	Zero	[11]Concentration	Span	Concentration	[12]Type	[13]Frequency	Time(s)
Oxides of Nitrogen as (NO)	Y	0 ppm	Y	197 ppm	Reference Gas	Monthly	Variable
Carbon Monoxide	Y	0 ppm	Y	197.5 ppm	Reference Gas	Monthly	Variable
Oxygen (Dry)	Y	0 %Vol	Y	20.9 %Vol	Ambient Air	Monthly	Variable

10 Please state continuous or batch process
11 This value is typically zero, although for some analysers, it may be a low concentration value.
12 Indicate reference gas, gas filled cell, filter, other (specify).
13 Indicate daily, fortnightly, monthly etc.

2.2.1.2 Historical Data Analysis and Expected Process Variation

Substance to be Monitored	Duration of Data Analysed (hours)	Daily ELV	Mean Hourly Averaged Value	Maximum Hourly Averaged Value	Minimum Hourly Averaged Value	Variation >30% ELV?	Standard Deviation of Hourly Averaged Value
Nitrogen Monoxide (NO)	18 hours	125 mg/m^3	30.85 mg/m^3	40.59 mg/m^3	23.86 mg/m^3	NO	6.46 mg/m^3
Carbon Monoxide (CO)	18 hours	80 mg/m^3	14.14 mg/m^3	27.60 mg/m^3	0.86 mg/m^3	YES	8.96 mg/m^3
Oxygen (O_2)	18 hours	21 %Vol	12.52 %Vol	15.97 %Vol	8.12 %Vol	YES	3.24 %Vol

- NO and CO data is expressed at reference conditions 273K, 101.3kPa, 15% Oxygen, Dry Gas.
- O_2 data is expressed at reference conditions 273K, 101.3kPa, Dry Gas.
- The historical data is taken from the 2012 QAL2 on A1 HR001-A. The data for A2 & A3 has a very similar profile, i.e. limited process variation especially for NO.

2.2.2 Fuel Details

Emission Point Reference	Date(s)	Primary Fuel	Typical Operating Hours on Primary Fuel (as % of Total)	Secondary Fuel	Typical Operating Hours on Secondary Fuel (as % of Total)	Emissions Profile for Secondary Fuel Significantly Different?	Independent AST Required?
A1	02/09/2014	Gas	>95 %	Fuel Oil	< 5%	NO	NO
A2	03/09/2014	Gas	>95 %	Fuel Oil	< 5%	NO	NO
A3	04/09/2014	Gas	>95 %	Fuel Oil	< 5%	NO	NO

2.2.3 Type of Abatement and Effect on Emissions

Emission Point Reference	Abatement (eg. ESP, Bag Filter etc)	Effect on Emissions (if none state 'None')
A1, A2 & A3	NONE	NOT APPLICABLE

2.3 Monitoring provisions at the installation – Periodic Monitoring

2.3.1 Stack and Sampling Ports

HR-001A	A1
FB-001	A2
HR-001B	A3

Stack Shape	Circular
Dimensions (m)	A1 is 1.64m, A2 is 1.58m & A3 is 1.59m
Number of Sampling Ports	2 per stack
Orientation of sampling ports	90 degrees
Height of Ports from Sampling Platform (m)	1m
Sample platform width back from the sample port (m)	1m
Height of Platform from Ground Level (m)	11.9m
Details of access to sampling platform	Two vertical ladders A1, A2 & A3 share one common platform

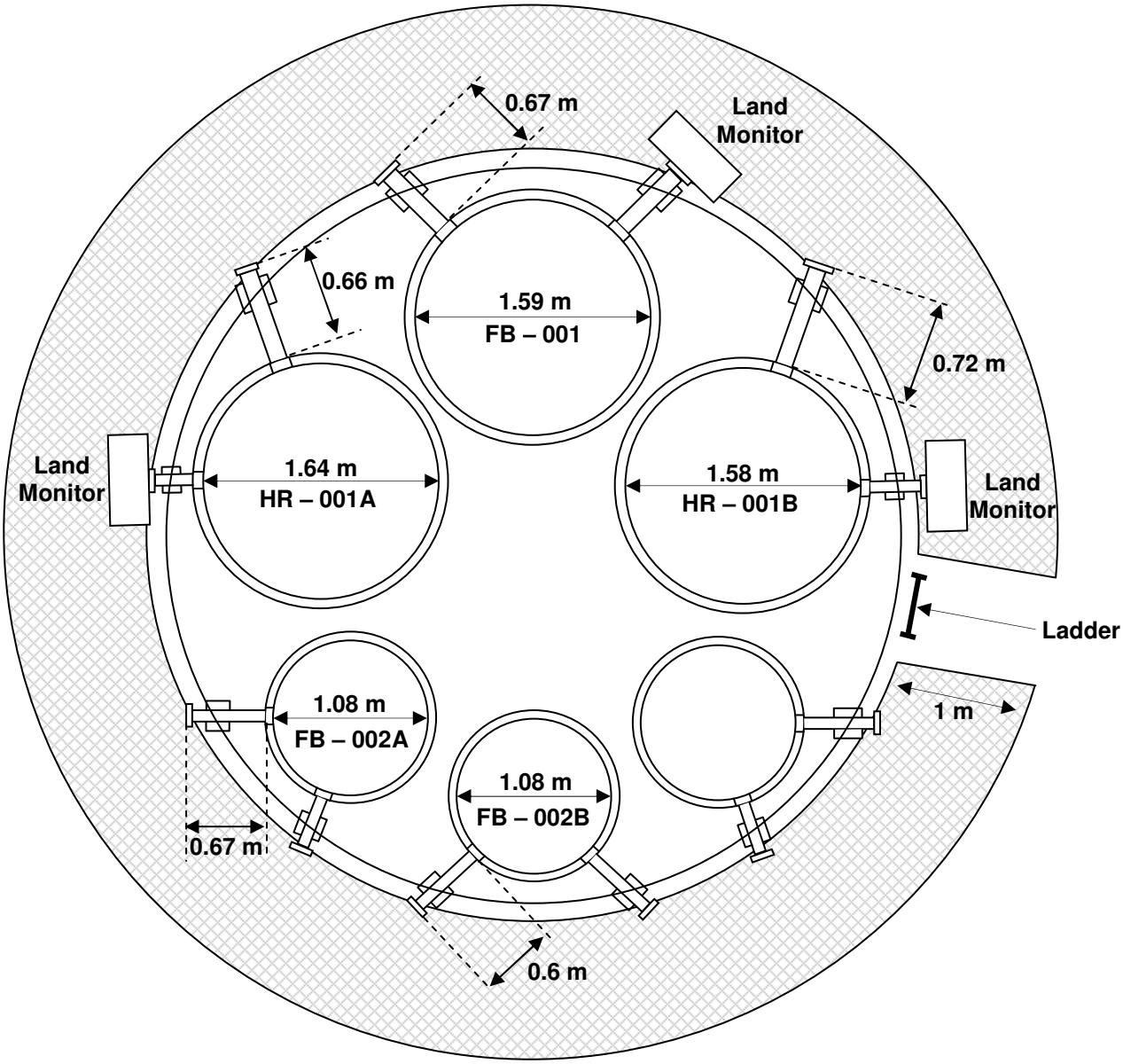


Figure 1. Diagram of sampling location

2.3.2 Monitoring platform and site-provisions inc details on grid sampling (where apt)

Test Component	Yes	No	Notes
Safe and clean working environment with sufficient space and weather protection?	✓		CEMs on platform but weather protected
Easy and safe access to all elements of the CEM	✓		Ok
Adequate supplies of reference materials, tools and spare parts	✓		Available in office
Facilities to introduce the reference materials for gaseous-monitoring systems are available both at the inlet of the sampling line (where present), and at the inlet of the CEM?	✓		Lines running up from ground level
Has homogeneity at the sample plane been determined for all measured components? If yes, state date and report ref in 'Notes.'	✓		See report JCC7671/R/10/81184/05
Does the sampling platform currently meet the requirements detailed in MID 15259 & *Technical Guidance Note (Monitoring) M1"Sampling requirements for stack-emission monitoring" Environment Agency,*	✓		Small platform dimensions but sufficient for combustion gas sampling
Was grid sampling undertaken (if Yes, state ratio of highest to lowest flowrates in 'Notes'		✓	Not applicable

2.4 Continuous Emission Monitoring Systems (CEMs) at the Installation

2.4.1 Details of CEM for each Regulated Determinand

Substance to be monitored	Instrument				Instrument Auto - Calibration[14]		Upper limit of		Minimum Certified Range Meets QAL1 Multiplier[15] Rule?
	Type (e.g. cross-duct, in-situ or extractive)	Brand	Model	Measurement Principle	Zero	Span	Certified Range	Operational Range	
Oxides of Nitrogen as (NO)	Extractive	LAND	FGA950E	Electrochemical Cell	Y	Y	[16] 0 – 200 mg/m^3	0 – 400 mg/m^3	Y
Carbon Monoxide	Extractive	LAND	FGA950E	Electrochemical Cell	Y	Y	[17] 0 – 150 mg/m^3	0 – 300 mg/m^3	Y

2.4.2 Details of CEM for each Peripheral Determinand

Substance to be monitored	Measured & Recorded?	Instrument				Instrument Auto - Calibration[14]		Upper limit of	
		Type	Brand	Model	Measurement Principle	Zero	Span	Certified Range	Operational Range
Oxygen (Dry)	Yes	Extractive	LAND	FGA950E	Electrochemical Cell	Y	Y	[18] 0 – 12 %Vol	0 – 25 %Vol
Oxygen (Wet)	No	Not applicable							
Moisture	No								
Temperature	No								
Pressure	No								

[14] Measured data pairs recorded during automatic zero and span operations are not included in the valid time averaged data used to calculate the ongoing validity of the QAL2 calibration functions.
[15] Typically, minimum certified range should not exceed 1.5 X Daily ELV for WID sites and 2.5 X Daily ELV for LCPD sites.
[16] Certified range is the lowest quoted on from certificate no. Sira MC 040019/04. This certificate has now expired but please note that the instruments on-site are still valid as they were manufactured before 15/02/2014.
[17] Certified range is the lowest quoted on from certificate no. Sira MC 040019/04. This certificate has now expired but please note that the instruments on-site are still valid as they were manufactured before 15/02/2014.
[18] Certified range is the lowest quoted on from certificate no. Sira MC 040019/04. This certificate has now expired but please note that the instruments on-site are still valid as they were manufactured before 15/02/2014.

3.0 Monitoring Campaign

3.1 Site Team Details

Name	Dates on Site	MCERTS Number	LEVEL	TE	Expiry Date
Mike Mullett	1st to 5th September 2014	MM 05 683	2	TE1	30.06.17
				TE2	31.03.15
				TE3	30.09.17
				TE4	30.06.19

Name	Dates on Site	MCERTS Number	LEVEL	TE	Expiry Date
Ian Hick	1st and 5th September 2014 only	MM 12 1192	1	TE1	…
				TE2	…
				TE3	…
				TE4	…

TE1 – **Isokinetic** Particulates, Oxygen, Moisture, Temperature & Velocity Profiles.
TE2 – **Isokinetic** Extractive Pollutants:- Metals, Dioxin & Furans, PAHs, PCBs, HCl, HF.
TE3 – **Non-Isokinetic** Extractive Pollutants:- Speciated VOCs, HF, HCl, Cyanide.
TE4 – **Continuous Analysers** (Combustion Gases):- VOCs, CO, NOx, SO_2, O_2.

3.2 Standard Reference Methods (SRMs)

Substance to be monitored	Instrument	Measurement Principle	Reference	Operational Range	Minimum Certified Range	Expanded Uncertainty @ 95% Confidence	UKAS Accreditation For Method?	Tick if non-conforming test (see Section 1C)
Oxides of Nitrogen as (NO)	Horiba PG250	Chemiluminescence	BS EN 14792: 2005	…	0 – 125mg/m^3	[19] 3%	YES	
Carbon Monoxide	Horiba PG250	NDIR	BS EN 15058: 2006	…..	0 – 95mg/m^3	[20] 4%	YES	
Oxygen	Horiba PG250	Zirconia Cell	BS EN 14789:2005	…..	0 – 25%	[21] 2%	YES	

[19] Based on an applied span of 260.02 mg/m^3 at 273K, 101.3 kPa, Dry Gas.
[20] Based on an applied span of 129.78 mg/m^3 at 273K, 101.3 kPa, Dry Gas.
[21] Based on an applied span of 15.44 %Vol at 273K, 101.3 kPa, Dry Gas.

3.3 Introduction

Environmental Compliance Ltd (ECL) was commissioned by **Cofely (GDF Suez)** to undertake an Annual Surveillance Test (AST) on the of their plant located at **Cofely CHP Site**, **Dow Corning Gate 7**, **Wimborne Road**, **Dock No.2, Barry**, **CF63 3DH.** This report presents the findings of the study.

The AST testing was carried out by the site sampling team detailed in the table below at the request of **Paul Gardner** in accordance with quotation reference **MM/P2099/Q001.**

Report Reviewer

Name	MCERTS Number	LEVEL	TE	Expiry Date
David Boles	MM 03 215	2	TE1	30.09.18
			TE2	31.03.15
			TE3	30.09.17
			TE4	30.06.19

Technical Endorsement Key:-

TE1 – Isokinetic Particulates, Oxygen, Moisture, Temperature & Velocity Profiles.
TE2 – Isokinetic Extractive Pollutants:- Metals, Dioxin & Furans, PAHs, PCBs, HCl, HF.
TE3 – Non-Isokinetic Extractive Pollutants:- Speciated VOCs, HF, HCl, Cyanide.
TE4 – Continuous Analysers (Combustion Gases):- VOCs, CO, NOx, SO_2, O_2.

3.4 Objectives

The objective of the survey was to record parallel measurements of the concentrations of pollutants from the processes / locations, as detailed in the Executive Summary, using the in-situ Continuous Emissions Monitoring System (CEM) and a suitable Standard Reference Method (SRM).

Sampling is carried out over a minimum of 1 day with the sampling period spread evenly over the entire test day. Typically, a minimum of eight hours of data is collected over the test day unless limited by the process duration.

Parallel measurements made for the purpose of AST testing were subsequently analysed in accordance with the requirements of BS EN 14181 & MID, and the Environment Agency's Technical Guidance Note M20 in order to determine the ongoing validity of the calibration function and valid calibration range, derived during the previous QAL2, for each measured determinand.

3.5 Sampling Protocols / Methodologies

Any required modifications to the Technical Procedure Documents (TPDs) specified below will be detailed in section 1C of this report.

3.5.1 Combustion Gases (NO, CO & O_2)

Measurements of combustion gases were carried out using an MCERTS Certified Horiba PG 250 portable stack analyser. Continuous monitoring of emissions was undertaken over each test period recording minute averaged data (one measurement every 60 seconds). The measurement techniques for each determinand are as follows:

Determinand	Technique	SRM
• NO	Chemiluminescence	BS EN 14792: 2005
• CO	Non dispersive infrared	BS EN 15058: 2006
• O_2	Galvanic / Zirconia	BS EN 14789: 2005

The analyser was set up with reference to the manufacturers operator handbook and the in-house technical procedure **ECL/TPD/033c**. The analyser was calibrated on site using certified gases which are traceable to ISO 17025. (with uncertainty $<2\%$). Zero measurements were performed using Nitrogen. The analyser was calibrated directly into the sample inlet and then checked through the entire sampling system (including sampling probe, heated & unheated gas transport lines and gas drying/ conditioning system).

4B MONITORING DATA & CALCULATIONS

A1 HR-001A

B4.1a & B4.2a
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for NO A1

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
02/09/2014	09:31 - 10:30	24.72	-	-	-	-	33.10
02/09/2014	10:31 - 11:30	24.80	-	-	-	-	33.20
02/09/2014	11:31 - 12:30	25.08	-	-	-	-	33.58
02/09/2014	12:31 - 13:30	25.45	-	-	-	-	34.08
02/09/2014	13:31 - 14:30	25.36	-	-	-	-	33.95
02/09/2014	14:31 - 15:30	25.32	-	-	-	-	33.90

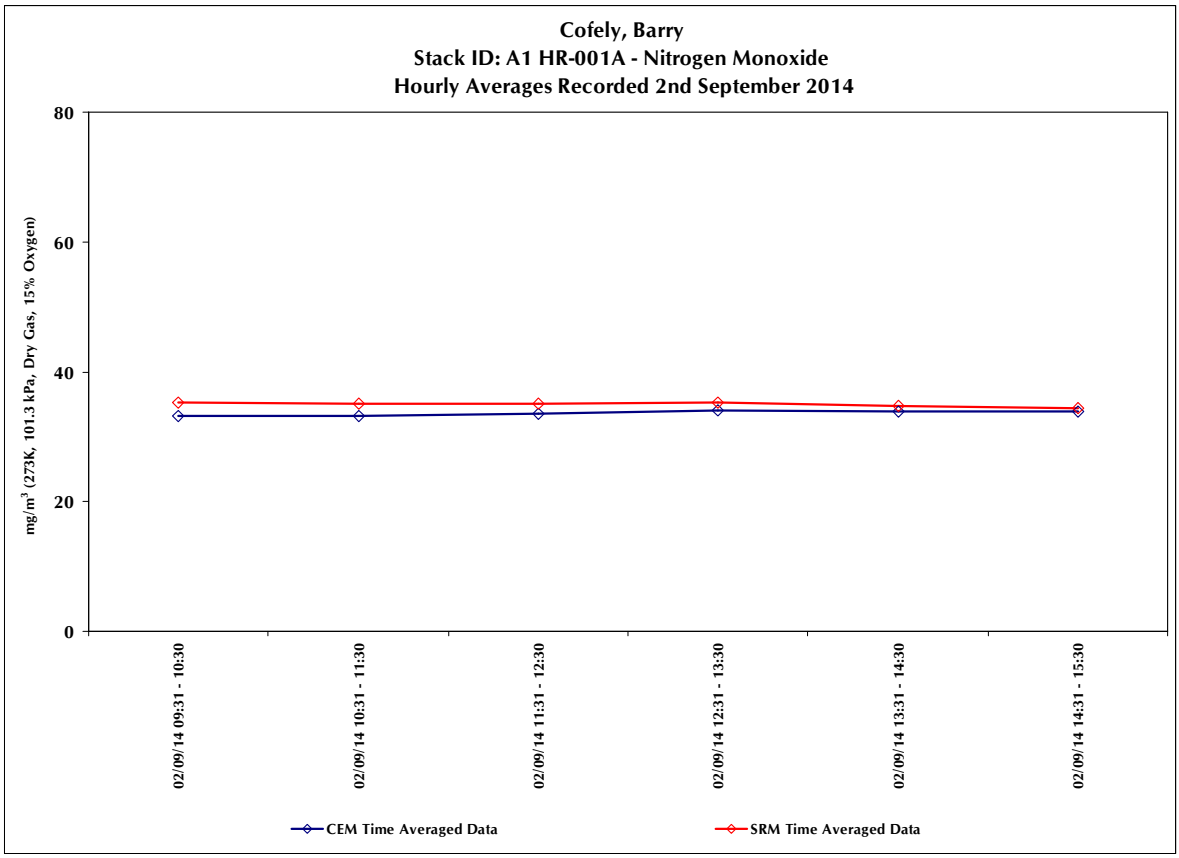
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
02/09/2014	09:31 - 10:30	26.39	-	-	-	-	35.33
02/09/2014	10:31 - 11:30	26.21	-	-	-	-	35.10
02/09/2014	11:31 - 12:30	26.20	-	-	-	-	35.08
02/09/2014	12:31 - 13:30	26.33	-	-	-	-	35.26
02/09/2014	13:31 - 14:30	25.90	-	-	-	-	34.67
02/09/2014	14:31 - 15:30	25.67	-	-	-	-	34.37

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3a
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for NO A1



B4.4a
Calculation and procedure – Elimination of outliers for NO A1

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	02/09/2014	09:31 - 10:30	26.39	24.72	1.67	0.67	YES
2	02/09/2014	10:31 - 11:30	26.21	24.80	1.41	0.42	YES
3	02/09/2014	11:31 - 12:30	26.20	25.08	1.12	0.13	YES
4	02/09/2014	12:31 - 13:30	26.33	25.45	0.88	0.12	YES
5	02/09/2014	13:31 - 14:30	25.90	25.36	0.54	0.45	YES
6	02/09/2014	14:31 - 15:30	25.67	25.32	0.35	0.65	YES

Slope	-0.45	**Mean**	1.00
Intercept	37.47	**Stdev**	0.5076
R^2	0.25		

B4.5a
Table 4.3 – data used to calculate calibrated values for NO A1

QAL2 Calibration function: y=1.0056x-0.9335								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
02/09/2014	09:31 - 10:30	24.72	23.92	-	-	-	-	32.03	35.33
02/09/2014	10:31 - 11:30	24.80	24.00	-	-	-	-	32.14	35.10
02/09/2014	11:31 - 12:30	25.08	24.29	-	-	-	-	32.52	35.08
02/09/2014	12:31 - 13:30	25.45	24.66	-	-	-	-	33.02	35.26
02/09/2014	13:31 - 14:30	25.36	24.56	-	-	-	-	32.89	34.67
02/09/2014	14:31 - 15:30	25.32	24.53	-	-	-	-	32.84	34.37

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6a & B4.7a
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for NO A1

Determinand: Nitrogen Monoxide — **QAL2 Calibration function: y=1.0056x-0.9335**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
33.10	35.33	32.03	35.33	33.10	32.03	3.30	0.91	0.82
33.20	35.10	32.14	35.10	33.20	32.14	2.96	0.56	0.32
33.58	35.08	32.52	35.08	33.58	32.52	2.56	0.17	0.028
34.08	35.26	33.02	35.26	34.08	33.02	2.24	-0.16	0.025
33.95	34.67	32.89	34.67	33.95	32.89	1.78	-0.61	0.37
33.90	34.37	32.84	34.37	33.90	32.84	1.52	-0.87	0.76
					Sum	14.37	0.00	2.32

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 2.39$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.46) = 0.68$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 20$$
$$E = 82$$

$$\sigma_0 = \frac{pE}{1.96} = 8.32$$

$$1.5\sigma_0 k_v = 11.64$$

$$s_D \le 1.5\sigma_0 k_v = 0.68 \text{ mg/m}^3 < 11.64 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

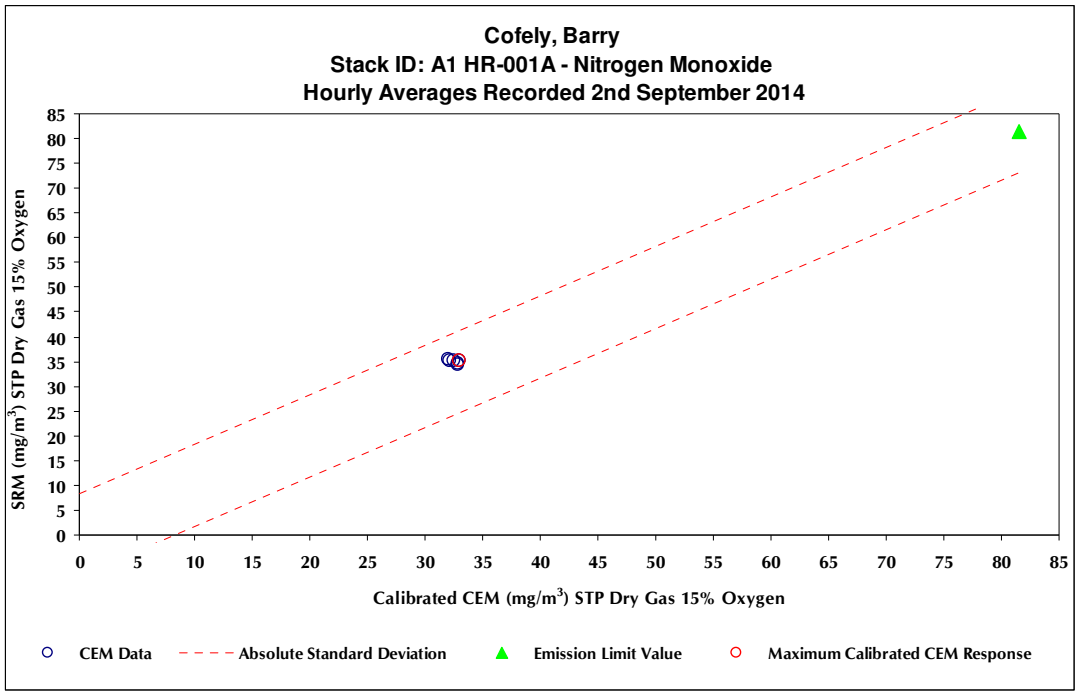
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 8.88$$

$$|\overline{D}| \quad 2.39\text{mg/m}^3 < 8.88\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8a
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for NO A1



B4.9a
Summary of the Valid Calibration Range for NO A1

Summary of Valid Calibration Range

Slope:	1.0056	...
Intercept:	-0.9335	mg/m^3
Daily ELV	81.52	mg/m^3
Allowable 95% Confidence Interval	± 8.32	mg/m^3
Upper Limit of Current Valid Calibration Range	57.88	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	33.02	mg/m^3
Corresponding SRM @ Reference Conditions	35.26	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	26.94 - 43.58	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1b & B4.2b
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for CO A1

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
02/09/2014	09:31 - 10:30	-0.10	-	-	-	-	-0.13
02/09/2014	10:31 - 11:30	0.02	-	-	-	-	0.03
02/09/2014	11:31 - 12:30	0.17	-	-	-	-	0.21
02/09/2014	12:31 - 13:30	0.35	-	-	-	-	0.43
02/09/2014	13:31 - 14:30	0.58	-	-	-	-	0.73
02/09/2014	14:31 - 15:30	0.33	-	-	-	-	0.42

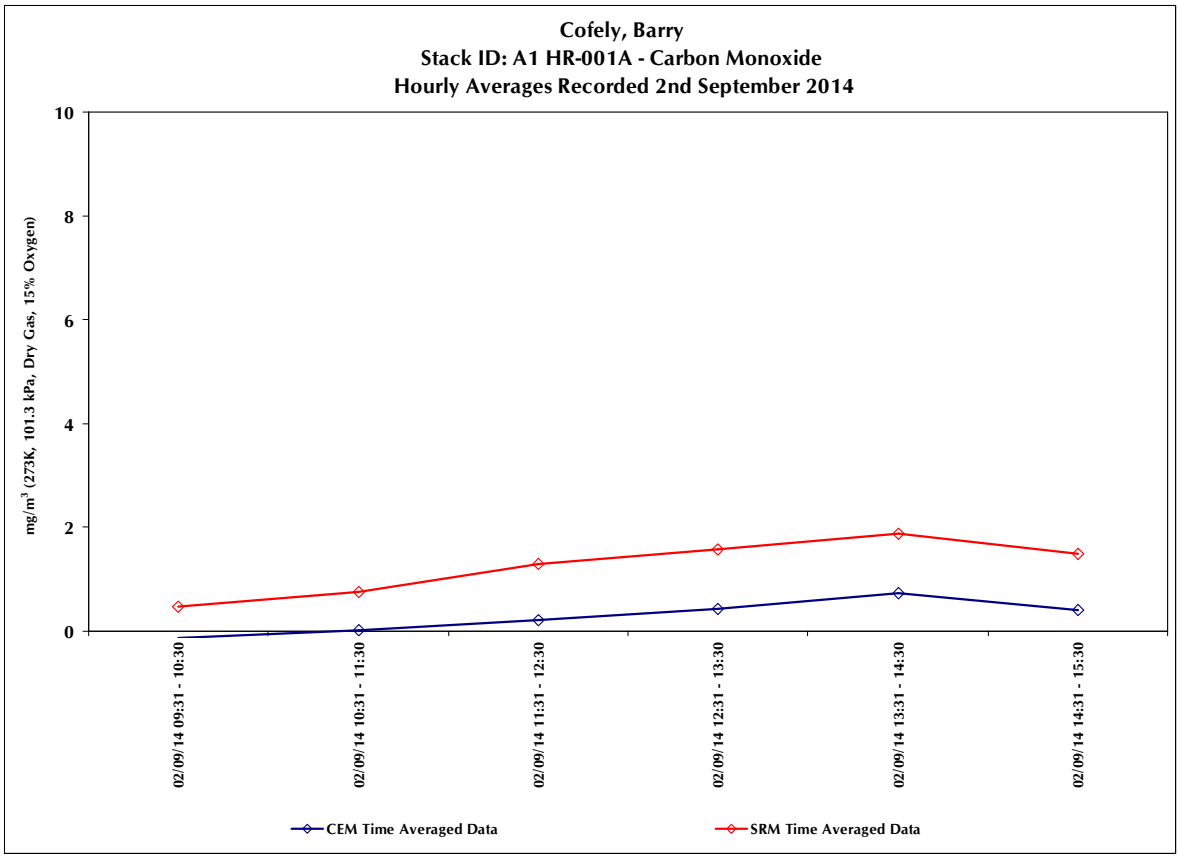
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
02/09/2014	09:31 - 10:30	0.37	-	-	-	-	0.46
02/09/2014	10:31 - 11:30	0.60	-	-	-	-	0.76
02/09/2014	11:31 - 12:30	1.04	-	-	-	-	1.30
02/09/2014	12:31 - 13:30	1.26	-	-	-	-	1.57
02/09/2014	13:31 - 14:30	1.51	-	-	-	-	1.88
02/09/2014	14:31 - 15:30	1.19	-	-	-	-	1.49

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3b
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for CO A1



B4.4b
Calculation and procedure – Elimination of outliers for CO A1

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	02/09/2014	09:31 - 10:30	0.37	-0.10	0.47	0.29	YES
2	02/09/2014	10:31 - 11:30	0.60	0.02	0.58	0.18	YES
3	02/09/2014	11:31 - 12:30	1.04	0.17	0.87	0.10	YES
4	02/09/2014	12:31 - 13:30	1.26	0.35	0.91	0.14	YES
5	02/09/2014	13:31 - 14:30	1.51	0.58	0.93	0.16	YES
6	02/09/2014	14:31 - 15:30	1.19	0.33	0.86	0.09	YES

Slope	1.69	**Mean**	0.77
Intercept	0.61	**Stdev**	0.1905
R^2	0.96		

B4.5b
Table 4.3 – data used to calculate calibrated values for CO A1

QAL2 Calibration function: y=1.0096x+0.3218								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
02/09/2014	09:31 - 10:30	-0.10	0.22	-	-	-	-	0.27	0.46
02/09/2014	10:31 - 11:30	0.02	0.34	-	-	-	-	0.43	0.76
02/09/2014	11:31 - 12:30	0.17	0.50	-	-	-	-	0.62	1.30
02/09/2014	12:31 - 13:30	0.35	0.67	-	-	-	-	0.84	1.57
02/09/2014	13:31 - 14:30	0.58	0.91	-	-	-	-	1.14	1.88
02/09/2014	14:31 - 15:30	0.33	0.66	-	-	-	-	0.82	1.49

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6b & B4.7b
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for CO A1

Determinand: Carbon Monoxide — **QAL2 Calibration function: y=1.0096x+0.3218**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
-0.13	0.46	0.27	0.46	-0.13	0.27	0.19	-0.36	0.13
0.03	0.76	0.43	0.76	0.03	0.43	0.33	-0.23	0.05
0.21	1.30	0.62	1.30	0.21	0.62	0.68	0.12	0.015
0.43	1.57	0.84	1.57	0.43	0.84	0.73	0.17	0.030
0.73	1.88	1.14	1.88	0.73	1.14	0.75	0.19	0.04
0.42	1.49	0.82	1.49	0.42	0.82	0.66	0.11	0.01
					Sum	3.34	0.00	0.28

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 0.56$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.06) = 0.24$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 10$$
$$E = 80$$

$$\sigma_0 = \frac{pE}{1.96} = 4.08$$

$$1.5\sigma_0 k_v = 5.71$$

$$s_D \le 1.5\sigma_0 k_v = 0.24 \text{ mg/m}^3 < 5.71 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

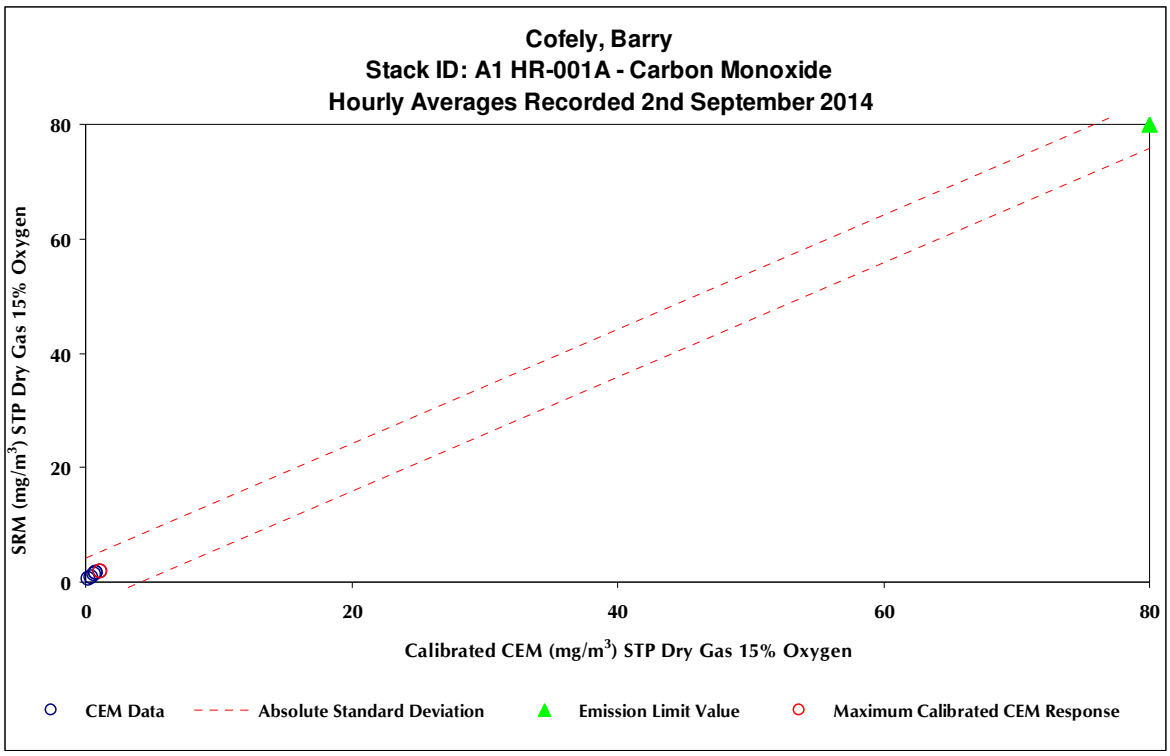
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 4.28$$

$$|\overline{D}| \quad 0.56\text{mg/m}^3 < 4.28\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8b
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for CO A1



B4.9b
Summary of the Valid Calibration Range for CO A1

Summary of Valid Calibration Range

Slope:	1.0096	...
Intercept:	0.3218	mg/m^3
Daily ELV	80.00	mg/m^3
Allowable 95% Confidence Interval	± 4.08	mg/m^3
Upper Limit of Current Valid Calibration Range	31.01	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	1.14	mg/m^3
Corresponding SRM @ Reference Conditions	1.88	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 4.08%	-2.2 - 5.97	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1c & B4.2c
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A1

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
02/09/2014	09:31 - 10:30	6.98	-	-	-	-	6.98
02/09/2014	10:31 - 11:30	7.49	-	-	-	-	7.49
02/09/2014	11:31 - 12:30	8.16	-	-	-	-	8.16
02/09/2014	12:31 - 13:30	8.58	-	-	-	-	8.58
02/09/2014	13:31 - 14:30	8.64	-	-	-	-	8.64
02/09/2014	14:31 - 15:30	8.39	-	-	-	-	8.39

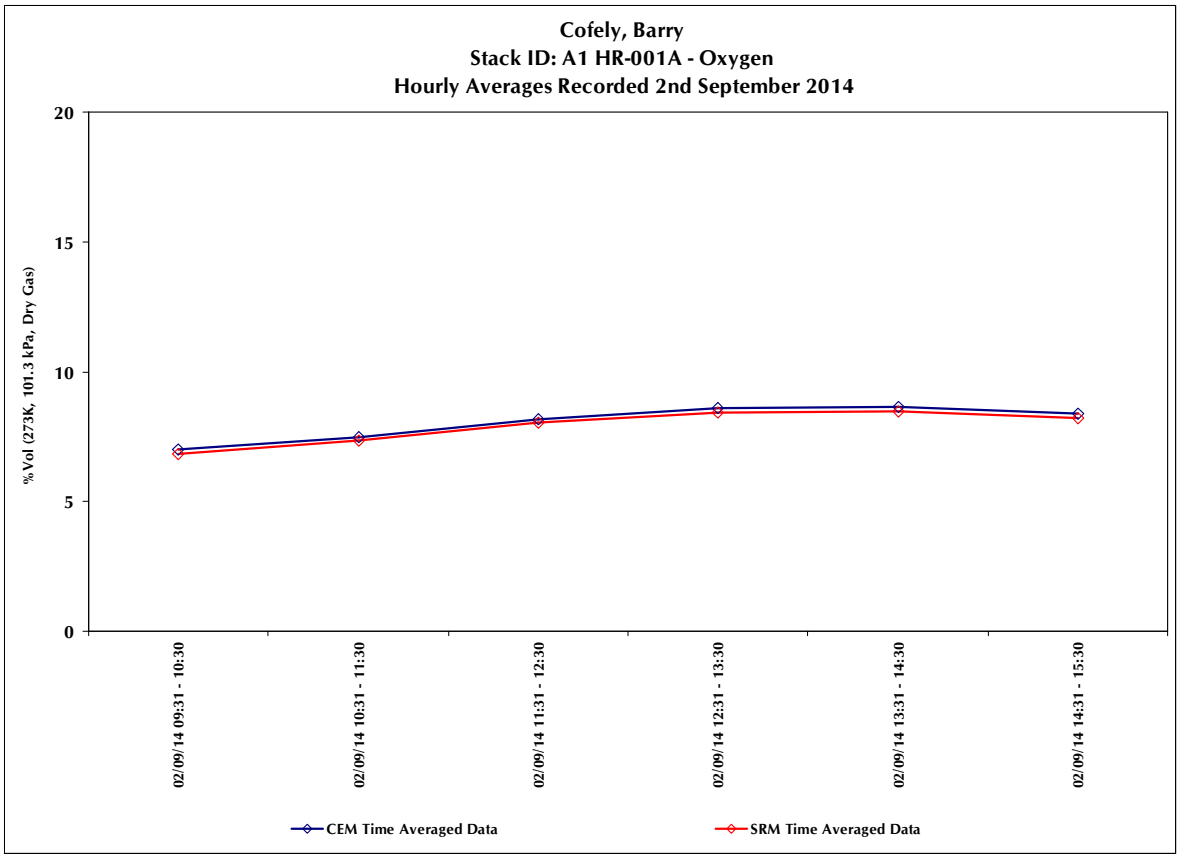
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages %Vol (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages %Vol (4)
02/09/2014	09:31 - 10:30	6.83	-	-	-	-	6.83
02/09/2014	10:31 - 11:30	7.34	-	-	-	-	7.34
02/09/2014	11:31 - 12:30	8.03	-	-	-	-	8.03
02/09/2014	12:31 - 13:30	8.44	-	-	-	-	8.44
02/09/2014	13:31 - 14:30	8.49	-	-	-	-	8.49
02/09/2014	14:31 - 15:30	8.22	-	-	-	-	8.22

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas

B4.3c
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for O2 A1



B4.4c
Calculation and procedure – Elimination of outliers for O2 A1

n	Date	Time	SRM % Vol	CEM % Vol	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	02/09/2014	09:31 - 10:30	6.83	6.98	-0.15	0.00	YES
2	02/09/2014	10:31 - 11:30	7.34	7.49	-0.15	0.00	YES
3	02/09/2014	11:31 - 12:30	8.03	8.16	-0.13	0.02	YES
4	02/09/2014	12:31 - 13:30	8.44	8.58	-0.14	0.01	YES
5	02/09/2014	13:31 - 14:30	8.49	8.64	-0.16	0.01	YES
6	02/09/2014	14:31 - 15:30	8.22	8.39	-0.17	0.02	YES

Slope	1.00	**Mean**	-0.15
Intercept	-0.14	**Stdev**	0.0157
R^2	1.00		

B4.5c
Table 4.3 – data used to calculate calibrated values for O2 A1

QAL2 Calibration function: y=1.0249x-0.4262								Standardised Data	
Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	CEM Hourly averages %Vol Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages %Vol Calibrated (2)	SRM Hourly averages %Vol (2)
02/09/2014	09:31 - 10:30	6.98	6.73	-	-	-	-	6.73	6.83
02/09/2014	10:31 - 11:30	7.49	7.25	-	-	-	-	7.25	7.34
02/09/2014	11:31 - 12:30	8.16	7.93	-	-	-	-	7.93	8.03
02/09/2014	12:31 - 13:30	8.58	8.37	-	-	-	-	8.37	8.44
02/09/2014	13:31 - 14:30	8.64	8.43	-	-	-	-	8.43	8.49
02/09/2014	14:31 - 15:30	8.39	8.17	-	-	-	-	8.17	8.22

(1) 273K, 101.3 kPa, Dry Gas
(2) 273K, 101.3 kPa, Dry Gas

B4.6c & B4.7c
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for O2 A1

Determinand: Oxygen — **QAL2 Calibration function: y=1.0249x-0.4262**

CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
6.98	6.83	6.73	6.83	6.98	6.73	0.10	0.02	0.00
7.49	7.34	7.25	7.34	7.49	7.25	0.09	0.02	0.00
8.16	8.03	7.93	8.03	8.16	7.93	0.10	0.02	0.000
8.58	8.44	8.37	8.44	8.58	8.37	0.07	-0.01	0.000
8.64	8.49	8.43	8.49	8.64	8.43	0.05	-0.02	0.00
8.39	8.22	8.17	8.22	8.39	8.17	0.04	-0.03	0.00
					Sum	0.45	0.00	0.00

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 0.08$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT(0)} = 0.02$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 10$$
$$E = 21$$

$$\sigma_0 = \frac{pE}{1.96} = 1.07$$

$$1.5\sigma_0 k_v = 1.50$$

$$s_D \leq 1.5\sigma_0 k_v = 0.02\ \%\text{Vol} < 1.5\ \%\text{Vol}$$ - Pass Variability Test

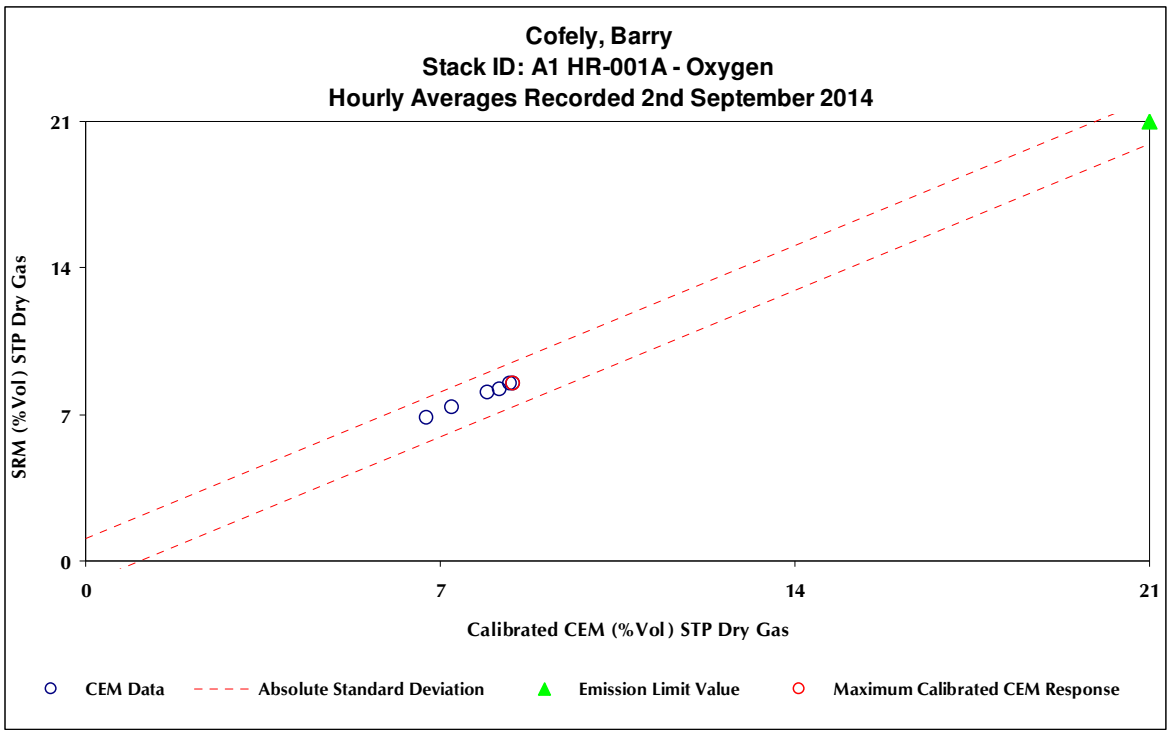
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 1.09$$

$$|\overline{D}|\ 0.08\%\text{Vol} < 1.09\%\text{Vol}$$ - Calibration Remains Valid

Reference Conditions 273K, 101.3 kPa, Dry Gas

B4.8c
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for O2 A1



B4.9c
Summary of the Valid Calibration Range for O2 A1

Summary of Valid Calibration Range

Slope:	1.0249	...
Intercept:	-0.4262	%Vol
Daily ELV	21.00	%Vol
Allowable 95% Confidence Interval	± 1.07	%Vol
Upper Limit of Current Valid Calibration Range	17.47	%Vol
Maximum Calibrated CEM @ Reference Conditions	8.43	%Vol
Corresponding SRM @ Reference Conditions	8.49	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	7.41 - 9.56	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	%Vol

A2 FB-001

B4.1a & B4.2a
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for NO A2

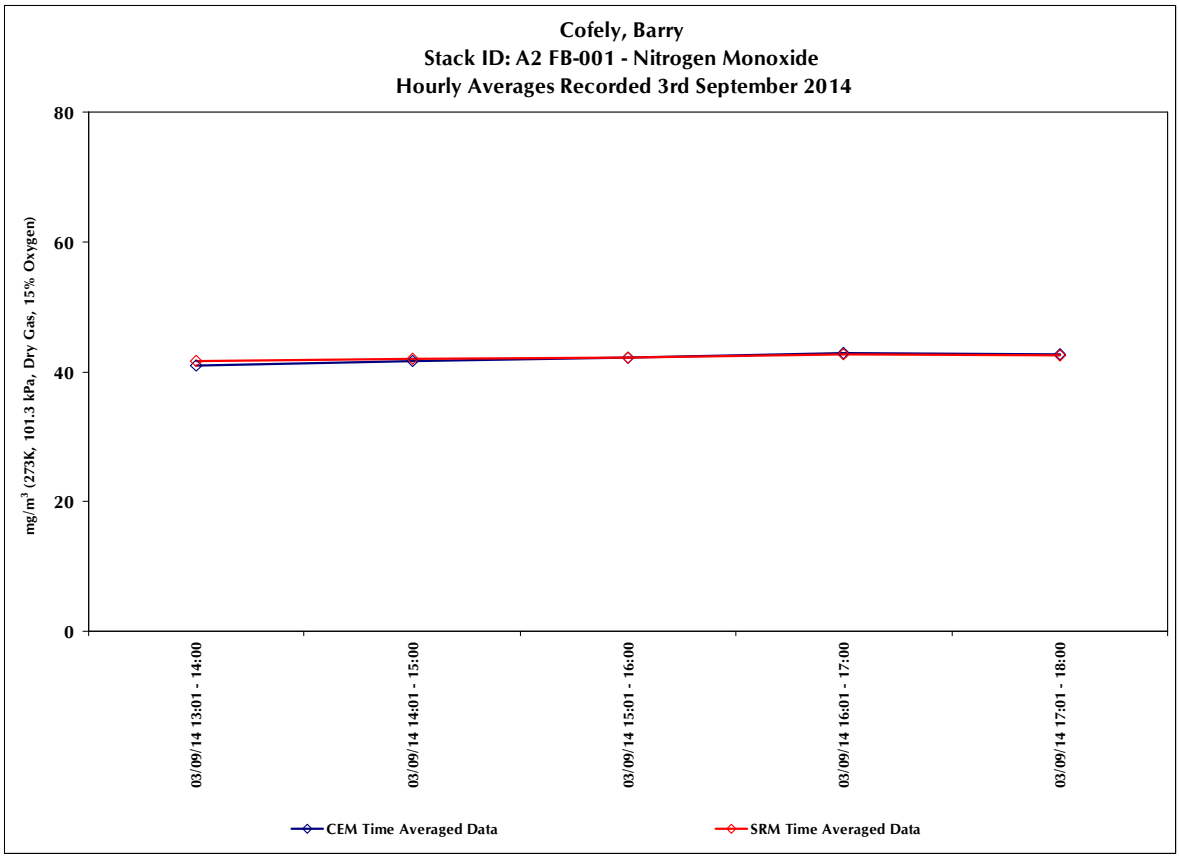
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
03/09/2014	13:01 - 14:00	30.64	-	-	-	-	41.03
03/09/2014	14:01 - 15:00	31.09	-	-	-	-	41.63
03/09/2014	15:01 - 16:00	31.47	-	-	-	-	42.14
03/09/2014	16:01 - 17:00	32.01	-	-	-	-	42.85
03/09/2014	17:01 - 18:00	31.88	-	-	-	-	42.68

(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data							Standardised Data
Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
03/09/2014	13:01 - 14:00	31.12	-	-	-	-	41.67
03/09/2014	14:01 - 15:00	31.34	-	-	-	-	41.96
03/09/2014	15:01 - 16:00	31.46	-	-	-	-	42.13
03/09/2014	16:01 - 17:00	31.87	-	-	-	-	42.68
03/09/2014	17:01 - 18:00	31.70	-	-	-	-	42.45

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3a
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for NO A2



B4.4a
Calculation and procedure – Elimination of outliers for NO A2

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	03/09/2014	13:01 - 14:00	31.12	30.64	0.48	0.40	YES
2	03/09/2014	14:01 - 15:00	31.34	31.09	0.25	0.17	YES
3	03/09/2014	15:01 - 16:00	31.46	31.47	-0.01	0.09	YES
4	03/09/2014	16:01 - 17:00	31.87	32.01	-0.13	0.22	YES
5	03/09/2014	17:01 - 18:00	31.70	31.88	-0.18	0.26	YES

Slope	0.52	**Mean**	0.08
Intercept	15.26	**Stdev**	0.2767
R^2	0.97		

B4.5a
Table 4.3 – data used to calculate calibrated values for NO A2

QAL2 Calibration function: y=0.9141x+0.0091								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
03/09/2014	13:01 - 14:00	30.64	28.02	-	-	-	-	37.52	41.67
03/09/2014	14:01 - 15:00	31.09	28.43	-	-	-	-	38.06	41.96
03/09/2014	15:01 - 16:00	31.47	28.78	-	-	-	-	38.53	42.13
03/09/2014	16:01 - 17:00	32.01	29.26	-	-	-	-	39.19	42.68
03/09/2014	17:01 - 18:00	31.88	29.15	-	-	-	-	39.03	42.45

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6a & B4.7a
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for NO A2

Determinand: Nitrogen Monoxide — **QAL2 Calibration function: y=0.9141x+0.0091**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
41.03	41.67	37.52	41.67	41.03	37.52	4.15	0.44	0.20
41.63	41.96	38.06	41.96	41.63	38.06	3.90	0.18	0.03
42.14	42.13	38.53	42.13	42.14	38.53	3.60	-0.11	0.013
42.85	42.68	39.19	42.68	42.85	39.19	3.49	-0.22	0.049
42.68	42.45	39.03	42.45	42.68	39.03	3.42	-0.29	0.09
					Sum	18.56	0.00	0.38

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 3.71$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.09) = 0.31$$

$$N = 5$$
$$K_v = 0.92$$
$$p = 20$$
$$E = 82$$

$$\sigma_0 = \frac{pE}{1.96} = 8.32$$

$$1.5\sigma_0 k_v = 11.43$$

$$s_D \le 1.5\sigma_0 k_v = 0.31 \text{ mg/m}^3 < 11.43 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

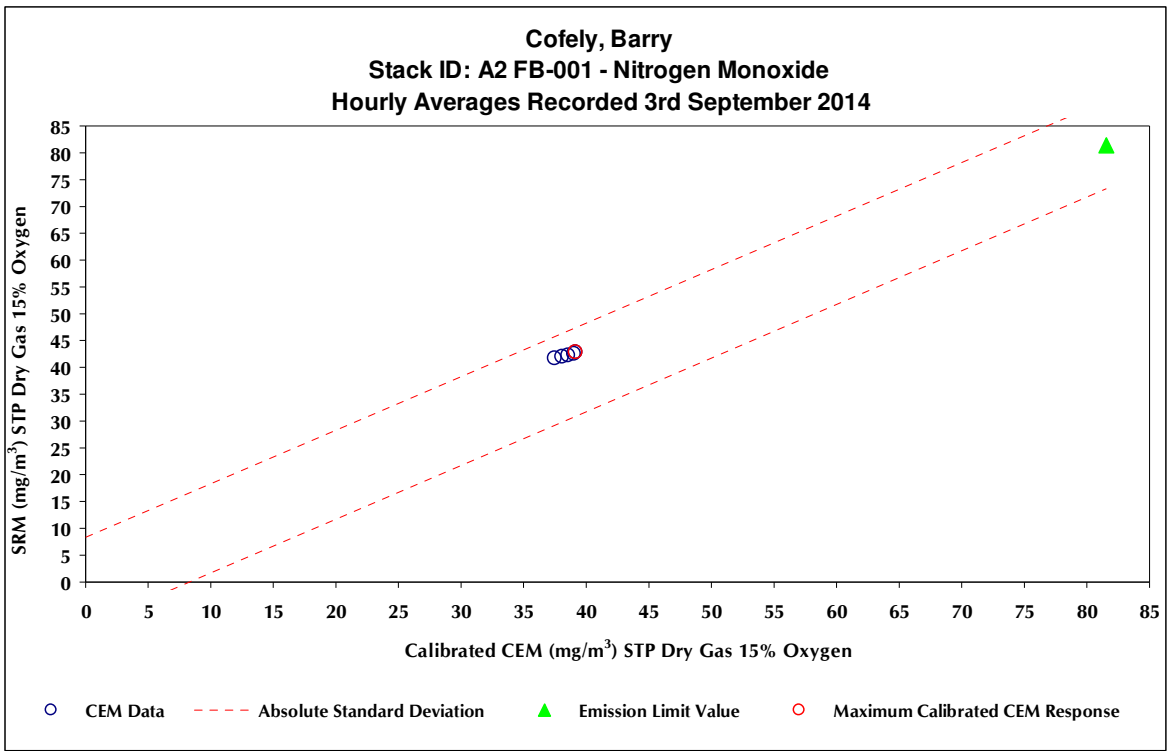
$$t_{0.95}(N-1) = 2.13$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 8.61$$

$$\left|\overline{D}\right| \quad 3.71\text{mg/m}^3 < 8.61\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8a
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for NO A2



B4.9a
Summary of the Valid Calibration Range for NO A2

Summary of Valid Calibration Range

Slope:	0.9141	...
Intercept:	0.0091	mg/m^3
Daily ELV	81.52	mg/m^3
Allowable 95% Confidence Interval	± 8.32	mg/m^3
Upper Limit of Current Valid Calibration Range	51.32	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	39.19	mg/m^3
Corresponding SRM @ Reference Conditions	42.68	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	34.36 - 51	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1b & B4.2b
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for CO A2

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
03/09/2014	13:01 - 14:00	1.14	-	-	-	-	1.42
03/09/2014	14:01 - 15:00	0.47	-	-	-	-	0.58
03/09/2014	15:01 - 16:00	0.09	-	-	-	-	0.11
03/09/2014	16:01 - 17:00	-0.18	-	-	-	-	-0.22
03/09/2014	17:01 - 18:00	-0.19	-	-	-	-	-0.23

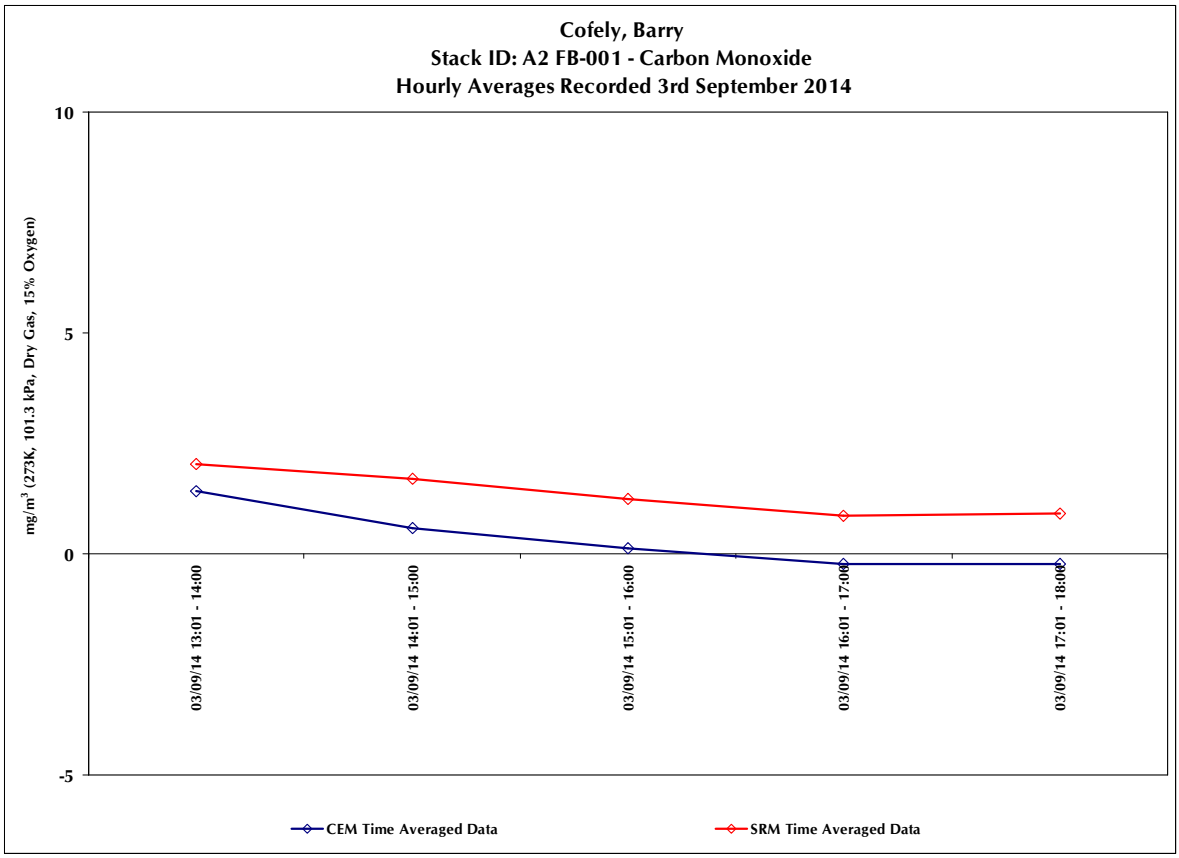
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
03/09/2014	13:01 - 14:00	1.63	-	-	-	-	2.04
03/09/2014	14:01 - 15:00	1.36	-	-	-	-	1.70
03/09/2014	15:01 - 16:00	0.99	-	-	-	-	1.24
03/09/2014	16:01 - 17:00	0.70	-	-	-	-	0.87
03/09/2014	17:01 - 18:00	0.73	-	-	-	-	0.92

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3b
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for CO A2



B4.4b
Calculation and procedure – Elimination of outliers for CO A2

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	03/09/2014	13:01 - 14:00	1.63	1.14	0.49	0.32	YES
2	03/09/2014	14:01 - 15:00	1.36	0.47	0.89	0.08	YES
3	03/09/2014	15:01 - 16:00	0.99	0.09	0.90	0.08	YES
4	03/09/2014	16:01 - 17:00	0.70	-0.18	0.87	0.06	YES
5	03/09/2014	17:01 - 18:00	0.73	-0.19	0.92	0.10	YES

Slope	0.71	**Mean**	0.82
Intercept	0.89	**Stdev**	0.1810
R^2	0.95		

B4.5b
Table 4.3 – data used to calculate calibrated values for CO A2

QAL2 Calibration function: y=1.0552x+0.1111								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
03/09/2014	13:01 - 14:00	1.14	1.31	-	-	-	-	1.64	2.04
03/09/2014	14:01 - 15:00	0.47	0.60	-	-	-	-	0.75	1.70
03/09/2014	15:01 - 16:00	0.09	0.21	-	-	-	-	0.26	1.24
03/09/2014	16:01 - 17:00	-0.18	-0.08	-	-	-	-	-0.09	0.87
03/09/2014	17:01 - 18:00	-0.19	-0.08	-	-	-	-	-0.11	0.92

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6b & B4.7b
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for CO A2

Determinand: Carbon Monoxide — **QAL2 Calibration function: y=1.0552x+0.1111**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
1.42	2.04	1.64	2.04	1.42	1.64	0.40	-0.46	0.21
0.58	1.70	0.75	1.70	0.58	0.75	0.95	0.09	0.01
0.11	1.24	0.26	1.24	0.11	0.26	0.98	0.11	0.013
-0.22	0.87	-0.09	0.87	-0.22	-0.09	0.97	0.10	0.011
-0.23	0.92	-0.11	0.92	-0.23	-0.11	1.02	0.16	0.03
					Sum	4.31	0.00	0.27

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 0.86$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.07) = 0.26$$

$$N = 5$$
$$K_v = 0.92$$
$$p = 10$$
$$E = 80$$

$$\sigma_0 = \frac{pE}{1.96} = 4.08$$

$$1.5\sigma_0 k_v = 5.61$$

$$s_D \leq 1.5\sigma_0 k_v = 0.26 \text{ mg/m}^3 < 5.61 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

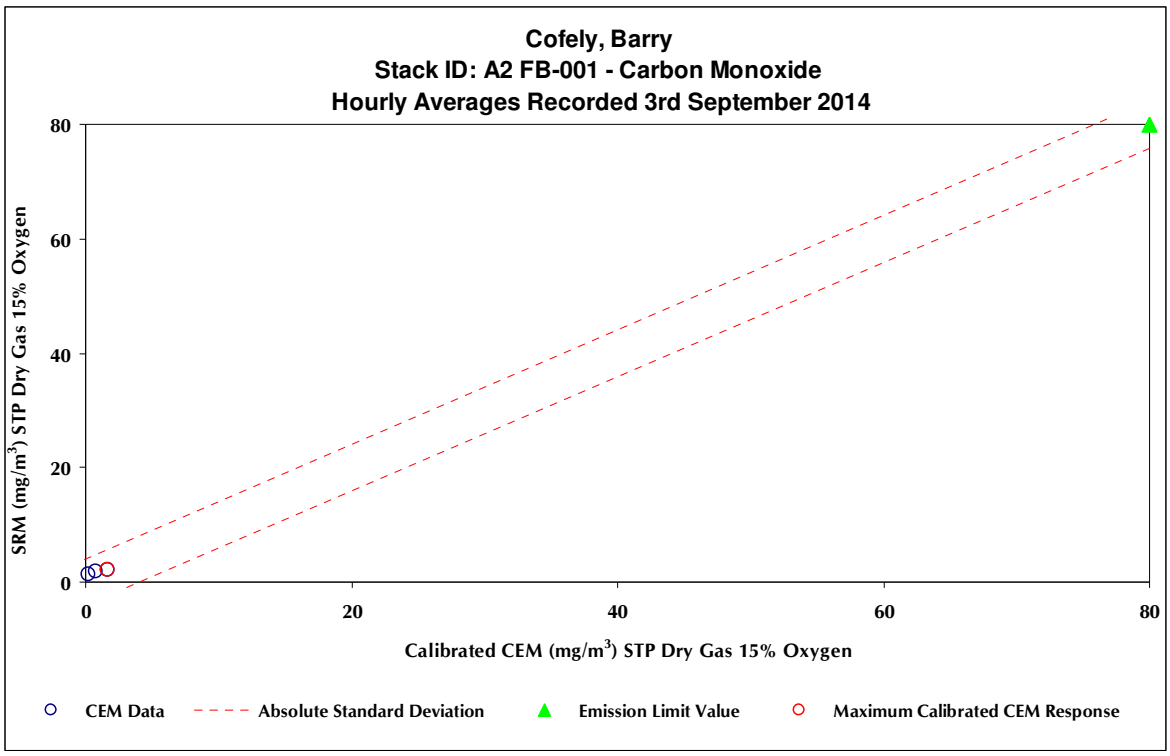
$$t_{0.95}(N-1) = 2.13$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 4.33$$

$$|\overline{D}| \quad 0.86\text{mg/m}^3 < 4.33\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8b
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for CO A2



B4.9b
Summary of the Valid Calibration Range for CO A2

Summary of Valid Calibration Range

Slope:	1.0552	...
Intercept:	0.1111	mg/m^3
Daily ELV	80.00	mg/m^3
Allowable 95% Confidence Interval	± 4.08	mg/m^3
Upper Limit of Current Valid Calibration Range	22.59	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	1.64	mg/m^3
Corresponding SRM @ Reference Conditions	2.04	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 4.08%	-2.04 - 6.12	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1c & B4.2c
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A2

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
03/09/2014	13:01 - 14:00	8.20	-	-	-	-	8.20
03/09/2014	14:01 - 15:00	8.00	-	-	-	-	8.00
03/09/2014	15:01 - 16:00	8.02	-	-	-	-	8.02
03/09/2014	16:01 - 17:00	7.78	-	-	-	-	7.78
03/09/2014	17:01 - 18:00	7.89	-	-	-	-	7.89

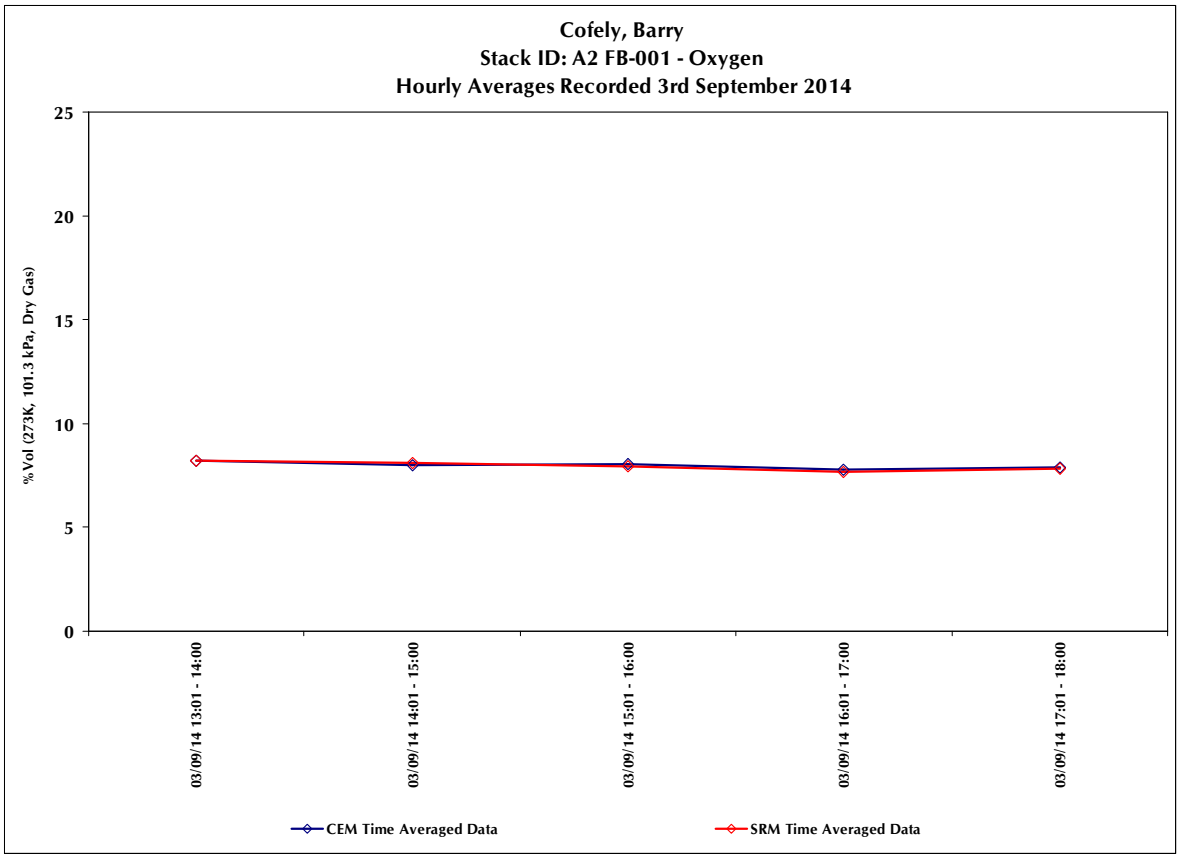
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages %Vol (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages %Vol (4)
03/09/2014	13:01 - 14:00	8.19	-	-	-	-	8.19
03/09/2014	14:01 - 15:00	8.08	-	-	-	-	8.08
03/09/2014	15:01 - 16:00	7.96	-	-	-	-	7.96
03/09/2014	16:01 - 17:00	7.68	-	-	-	-	7.68
03/09/2014	17:01 - 18:00	7.81	-	-	-	-	7.81

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas

B4.3c
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for O2 A2



B4.4c
Calculation and procedure – Elimination of outliers for O2 A2

n	Date	Time	SRM % Vol	CEM % Vol	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	03/09/2014	13:01 - 14:00	8.19	8.20	-0.01	0.02	YES
2	03/09/2014	14:01 - 15:00	8.08	8.00	0.08	0.11	YES
3	03/09/2014	15:01 - 16:00	7.96	8.02	-0.06	0.02	YES
4	03/09/2014	16:01 - 17:00	7.68	7.78	-0.10	0.06	YES
5	03/09/2014	17:01 - 18:00	7.81	7.89	-0.08	0.05	YES

Slope	1.25	**Mean**	-0.03
Intercept	-2.01	**Stdev**	0.0705
R^2	0.92		

B4.5c
Table 4.3 – data used to calculate calibrated values for O2 A2

QAL2 Calibration function: y=0.9788x+0.0098								Standardised Data	
Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	CEM Hourly averages %Vol Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages %Vol Calibrated (2)	SRM Hourly averages %Vol (2)
03/09/2014	13:01 - 14:00	8.20	8.03	-	-	-	-	8.03	8.19
03/09/2014	14:01 - 15:00	8.00	7.84	-	-	-	-	7.84	8.08
03/09/2014	15:01 - 16:00	8.02	7.86	-	-	-	-	7.86	7.96
03/09/2014	16:01 - 17:00	7.78	7.62	-	-	-	-	7.62	7.68
03/09/2014	17:01 - 18:00	7.89	7.73	-	-	-	-	7.73	7.81

(1) 273K, 101.3 kPa, Dry Gas
(2) 273K, 101.3 kPa, Dry Gas

B4.6c & B4.7c
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for O2 A2

Determinand: Oxygen — **QAL2 Calibration function: y=0.9788x+0.0098**

CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
8.20	8.19	8.03	8.19	8.20	8.03	0.15	0.03	0.00
8.00	8.08	7.84	8.08	8.00	7.84	0.24	0.11	0.01
8.02	7.96	7.86	7.96	8.02	7.86	0.10	-0.02	0.001
7.78	7.68	7.62	7.68	7.78	7.62	0.06	-0.07	0.005
7.89	7.81	7.73	7.81	7.89	7.73	0.08	-0.05	0.00
					Sum	0.63	0.00	0.02

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 0.13$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.01) = 0.07$$

$N = 5$
$K_v = 0.92$
$p = 10$
$E = 21$

$$\sigma_0 = \frac{pE}{1.96} = 1.07$$

$$1.5\sigma_0 k_v = 1.47$$

$s_D \le 1.5\sigma_0 k_v =$ 0.07 %Vol < 1.47 %Vol - Pass Variability Test

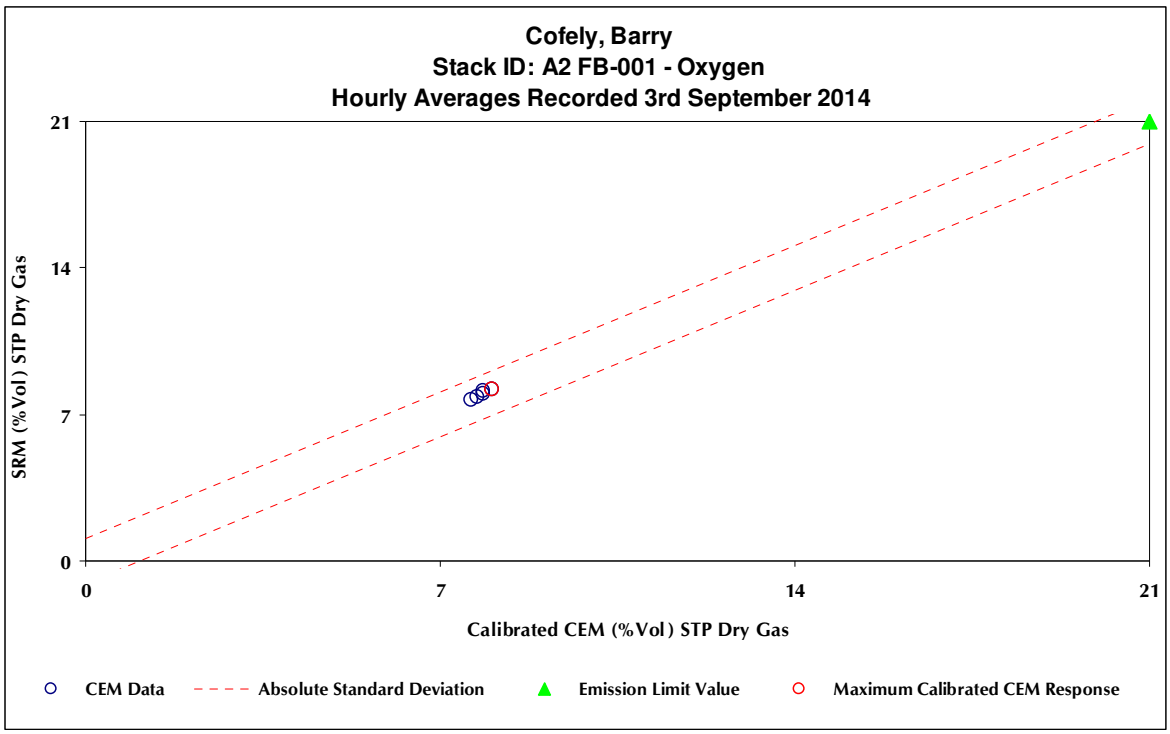
$t_{0.95}(N-1) = 2.13$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 1.14$$

$|\overline{D}|$ 0.13%Vol < 1.14%Vol - Calibration Remains Valid

Reference Conditions 273K, 101.3 kPa, Dry Gas

B4.8c
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for O2 A2



B4.9c
Summary of the Valid Calibration Range for O2 A2

Summary of Valid Calibration Range

Slope:	0.9788	...
Intercept:	0.0098	%Vol
Daily ELV	21.00	%Vol
Allowable 95% Confidence Interval	± 1.07	%Vol
Upper Limit of Current Valid Calibration Range	10.07	%Vol
Maximum Calibrated CEM @ Reference Conditions	8.03	%Vol
Corresponding SRM @ Reference Conditions	8.19	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	7.12 - 9.26	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	%Vol

A3 HR-001B

B4.1a & B4.2a
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for NO A3

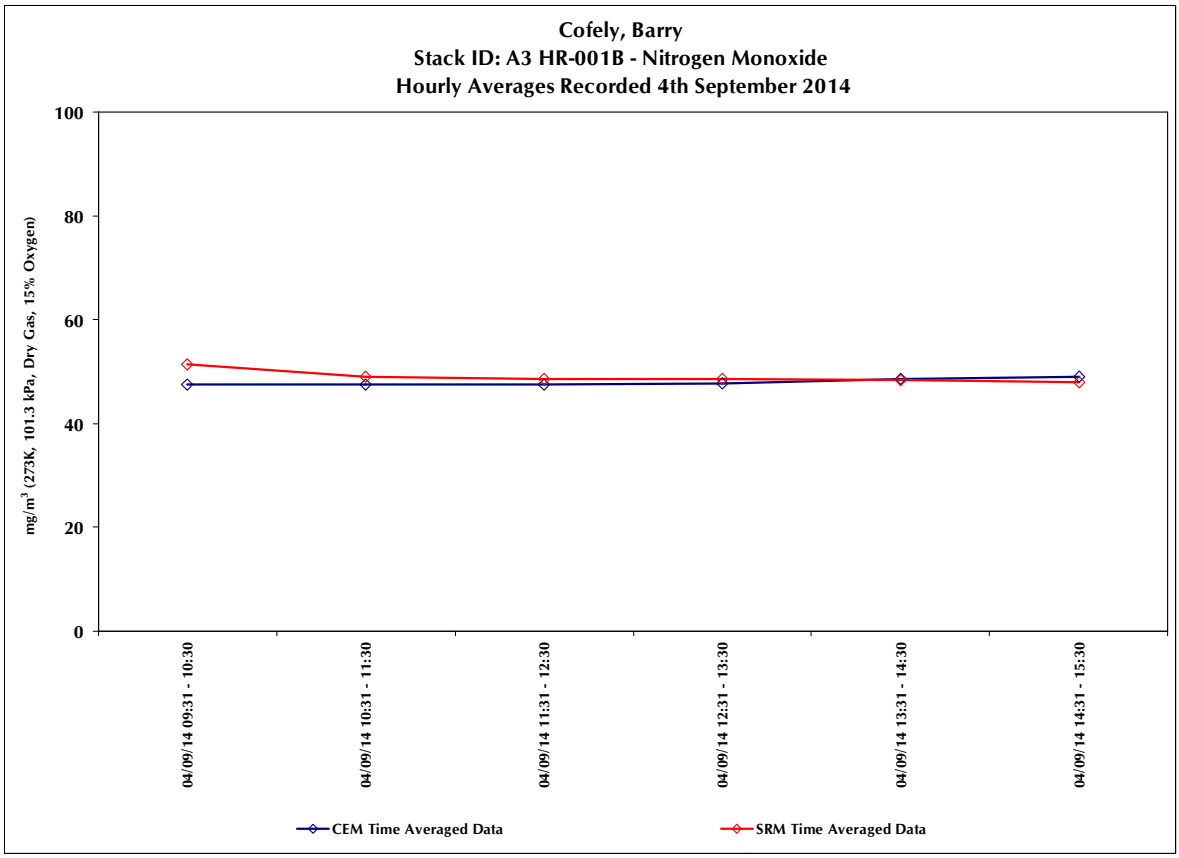
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
04/09/2014	09:31 - 10:30	35.53	-	-	-	-	47.57
04/09/2014	10:31 - 11:30	35.55	-	-	-	-	47.60
04/09/2014	11:31 - 12:30	35.51	-	-	-	-	47.54
04/09/2014	12:31 - 13:30	35.71	-	-	-	-	47.82
04/09/2014	13:31 - 14:30	36.23	-	-	-	-	48.51
04/09/2014	14:31 - 15:30	36.65	-	-	-	-	49.08

(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data							Standardised Data
Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
04/09/2014	09:31 - 10:30	38.46	-	-	-	-	51.50
04/09/2014	10:31 - 11:30	36.65	-	-	-	-	49.07
04/09/2014	11:31 - 12:30	36.35	-	-	-	-	48.68
04/09/2014	12:31 - 13:30	36.24	-	-	-	-	48.52
04/09/2014	13:31 - 14:30	36.12	-	-	-	-	48.37
04/09/2014	14:31 - 15:30	35.85	-	-	-	-	48.00

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3a
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for NO A3



B4.4a
Calculation and procedure – Elimination of outliers for NO A3

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	04/09/2014	09:31 - 10:30	38.46	35.53	2.94	2.19	YES
2	04/09/2014	10:31 - 11:30	36.65	35.55	1.10	0.35	YES
3	04/09/2014	11:31 - 12:30	36.35	35.51	0.85	0.10	YES
4	04/09/2014	12:31 - 13:30	36.24	35.71	0.53	0.22	YES
5	04/09/2014	13:31 - 14:30	36.12	36.23	-0.11	0.86	YES
6	04/09/2014	14:31 - 15:30	35.85	36.65	-0.80	1.55	YES

Slope	-1.13	**Mean**	0.75
Intercept	77.21	**Stdev**	1.2731
R^2	0.32		

B4.5a
Table 4.3 – data used to calculate calibrated values for NO A3

QAL2 Calibration function: y=0.9849x-1.5148								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
04/09/2014	09:31 - 10:30	35.53	33.48	-	-	-	-	44.82	51.50
04/09/2014	10:31 - 11:30	35.55	33.50	-	-	-	-	44.85	49.07
04/09/2014	11:31 - 12:30	35.51	33.46	-	-	-	-	44.80	48.68
04/09/2014	12:31 - 13:30	35.71	33.66	-	-	-	-	45.07	48.52
04/09/2014	13:31 - 14:30	36.23	34.16	-	-	-	-	45.75	48.37
04/09/2014	14:31 - 15:30	36.65	34.59	-	-	-	-	46.31	48.00

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6a & B4.7a
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for NO A3

Determinand: Nitrogen Monoxide **QAL2 Calibration function: y=0.9849x-1.5148**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
47.57	51.50	44.82	51.50	47.57	44.82	6.68	2.92	8.53
47.60	49.07	44.85	49.07	47.60	44.85	4.22	0.46	0.21
47.54	48.68	44.80	48.68	47.54	44.80	3.88	0.12	0.015
47.82	48.52	45.07	48.52	47.82	45.07	3.45	-0.30	0.093
48.51	48.37	45.75	48.37	48.51	45.75	2.62	-1.14	1.30
49.08	48.00	46.31	48.00	49.08	46.31	1.69	-2.06	4.26
					Sum	22.55	0.00	14.40

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 3.76$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(2.88) = 1.70$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 20$$
$$E = 82$$

$$\sigma_0 = \frac{pE}{1.96} = 8.32$$

$$1.5\sigma_0 k_v = 11.64$$

$$s_D \le 1.5\sigma_0 k_v = 1.7 \text{ mg/m}^3 < 11.64 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

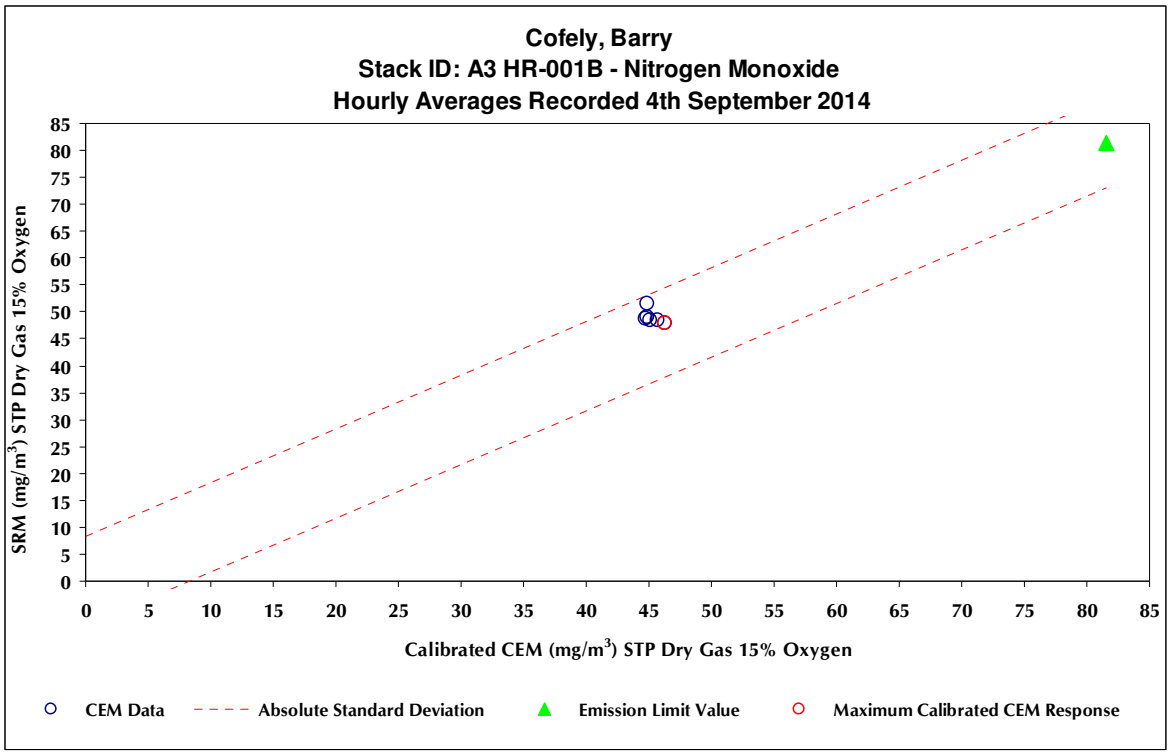
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 9.71$$

$$|\overline{D}| \quad 3.76\text{mg/m}^3 < 9.71\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8a
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for NO A3



B4.9a
Summary of the Valid Calibration Range for NO A3

Summary of Valid Calibration Range

Slope:	0.9849	...
Intercept:	-1.5148	mg/m^3
Daily ELV	81.52	mg/m^3
Allowable 95% Confidence Interval	± 8.32	mg/m^3
Upper Limit of Current Valid Calibration Range	51.22	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	46.31	mg/m^3
Corresponding SRM @ Reference Conditions	48.00	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	39.69 - 56.32	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1b & B4.2b
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for CO A3

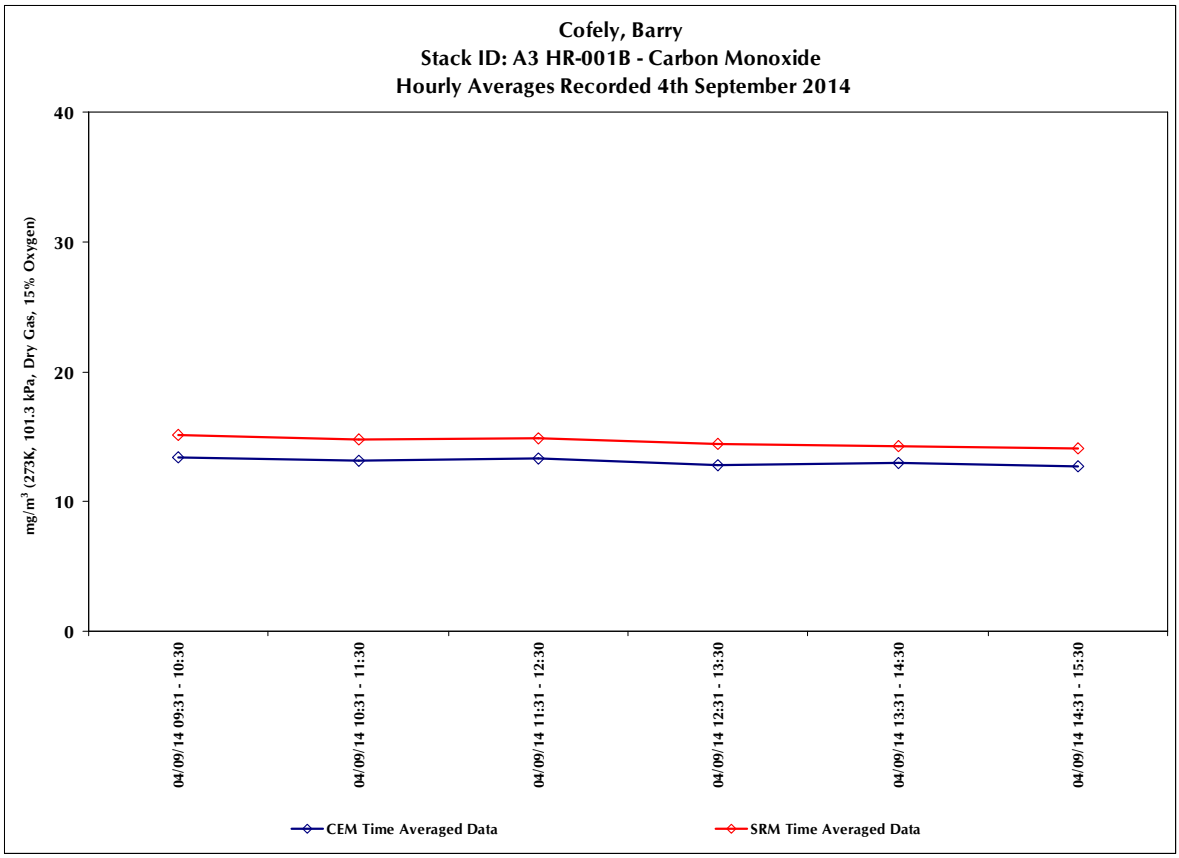
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m^3 Uncalibrated (2)
04/09/2014	09:31 - 10:30	10.69	-	-	-	-	13.37
04/09/2014	10:31 - 11:30	10.53	-	-	-	-	13.16
04/09/2014	11:31 - 12:30	10.63	-	-	-	-	13.28
04/09/2014	12:31 - 13:30	10.26	-	-	-	-	12.83
04/09/2014	13:31 - 14:30	10.35	-	-	-	-	12.94
04/09/2014	14:31 - 15:30	10.19	-	-	-	-	12.74

(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Raw Monitoring SRM Data							Standardised Data
Date	Time	SRM Hourly averages ppm (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages mg/m^3 (4)
04/09/2014	09:31 - 10:30	12.12	-	-	-	-	15.15
04/09/2014	10:31 - 11:30	11.84	-	-	-	-	14.80
04/09/2014	11:31 - 12:30	11.87	-	-	-	-	14.84
04/09/2014	12:31 - 13:30	11.51	-	-	-	-	14.39
04/09/2014	13:31 - 14:30	11.44	-	-	-	-	14.29
04/09/2014	14:31 - 15:30	11.24	-	-	-	-	14.05

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.3b
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for CO A3



B4.4b
Calculation and procedure – Elimination of outliers for CO A3

n	Date	Time	SRM mg/m³	CEM mg/m³	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	04/09/2014	09:31 - 10:30	12.12	10.69	1.42	0.20	YES
2	04/09/2014	10:31 - 11:30	11.84	10.53	1.31	0.08	YES
3	04/09/2014	11:31 - 12:30	11.87	10.63	1.24	0.02	YES
4	04/09/2014	12:31 - 13:30	11.51	10.26	1.25	0.03	YES
5	04/09/2014	13:31 - 14:30	11.44	10.35	1.08	0.14	YES
6	04/09/2014	14:31 - 15:30	11.24	10.19	1.05	0.18	YES

Slope	1.54	**Mean**	1.23
Intercept	-4.37	**Stdev**	0.1403
R^2	0.93		

B4.5b
Table 4.3 – data used to calculate calibrated values for CO A3

QAL2 Calibration function: y=0.8611x+1.2686								Standardised Data	
Date	Time	CEM Hourly averages ppm Uncalibrated (1)	CEM Hourly averages ppm Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages mg/m³ Calibrated (2)	SRM Hourly averages mg/m³ (2)
04/09/2014	09:31 - 10:30	10.69	10.48	-	-	-	-	13.10	15.15
04/09/2014	10:31 - 11:30	10.53	10.34	-	-	-	-	12.92	14.80
04/09/2014	11:31 - 12:30	10.63	10.42	-	-	-	-	13.02	14.84
04/09/2014	12:31 - 13:30	10.26	10.10	-	-	-	-	12.63	14.39
04/09/2014	13:31 - 14:30	10.35	10.18	-	-	-	-	12.73	14.29
04/09/2014	14:31 - 15:30	10.19	10.04	-	-	-	-	12.56	14.05

(1) 273K, 101.3 kPa, Dry Gas, 15% Oxygen
(2) 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.6b & B4.7b
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for CO A3

Determinand: Carbon Monoxide **QAL2 Calibration function: y=0.8611x+1.2686**

CEM Measured mg/m³	SRM Measured mg/m³	Calibrated CEM mg/m³	SRM Measured @ Reference conditions mg/m³	CEM Measured @ Reference conditions mg/m³	Calibrated CEM @ Reference Conditions mg/m³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
13.37	15.15	13.10	15.15	13.37	13.10	2.05	0.29	0.08
13.16	14.80	12.92	14.80	13.16	12.92	1.88	0.12	0.01
13.28	14.84	13.02	14.84	13.28	13.02	1.81	0.05	0.003
12.83	14.39	12.63	14.39	12.83	12.63	1.76	0.00	0.000
12.94	14.29	12.73	14.29	12.94	12.73	1.56	-0.20	0.04
12.74	14.05	12.56	14.05	12.74	12.56	1.50	-0.26	0.07
					Sum	10.57	0.00	0.21

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = 1.76$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT}(0.04) = 0.20$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 10$$
$$E = 80$$

$$\sigma_0 = \frac{pE}{1.96} = 4.08$$

$$1.5\sigma_0 k_v = 5.71$$

$$s_D \le 1.5\sigma_0 k_v = 0.2 \text{ mg/m}^3 < 5.71 \text{ mg/m}^3 \text{ - Pass Variability Test}$$

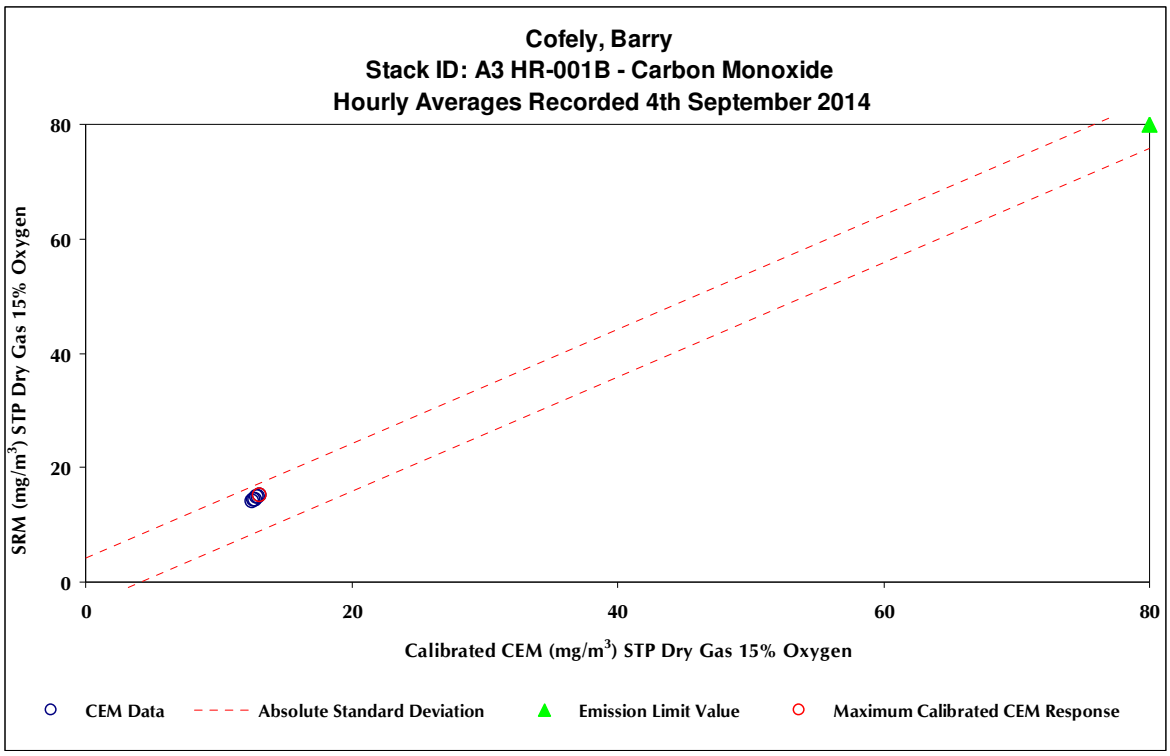
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 4.25$$

$$|\overline{D}| \quad 1.76\text{mg/m}^3 < 4.25\text{mg/m}^3 \text{ - Calibration Remains Valid}$$

Reference Conditions 273K, 101.3 kPa, Dry Gas, 15% Oxygen

B4.8b
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for CO A3



B4.9b
Summary of the Valid Calibration Range for CO A3

Summary of Valid Calibration Range

Slope:	0.8611	...
Intercept:	1.2686	mg/m^3
Daily ELV	80.00	mg/m^3
Allowable 95% Confidence Interval	± 4.08	mg/m^3
Upper Limit of Current Valid Calibration Range	15.95	mg/m^3
Maximum Calibrated CEM @ Reference Conditions	13.10	mg/m^3
Corresponding SRM @ Reference Conditions	15.15	mg/m^3
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 4.08%	11.06 - 19.23	mg/m^3
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	mg/m^3

B4.1c & B4.2c
Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A3

Raw Monitoring CEM Data | **Standardised Data**

Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
04/09/2014	09:31 - 10:30	16.09	-	-	-	-	16.09
04/09/2014	10:31 - 11:30	16.09	-	-	-	-	16.09
04/09/2014	11:31 - 12:30	16.10	-	-	-	-	16.10
04/09/2014	12:31 - 13:30	16.11	-	-	-	-	16.11
04/09/2014	13:31 - 14:30	16.13	-	-	-	-	16.13
04/09/2014	14:31 - 15:30	16.14	-	-	-	-	16.14

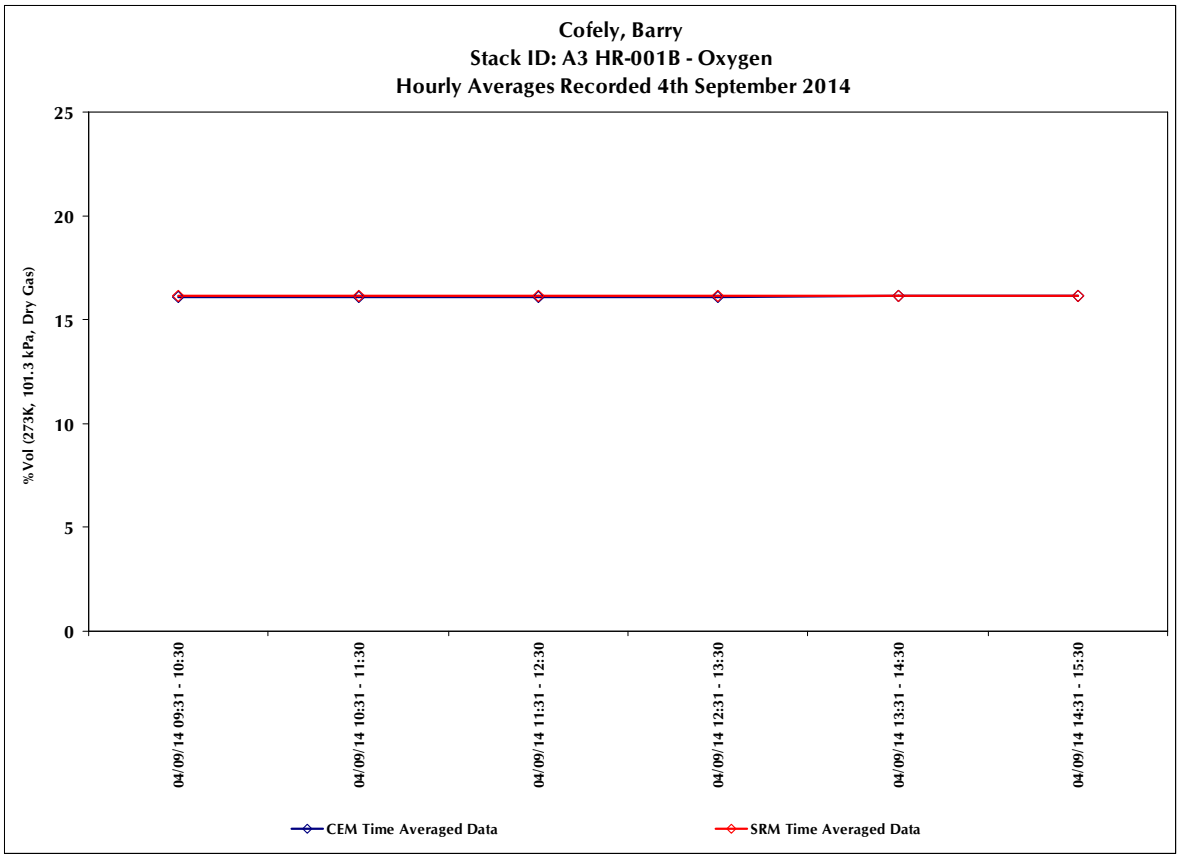
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas

Raw Monitoring SRM Data | **Standardised Data**

Date	Time	SRM Hourly averages %Vol (3)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	SRM Hourly averages %Vol (4)
04/09/2014	09:31 - 10:30	16.13	-	-	-	-	16.13
04/09/2014	10:31 - 11:30	16.13	-	-	-	-	16.13
04/09/2014	11:31 - 12:30	16.13	-	-	-	-	16.13
04/09/2014	12:31 - 13:30	16.14	-	-	-	-	16.14
04/09/2014	13:31 - 14:30	16.14	-	-	-	-	16.14
04/09/2014	14:31 - 15:30	16.12	-	-	-	-	16.12

(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas

B4.3c
Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for O2 A3



B4.4c
Calculation and procedure – Elimination of outliers for O2 A3

n	Date	Time	SRM % Vol	CEM % Vol	$\lvert D_i \rvert$	$\lvert (D_i - \overline{D_i}) \rvert$	$\lvert (D_i - \overline{D_i}) \rvert < 2\sigma$?
1	04/09/2014	09:31 - 10:30	16.13	16.09	0.04	0.02	YES
2	04/09/2014	10:31 - 11:30	16.13	16.09	0.04	0.02	YES
3	04/09/2014	11:31 - 12:30	16.13	16.10	0.03	0.01	YES
4	04/09/2014	12:31 - 13:30	16.14	16.11	0.03	0.01	YES
5	04/09/2014	13:31 - 14:30	16.14	16.13	0.01	0.01	YES
6	04/09/2014	14:31 - 15:30	16.12	16.14	-0.02	0.04	YES

Slope	-0.06	**Mean**	0.02
Intercept	17.15	**Stdev**	0.0244
R^2	0.03		

B4.5c
Table 4.3 – data used to calculate calibrated values for O2 A3

QAL2 Calibration function: y=1.0149x-0.1857 | **Standardised Data**

Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	CEM Hourly averages %Vol Calibrated (1)	CEM Temp (K)	CEM Pressure (kPa)	CEM Moisture (%)	CEM Oxygen (%) Dry	CEM Hourly averages %Vol Calibrated (2)	SRM Hourly averages %Vol (2)
04/09/2014	09:31 - 10:30	16.09	16.14	-	-	-	-	16.14	16.13
04/09/2014	10:31 - 11:30	16.09	16.14	-	-	-	-	16.14	16.13
04/09/2014	11:31 - 12:30	16.10	16.16	-	-	-	-	16.16	16.13
04/09/2014	12:31 - 13:30	16.11	16.16	-	-	-	-	16.16	16.14
04/09/2014	13:31 - 14:30	16.13	16.19	-	-	-	-	16.19	16.14
04/09/2014	14:31 - 15:30	16.14	16.19	-	-	-	-	16.19	16.12

(1) 273K, 101.3 kPa, Dry Gas
(2) 273K, 101.3 kPa, Dry Gas

B4.6c & B4.7c
Incorporating: Table 4.5 – Data used for the variability test & Calculation – the variability test and the acceptance test for O2 A3

Determinand: Oxygen | **QAL2 Calibration function: y=1.0149x-0.1857**

CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$
16.09	16.13	16.14	16.13	16.09	16.14	-0.01	0.02	0.00
16.09	16.13	16.14	16.13	16.09	16.14	-0.01	0.02	0.00
16.10	16.13	16.16	16.13	16.10	16.16	-0.03	0.01	0.000
16.11	16.14	16.16	16.14	16.11	16.16	-0.03	0.01	0.000
16.13	16.14	16.19	16.14	16.13	16.19	-0.05	-0.02	0.00
16.14	16.12	16.19	16.12	16.14	16.19	-0.07	-0.04	0.00
					Sum	-0.19	0.00	0.00

$$\overline{D} = \frac{1}{N}\sum_{i=1}^{N} D_i = -0.03$$

$$S_D = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(D_i - \overline{D})^2} = \text{SQRT(0)} = 0.02$$

$$N = 6$$
$$K_v = 0.93$$
$$p = 10$$
$$E = 21$$

$$\sigma_0 = \frac{pE}{1.96} = 1.07$$

$$1.5\sigma_0 k_v = 1.50$$

$$s_D \le 1.5\sigma_0 k_v = 0.02\ \%\text{Vol} < 1.5\ \%\text{Vol}$$ - Pass Variability Test

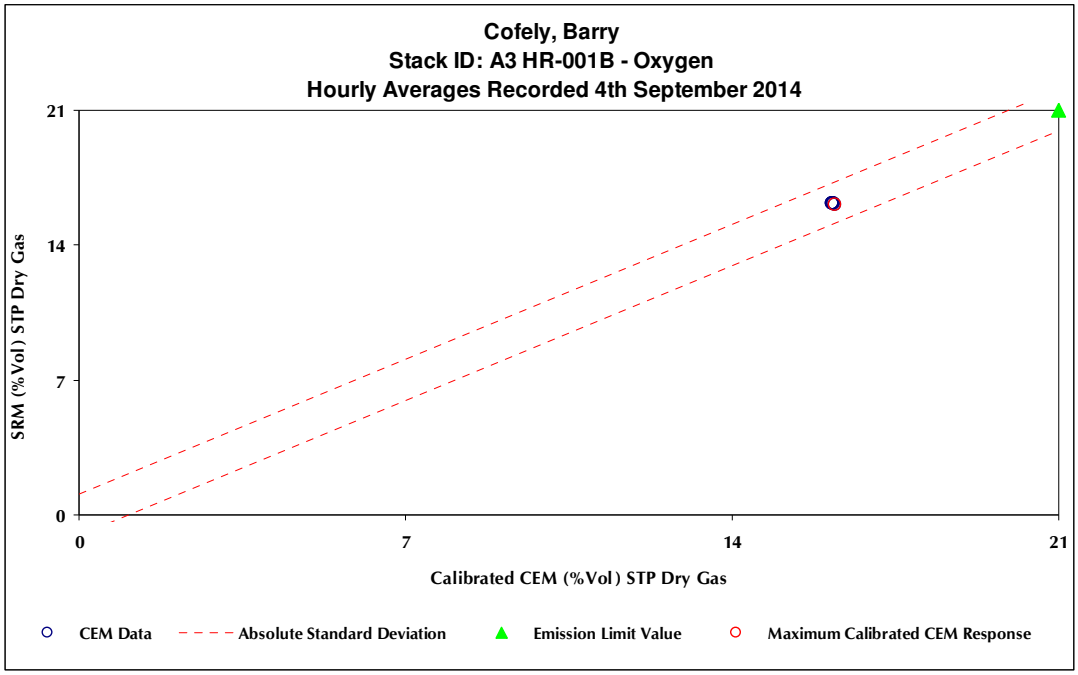
$$t_{0.95}(N-1) = 2.02$$

$$t_{0.95}(N-1)\frac{S_D}{\sqrt{N}} + \sigma_0 = 1.09$$

$$|\overline{D}|\ 0.03\%\text{Vol} < 1.09\%\text{Vol}$$ - Calibration Remains Valid

Reference Conditions 273K, 101.3 kPa, Dry Gas

B4.8c
Plot 2 – X-Y Plot of Standardised SRM Data Versus Standardised CEM Data for O2 A3



B4.9c
Summary of the Valid Calibration Range for O2 A3

Summary of Valid Calibration Range

Slope:	1.0149	...
Intercept:	-0.1857	%Vol
Daily ELV	21.00	%Vol
Allowable 95% Confidence Interval	± 1.07	%Vol
Upper Limit of Current Valid Calibration Range	17.86	%Vol
Maximum Calibrated CEM @ Reference Conditions	16.19	%Vol
Corresponding SRM @ Reference Conditions	16.12	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	15.05 - 17.19	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions < 1.5 × Original Calibration Range (QAL2)	N/A	...
Extended Valid Calibration Range	N/A	%Vol

5 – RESULTS OF THE FUNCTIONAL TESTS

5.1 Functional Test Summary

Requirement	Y/N	Notes
5.1.1 Alignment & Cleanliness (non-extractive systems only)		**Yes** ☐ **No** ☐ **N/A** ✓
A visual inspection was carried out with checks on the following (where applicable)		
• Internal check of the Analyser	**N**	**N/a**
• Cleanliness of optical components	**N**	
• Flushing air supply	**N**	
• Obstructions in optical path	**N**	
Following re-assembly at the sampling location, the following minimum checks have been carried out:		
• Alignment of the measuring system	**N**	**N/a**
• Contamination control (internal check of optical surfaces)	**N**	
• Flushing air supply	**N**	
5.1.2 Sampling Systems		**Yes** ✓ **No** ☐ **N/A** ☐
A visual inspection has been carried out and the condition of the elements of the sampling system noted (where applicable):		
• Sampling. Probe	**Y**	**Ametek carried out 6 monthly service.** **Power checked, ok.** **System leak checked performed, ok.** **No new parts required, ok.**
• Gas conditioning systems	**Y**	
• Pumps	**Y**	
• All connections	**Y**	
• Sample lines	**Y**	
• Power supplies	**Y**	
• Filters	**Y**	
• The sampling system shall be in good condition and free of any visible faults, which may decrease the quality of data	**Y**	
5.1.3 Leak testing		**Yes** ✓ **No** ☐ **N/A** ☐
• Leak testing shall be performed according to the CEMs manuals. The test shall cover the entire sampling system.	**Y**	**System leak checked performed by Ametek, ok.**
5.1.4 Zero and Span check		**Yes** ✓ **No** ☐ **N/A** ☐
• Reference zero and span materials shall be used to verify the corresponding readings of the CEM.	**Y**	**Instrument calibration carried out by Ametek, ok.** **Extractive CEM only.**
• In case of non-extractive CEM, zero and span checks shall be performed using a reference-path free of flue gas before and after readjustment and after re-assembly of the CEM at the measurement location.	**N**	

Requirement	Y/N	Notes
5.1.5 Linearity		Yes ✓ No [ ] N/A [ ]
• The linearity of the analyser response for each measured determinand is checked using suitable reference materials.	**Y**	**Reference gas**
• During the testing, instrument output is identical to output logged by the DCS.	**Y**	**Witnessed by ECL on site**
• DCS logged values included in the instrument service report.	**N**	**Not included in Ametek service report**
• The linearity of the CEM's response shall be checked using reference material at 5 different concentrations including zero.	**Y**	**Ok**
• All reference materials have a verifiable quantity and quality (traceable to national standards).	**Y**	**Calibration certificates provided with gases**
• Reference material concentrations obtained from separate cylinders.	**Y**	**NO, CO and O2 cylinders used**
• Reference material concentrations obtained from a single cylinder using a dilution system.	**N**	**Separate cylinders used by ECL**
• Reference materials at concentrations of 0% and approximately 20%, 40%, 60% & 80% of 2×daily ELV used.	**Y**	**Ok**
• Concentrations applied in a random sequence with Zero being applied twice.	**Y**	**Done randomly**
• Dry reference material shall be applied directly to the inlet of the CEM.	**Y**	**Ok**
• Following each change in concentration, a period equal to at least three times the response time has passed prior to taking the first instrument reading.	**Y**	**Ok**
• A minimum of three readings recorded at each concentration?	**Y**	**At least three steady readings at each concentration**
• The start of each reading is separated by 4× the response time of the CEM?	**Y**	**Ok**
• Residuals calculated in accordance with Annex B of BS EN 14181.	**Y**	**Ok**
Note • Where no other method is possible, the linearity can also be performed with the aid of reference materials such as grating filters or gas filters.		

5.1.6 Interferences		Yes ✓ No [ ] N/A [ ]
• A test shall be undertaken if the process gases to be monitored contain components that are known interferences, as identified during QAL1.	**N**	**No details in Ametek service report.**

5.1.7 Zero and Span drift (Audit)		Yes ✓ No [ ] N/A [ ]
• The zero point and span drift shall be obtained from and evaluated on the basis of the records of QAL3.	**Y**	**Control charts provide for NO, CO and O2 on all stack, audit ok.**

5.1.8 Response Time	Yes ✓	No	N/A	
Length of sample line (m) if known: Unknown, analyzer at sample location so likely to be short				
• The response time of the CEM for each measured determinand has been checked.	N	**No details on response time in Ametek service report.**		
• The test includes the sampling system (e.g. sampling probe & line) where applicable.	N			
• The response time for each determinand shall not exceed the measured value that has been identified during QAL1.	N			

Requirement	Y/N	Notes
5.1.9 Service Report	Yes ✓	No	N/A	
As a minimum requirement the engineers service report should include the following:		
• Document reference for work instruction for the type of work being undertaken	Y	**Sequence no. SD15E, purchase order 4700085813, S/O no. 57343**
• Instrument manufacturer	N	**No details**
• Instrument type	N	**No details**
• Instrument model	Y	**All analysers are FGA950E**
• Instrument Serial No	Y	**0292699, 9492050, 0292697 respectively**
• Instrument configuration including computer file and name if available	N	**No details in Ametek report**
• Operating principle	N	**No details in Ametek report**
• Operating range	N	**No details in Ametek report**
• Measuring condition	N	**No details in Ametek report**
• Certification details	N	**No details in Ametek report**
• Compliance with MCERTS (including certificate no.)	N	**No details in Ametek report**
• Location	Y	**HRSG001A, HRSG001B, HP Fired Boiler respectively**
• Date and time work was undertaken	Y	**14/08/14 14:45 – 17:30 and 15/08/14 08:45 – no end time given on Ametek report**
• Equipment used – type, serial no's, calibration dates	N	**No details in Ametek report**
• Gases used – certificate numbers, expiry dates, binary / mix	Y	**Linearity carried out by ECL, details on gases used are available. No details on site gases in Ametek report**
• Calibration and linearity data as required by EN14181	Y	**Linearity carried out by ECL, compliant with EN 14181**
• Logged data for period of calibration and linearity	Y	**Provided by Cofely following request by ECL**
• Name and signature of service engineer	Y	**David McGEE signed 15/08/14**

5.2 Documentation & Records

Test	Test Component	Yes	No	Notes
5.2.1. Documentation & Records (These must be controlled, readily accessible & up to date)	The CEM is covered by a current service contract[22] with the CEM manufacturer / supplier or other 3rd party.	✓		LAND 6 and 12 monthly visits
	The CEM manual / service agreement clearly indicate the elements covered at each service together with the associated service intervals.	✓		Stored with Paul Gardner
	Records of service / maintenance	✓		In-house folder "ENV 12"
	Log books[23]	✓		In-house folder "ENV 12" and shift operator log.
	QAL3 documentation[24]	✓		Envirosoft software
	A management procedure[25] is in place to ensure maintenance / calibration & service is carried out at the required intervals, & suitable training is provided	✓		In house SAM FM automatically generates work orders
	Training records[26]	✓		Two staff trained by LAND, see In-house folder "ENV 12"
	Plan of the CEM[27]	✓		In-house folder "ENV 12"
	All manuals (maintenance, user etc.)	✓		Stored in control room
	Auditing plans / records[28]	✓		Stored in control room

[22] If the CEM is not currently covered by a servicing or maintenance contract, indicate in the notes section what procedures are currently in place to ensure the CEM remains at a functional level suitable for its purpose. Elements included are typically sampling probe, gas conditioning system, pumps, all connections, sample lines, power supplies, filters etc.

[23] Documentation of CEM performance e.g. possible malfunctions, remedial actions taken etc.

[24] Following QAL2 calibration testing a QAL3, as outlined in BS EN 14181, should be implemented to ensure the continuing validity of CEM data. Further details of the QAL3 requirements can be found in the Environment Agency's Technical Guidance Note M20.

[25] All internal procedures relating to the operation of the CEM, including maintenance, calibration and training.

[26] Evidence of all training undertaken by individuals operating or maintaining the CEM and associated software should be maintained on file. Training may be provided in-house or externally by suitably qualified personnel.

[27] A generic layout plan of the probe, sample lines & system (if present) and analyser may often be found in the CEM manual.

[28] On going assessment or review of the suitability of training, record keeping, calibration & service requirements.

5.3 Linearity Testing

5.3.1 Method

Dry reference gases traceable to national standards are applied to the CEM at several different concentrations[29] (approximately 20%, 40%, 60% & 80% of 2 X Daily ELV), with a zero (nitrogen) concentration being applied twice.

Gases are applied in a random order to avoid hysteresis effects, with a minimum of three readings recorded for each concentration applied. For each concentration, the start of each reading should be separated by a minimum of four times the response time.

Where individual gases at the required concentrations are unavailable, gas at a suitable concentration is blended with nitrogen to the required concentration.

Application of reference materials was undertaken by **Mike Mullett** on the **14th August 2014** and the data recorded. Manually recorded **data was verified** against data logged by the environmental data management software.

Data was analysed by Environmental Compliance Limited in accordance with the requirements of Annex B of BS EN 14181:2005.

5.3.2 Data Analysis

Coefficient "a"

The coefficient "a" is calculated as follows:

$$a = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Where:

a is the average value of the x values
x_i is the individual CEM readings
n is the number of measured signals

Coefficient "B"

The coefficient "B" is calculated as follows:

$$B = \frac{\sum_{i=1}^{n} x_i(c_i - \bar{c})}{\sum_{i=1}^{n}(c_i - \bar{c})^2}$$

Where:

$\bar{c}$ is the mean of the reference material values
c_i is the individual reference material value

29 Specific concentrations used in each linearity test will be specified in the calculation details for each determinand.

Coefficient "A"
The coefficient "A" is calculated as follows:

$$A = a - B\overline{c}$$

Regression Function for the Linearity Test
This is expressed as:

$$x_i = A + Bc_i$$

Establish the Mean CEM Reading
For each reference concentration, the corresponding mean CEM reading is calculated using the equation below:

$$\overline{x}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} x_{c,i}$$

Where:
$\overline{x}_c$ is the mean CEM reading at reference concentration c
$x_{c,i}$ is the individual CEM reading at reference concentration c
m_c is the number of repetitions at each reference concentration ($m_c = 3$)

Calculate the Residual d_c at Each Reference Concentration
At each reference concentration (c), the residual between the mean CEM response and the calibrated reference concentration is calculated using the equation below:

$$d_c = \overline{x}_c - (A + Bc)$$

Each residual is converted into a relative value to the upper limit of the analyser range (x_u) using the equation below:

$$d_{c,rel} = \frac{d_c}{x_u} \times 100$$

The magnitude of the relative residuals $d_{c,rel}$ must be $< 5\%$.

5.3.3 95% Confidence Interval (CI) & Prediction Interval (PI) of Regression

A regression line represents the mean values of $\hat{y}$ for each value of x_i. Each measured CEM value represents the mean of a normally distributed population of possible values of $\hat{y}$. We can therefore calculate the confidence interval of each measured CEM value using the following formula:

$$CI = \hat{y}_i \pm t_{\frac{\alpha}{2},N-2}\, SE \sqrt{\frac{1}{N} + \frac{(x_i - \bar{x})^2}{\sum_{i=1}^{N}(x_i - \bar{x})^2}}$$

Where:

$\hat{y}_i$	ith measured CEM value
$t_{\alpha/2,N-2}$	value from the students t distribution with N-2 degrees of freedom
N	number of data values
x_i	ith applied reference concentration
$\bar{x}$	mean applied reference concentration
SE	standard deviation of residuals

Where SE is the square root of the Standard Error of the Estimate (MSe):

$$SE = \sqrt{MSe} = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \hat{y}_i)^2}{N-2}}$$

y_i = ith CEM measured value

A plot of the resulting data points gives us the "Working-Hotelling Confidence Band" for the entire regression line which is based on the mean responses for each given value of x_i.

From a more practical perspective, we are often interested in future values of $\hat{y}$ based on values of x which are independent of any previous values of x_i used in calculating the linear relationship. For each future value of $\hat{y}$ we can calculate the "Prediction Interval" which is essentially a "Confidence Interval" for future observations using the following formula:

$$CI = \hat{y}_i \pm t_{\frac{\alpha}{2},N-2}\, SE \sqrt{1 + \frac{1}{N} + \frac{(x_i - \bar{x})^2}{\sum_{i=1}^{N}(x_i - \bar{x})^2}}$$

5.3.4 95% Confidence Interval (CI) for Slope (B) of Linearity Results

The 95% confidence interval of the linearity regression slope (coefficient B) is calculated as follows:

$$95\%\ CI = S_b \times t_{\alpha/2,N-2}$$

Where:

S_b	standard error of the slope;
$t_{\alpha/2, N-2}$	Student's t value at a probability of α/2 with N-2 degrees of freedom.

The standard error of the slope is calculated using:

$$s_b = \frac{s_{est}}{\sqrt{SSX}}$$

Where:

S_{est}	standard deviation of the residuals of estimated values ($\hat{y}$) based on the linearity coefficients A & B.
SSX	sum of squares of x

Standard deviation of the residuals (S_{est}) is:

$$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}} = \sqrt{\frac{\sum(y_i - \hat{y})^2}{N-2}}$$

Where:

y_i	mean measured CEM concentration at concentration *i*;
$\hat{y}$	estimated concentration based on linearity coefficients A & B;
N	number of applied concentrations *i*.

Sum of squares of x is:

$$SSX = \sum(x_i - \bar{x})^2$$

Where:

x_i	applied reference concentration *i*;
$\bar{x}$	mean applied reference concentration.

5.3.5 95% Confidence Interval (CI) for Intercept (A) of Linearity Results

The 95% confidence interval of the linearity regression intercept (coefficient A) is calculated as follows:

$$95\%\ CI = S_a \times t_{\alpha/2,N-2}$$

Where:

S_a	standard error of the intercept;
$t_{\alpha/2, N-2}$	Student's t value at a probability of α/2 with N-2 degrees of freedom.

The standard error of the intercept is calculated using:

$$s_a = s_{est}\sqrt{\frac{\sum x_i^2}{N\sum\left(x_i - \bar{x}\right)^2}}$$

Where

S_{est}	standard deviation of the residuals of estimated values ($\hat{y}$) based on the linearity coefficients A & B;
x_i	applied reference concentration *i*;
$\bar{x}$	mean applied reference concentration;
N	number of applied concentrations *i*.

5.3.6 Linearity Results

HR-001A – A1

5.3.6.1.1 Linearity Calculations for NO A1

Cofely
Linearity test for Nitrogen Monoxide - 14th August 2014
Daily ELV: 81.52 mg/m3
Linearised Range: 163.04 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m³	Measured CEM Concentration mg/m³	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m³	$(x_i - x_z)$ mg/m³	$(x_i - x_z)^2$ mg/m³	$y_i(x_i - x_z)$ mg/m³	$d_c = \bar{Y}_c - (A+Bc)$ mg/m³	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	-0.13	-0.13	-54.33	2952.11	7.28	2.39	1.47%	PASS
	13:40			-0.13				7.28			
	13:41			-0.13				7.28			
14/08/14	15:52	60%	97.8	89.71	89.94	43.47	1889.35	3899.53	-5.68	-3.48%	PASS
	15:53			90.11				3916.99			
	15:54			89.98				3911.17			
14/08/14	16:04	20%	32.6	28.92	28.74	-21.73	472.34	-628.58	-1.44	-0.89%	PASS
	16:05			28.65				-622.76			
	16:06			28.65				-622.76			
14/08/14	16:30	80%	130.4	135.11	135.24	76.07	5786.14	10276.99	6.91	4.24%	PASS
	16:31			135.37				10297.37			
	16:32			135.24				10287.18			
14/08/14	17:12	40%	65.2	58.78	58.34	10.87	118.08	638.77	-4.57	-2.80%	PASS
	17:13			58.25				632.95			
	17:14			57.98				630.04			
14/08/14	17:32	0%	0	-0.13	-0.13	-54.33	2952.11	7.28	2.39	1.47%	PASS
	17:33			-0.13				7.28			
	17:34			-0.13				7.28			

Sum	978.00	935.96
Mean (X_z)	54.33	52.00
Count (n)	...	18

42510.40	42660.51

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **52.00**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0035** ±0.125

$A = a - BX_z$ = **-2.5274** ±9.092

Range (X_u) = **163** mg/m³

5.3.6.1.2 95% CI & PI Calculations for NO A1

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-2.53	5.729	0.00	2973.00	9.09	17.41
95.62	32.283	9564.84	1902.72	8.13	16.93
30.19	2.08	1062.76	475.68	6.64	16.26
128.33	47.691	17004.16	5827.07	11.26	18.63
62.90	20.86	4251.04	118.92	6.21	16.09
-2.53	5.73	0.00	2973.00	9.09	17.41

MSE: 28.59

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **5.3473**

$\sqrt{SSX}$ **119.04**

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ **0.0449**

$t_{\alpha/2,N-2}$ **2.78**

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ **0.125**

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **5.3473**

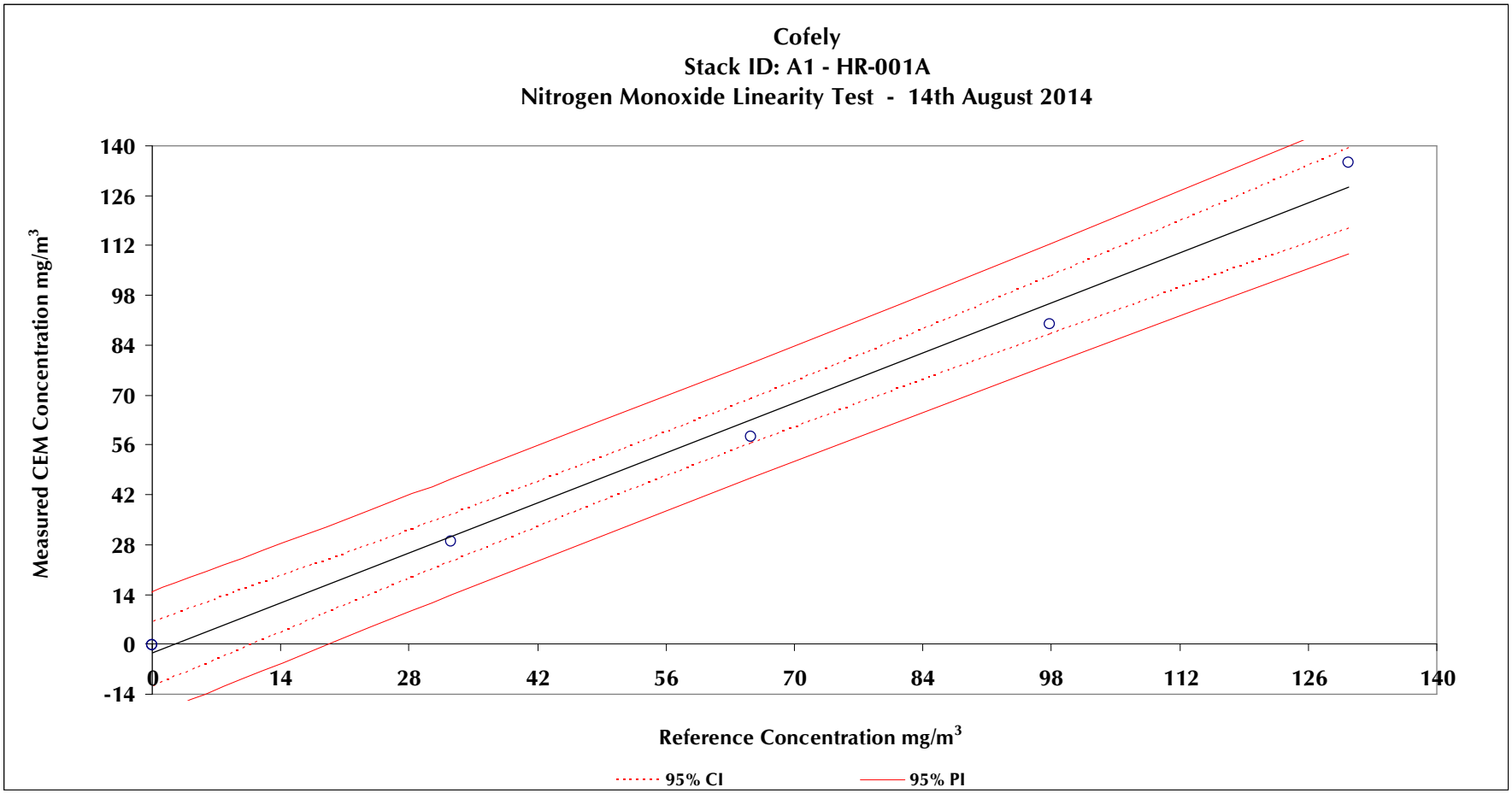
$n\sum(x-\bar{x})^2$ **85020.80**

$\sum x^2$ **31882.80**

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ **3.27**

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ **9.09**

5.3.6.1.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for NO A1



5.3.6.2.1 Linearity Calculations for CO A1

Cofely
Linearity test for Carbon Monoxide - 14th August 2014
Daily ELV: 80 mg/m3
Linearised Range: 160 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m^3	Measured CEM Concentration mg/m^3	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m^3	$(x_i - x_z)$ mg/m^3	$(x_i - x_z)^2$ mg/m^3	$y_i(x_i - x_z)$ mg/m^3	$d_c = \bar{Y}_c - (A+Bc)$ mg/m^3	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	-0.13	-0.13	-53.33	2844.44	6.67	-0.03	-0.02%	PASS
	13:40			-0.13				6.67			
	13:41			-0.13				6.67			
14/08/14	14:58	60%	96	100.38	100.50	42.67	1820.44	4282.67	2.41	1.51%	PASS
	14:59			100.50				4288.00			
	15:00			100.63				4293.33			
14/08/14	15:07	20%	32	33.75	33.79	-21.33	455.11	-720.00	1.16	0.72%	PASS
	15:08			33.88				-722.67			
	15:09			33.75				-720.00			
14/08/14	15:33	80%	128	130.25	130.25	74.67	5575.11	9725.33	-0.56	-0.35%	PASS
	15:34			130.25				9725.33			
	15:35			130.25				9725.33			
14/08/14	15:45	40%	64	62.25	62.29	10.67	113.78	664.00	-3.07	-1.92%	PASS
	15:46			62.50				666.67			
	15:47			62.13				662.67			
14/08/14	16:56	0%	0	0.00	0.00	-53.33	2844.44	0.00	0.09	0.06%	PASS
	16:57			0.00				0.00			
	16:58			0.00				0.00			

Sum	960.00	980.13
Mean (X_z)	53.33	54.45
Count (n)	...	18

40960.00	41890.67

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **54.45**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0227** ±0.049

$A = a - BX_z$ = **-0.0938** ±3.496

Range (X_u) = **160** mg/m^3

5.3.6.2.2 95% CI & PI Calculations for CO A1

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-0.09	0.001	0.00	2975.17	3.50	6.69
98.09	5.820	9216.00	1904.11	3.13	6.51
32.63	1.34	1024.00	476.03	2.55	6.25
130.81	0.319	16384.00	5831.34	4.33	7.16
65.36	9.42	4096.00	119.01	2.39	6.19
-0.09	0.01	0.00	2975.17	3.50	6.69

MSE: 4.23

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 2.0559

$\sqrt{SSX}$ 116.85

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ 0.0176

$t_{\alpha/2,N-2}$ 2.78

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ 0.049

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 2.0559

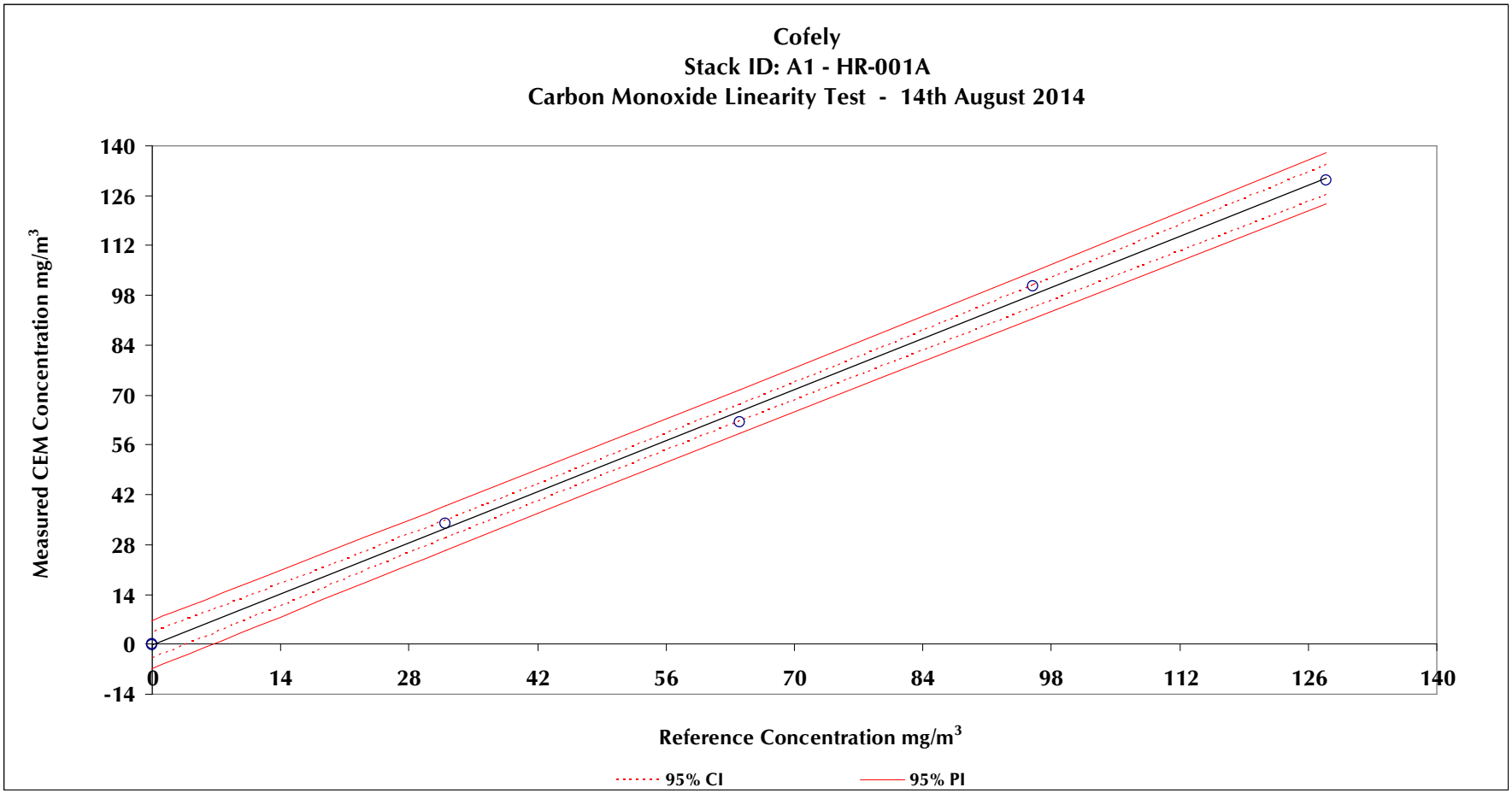
$n\sum(x-\bar{x})^2$ 81920.00

$\sum x^2$ 30720.00

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ 1.26

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ 3.50

5.3.6.2.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for CO A1



5.3.6.3.1 Linearity Calculations for O2 A1

Cofely
Linearity test for Oxygen - 14th August 2014
Daily ELV: 21 %Vol
Linearised Range: 25 %Vol

Date	Time	% Linearised Range	Reference Concentration %Vol	Measured CEM Concentration %Vol	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ %Vol	$(x_i - x_z)$ %Vol	$(x_i - x_z)^2$ %Vol	$y_i(x_i - x_z)$ %Vol	$d_c = \bar{Y}_c - (A+Bc)$ %Vol	$d_{c,rel} = \frac{d_c}{x_u} \times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	-0.02	-0.02	-8.34	69.56	0.17	0.18	0.73%	PASS
	13:40			-0.02				0.17			
	13:41			-0.02				0.17			
14/08/14	13:53	60%	15.02	15.16	15.16	6.68	44.62	101.27	-0.24	-0.98%	PASS
	13:54			15.16				101.27			
	13:55			15.16				101.27			
14/08/14	14:05	20%	5.02	4.86	4.86	-3.32	11.02	-16.14	-0.15	-0.62%	PASS
	14:06			4.86				-16.14			
	14:07			4.86				-16.14			
14/08/14	14:18	80%	20	20.99	20.99	11.66	135.96	244.74	0.41	1.64%	PASS
	14:19			20.99				244.74			
	14:20			20.99				244.74			
14/08/14	14:45	40%	10	9.81	9.81	1.66	2.76	16.28	-0.38	-1.50%	PASS
	14:46			9.82				16.30			
	14:47			9.81				16.28			
14/08/14	16:56	0%	0	-0.02	-0.02	-8.34	69.56	0.17	0.18	0.73%	PASS
	16:57			-0.02				0.17			
	16:58			-0.02				0.17			

Sum	150.12	152.35
Mean (X_z)	8.34	8.46
Count (n)	...	18

1000.40	1039.50

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **8.46**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0391** ±0.052

$A = a - BX_z$ = **-0.2021** ±0.576

Range (X_u) = **25** %Vol

5.3.6.3.2 95% CI & PI Calculations for O2 A1

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-0.20	0.033	0.00	75.10	0.58	1.10
15.40	0.060	225.60	48.18	0.52	1.07
5.01	0.02	25.20	11.90	0.42	1.03
20.58	0.168	400.00	146.79	0.71	1.18
10.19	0.14	100.00	2.98	0.39	1.02
-0.20	0.03	0.00	75.10	0.58	1.10

MSE: 0.11

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **0.3389**

$\sqrt{SSX}$ **18.26**

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ **0.0186**

$t_{\alpha/2,N-2}$ **2.78**

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ **0.052**

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **0.3389**

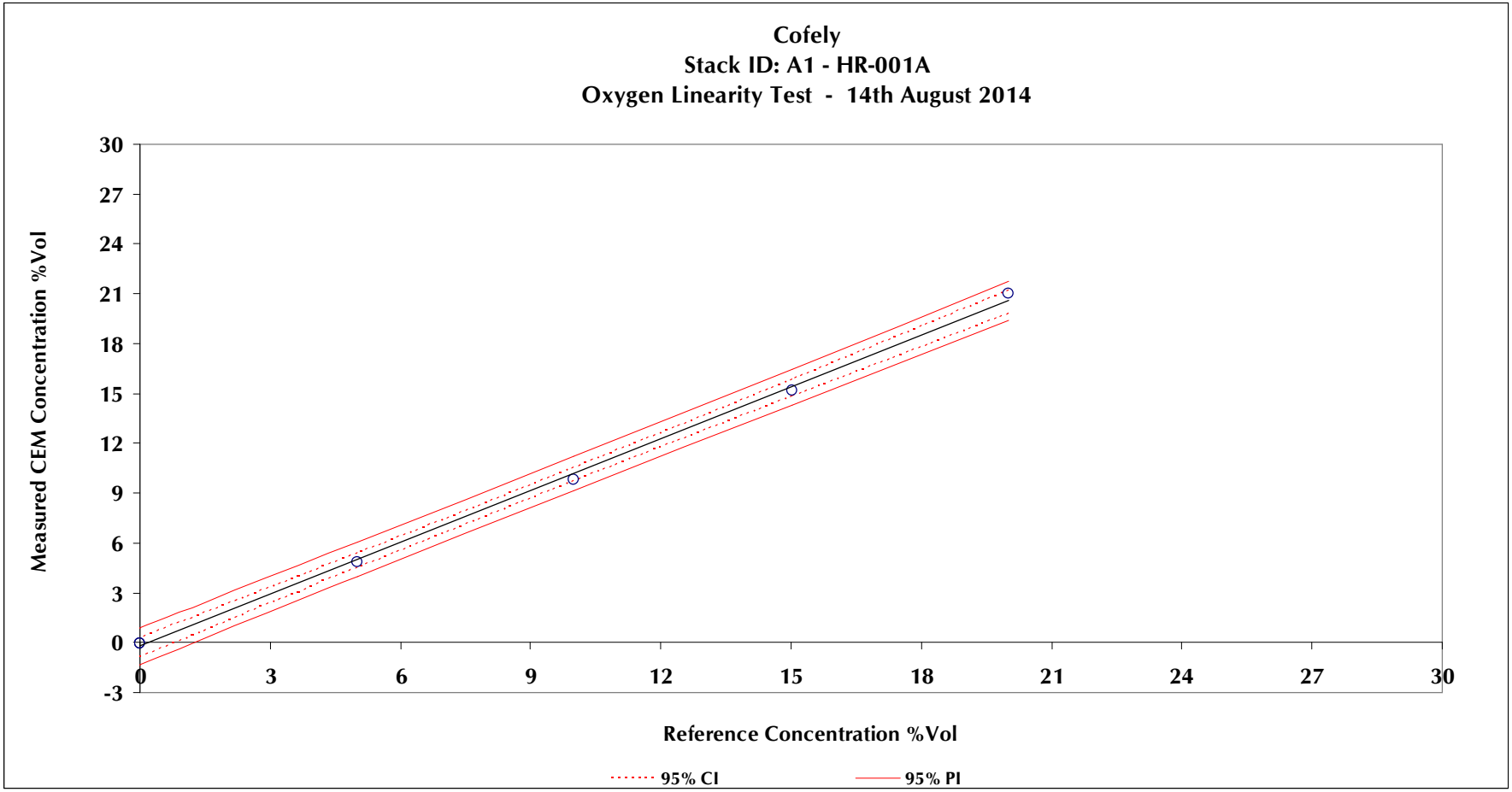
$n\sum(x-\bar{x})^2$ **2000.80**

$\sum x^2$ **750.80**

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ **0.21**

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ **0.58**

5.3.6.3.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for O2 A1



FB-001 – A2

5.3.6.1.1 Linearity Calculations for NO A2

Cofely
Linearity test for Nitrogen Monoxide - 14th August 2014
Daily ELV: 81.52 mg/m3
Linearised Range: 163.04 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m³	Measured CEM Concentration mg/m³	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m³	$(x_i - x_z)$ mg/m³	$(x_i - x_z)^2$ mg/m³	$y_i(x_i - x_z)$ mg/m³	$d_c = \bar{Y}_c - (A+Bc)$ mg/m³	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	10:00	0%	0	-0.80	-0.80	-54.60	2981.40	43.87	0.81	0.50%	PASS
	10:01			-0.80				43.87			
	10:02			-0.80				43.87			
14/08/14	11:27	60%	98.2826	101.50	101.59	43.68	1907.98	4433.40	1.40	0.86%	PASS
	11:28			101.50				4433.40			
	11:29			101.76				4445.09			
14/08/14	11:38	20%	32.76533	29.99	30.13	-21.84	476.85	-654.97	-2.20	-1.35%	PASS
	11:39			30.40				-663.74			
	11:40			29.99				-654.97			
14/08/14	12:00	80%	131.04793	134.57	134.48	76.45	5843.95	10287.27	0.36	0.22%	PASS
	12:01			134.44				10277.03			
	12:02			134.44				10277.03			
14/08/14	12:13	40%	65.51727	64.67	64.54	10.92	119.14	705.92	-1.71	-1.05%	PASS
	12:14			64.27				701.53			
	12:15			64.67				705.92			
14/08/14	13:35	0%	0	-0.27	-0.27	-54.60	2981.40	14.62	1.34	0.82%	PASS
	13:36			-0.27				14.62			
	13:37			-0.27				14.62			

Sum	982.84	988.99
Mean (X_z)	54.60	54.94
Count (n)	...	18

42932.15	44468.38

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **54.94**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0358** ±0.041

$A = a - BX_z$ = **-1.6124** ±2.981

Range (X_u) = **163** mg/m³

5.3.6.1.2 95% CI & PI Calculations for NO A2

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-1.61	0.654	0.00	3198.58	2.98	5.71
100.19	1.956	9659.47	2046.97	2.67	5.55
32.33	4.83	1073.57	511.58	2.18	5.33
134.12	0.126	17173.56	6269.66	3.69	6.11
66.25	2.92	4292.51	127.82	2.04	5.28
-1.61	1.81	0.00	3198.58	2.98	5.71

MSE: 3.07

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 1.7534

$\sqrt{SSX}$ 119.63

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ 0.0147

$t_{\alpha/2,N-2}$ 2.78

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ 0.041

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 1.7534

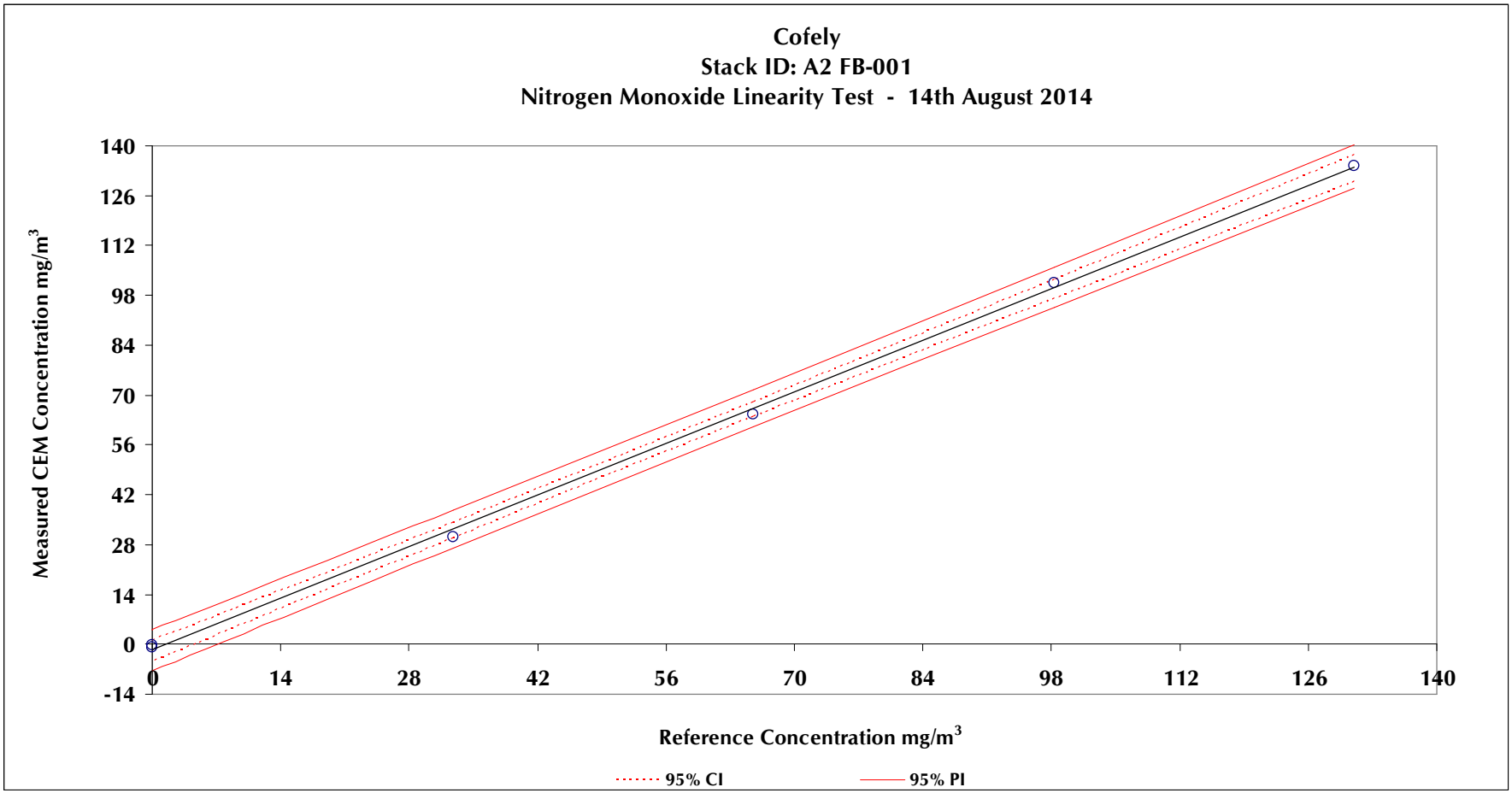
$n\sum(x-\bar{x})^2$ 85864.29

$\sum x^2$ 32199.11

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ 1.07

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ 2.98

5.3.6.1.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for NO A2



5.3.6.2.1 Linearity Calculations for CO A2

Cofely
Linearity test for Carbon Monoxide - 14th August 2014
Daily ELV: 80 mg/m3
Linearised Range: 160 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m³	Measured CEM Concentration mg/m³	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m³	$(x_i - x_z)$ mg/m³	$(x_i - x_z)^2$ mg/m³	$y_i(x_i - x_z)$ mg/m³	$d_c = \bar{Y}_c - (A+Bc)$ mg/m³	$d_{c,rel} = \frac{d_c}{x_u} \times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	10:00	0%	0	0.00	0.04	-53.30	2840.45	0.00	0.53	0.33%	PASS
	10:01			0.00				0.00			
	10:02			0.13				-6.93			
14/08/14	10:12	60%	95.7625	97.88	97.88	42.47	1803.42	4156.43	-0.34	-0.21%	PASS
	10:13			97.88				4156.43			
	10:14			97.88				4156.43			
14/08/14	10:23	20%	31.6375	31.75	31.75	-21.66	469.08	-687.65	-0.37	-0.23%	PASS
	10:24			31.75				-687.65			
	10:25			31.75				-687.65			
14/08/14	10:48	80%	128.25	132.50	132.38	74.95	5618.13	9931.43	0.67	0.42%	PASS
	10:49			132.25				9912.69			
	10:50			132.38				9922.06			
14/08/14	11:08	40%	64.125	64.88	64.96	10.83	117.27	702.54	-0.65	-0.41%	PASS
	11:09			65.00				703.90			
	11:10			65.00				703.90			
14/08/14	13:35	0%	0	-0.38	-0.33	-53.30	2840.45	19.99	0.16	0.10%	PASS
	13:36			-0.38				19.99			
	13:37			-0.25				13.32			

Sum	959.33	980.01	41066.37	42329.19
Mean (X_z)	53.30	54.44		
Count (n)	...	18		

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = 54.44

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = 1.0308 ±0.014

$A = a - BX_z$ = -0.4900 ±1.017

Range (X_u) = 160 mg/m³

5.3.6.2.2 95% CI & PI Calculations for CO A2

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-0.49	0.284	0.00	3017.82	1.02	1.95
98.22	0.117	9170.46	1916.04	0.91	1.89
32.12	0.14	1000.93	498.38	0.75	1.82
131.70	0.451	16448.06	5968.96	1.26	2.09
65.61	0.42	4112.02	124.59	0.70	1.80
-0.49	0.02	0.00	3017.82	1.02	1.95

MSE: 0.36

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 0.5988

$\sqrt{SSX}$ 117.00

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ 0.0051

$t_{\alpha/2,N-2}$ 2.78

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ 0.014

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 0.5988

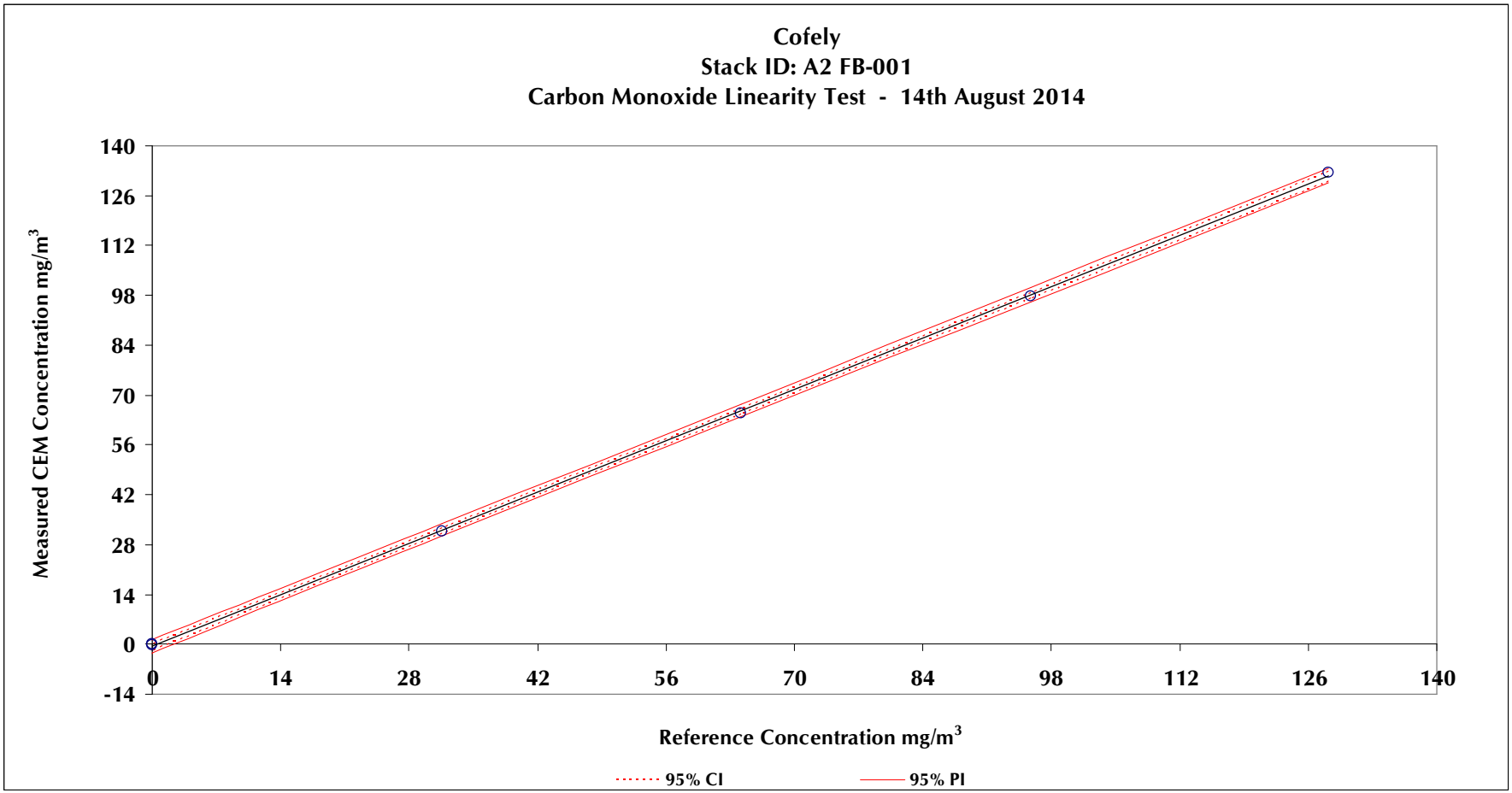
$n\sum(x-\bar{x})^2$ 82132.75

$\sum x^2$ 30731.47

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ 0.37

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ 1.02

5.3.6.2.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for CO A2



5.3.6.3.1 Linearity Calculations for O2 A2

Cofely
Linearity test for Oxygen - 14th August 2014
Daily ELV: 21 %Vol
Linearised Range: 25 %Vol

Date	Time	% Linearised Range	Reference Concentration %Vol	Measured CEM Concentration %Vol	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ %Vol	$(x_i - x_z)$ %Vol	$(x_i - x_z)^2$ %Vol	$y_i(x_i - x_z)$ %Vol	$d_c = \bar{Y}_c - (A+Bc)$ %Vol	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	10:00	0%	0	-0.01	-0.01	-8.34	69.56	0.08	0.08	0.31%	PASS
	10:01			-0.01				0.08			
	10:02			-0.01				0.08			
14/08/14	12:24	60%	15.02	15.33	15.32	6.68	44.62	102.40	-0.26	-1.04%	PASS
	12:25			15.32				102.34			
	12:26			15.32				102.34			
14/08/14	12:34	20%	5.02	5.12	5.12	-3.32	11.02	-17.00	-0.03	-0.12%	PASS
	12:35			5.12				-17.00			
	12:36			5.12				-17.00			
14/08/14	13:00	80%	20	21.06	21.05	11.66	135.96	245.56	0.27	1.09%	PASS
	13:01			21.05				245.44			
	13:02			21.05				245.44			
14/08/14	13:11	40%	10	10.22	10.21	1.66	2.76	16.97	-0.14	-0.56%	PASS
	13:12			10.20				16.93			
	13:13			10.20				16.93			
14/08/14	13:35	0%	0	-0.01	-0.01	-8.34	69.56	0.08	0.08	0.31%	PASS
	13:36			-0.01				0.08			
	13:37			-0.01				0.08			

Sum	150.12	155.05
Mean (X_z)	8.34	8.61
Count (n)	...	18

1000.40	1043.86

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **8.61**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0434** ± 0.032

$A = a - BX_z$ = **-0.0884** ± 0.356

Range (X_u) = **25** %Vol

5.3.6.3.2 95% CI & PI Calculations for O2 A2

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-0.09	0.006	0.00	75.73	0.36	0.68
15.58	0.068	225.60	48.58	0.32	0.66
5.15	0.00	25.20	12.00	0.26	0.64
20.78	0.074	400.00	148.02	0.44	0.73
10.35	0.02	100.00	3.00	0.24	0.63
-0.09	0.01	0.00	75.73	0.36	0.68

MSE: 0.04

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 0.2092

$\sqrt{SSX}$ 18.26

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ 0.0115

$t_{\alpha/2,N-2}$ 2.78

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ 0.032

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 0.2092

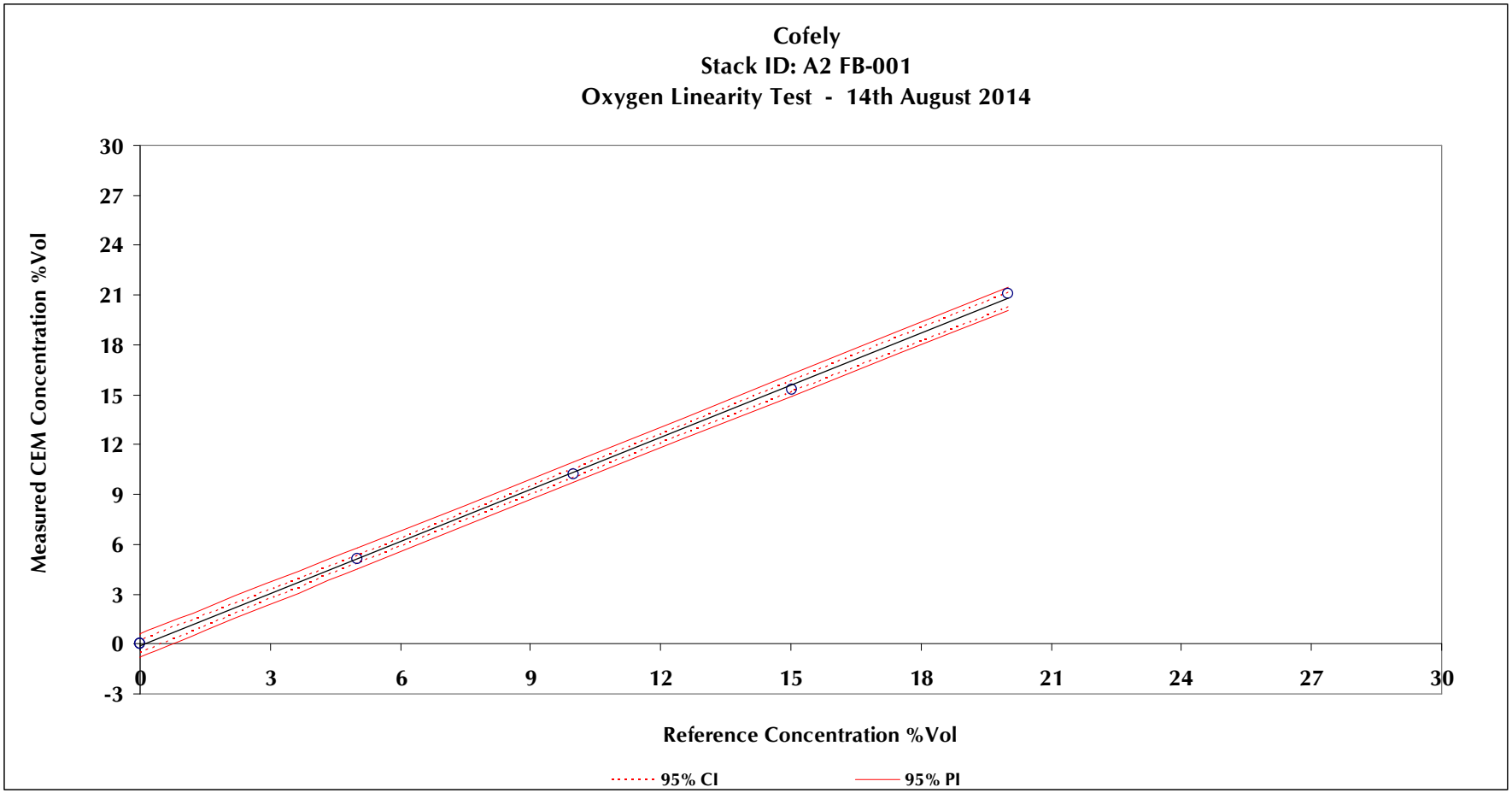
$n\sum(x-\bar{x})^2$ 2000.80

$\sum x^2$ 750.80

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ 0.13

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ 0.36

5.3.6.3.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for O2 A2



HR-001B – A3

5.3.6.1.1 Linearity Calculations for NO A3

Cofely
Linearity test for Nitrogen Monoxide - 14th August 2014
Daily ELV: 81.52 mg/m3
Linearised Range: 163.04 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m³	Measured CEM Concentration mg/m³	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m³	$(x_i - x_z)$ mg/m³	$(x_i - x_z)^2$ mg/m³	$y_i(x_i - x_z)$ mg/m³	$d_c = \bar{Y}_c - (A+Bc)$ mg/m³	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	0.00	0.00	-54.33	2952.11	0.00	1.03	0.63%	PASS
	13:40			0.00				0.00			
	13:41			0.00				0.00			
14/08/14	15:52	60%	97.8	90.38	90.43	43.47	1889.35	3928.63	-6.47	-3.97%	PASS
	15:53			90.38				3928.63			
	15:54			90.52				3934.45			
14/08/14	16:04	20%	32.6	31.06	30.98	-21.73	472.34	-675.14	-0.64	-0.39%	PASS
	16:05			31.06				-675.14			
	16:06			30.80				-669.32			
14/08/14	16:59	80%	130.4	134.97	134.93	76.07	5786.14	10266.81	5.38	3.30%	PASS
	17:00			134.84				10256.62			
	17:01			134.97				10266.81			
14/08/14	17:12	40%	65.2	64.41	63.51	10.87	118.08	699.88	-0.74	-0.46%	PASS
	17:13			63.20				686.78			
	17:14			62.93				683.87			
14/08/14	17:32	0%	0	0.54	0.40	-54.33	2952.11	-29.10	1.43	0.88%	PASS
	17:33			0.27				-14.55			
	17:34			0.40				-21.83			

Sum	978.00	960.73
Mean (X_z)	54.33	53.37
Count (n)	...	18

42510.40	42567.39

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = 53.37

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = 1.0013 ±0.101

$A = a - BX_z$ = -1.0321 ±7.36

Range (X_u) = 163 mg/m³

5.3.6.1.2 95% CI & PI Calculations for NO A3

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-1.03	1.065	0.00	2960.03	7.36	14.09
96.90	41.885	9564.84	1894.42	6.58	13.70
31.61	0.40	1062.76	473.61	5.37	13.17
129.54	28.986	17004.16	5801.66	9.11	15.08
64.26	0.55	4251.04	118.40	5.03	13.03
-1.03	2.06	0.00	2960.03	7.36	14.09

MSE: 18.74

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **4.3286**

$\sqrt{SSX}$ **119.04**

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ **0.0364**

$t_{\alpha/2,N-2}$ **2.78**

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ **0.101**

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **4.3286**

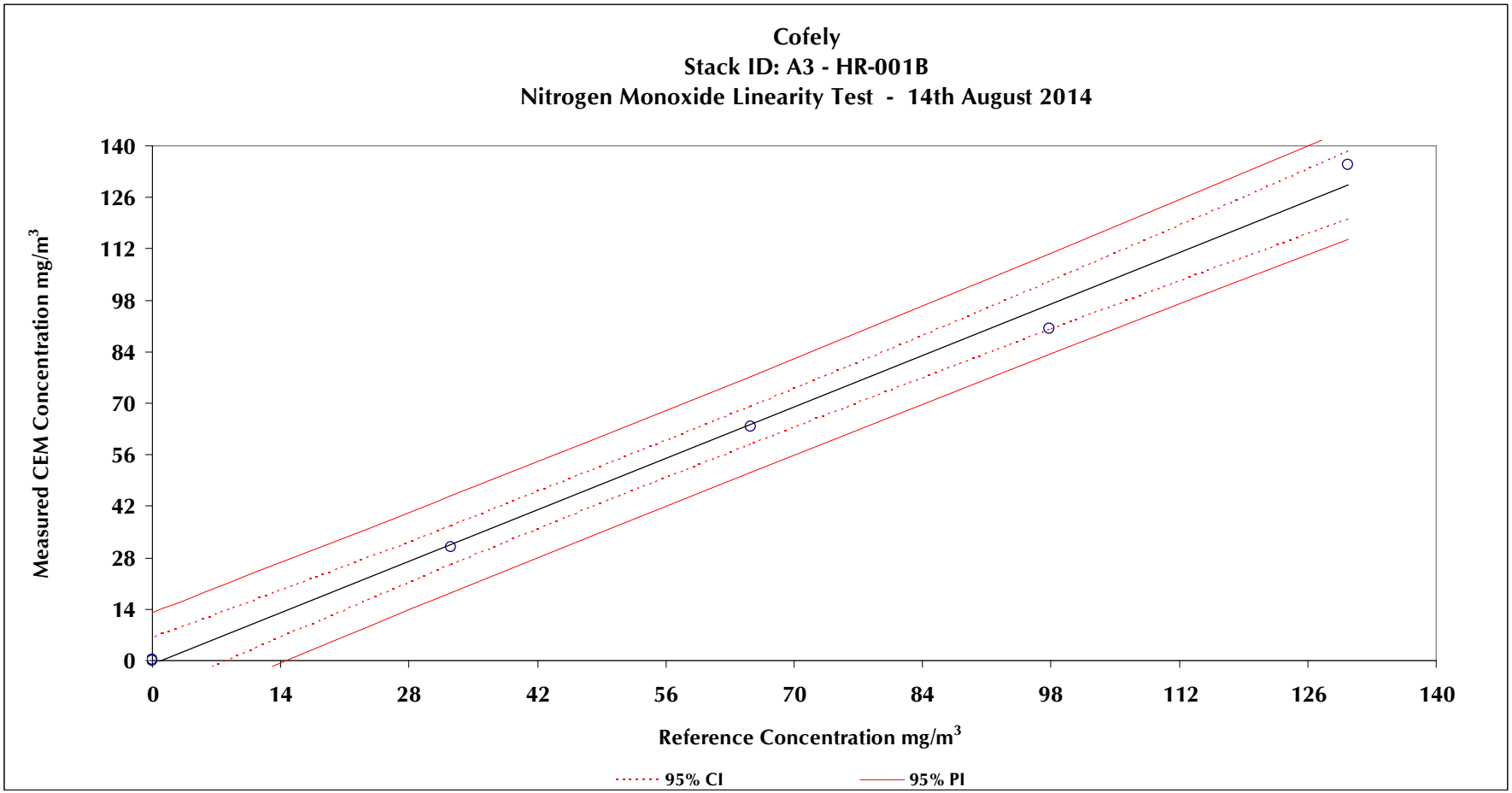
$n\sum(x-\bar{x})^2$ **85020.80**

$\sum x^2$ **31882.80**

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ **2.65**

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ **7.36**

5.3.6.1.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for NO A3



5.3.6.2.1 Linearity Calculations for CO A3

Cofely
Linearity test for Carbon Monoxide - 14th August 2014
Daily ELV: 80 mg/m3
Linearised Range: 160 mg/m3

Date	Time	% Linearised Range	Reference Concentration mg/m³	Measured CEM Concentration mg/m³	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ mg/m³	$(x_i - x_z)$ mg/m³	$(x_i - x_z)^2$ mg/m³	$y_i(x_i - x_z)$ mg/m³	$d_c = \bar{Y}_c - (A+Bc)$ mg/m³	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	1.38	1.38	-53.33	2844.44	-73.33	0.81	0.50%	PASS
	13:40			1.38				-73.33			
	13:41			1.38				-73.33			
14/08/14	14:58	60%	96	97.00	97.17	42.67	1820.44	4138.67	0.55	0.34%	PASS
	14:59			97.13				4144.00			
	15:00			97.38				4154.67			
14/08/14	15:07	20%	32	33.13	33.21	-21.33	455.11	-706.67	0.62	0.39%	PASS
	15:08			33.25				-709.33			
	15:09			33.25				-709.33			
14/08/14	15:33	80%	128	129.38	129.42	74.67	5575.11	9660.00	0.78	0.49%	PASS
	15:34			129.38				9660.00			
	15:35			129.50				9669.33			
14/08/14	15:45	40%	64	62.25	61.92	10.67	113.78	664.00	-2.69	-1.68%	PASS
	15:46			62.38				665.33			
	15:47			61.13				652.00			
14/08/14	17:32	0%	0	0.50	0.50	-53.33	2844.44	-26.67	-0.07	-0.04%	PASS
	17:33			0.50				-26.67			
	17:34			0.50				-26.67			

Sum	960.00	970.75	40960.00	40982.67
Mean (X_z)	53.33	53.93		
Count (n)	...	18		

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **53.93**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0006** ± 0.036

$A = a - BX_z$ = **0.5677** ± 2.574

Range (X_u) = **160** mg/m³

5.3.6.2.2 95% CI & PI Calculations for CO A3

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
0.57	0.652	0.00	2847.59	2.57	4.93
96.62	0.298	9216.00	1822.46	2.30	4.79
32.59	0.39	1024.00	455.61	1.88	4.60
128.64	0.605	16384.00	5581.28	3.19	5.27
64.60	7.22	4096.00	113.90	1.76	4.56
0.57	0.00	0.00	2847.59	2.57	4.93

MSE: 2.29

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 1.5137

$\sqrt{SSX}$ 116.85

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ 0.0130

$t_{\alpha/2,N-2}$ 2.78

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ 0.036

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ 1.5137

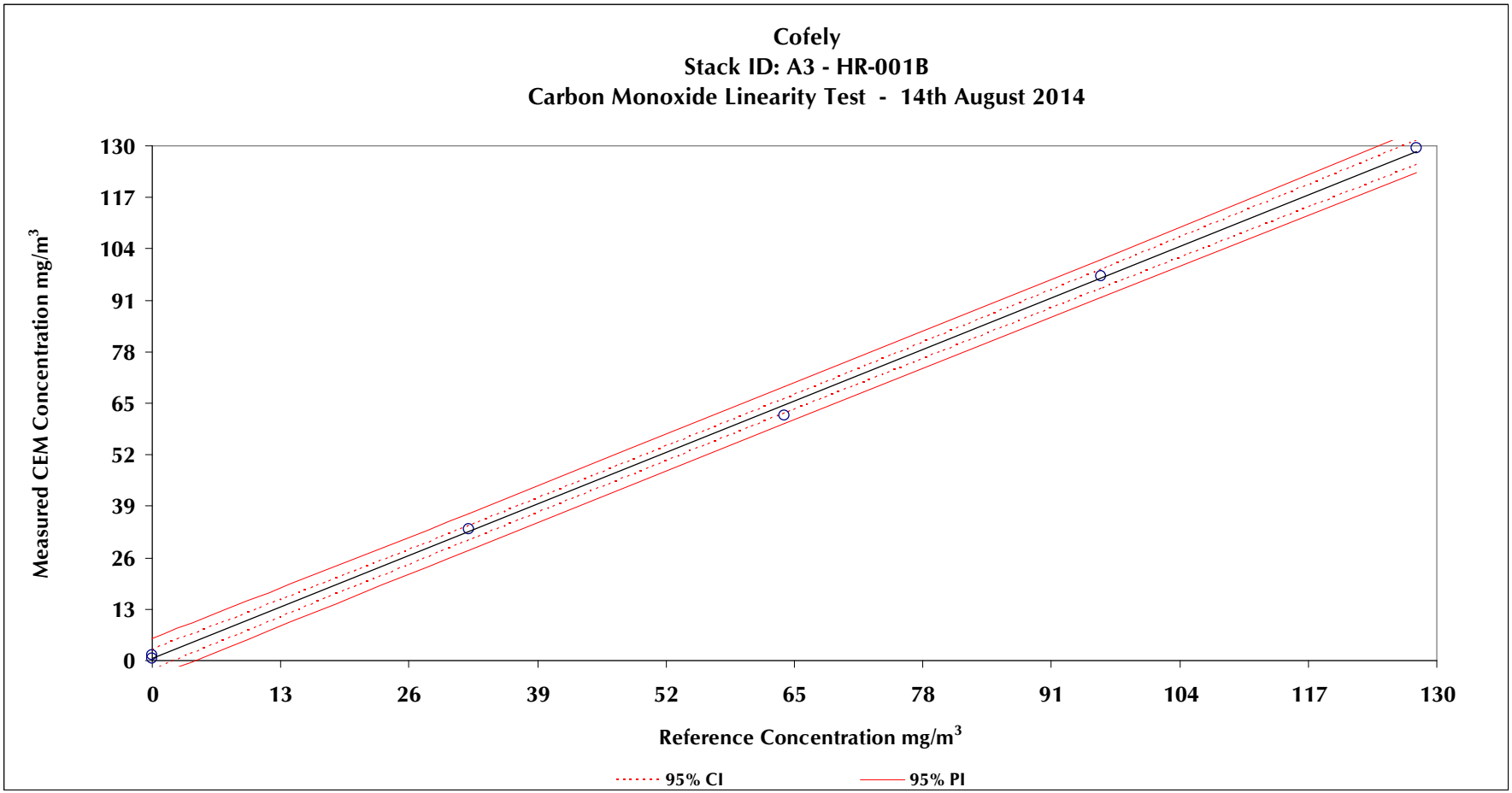
$n\sum(x-\bar{x})^2$ 81920.00

$\sum x^2$ 30720.00

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ 0.93

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ 2.57

5.3.6.2.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for CO A3



5.3.6.3.1 Linearity Calculations for O2 A3

Cofely
Linearity test for Oxygen - 14th August 2014
Daily ELV: 21 %Vol
Linearised Range: 25 %Vol

Date	Time	% Linearised Range	Reference Concentration %Vol	Measured CEM Concentration %Vol	$\bar{Y}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} Y_{c,i}$ %Vol	$(x_i - x_z)$ %Vol	$(x_i - x_z)^2$ %Vol	$y_i(x_i - x_z)$ %Vol	$d_c = \bar{Y}_c - (A+Bc)$ %Vol	$d_{c,rel} = \frac{d_c}{x_u}\times 100\%$	$d_{c,rel} <$ 5%?
14/08/14	13:39	0%	0	0.01	0.01	-8.34	69.56	-0.08	0.27	1.06%	PASS
	13:40			0.01				-0.08			
	13:41			0.01				-0.08			
14/08/14	13:53	60%	15.02	15.44	15.39	6.68	44.62	103.14	-0.43	-1.72%	PASS
	13:54			15.39				102.81			
	13:55			15.35				102.54			
14/08/14	14:05	20%	5.02	4.92	4.91	-3.32	11.02	-16.33	-0.21	-0.83%	PASS
	14:06			4.91				-16.30			
	14:07			4.90				-16.27			
14/08/14	14:18	80%	20	21.55	21.80	11.66	135.96	251.27	0.64	2.57%	PASS
	14:19			21.95				255.94			
	14:20			21.89				255.24			
14/08/14	14:45	40%	10	9.90	9.91	1.66	2.76	16.43	-0.54	-2.15%	PASS
	14:46			9.90				16.43			
	14:47			9.93				16.48			
14/08/14	17:32	0%	0	0.01	0.01	-8.34	69.56	-0.08	0.27	1.06%	PASS
	17:33			0.01				-0.08			
	17:34			0.01				-0.08			

Sum	150.12	156.09
Mean (X_z)	8.34	8.67
Count (n)	...	18

1000.40	1070.88

$a = \frac{1}{n}\sum_{i=1}^{n} Y_i$ = **8.67**

$B = \frac{\sum_{i=1}^{n} Y_i (X_i - X_z)}{\sum_{i=1}^{n} (X_i - X_z)^2}$ = **1.0704** ± 0.079

$A = a - BX_z$ = **-0.2559** ± 0.881

Range (X_u) = **25** %Vol

5.3.6.3.2 95% CI & PI Calculations for O2 A3

95% Confidence Intervals

$\hat{y}$	$(y-\hat{y})^2$	x^2	$(\hat{y}-\bar{y})^2$	95% CI	95% PI
-0.26	0.071	0.00	79.70	0.88	1.69
15.82	0.184	225.60	51.13	0.79	1.64
5.12	0.04	25.20	12.63	0.64	1.57
21.15	0.414	400.00	155.79	1.09	1.80
10.45	0.29	100.00	3.16	0.60	1.56
-0.26	0.07	0.00	79.70	0.88	1.69

MSE: 0.27

95% Confidence Interval of Slope

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **0.5179**

$\sqrt{SSX}$ **18.26**

$s_b = \frac{s_{est}}{\sqrt{SSX}}$ **0.0284**

$t_{\alpha/2,N-2}$ **2.78**

$95\%\ CI = S_b \times t_{\alpha/2,N-2}$ **0.079**

95% Confidence Interval of Intercept

$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}}$ **0.5179**

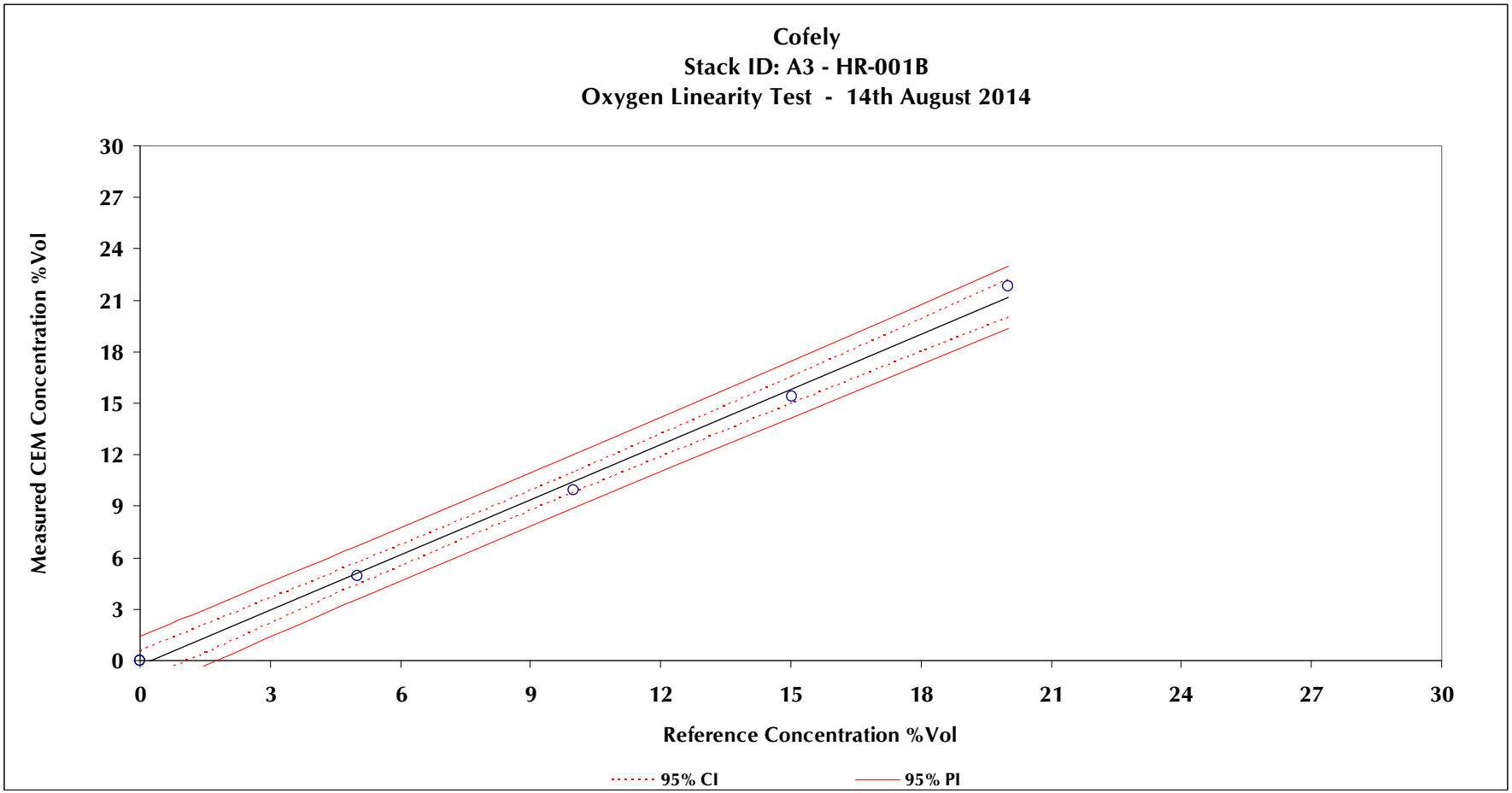
$n\sum(x-\bar{x})^2$ **2000.80**

$\sum x^2$ **750.80**

$s_a = s_{est}\sqrt{\frac{\sum x^2}{n\sum(x-\bar{x})^2}}$ **0.32**

$95\%\ CI = S_a \times t_{\alpha/2,N-2}$ **0.88**

5.3.6.3.3 XY Plot of Measured CEM Concentration Vs Concentration of Applied Reference Materials for O2 A3



6 UNCERTAINTY CALCULATIONS

6.1.1 Contributing Factors to Combustion Gases Uncertainty

The following contributing factors have been included in the determination of the analyser uncertainty for combustion gases measured by the **Horiba PG250:**

Performance Characteristic	Standard Uncertainty	Value of Standard Uncertainty
Lack of fit	u_{lof}	[30] $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
Span drift	$u_{d,s}$	$u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
Repeatability Standard Deviation (span)	u_r	$\sigma_i = \Delta x_i$
Losses / leakage in the sample system	u_{loss}	[31] $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
Temperature dependant span drift See Note	u_t	$u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$
Interferents	u_i	$u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \Delta x_i$
[32]Effect of Voltage Fluctuation See Note	u_v	$u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$
[33]Effect of Oxygen Synergism	u_{syn}	$u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$		
Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$		

The MCERTS certificate for the Horiba PG250 (certificate number: Sira MC050056/04) issued on the 23rd March 2009 states the following:

- Tests for the effects of vibration, sample gas pressure and temperature are not required.
- No value for effect of voltage fluctuations has been included in this certificate.

Note:

Where $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

30 Where Δx_i is the percent of range in mg/m^3 (or %Vol).

31 Where Δx_i is the percent of the measured value in mg/m^3 (or %Vol).

32 Applies to TOC analyser only.

33 Applies to TOC analyser only.

6.1.2 Combustion Gas Uncertainty

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i)		
			NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.29	0.029
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	2.34	1.15	0.094
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	1.92	0.073	0.31
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.18	0.050	0.070
Interferents[1]	u_i	Rectangular (Divisor = √3)	1.20	2.90	0.56
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	4.55	2.27	0.15

Note:

$$when \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol inc additional uncertainty of 2% for gas blending
7 Applies to TVOC only

Measurement Uncertainty Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.29	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	2.34	1.15	0.094
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	1.38	0.040	0.044
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.15	0.032	0.012
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	2.63	1.31	0.089
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	3.89	2.38	0.16
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	7.79	4.75	0.32
Applied Span Concentration			262.61	130.94	15.38
Measured Span Concentration, STP Dry Gas			260.02	129.78	15.44
Expanded measurement uncertainty as % of Applied Span			3%	4%	2%

7 REFERENCE MATERIALS

7.1 SRM Reference Materials

Calibration Gas	Concentration [34]	Supplier	Cylinder Solution ID.	Expiry Date	Uncertainty
NO	256.2 ppm	Air Liquide	Gas / 1304	19/11/16	± 1%
CO	209.5 ppm	Air Liquide	Gas / 1207	29/08/15	± 1%
O_2	15.38 %Vol	Air Liquide	Gas / 1279	28/06/16	± 1%

[34] Please note that this is the cylinder concentration. Mass flow controllers were used to blend down this bottle concentration to a suitable concentration for calibration purposes. See Section 7.2 'SRM Calibration Validation Summary'.

7.2 SRM Calibration Validation Summary

	Horiba PG 250 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	512.5 mg/m³	250 mg/m³	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	-0.20	0.00	-0.09
Mean Confirmation Direct Zero	-0.26	0.35	-0.07
Difference in Direct Zero	0.06	0.35	0.01
Repeatability at Zero	4.10	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES
	Pre Zero Values (System)		
Mean Pre Test Zero	-0.30	-0.07	-0.01
% of Measurement Range?	-0.06%	-0.03%	-0.03%
Detection Limit (LOD)	0.07	0.55	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	262.61	130.94	15.38
	Pre Test System Zero Values		
Mean Pre Test System Zero	-0.30	-0.07	-0.01
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.11%	0.05%	0.05%
	Post Zero Values (System)		
Mean Post Test Zero	0.10	0.99	-0.02
% of Certified Range?	0.02%	0.40%	-0.08%
Zero Drift ≤ ± 5% of Applied Span?	0.15%	0.81%	0.08%
	Pre Test System Span Values		
Mean Pre Test System Span	260.21	130.87	15.46
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.91%	0.05%	0.50%
	Post Test System Span Values		
Mean Post Test System Span	259.90	129.13	15.42
Span Drift ≤ ± 5% Span Value?	0.12%	1.33%	0.21%
	0.15%	1.33%	0.21%
	See Note 3	See Note 3	See Note 3

NOTE 1: Data Invalid! Contact Quality Manager!
NOTE 2: Correct test data for drift!
NOTE 3: No drift correction required.

7.3 CEM Reference Materials

Calibration Gas	Concentration	Supplier	Cylinder Solution ID.	Expiry Date	Uncertainty
NO	197 ppm	Air Products	Unknown	Unknown ~2016	± 2%
CO	197.5 ppm	Air Products	Unknown	Unknown ~2016	± 2%
O_2	21 %Vol	Ambient Air			

8 DATA VALUES

8.1 Outlying Value Calculation Procedure

Once the SRM/CEM data pair averages have been established, calculate the difference between the SRM and CEM values (D_i) for each data pair and subsequently, the mean ($\overline{D}$) and standard deviation (σ) of the differences D_i. If the difference between D_i and $\overline{D}$ for each SRM/CEM pair is greater than twice σ, then that SRM/CEM pair may be considered a possible outlier and can be removed from further calculations.

The calibrated CEM value was then calculated and the magnitude of the associated residual ($|D_i|$) was found using:

$$D_i = y_i - x_i$$

Where:

D_i	calculated Residual
y_i	time averaged measurement of SRM
x_i	time averaged measurement of CEM

The mean residual ($\overline{D_i}$) and the standard deviation of the residuals are calculated as follows:

$$\overline{D_i} = \frac{\sum_{i=1}^{n} D_i}{n} \qquad S_{residuals} = \sqrt{\frac{\sum_{i=1}^{n} (D_i - \overline{D_i})^2}{n-1}}$$

Where:

n = Number of half hourly averages

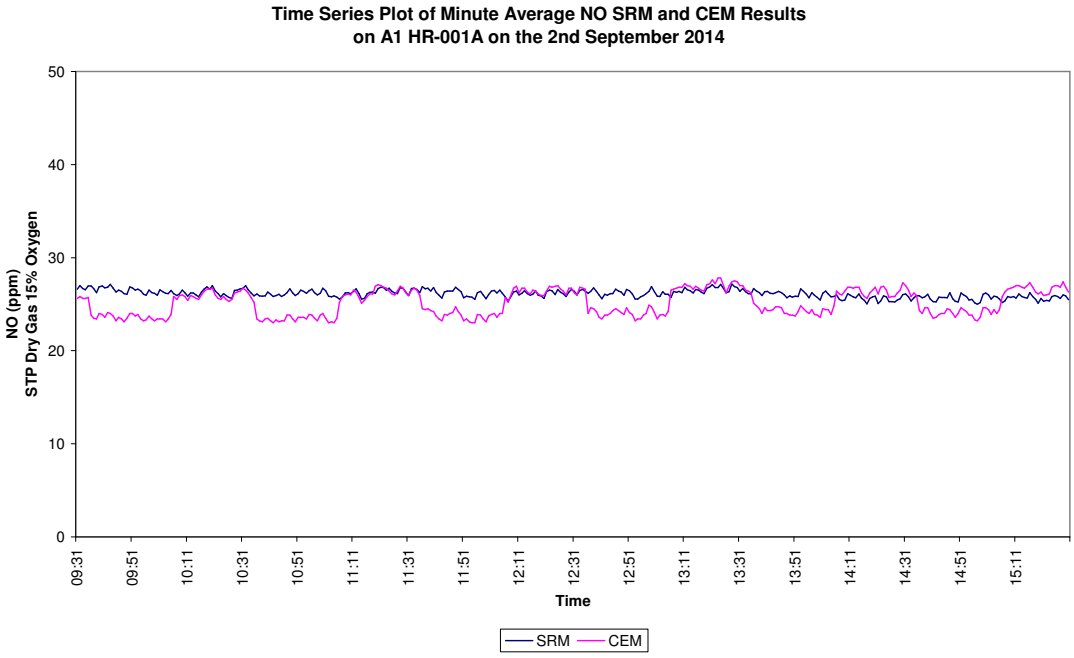
The magnitude of the difference between each residual (D_i) and the mean residual ($\overline{D_i}$) is calculated and compared with $S_{residuals}$. Where $\left|D_i - \overline{D_i}\right| > 2 \times S_{residuals}$ (i.e. 2 × standard deviation ~ 95% confidence), the SRM / CEM data pair is discarded from future consideration as a potential outlier. The above procedure should be repeated no more than once.

Care should be taken when deciding whether an SRM/CEM data pair is a potential outlier. Where the value of the slope & intercept of the SRM & CEM data pairs is non-significant as indicated by the R^2 value, the range of data is less than 15% of the Daily ELV or the data is unduly influenced by upscale data points, false positives may be identified.

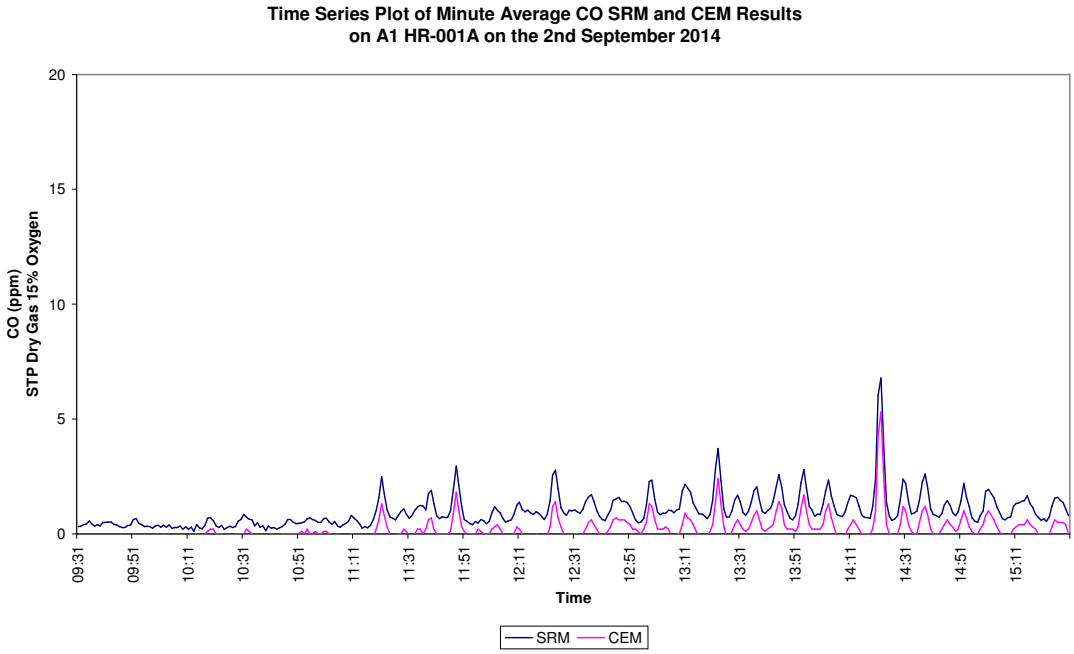
8.2 Time Series Plots of Minute Averages

HR-001A A1

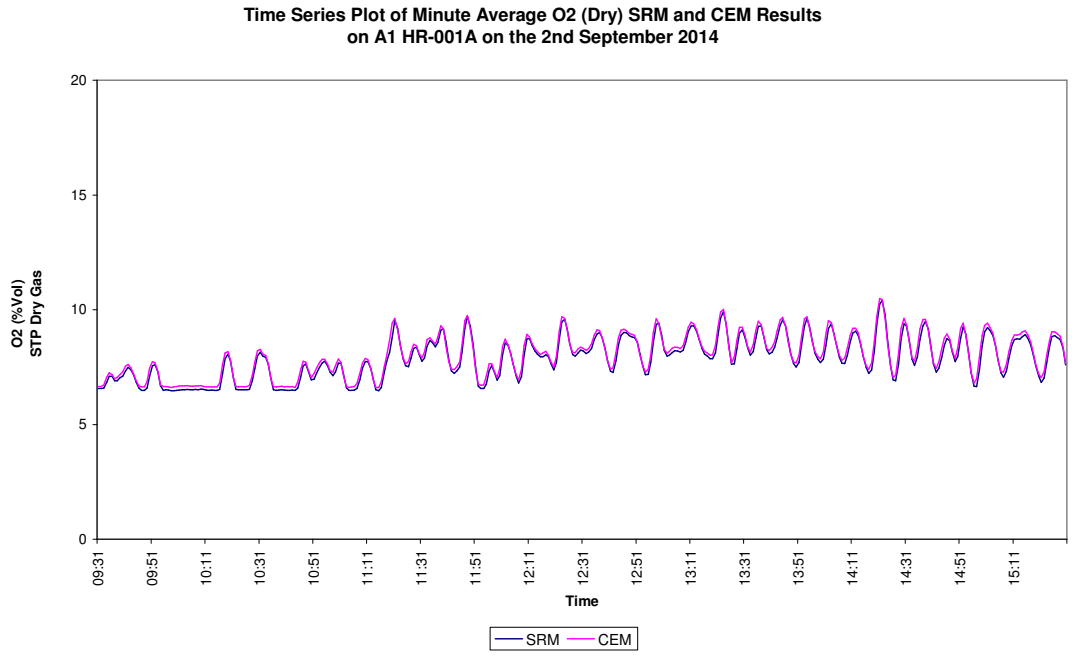
NO



CO

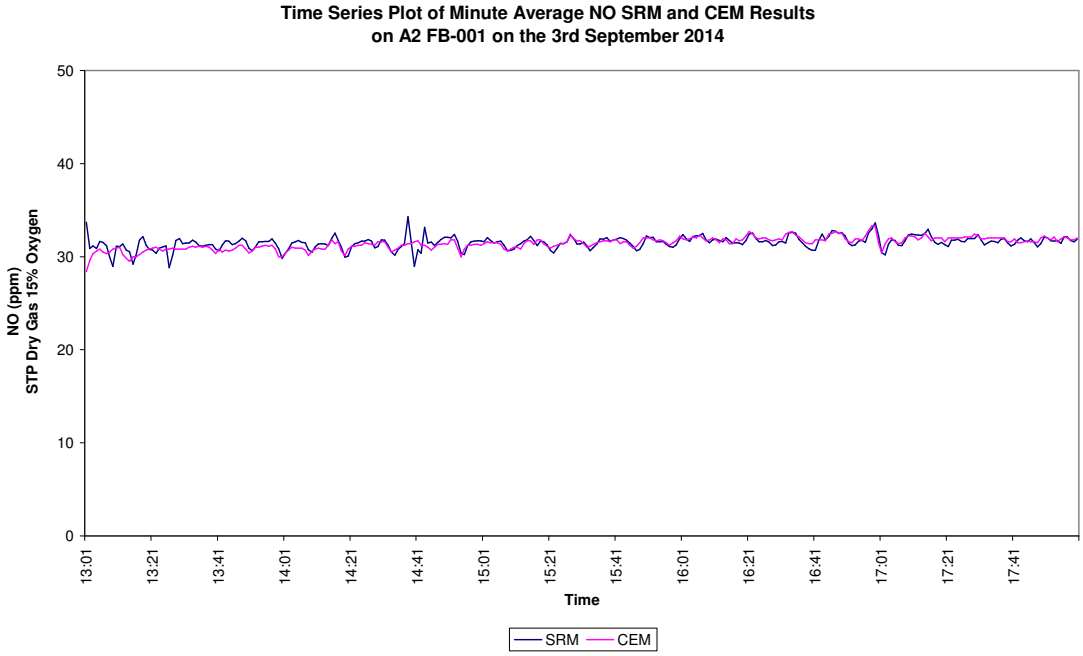


O2

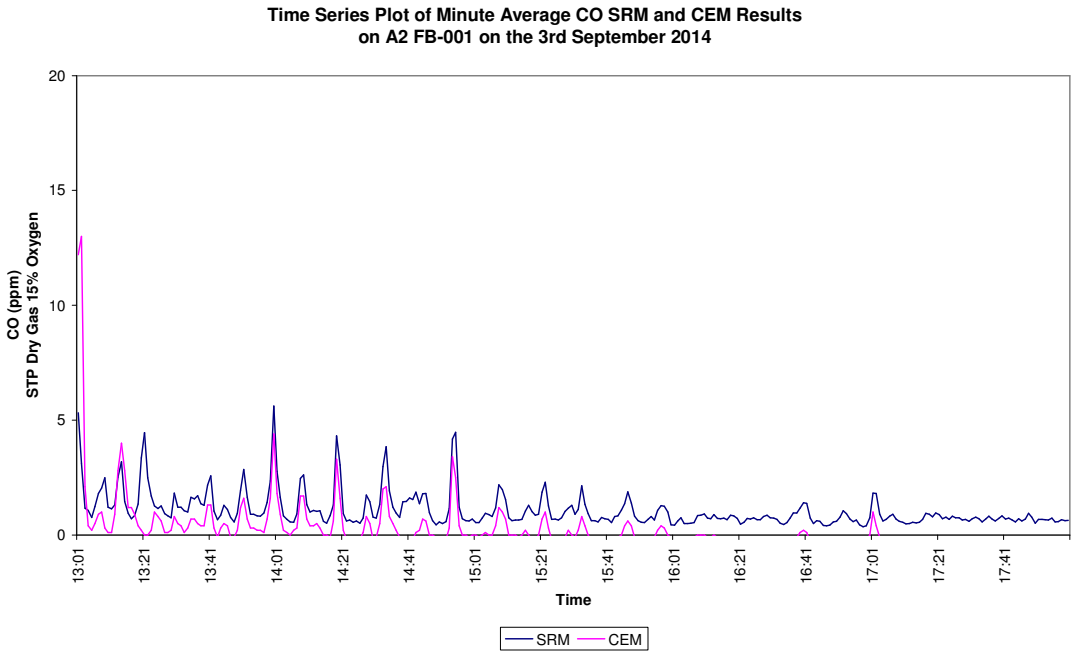


FB-001 A2

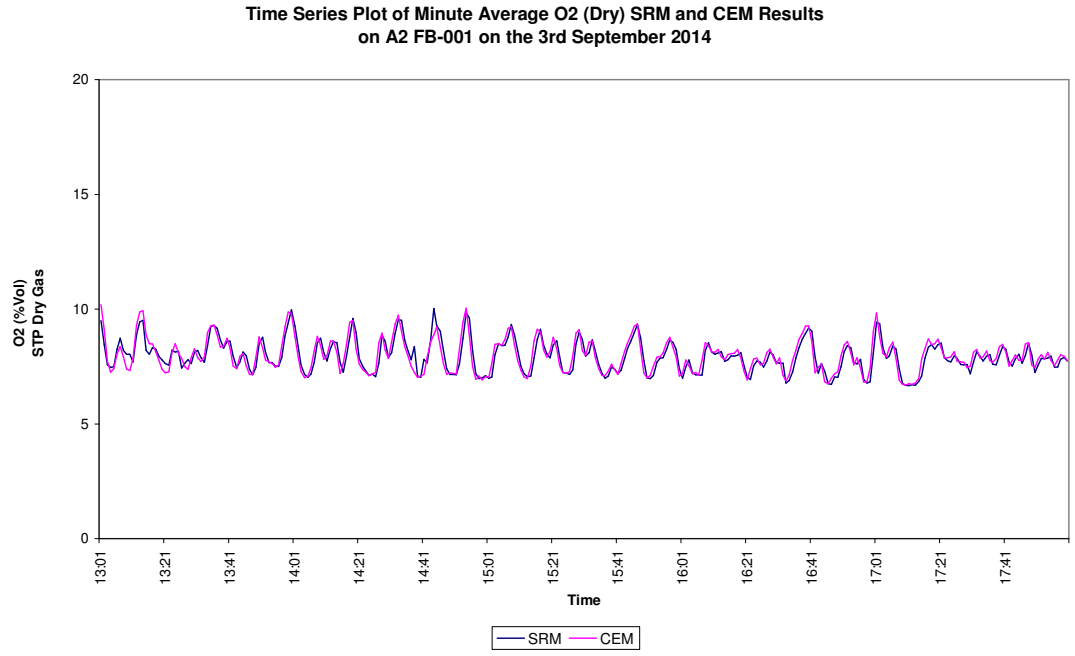
NO



CO

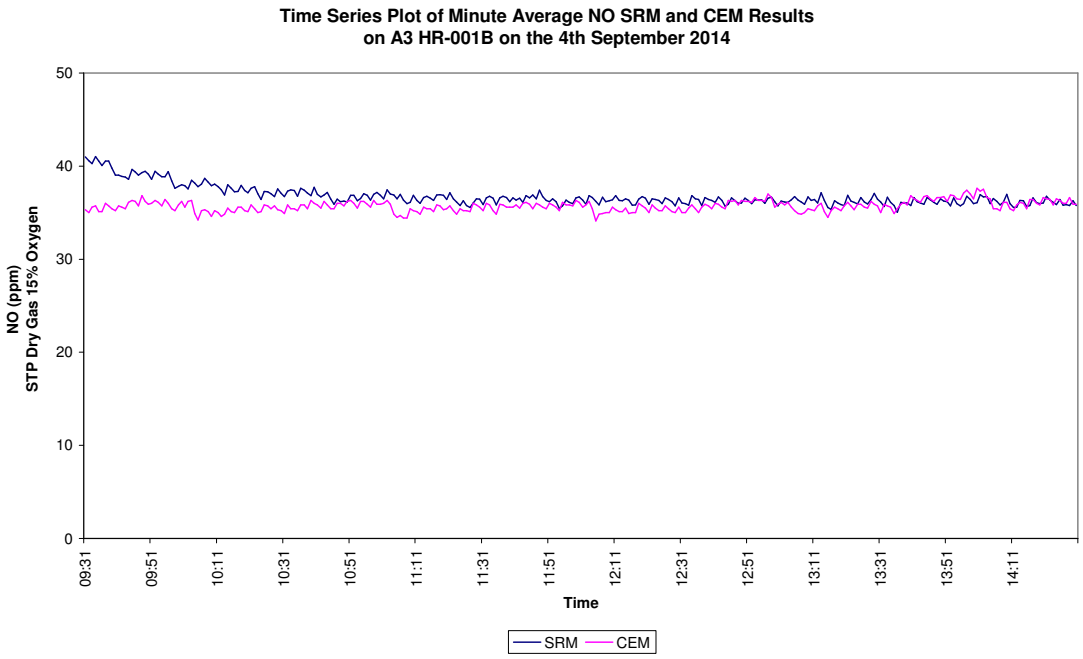

Time Series Plot of Minute Average CO SRM and CEM Results
on A2 FB-001 on the 3rd September 2014
CO (ppm)
STP Dry Gas 15% Oxygen
20
15
10
5
0
13:01
13:21
13:41
14:01
14:21
14:41
15:01
15:21
15:41
16:01
16:21
16:41
17:01
17:21
17:41
Time
SRM
CEM

O2

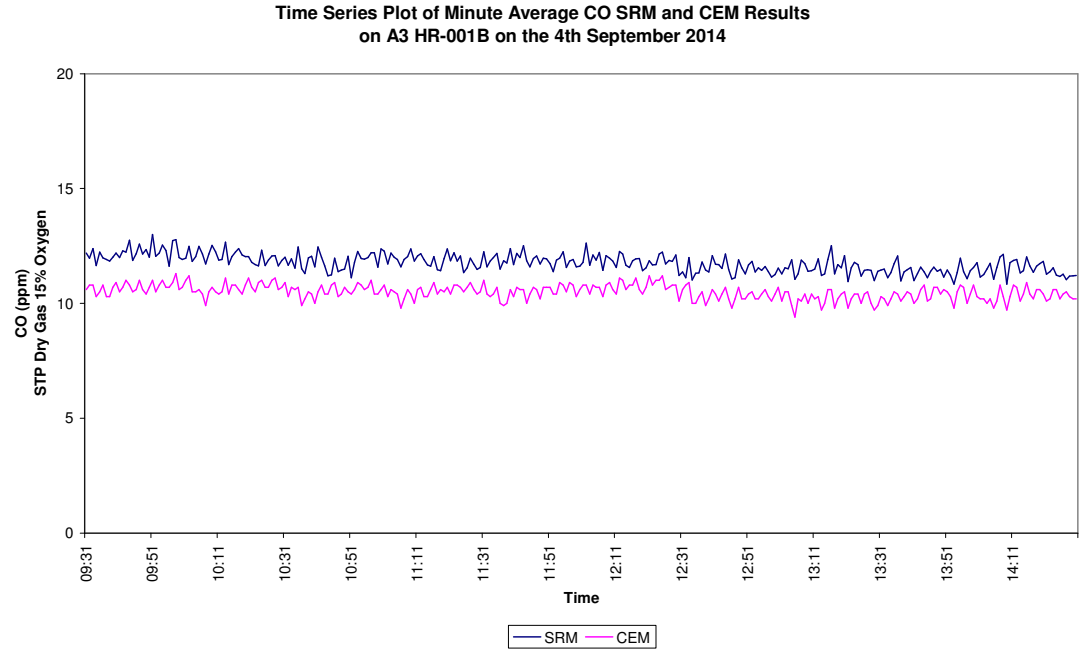

Time Series Plot of Minute Average O2 (Dry) SRM and CEM Results
on A2 FB-001 on the 3rd September 2014
O2 (%Vol)
STP Dry Gas
20
15
10
5
0
13:01
13:21
13:41
14:01
14:21
14:41
15:01
15:21
15:41
16:01
16:21
16:41
17:01
17:21
17:41
Time
SRM
CEM

HR-001B A3

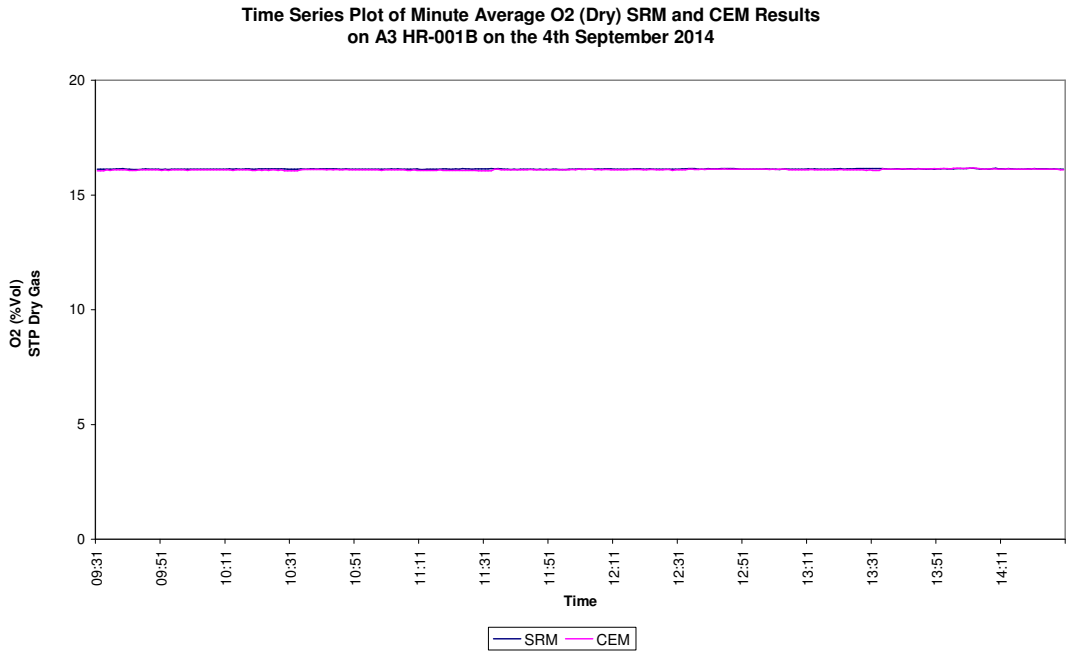
NO



CO



O2


Time Series Plot of Minute Average O2 (Dry) SRM and CEM Results
on A3 HR-001B on the 4th September 2014
O2 (%Vol)
STP Dry Gas
20
15
10
5
0
09:31
09:51
10:11
10:31
10:51
11:11
11:31
11:51
12:11
12:31
12:51
13:11
13:31
13:51
14:11
Time
SRM
CEM

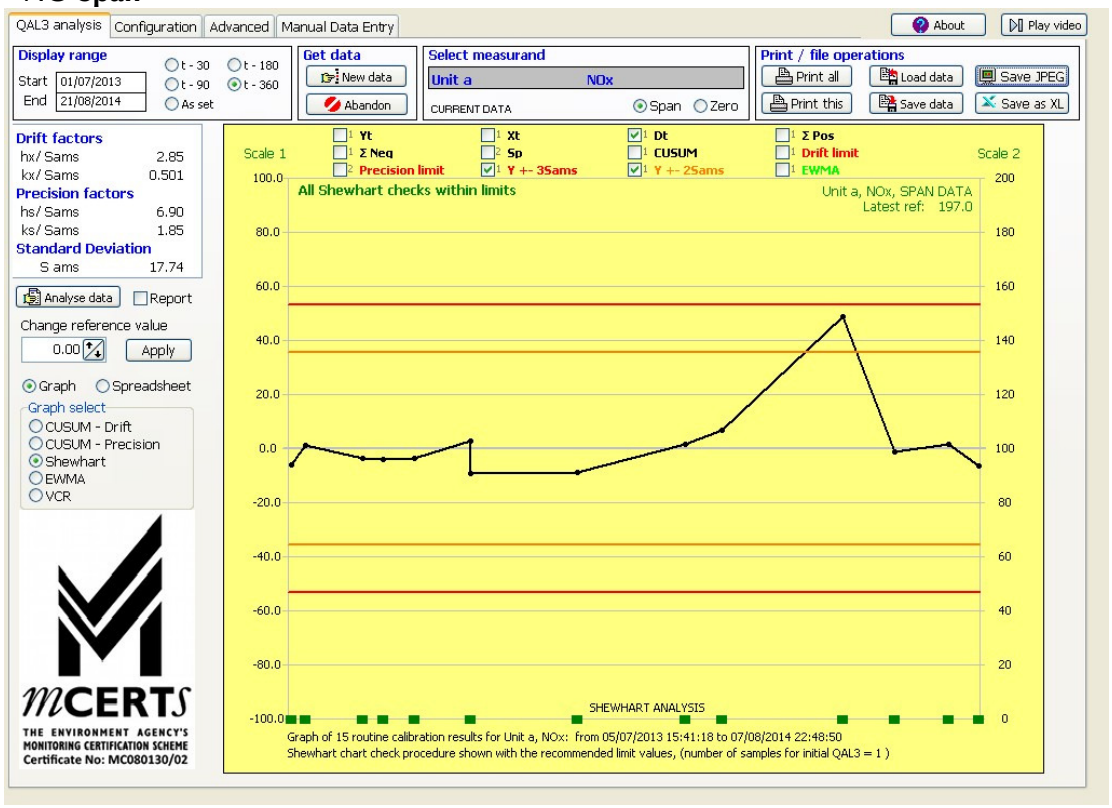
9 CEM QAL3 DATA

9.1 QAL3 Control Charts

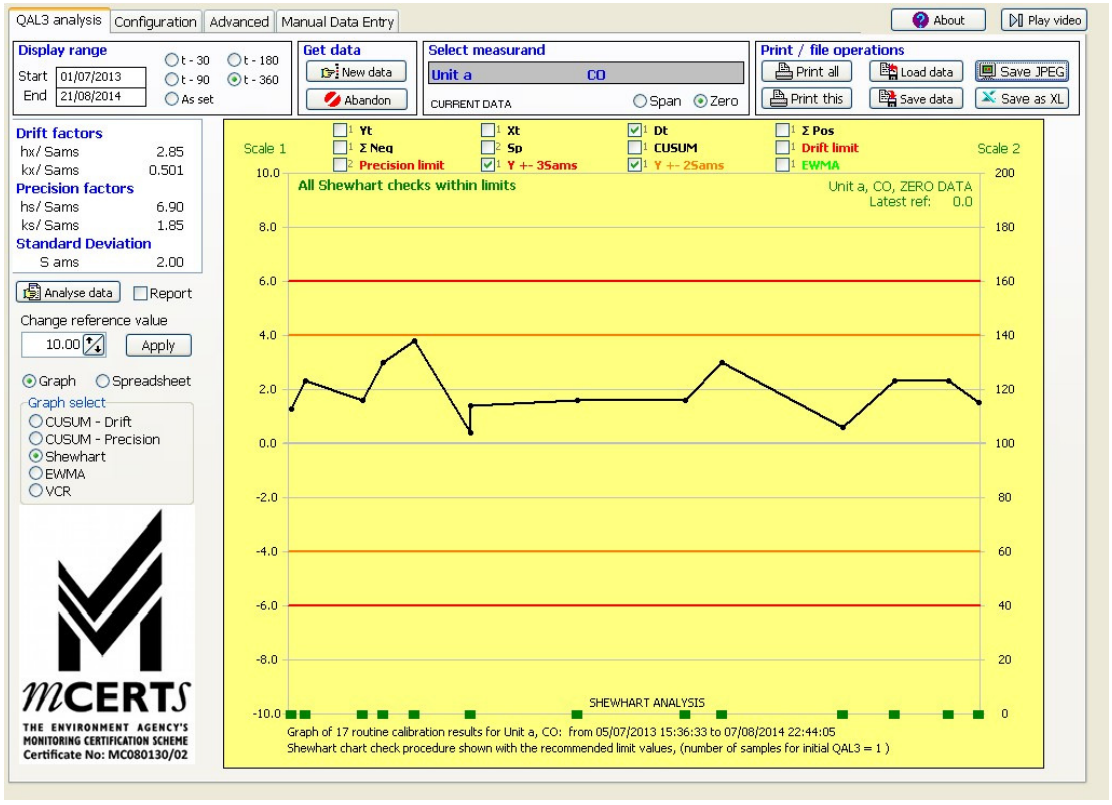
HR-001A A1

NO Zero

NO Span



CO Zero



CO Span

O2 Zero

O2 Span

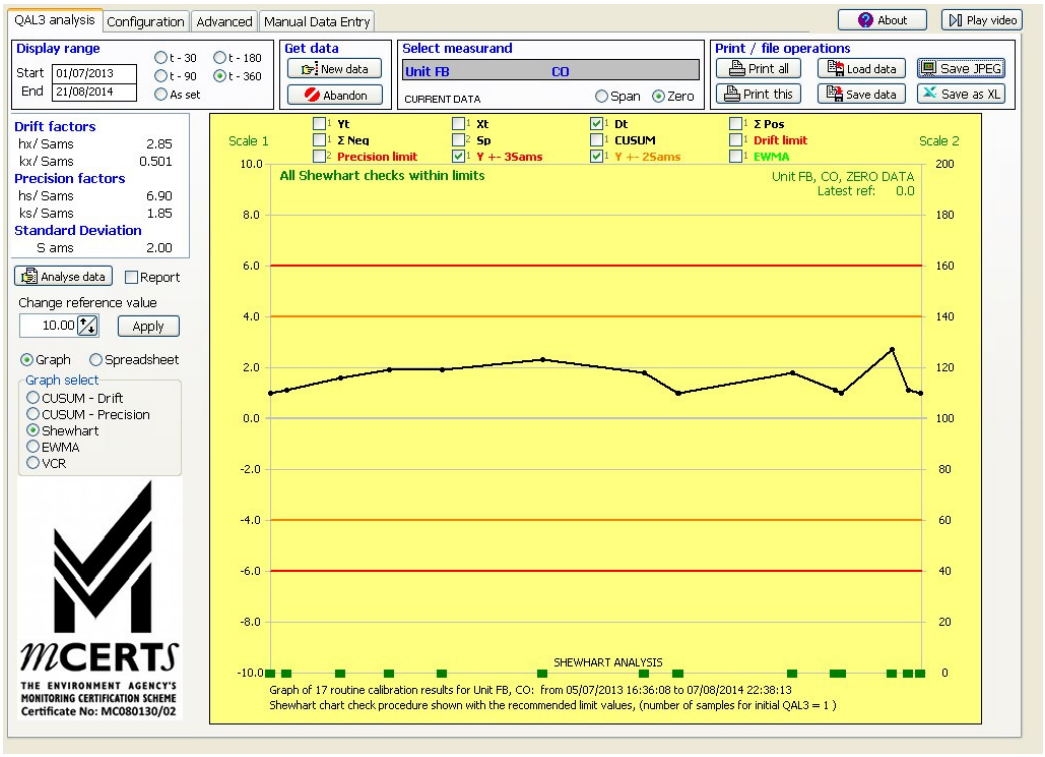

QAL3 analysis
Configuration
Advanced
Manual Data Entry
About
Play video
Display range
Start 01/07/2013
End 21/08/2014
t - 30
t - 180
t - 90
t - 360
As set
Get data
New data
Abandon
Select measurand
Unit a O2
CURRENT DATA
Span
Zero
Print / file operations
Print all
Load data
Save JPEG
Print this
Save data
Save as XL
Drift factors
hx/ Sams 2.85
kx/ Sams 0.501
Precision factors
hs/ Sams 6.90
ks/ Sams 1.85
Standard Deviation
S ams 2.00
Analyse data
Report
Change reference value
0.00
Apply
Graph
Spreadsheet
Graph select
CUSUM - Drift
CUSUM - Precision
Shewhart
EWMA
VCR
MCERTS
THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME
Certificate No: MC080130/02
Yt
Σ Neg
Precision limit
Xt
Sp
Y +- 3Sams
Dt
CUSUM
Y +- 2Sams
Σ Pos
Drift limit
EWMA
Scale 1
Scale 2
All Shewhart checks within limits
Unit a, O2, SPAN DATA
Latest ref: 20.90
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
200
180
160
140
120
100
80
60
40
20
0
SHEWHART ANALYSIS
Graph of 15 routine calibration results for Unit a, O2: from 05/07/2013 15:36:38 to 07/08/2014 22:44:10
Shewhart chart check procedure shown with the recommended limit values, (number of samples for initial QAL3 = 1)

FB-001 A2

NO Zero

NO Span

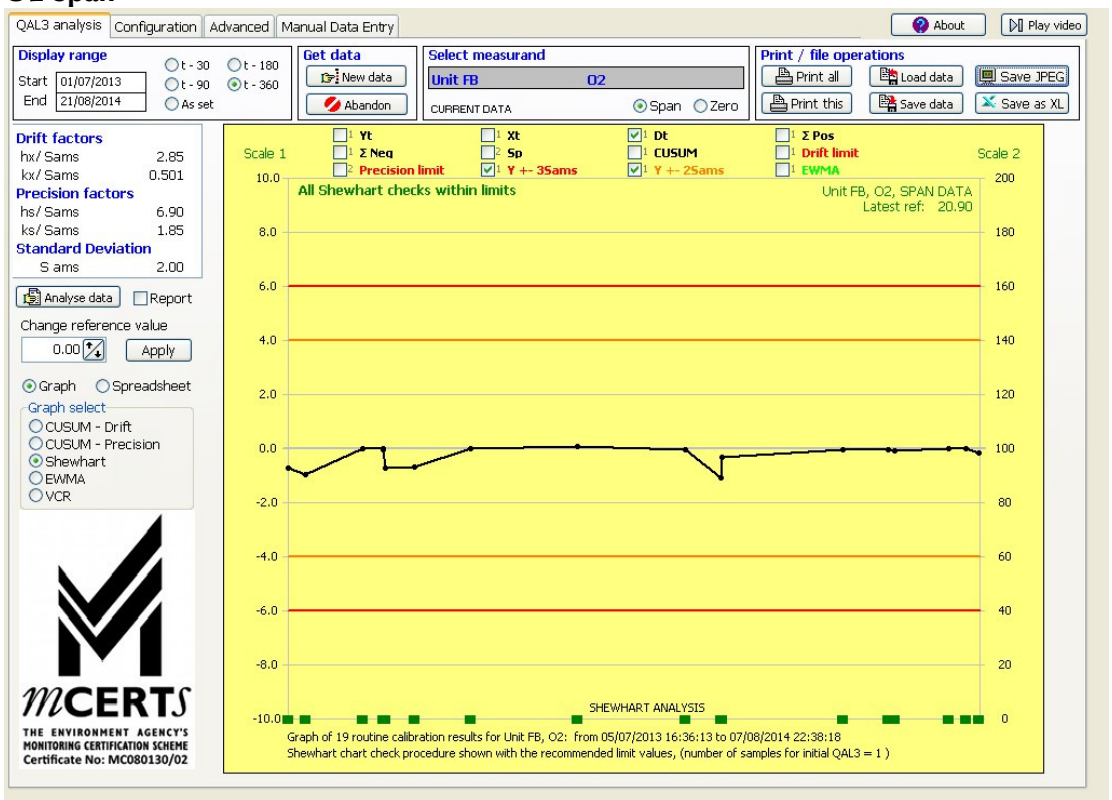
CO Zero



CO Span

O2 Zero

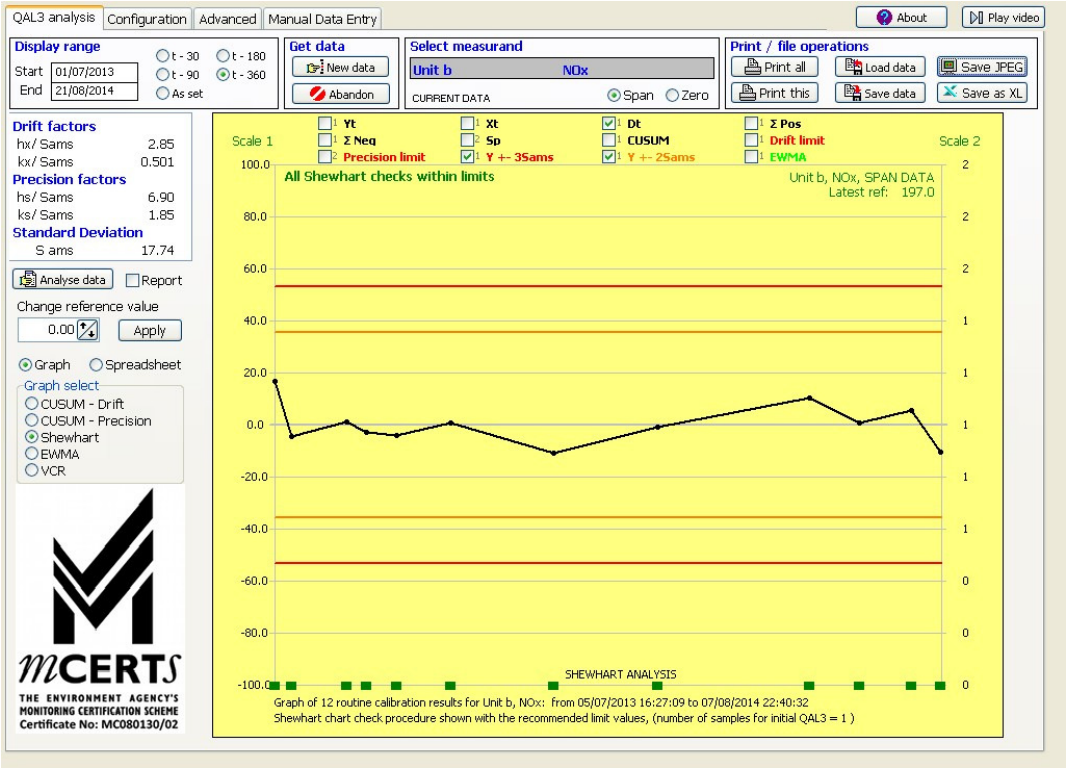
O2 Span



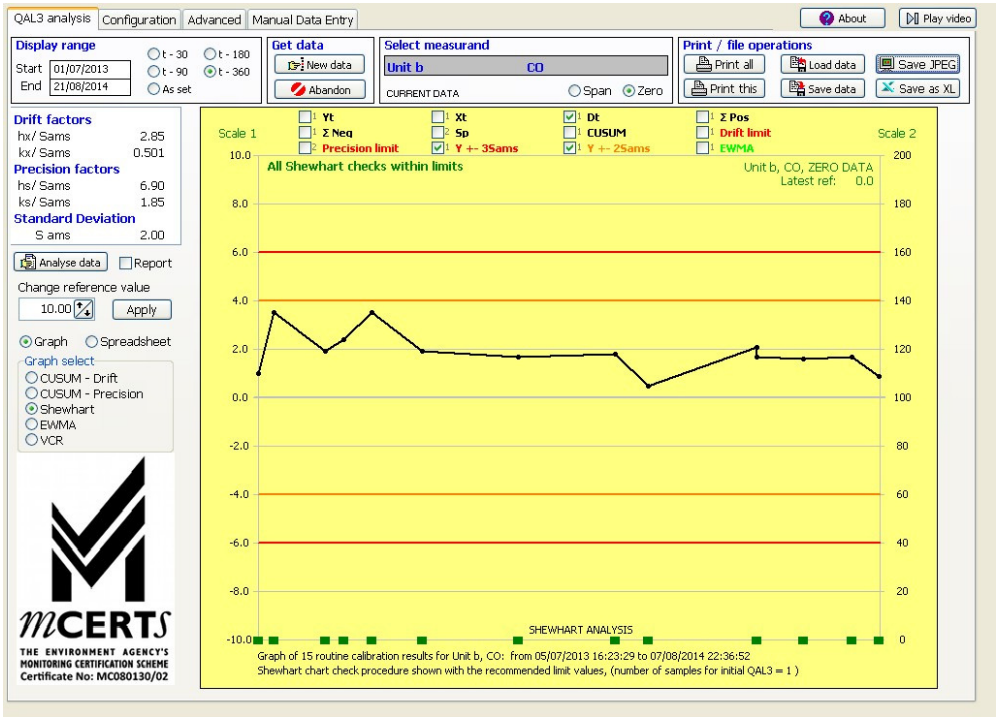
HR-001B A3

NO Zero

NO Span

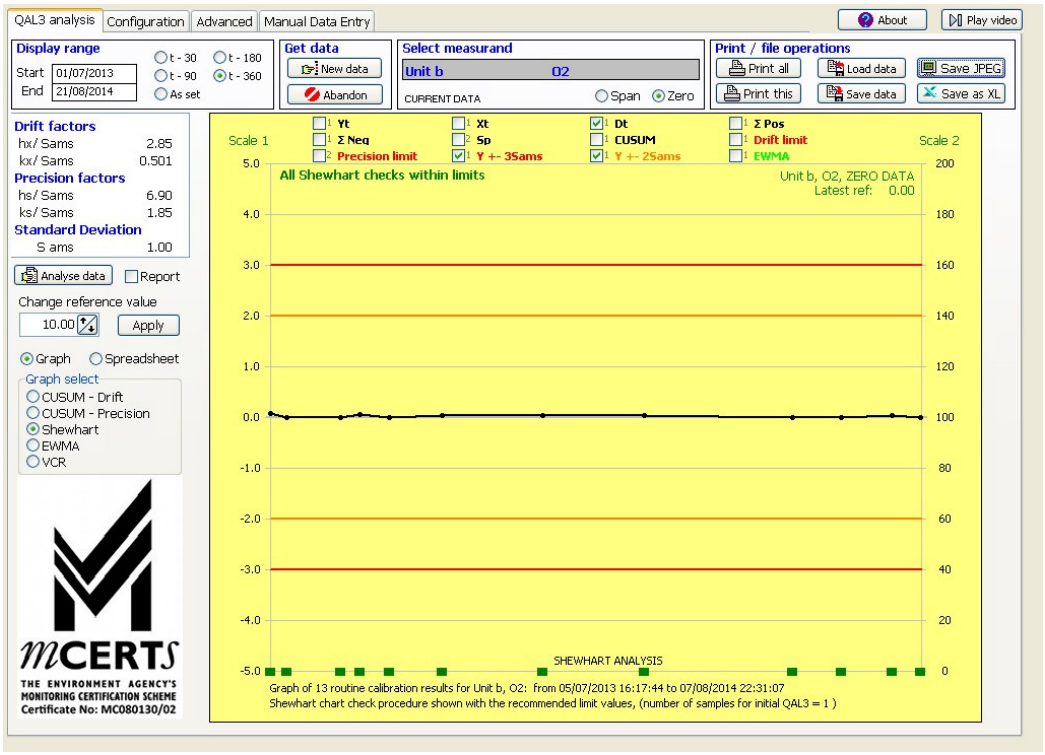


CO Zero



CO Span

O2 Zero



O2 Span

9.2 QAL3 CEM Logged Data

Not provided, but available on request if required.

10 EQUIPMENT USED

Equipment	Equipment Type	ID No:	ID No:	ID No:	ID No:
MST console/pump	E001				
MST Nozzle set					
MST "S" Type Pitot					
MST Probe					
MST Hot Box					
MST Impinger Arm					
Barometer		629			
Site Balance					
Site Check weights					
Horiba	E002	096			
Heated Probe Filter		572			
Chiller		972			
Sonimix / MFC		758	760		
Heated Line		854	853		
FID	E003				
Heated Line					
Heated Probe Filter					
Testo	E004				
FTIR	E005				
Heated Probe Filter					
Heated Line					
Stackmite	E006				
"L" Type Pitot					
Digital Manometer					
Stack Thermocouple					
Thermocouple Reader					
Nozzle Set					

Quantity of ice used: N/A bags