

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
Variation Number	: ...
Installation	: CHP Plant
Visit Details	: AST – 2015
Job Number	: P2522
Report Number	: R001
Report Issue Date	: 12 th November 2015
Survey Dates	: 7 th to 11 th September 2015

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Report Issue:		FINAL	
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Date:	10/11/2015	Date:	12/11/2015

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Environmental Compliance Limited

Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

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Any Opinions and Interpretation expressed within the results section are outside the scope of the UKAS accreditation.

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1.0 EXECUTIVE SUMMARY

Environmental Compliance Ltd (ECL) was commissioned by **Cofely (GDF Suez)** to undertake to undertake an AST calibration validation procedure in accordance with BS EN 14181, the Environment Agency's Technical Guidance Note M20 & MID.

This report presents the findings of the study.

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 monitoring¹ 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.*

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.

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1.1 Summary of Results

BS EN 14181 Test Designation:		AST			Stack Designation:	A1 HR-001A		
Determinands	Calibration Function		Units of Calibration Function	Conditions of Calibration Function	Valid Calibration Range Based on Calibrated CEMs Data ²	Extrapolated Range Based on Reference Materials (From Previous QAL 2)	PASS / FAIL	
	<i>a</i>	<i>b</i>					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) ³	- 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, once applied, only remains valid as long as the QAL3 data remains within control limits, and that there are no manual adjustments made to the CEMs other than those allowed to bring the settings back within QAL3 control limits.

Note: If exceedances of the valid calibration range are caused by plant failures, a new QAL2 is not needed after fixing the plant failure.

² Data from AST may be used to extend the valid calibration range to the maximum measured CEM value at reference conditions from the AST plus an extensions of 10% provided that the range does not exceed 50% of the ELV.

² Reference material at zero and a concentration close to ELV shall be used for linear extrapolation providing that the deviation at the ELV is less than the maximum permissible uncertainty and the deviation at zero is less than 10% of the ELV (EN 14181: 2014, Section 6.5).

³ Default values of 10% for the 95% confidence interval and 21% for the ELV were used for oxygen in this QAL2 (MID 14181, section 6.3 iv, a.)

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BS EN 14181 Test Designation:		AST			Stack Designation:	A2 FB-001		
Determinands	Calibration Function		Units of Calibration Function	Conditions of Calibration Function	Valid Calibration Range Based on Calibrated CEMs Data ⁴	Extrapolated Range Based on Reference Materials (From Previous QAL 2)	PASS / FAIL	
	<i>a</i>	<i>b</i>					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) ⁵	0.0098	0.9788	%Vol	273K, 101.3 kPa, Dry Gas	0 – 10.07 %Vol	0 – 20.49 %Vol	PASS	PASS

Note: The QAL2 calibration function, once applied, only remains valid as long as the QAL3 data remains within control limits, and that there are no manual adjustments made to the CEMs other than those allowed to bring the settings back within QAL3 control limits.

Note: If exceedances of the valid calibration range are caused by plant failures, a new QAL2 is not needed after fixing the plant failure.

⁴ Data from AST may be used to extend the valid calibration range to the maximum measured CEM value at reference conditions from the AST plus an extensions of 10% provided that the range does not exceed 50% of the ELV.

⁴ Reference material at zero and a concentration close to ELV shall be used for linear extrapolation providing that the deviation at the ELV is less than the maximum permissible uncertainty and the deviation at zero is less than 10% of the ELV (EN 14181: 2014, Section 6.5).

⁵ Default values of 10% for the 95% confidence interval and 21% for the ELV were used for oxygen in this QAL2 (MID 14181, section 6.3 iv, a.)

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BS EN 14181 Test Designation:		AST			Stack Designation:	A3 HR-001B		
Determinands	Calibration Function		Units of Calibration Function	Conditions of Calibration Function	Valid Calibration Range Based on Calibrated CEMs Data ⁶	Extrapolated Range Based on Reference Materials (From Previous QAL 2)	PASS / FAIL	
	<i>a</i>	<i>b</i>					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) ⁷	- 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, once applied, only remains valid as long as the QAL3 data remains within control limits, and that there are no manual adjustments made to the CEMs other than those allowed to bring the settings back within QAL3 control limits.

Note: If exceedances of the valid calibration range are caused by plant failures, a new QAL2 is not needed after fixing the plant failure.

⁶ Data from AST may be used to extend the valid calibration range to the maximum measured CEM value at reference conditions from the AST plus an extensions of 10% provided that the range does not exceed 50% of the ELV.

⁶ Reference material at zero and a concentration close to ELV shall be used for linear extrapolation providing that the deviation at the ELV is less than the maximum permissible uncertainty and the deviation at zero is less than 10% of the ELV (EN 14181: 2014, Section 6.5).

⁷ Default values of 10% for the 95% confidence interval and 21% for the ELV were used for oxygen in this QAL2 (MID 14181, section 6.3 iv, a.)

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1.2 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: David Boles (ECL)	MCERTS No.: MM 03 215
Were there any deviations from SRMs?	NO	
Were there any deviations from EN14181?	YES	
Were there any corrective actions required?	YES	

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 ppm dry and corrected to 15% oxygen	CEMs have oxygen correction selected at the analyzer on the sampling platform and calculations are done automatically by analyzer	None providing that the SRM data has been corrected and expressed at the same conditions as the CEM as detailed in Section 6.3 of EN 14181: 2014	If possible or practical select oxygen correction off at the analyzer so that raw data reaches the Envirosoft software and then the oxygen correction can then be implemented later on from within the software
CEM service carried out greater than one month before the AST parallel tests	CEM service done on 30 – 31/03/2015, AST survey 8 – 11/09/2015	AST deviates from Section 6.2 of EN 14181: 2014 however all parameters passed the AST calibration validation and variability tests and all linearity tests passed relevant checks. In addition, a follow up service was carried out on 29/09/2015 and no errors were reported.	Ensure future CEM service / functional tests are carried out no more than one month before the AST / QAL2 parallel SRM and CEM tests
Functional tests do not comply with requirements of Annex A, EN 14181: 2014	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). 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

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2.0 INSTALLATION INFORMATION

2.1 Regulatory Information

2.1.1 Installation

Barry Cogeneration Plant

2.1.2 Address

Cofely (GDF Suez), Barry Silicon Based Manufacturing Installation, Winbourne Road, Dock 2, Barry, CF63 3DH

2.1.3 Sector

LCPD

(WID & LCPD have been recast within the Industrial Emissions Directive 2010/75/EU)

2.1.4 Date of Previous QAL2 / AST

AST issued 21/10/2014

2.1.5 Regulated determinands

Determinand	Emission Point	Daily ELV	Allowable Uncertainty ⁸
Oxides of Nitrogen as (NO)	A1, A2 & A3	125 mg/m ³ for NO _x (as NO ₂)	20%
		Please note: NO equivalent of 81.5 mg/m ³ used for calculation purposes	
Carbon Monoxide		80 mg/m ³	* 10%

*** Please note: a 95% confidence interval of 20% may be used for CO for the test of variability (Section 8.5, MID 14181, TGN M20 Version 3).**

⁸ This is expressed as a 95% confidence interval within WID or LCPD

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2.2 Operating Information and site monitoring-provisions

2.2.1.1 Process Details

Emission Point Reference	Date(s)	Process Type	Process ⁹ Duration	Fuel	Abatement	Load
A1	08/09/2015	Gas Turbine	Continuous	Gas	None	100 to 125 hours steam
A2	09/09/2015	HP Boiler	Continuous	Gas	None	100 to 125 hours steam
A3	11/09/2015	Gas Turbine	Continuous	Gas	None	100 to 125 hours steam

Substance to be Monitored	CEM Zero & Span						
	Zero	¹⁰ Concentration	Span	Concentration	¹¹ Type	¹² Frequency	Time(s)
Oxides of Nitrogen as (NO)	Y	0 ppm	Y	196.8 ppm	Reference Gas	Monthly	Variable
Carbon Monoxide	Y	0 ppm	Y	200.5 ppm	Reference Gas	Monthly	Variable
Oxygen (Dry)	Y	0 %Vol	Y	20.9 %Vol	Ambient Air	Monthly	Variable

⁹ Please state continuous or batch process

¹⁰ This value is typically zero, although for some analysers, it may be a low concentration value.

¹¹ Indicate reference gas, gas filled cell, filter, other (specify)..

¹² Indicate daily, fortnightly, monthly etc.

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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.
- O₂ 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	08/09/2015	Gas	>95 %	Fuel Oil	< 5%	NO	NO
A2	09/09/2015	Gas	>95 %	Fuel Oil	< 5%	NO	NO
A3	11/09/2015	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

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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

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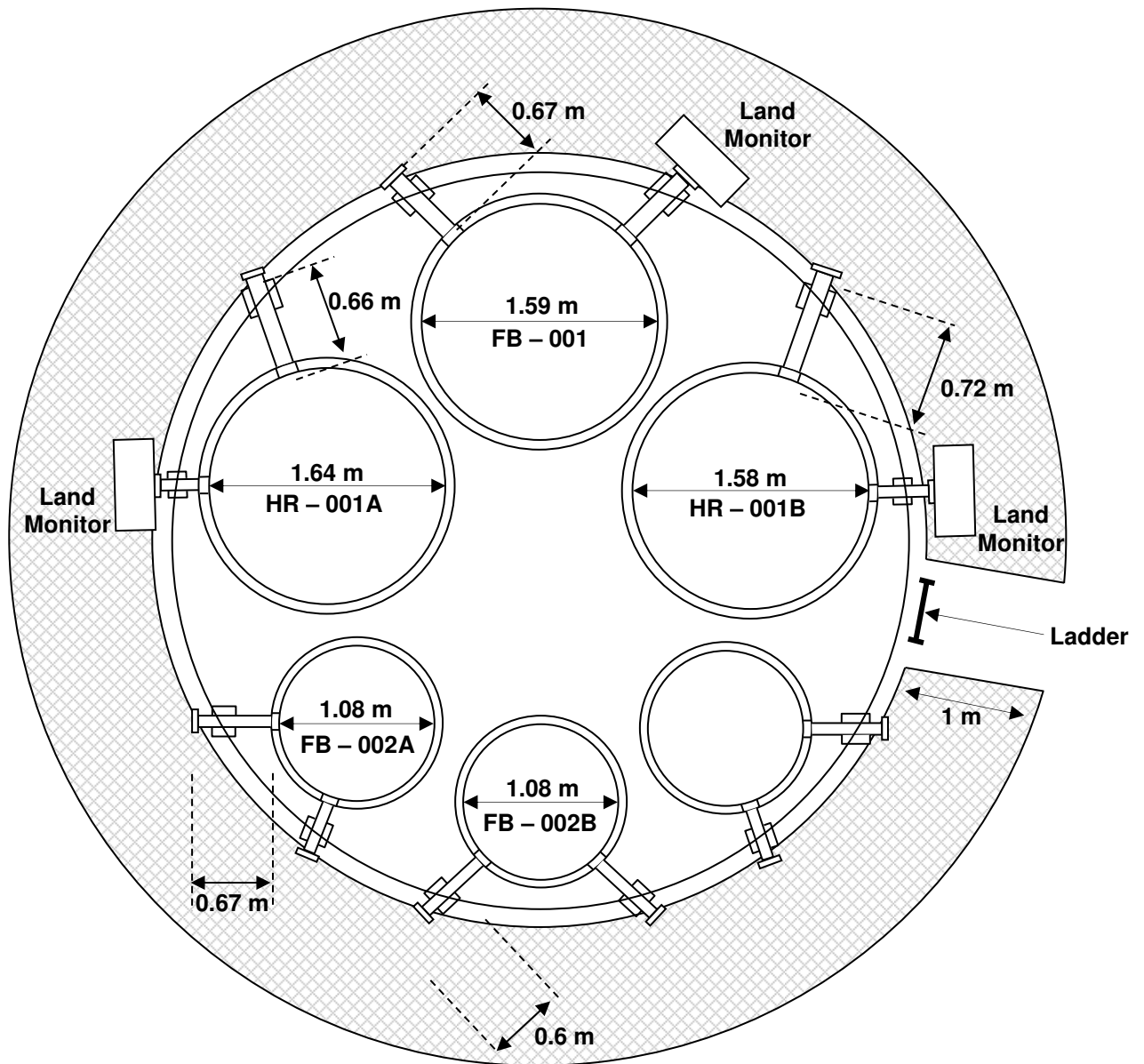


Figure 1. Diagram of sampling location

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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 all weather protected
Easy and safe access to all elements of the CEM	✓		Ok, accessed from permanent platform
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
Does the sampling platform currently meet the requirements detailed in <i>Technical Guidance Note (Monitoring) M1 "Sampling requirements for stack-emission monitoring" Environment Agency?</i>	✓		Small platform dimensions but sufficient for combustion gas sampling
Has homogeneity at the sample plane been determined to EN 15259 for all measured components? If yes, state date and report reference in 'Notes'. If no, is the stack exempt due to small dimensions?	✓		See report JCC7671/R/10/81184/05
If homogeneity has not been determined and the stack is not exempt, was grid sampling undertaken? If yes, state ratio of highest to lowest flowrates in 'Notes'. If no, detail the reasons in 'Notes'.		✓	Not applicable

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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 ¹³		Upper limit of		Minimum Certified Range Meets QAL1 Multiplier ¹⁴ 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	0 – 200 mg/m ³	0 – 400 mg/m ³	Y
Carbon Monoxide	Extractive	LAND	FGA950E	Electrochemical Cell	Y	Y	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 ¹³		Upper limit of	
		Type	Brand	Model	Measurement Principle	Zero	Span	Certified Range	Operational Range
Oxygen (Dry)	Yes	Extractive	LAND	FGA950E	Electrochemical Cell	Y	Y	0 – 12 %Vol	0 – 25 %Vol
Oxygen (Wet)	No	Not applicable							
Moisture	No								
Temperature	No								
Pressure	No								

¹³ 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.

¹⁴ Typically, minimum certified range should not exceed 1.5 X Daily ELV for WID sites and 2.5 X Daily ELV for LCPD sites.

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3.0 Monitoring Campaign

3.1 Site Team Details

Name	Dates on Site	MCERTS Number	LEVEL	TE	Expiry Date
David Boles	7 th – 11 th September 2015	MM 03 215	2	TE1	30.09.18
				TE2	31.03.20
				TE3	30.09.17
				TE4	30.06.19

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, NO_x, SO₂, O₂.

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3.2 Standard Reference Methods (SRMs)

Determinand	Instrument	Measurement Principle	SRM Standard	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 PG 250	Chemiluminescence	BS EN 14792: 2005		0 – 125 mg/m ³	¹⁵ 3%	YES	
Carbon Monoxide	Horiba PG 250	NDIR	BS EN 15058: 2006		0 – 95 mg/m ³	¹⁶ 3%	YES	
Oxygen	Horiba PG 250	Zirconia	BS EN 14789:2005		0 – 25 %	¹⁷ 3%	YES	

Stand alone velocity measurements and those made to support isokinetic sampling after 01/01/2015 are conducted using BS EN 16911-1:2013 & MID

¹⁵ Based on an applied span of 125.91 mg/m³ at 273K, 101.3 kPa, Dry Gas on 08/09/2015.

¹⁶ Based on an applied span of 151.70 mg/m³ at 273K, 101.3 kPa, Dry Gas on 08/09/2015.

¹⁷ Based on an applied span of 15.07 %Vol at 273K, 101.3 kPa, Dry Gas on 08/09/2015.

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3.3 Introduction

Environmental Compliance Ltd (ECL) was commissioned by **Cofely (GDF Suez)** to undertake an Annual Surveillance Test (AST) on **emissions point A1, A2 and A3** 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 Mr Paul Gardner in accordance with quotation reference **DHFB/P2522/Q001**.

Report Reviewer

Name	MCERTS Number	LEVEL	TE	Expiry Date
David Boles	MM 03 215	2	TE1	30.09.18
			TE2	31.03.20
			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, SO₂, O₂.

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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: 2014 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.

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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 & O₂)

Measurements of combustion gases were carried out using an MCERTS Certified Horiba PG 250 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:

<u>Determinand</u>	<u>Technique</u>	<u>SRM</u>
• 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).

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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

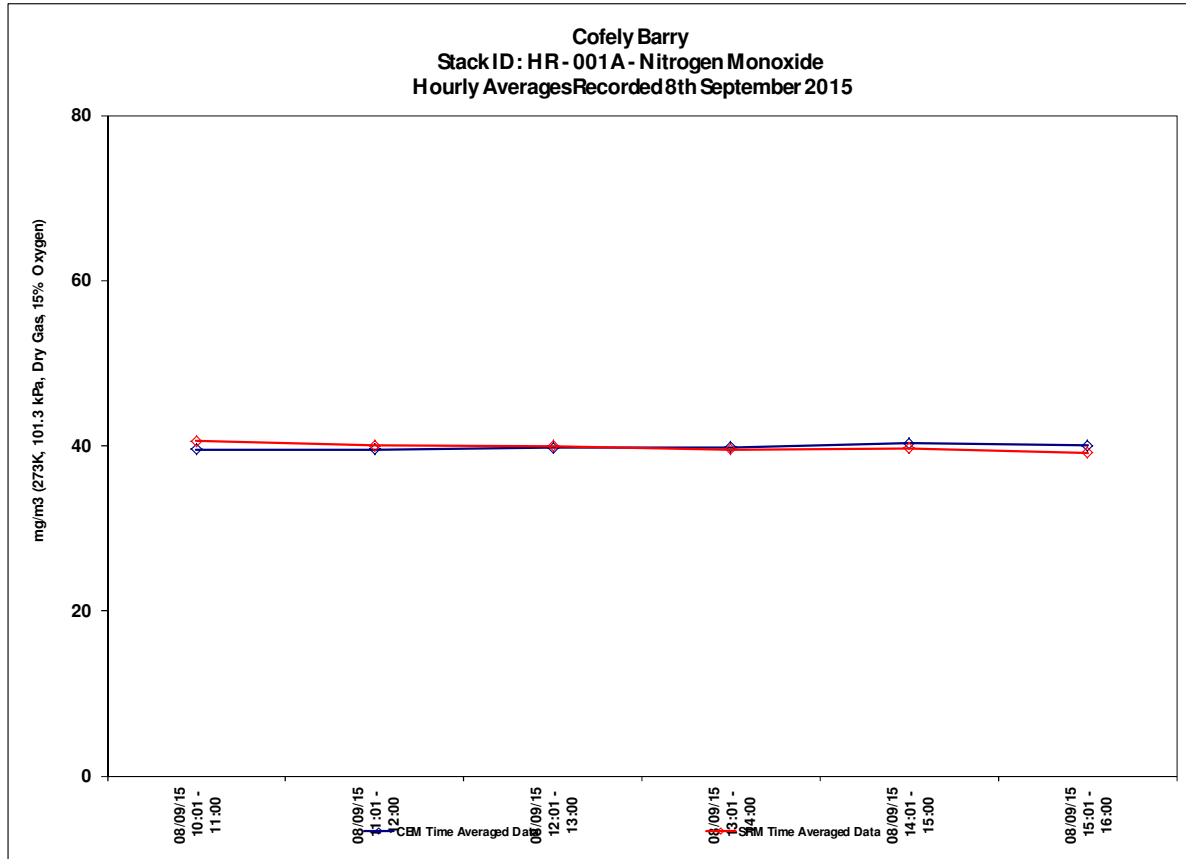
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated ⁽¹⁾	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m ³ Uncalibrated ⁽²⁾
08/09/2015	10:01 - 11:00	29.52	-	-	-	-	39.53
08/09/2015	11:01 - 12:00	29.56	-	-	-	-	39.59
08/09/2015	12:01 - 13:00	29.69	-	-	-	-	39.76
08/09/2015	13:01 - 14:00	29.73	-	-	-	-	39.81
08/09/2015	14:01 - 15:00	30.08	-	-	-	-	40.28
08/09/2015	15:01 - 16:00	29.90	-	-	-	-	40.04
(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⁾
08/09/2015	10:01 - 11:00	30.30	-	-	-	-	40.57
08/09/2015	11:01 - 12:00	29.88	-	-	-	-	40.02
08/09/2015	12:01 - 13:00	29.85	-	-	-	-	39.97
08/09/2015	13:01 - 14:00	29.55	-	-	-	-	39.57
08/09/2015	14:01 - 15:00	29.64	-	-	-	-	39.69
08/09/2015	15:01 - 16:00	29.24	-	-	-	-	39.16
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							

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B4.3a

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



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

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	08/09/2015	10:01 - 11:00	30.30	29.52	0.78	0.78	YES
2	08/09/2015	11:01 - 12:00	29.88	29.56	0.32	0.32	YES
3	08/09/2015	12:01 - 13:00	29.85	29.69	0.16	0.16	YES
4	08/09/2015	13:01 - 14:00	29.55	29.73	-0.18	0.18	YES
5	08/09/2015	14:01 - 15:00	29.64	30.08	-0.44	0.43	YES
6	08/09/2015	15:01 - 16:00	29.24	29.90	-0.66	0.65	YES

Slope	-1.18	Mean	0.00
Intercept	64.77	Stdev	0.5264
R ²	0.49		

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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
08/09/2015	10:01 - 11:00	29.52	28.75	-	-	-	-	38.50	40.57
08/09/2015	11:01 - 12:00	29.56	28.80	-	-	-	-	38.56	40.02
08/09/2015	12:01 - 13:00	29.69	28.93	-	-	-	-	38.73	39.97
08/09/2015	13:01 - 14:00	29.73	28.96	-	-	-	-	38.78	39.57
08/09/2015	14:01 - 15:00	30.08	29.32	-	-	-	-	39.25	39.69
08/09/2015	15:01 - 16:00	29.90	29.14	-	-	-	-	39.01	39.16

(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

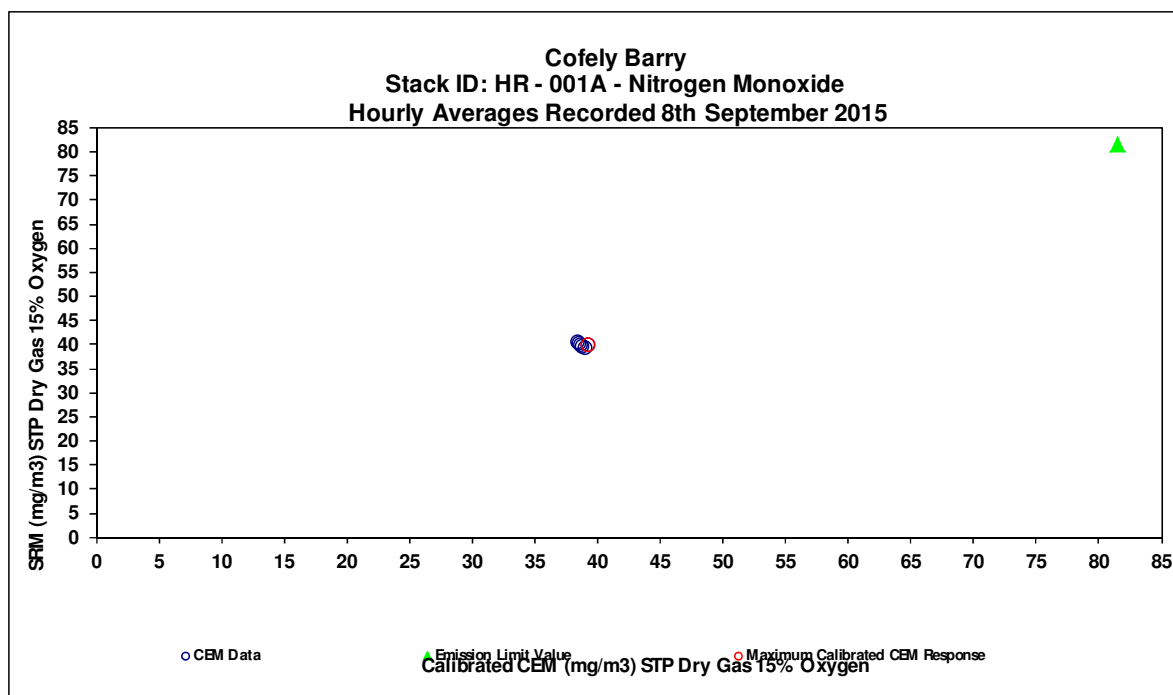
Determinand: Nitrogen Monoxide				QAL2 Calibration function: y=1.0056x-0.9335					
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference Conditions mg/m ³	Residual Value	Deviation of Residual from Mean		
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$	
39.53	40.57	38.50	40.57	39.53	38.50	2.07	1.05	1.09	
39.59	40.02	38.56	40.02	39.59	38.56	1.46	0.44	0.19	
39.76	39.97	38.73	39.97	39.76	38.73	1.24	0.21	0.046	
39.81	39.57	38.78	39.57	39.81	38.78	0.79	-0.24	0.056	
40.28	39.69	39.25	39.69	40.28	39.25	0.44	-0.58	0.34	
40.04	39.16	39.01	39.16	40.04	39.01	0.15	-0.88	0.77	
Sum						6.13	0.00	2.49	
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 1.02$									
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0.5) = 0.71$									
$N = 6$									
$K_v = 0.93$									
$p = 20$									
$E = 82$									
$\sigma_0 = \frac{pE}{1.96} = 8.32$									
$1.5\sigma_0 k_v = 11.64$									
$s_D \leq 1.5\sigma_0 k_v = 0.71 \text{ mg/m}^3 < 11.64 \text{ mg/m}^3 - \text{Pass Variability Test}$									
$t_{0.95}(N-1) = 2.13$									
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 8.93$									
$ \bar{D} \quad 1.02\text{mg/m}^3 < 8.93\text{mg/m}^3 - \text{Calibration Remains Valid}$									

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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	39.25	mg/m ³
Corresponding SRM @ Reference Conditions	39.69	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	31.38 - 48.01	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	mg/m ³

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B4.1b & B4.2b

Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for CO A1

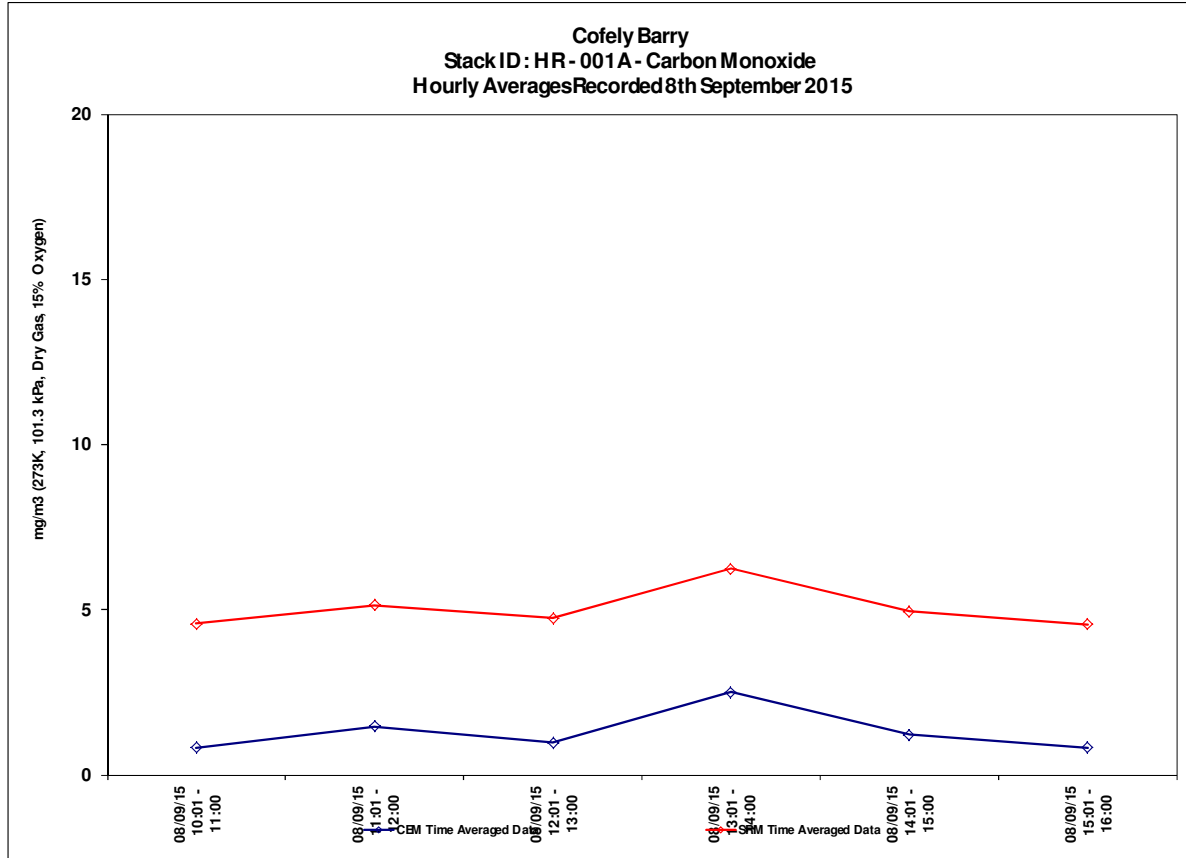
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated ⁽¹⁾	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m ³ Uncalibrated ⁽²⁾
08/09/2015	10:01 - 11:00	0.66	-	-	-	-	0.83
08/09/2015	11:01 - 12:00	1.18	-	-	-	-	1.47
08/09/2015	12:01 - 13:00	0.78	-	-	-	-	0.98
08/09/2015	13:01 - 14:00	2.00	-	-	-	-	2.50
08/09/2015	14:01 - 15:00	0.98	-	-	-	-	1.22
08/09/2015	15:01 - 16:00	0.67	-	-	-	-	0.83
(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⁾
08/09/2015	10:01 - 11:00	3.66	-	-	-	-	4.57
08/09/2015	11:01 - 12:00	4.11	-	-	-	-	5.14
08/09/2015	12:01 - 13:00	3.79	-	-	-	-	4.74
08/09/2015	13:01 - 14:00	4.99	-	-	-	-	6.23
08/09/2015	14:01 - 15:00	3.96	-	-	-	-	4.95
08/09/2015	15:01 - 16:00	3.65	-	-	-	-	4.56
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							

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B4.3b

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



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

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	08/09/2015	10:01 - 11:00	3.66	0.66	3.00	0.01	YES
2	08/09/2015	11:01 - 12:00	4.11	1.18	2.93	0.05	YES
3	08/09/2015	12:01 - 13:00	3.79	0.78	3.01	0.03	YES
4	08/09/2015	13:01 - 14:00	4.99	2.00	2.99	0.00	YES
5	08/09/2015	14:01 - 15:00	3.96	0.98	2.98	0.00	YES
6	08/09/2015	15:01 - 16:00	3.65	0.67	2.98	0.00	YES

Slope	0.99	Mean	2.98
Intercept	3.00	Stdev	0.0266
R ²	1.00		

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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
08/09/2015	10:01 - 11:00	0.66	0.99	-	-	-	-	1.24	4.57
08/09/2015	11:01 - 12:00	1.18	1.51	-	-	-	-	1.89	5.14
08/09/2015	12:01 - 13:00	0.78	1.11	-	-	-	-	1.39	4.74
08/09/2015	13:01 - 14:00	2.00	2.34	-	-	-	-	2.93	6.23
08/09/2015	14:01 - 15:00	0.98	1.31	-	-	-	-	1.63	4.95
08/09/2015	15:01 - 16:00	0.67	0.99	-	-	-	-	1.24	4.56

(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

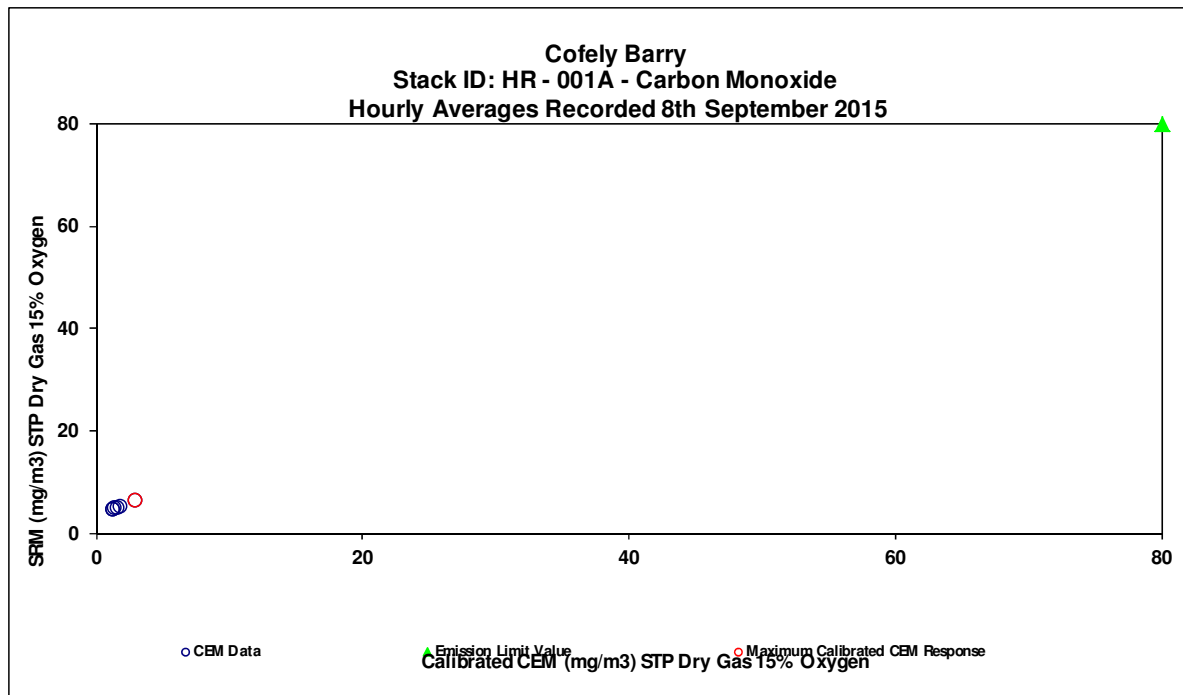
Determinand: Carbon Monoxide				QAL2 Calibration function: y=1.0096x+0.3218					
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference Conditions mg/m ³	Residual Value	Deviation of Residual from Mean		
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$	
0.83	4.57	1.24	4.57	0.83	1.24	3.34	0.023	0.00052	
1.47	5.14	1.89	5.14	1.47	1.89	3.25	-0.062	0.0038	
0.98	4.74	1.39	4.74	0.98	1.39	3.36	0.043	0.0018	
2.50	6.23	2.93	6.23	2.50	2.93	3.31	-0.0076	0.000057	
1.22	4.95	1.63	4.95	1.22	1.63	3.31	-0.0019	3.58E-06	
0.83	4.56	1.24	4.56	0.83	1.24	3.32	0.0059	0.000035	
Sum						19.88	8.88E-16	0.0062	
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 3.31$									
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0) = 0.035$									
$N = 6$									
$K_v = 0.93$									
$p = 20$									
$E = 80$									
$\sigma_0 = \frac{pE}{1.96} = 8.16$									
$1.5\sigma_0 k_v = 11.42$									
$s_D \leq 1.5\sigma_0 k_v = 0.04 \text{ mg/m}^3 < 11.42 \text{ mg/m}^3 - \text{Pass Variability Test}$									
$t_{0.95}(N-1) = 2.13$									
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 8.19$									
$ \bar{D} \quad 3.31\text{mg/m}^3 < 8.19\text{mg/m}^3 - \text{Calibration Remains Valid}$									

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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	± 8.16	mg/m ³
Upper Limit of Current Valid Calibration Range	31.01	mg/m ³
Maximum Calibrated CEM @ Reference Conditions	2.93	mg/m ³
Corresponding SRM @ Reference Conditions	6.23	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.16%	-1.93 - 14.39	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	mg/m ³

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B4.1c & B4.2c

Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A1

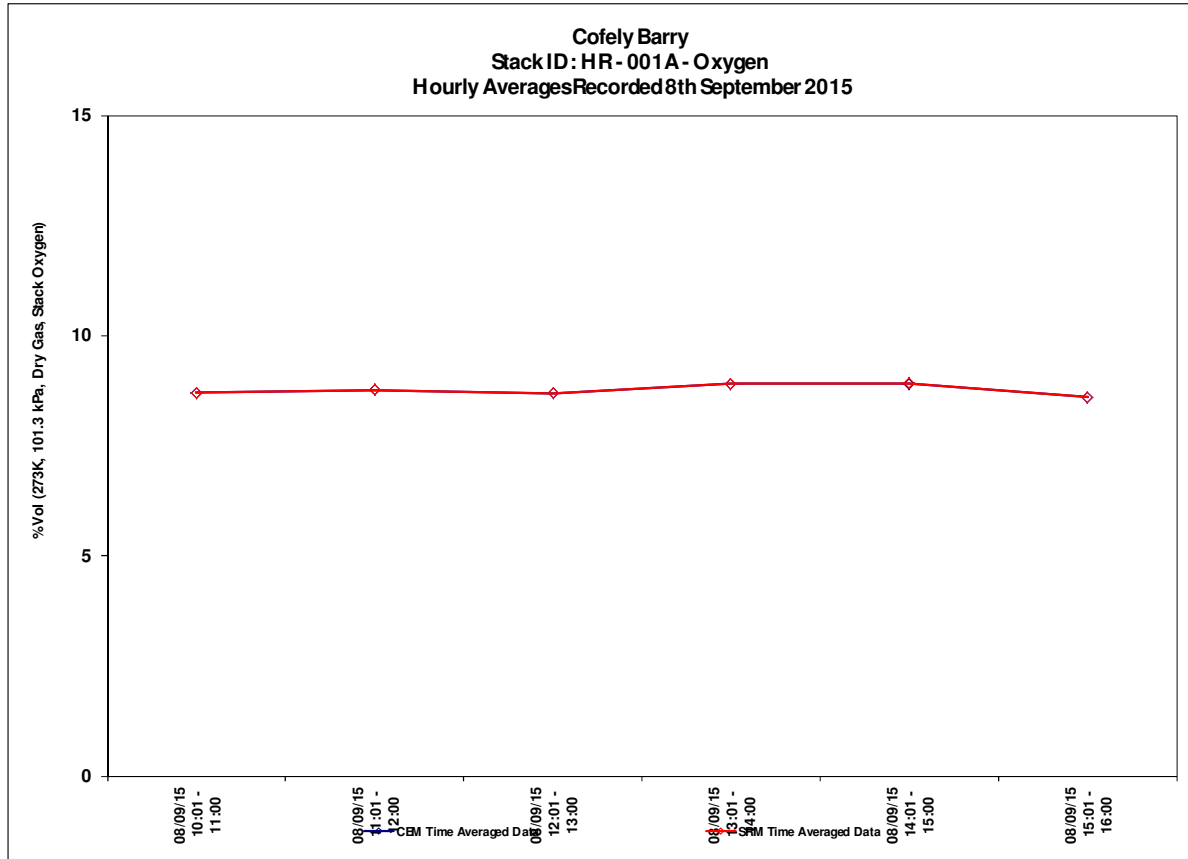
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
08/09/2015	10:01 - 11:00	8.70	-	-	-	-	8.70
08/09/2015	11:01 - 12:00	8.77	-	-	-	-	8.77
08/09/2015	12:01 - 13:00	8.69	-	-	-	-	8.69
08/09/2015	13:01 - 14:00	8.91	-	-	-	-	8.91
08/09/2015	14:01 - 15:00	8.91	-	-	-	-	8.91
08/09/2015	15:01 - 16:00	8.61	-	-	-	-	8.61
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas							
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							
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)
08/09/2015	10:01 - 11:00	8.71	-	-	-	-	8.71
08/09/2015	11:01 - 12:00	8.77	-	-	-	-	8.77
08/09/2015	12:01 - 13:00	8.69	-	-	-	-	8.69
08/09/2015	13:01 - 14:00	8.91	-	-	-	-	8.91
08/09/2015	14:01 - 15:00	8.92	-	-	-	-	8.92
08/09/2015	15:01 - 16:00	8.61	-	-	-	-	8.61
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							

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B4.3c

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



Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM % Vol	CEM % Vol	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	08/09/2015	10:01 - 11:00	8.71	8.70	0.01	0.01	YES
2	08/09/2015	11:01 - 12:00	8.77	8.77	0.00	0.00	YES
3	08/09/2015	12:01 - 13:00	8.69	8.69	-0.01	0.01	YES
4	08/09/2015	13:01 - 14:00	8.91	8.91	0.00	0.00	YES
5	08/09/2015	14:01 - 15:00	8.92	8.91	0.01	0.00	YES
6	08/09/2015	15:01 - 16:00	8.61	8.61	0.00	0.00	YES

Slope	1.02	Mean	0.00
Intercept	-0.13	Stdev	0.0057
R ²	1.00		

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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⁾
08/09/2015	10:01 - 11:00	8.70	8.49	-	-	-	-	8.49	8.71
08/09/2015	11:01 - 12:00	8.77	8.56	-	-	-	-	8.56	8.77
08/09/2015	12:01 - 13:00	8.69	8.48	-	-	-	-	8.48	8.69
08/09/2015	13:01 - 14:00	8.91	8.70	-	-	-	-	8.70	8.91
08/09/2015	14:01 - 15:00	8.91	8.71	-	-	-	-	8.71	8.92
08/09/2015	15:01 - 16:00	8.61	8.39	-	-	-	-	8.39	8.61

(1) 273K, 101.3 kPa, Dry Gas

(2) 273K, 101.3 kPa, Dry Gas, Stack Oxygen

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

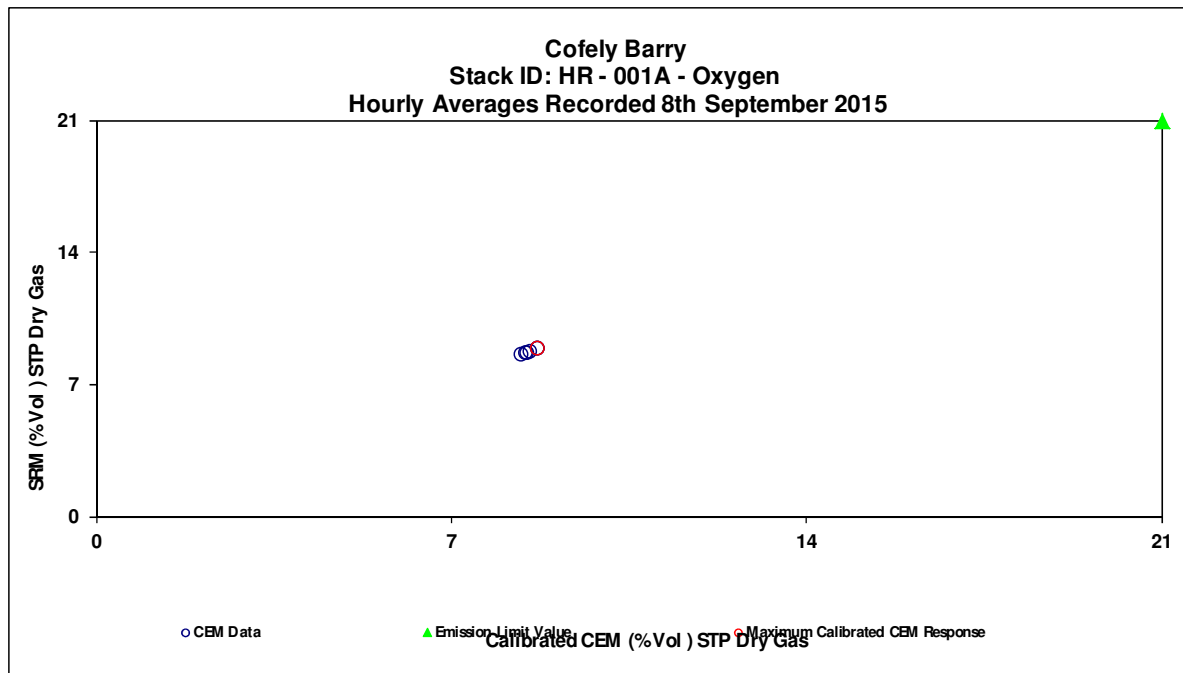
Determinand: Oxygen				QAL2 Calibration function: y=1.0249x-0.4262				
CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$
8.70	8.71	8.49	8.71	8.70	8.49	0.22	0.0086	0.000073
8.77	8.77	8.56	8.77	8.77	8.56	0.20	-0.0042	0.000017
8.69	8.69	8.48	8.69	8.69	8.48	0.20	-0.0066	0.000043
8.91	8.91	8.70	8.91	8.91	8.70	0.21	-0.0020	3.84E-06
8.91	8.92	8.71	8.92	8.91	8.71	0.21	0.0011	1.20E-06
8.61	8.61	8.39	8.61	8.61	8.39	0.21	0.0031	9.42E-06
Sum						1.25	5.55E-17	0.00015
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 0.21$								
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0) = 0.0055$								
$\begin{aligned} N &= 6 \\ K_v &= 0.93 \\ p &= 10 \\ E &= 21 \end{aligned}$								
$\sigma_0 = \frac{pE}{1.96} = 1.07$								
$1.5\sigma_0 k_v = 1.50$								
$s_D \leq 1.5\sigma_0 k_v = 0.01 \text{ %Vol} < 1.5 \text{ %Vol} - \text{Pass Variability Test}$								
$t_{0.95}(N-1) = 2.13$								
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 1.08$								
$ \bar{D} \quad 0.21\% \text{Vol} < 1.08\% \text{Vol} - \text{Calibration Remains Valid}$								

Cofely (GDF Suez)
 Permit No : JP3632ZH
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Installation Name : CHP
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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	8.71	%Vol
Corresponding SRM @ Reference Conditions	8.92	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	7.84 - 9.99	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	%Vol

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
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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⁾
09/09/2015	10:01 - 11:00	30.45	-	-	-	-	40.78
09/09/2015	11:01 - 12:00	30.36	-	-	-	-	40.66
09/09/2015	12:01 - 13:00	31.38	-	-	-	-	42.02
09/09/2015	13:01 - 14:00	31.83	-	-	-	-	42.62
09/09/2015	14:01 - 15:00	31.90	-	-	-	-	42.71
09/09/2015	15:01 - 16:00	32.11	-	-	-	-	43.00

(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⁾
09/09/2015	10:01 - 11:00	29.03	-	-	-	-	38.88
09/09/2015	11:01 - 12:00	28.04	-	-	-	-	37.54
09/09/2015	12:01 - 13:00	28.75	-	-	-	-	38.50
09/09/2015	13:01 - 14:00	28.98	-	-	-	-	38.80
09/09/2015	14:01 - 15:00	29.03	-	-	-	-	38.87
09/09/2015	15:01 - 16:00	29.23	-	-	-	-	39.14

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

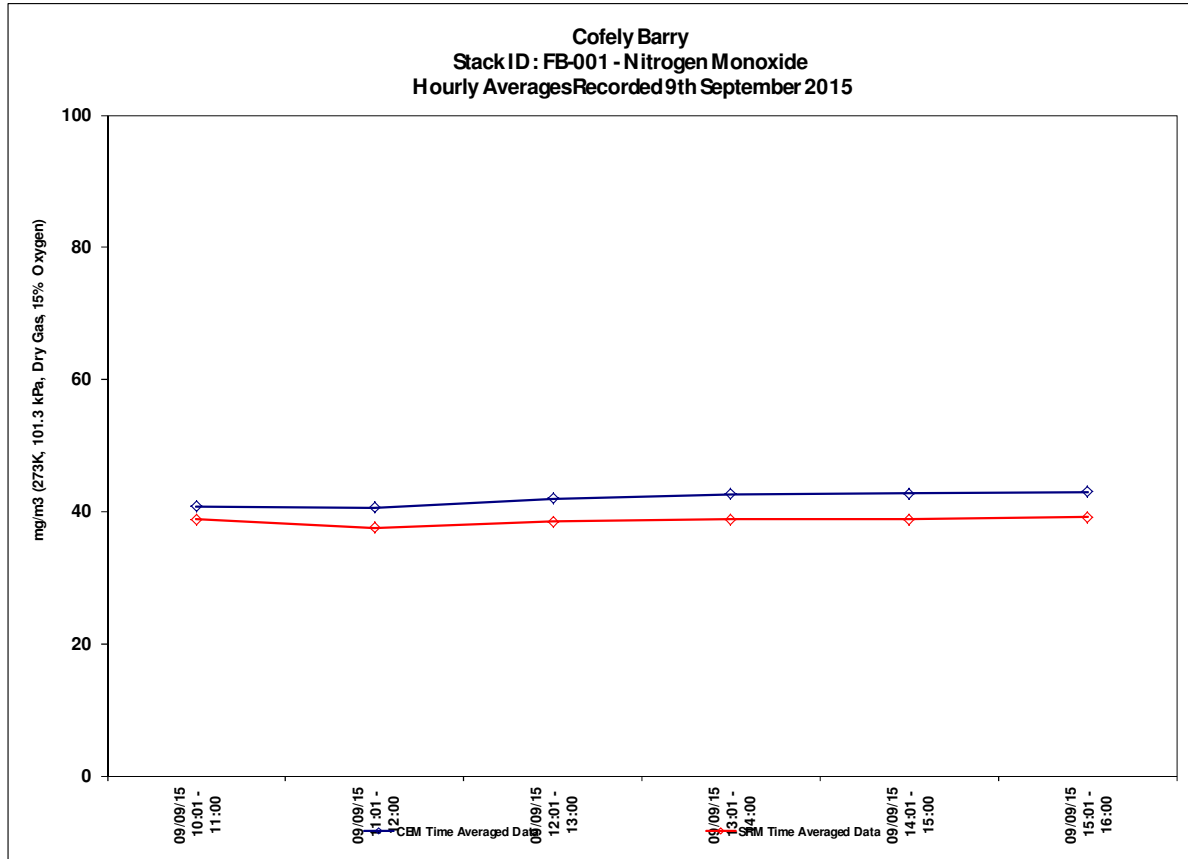
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

Cofely (GDF Suez)
 Permit No : JP3632ZH
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Installation Name : CHP
 Visit Details : AST – 2015
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B4.3a

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



Cofely (GDF Suez)
 Permit No : JP3632ZH
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 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	09/09/2015	10:01 - 11:00	29.03	30.45	-1.42	1.08	YES
2	09/09/2015	11:01 - 12:00	28.04	30.36	-2.33	0.17	YES
3	09/09/2015	12:01 - 13:00	28.75	31.38	-2.63	0.13	YES
4	09/09/2015	13:01 - 14:00	28.98	31.83	-2.85	0.35	YES
5	09/09/2015	14:01 - 15:00	29.03	31.90	-2.87	0.37	YES
6	09/09/2015	15:01 - 16:00	29.23	32.11	-2.88	0.39	YES

Slope	0.38	Mean	-2.50
Intercept	17.07	Stdev	0.5692
R ²	0.45		

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
09/09/2015	10:01 - 11:00	30.45	27.85	-	-	-	-	37.29	38.88
09/09/2015	11:01 - 12:00	30.36	27.76	-	-	-	-	37.18	37.54
09/09/2015	12:01 - 13:00	31.38	28.69	-	-	-	-	38.42	38.50
09/09/2015	13:01 - 14:00	31.83	29.10	-	-	-	-	38.97	38.80
09/09/2015	14:01 - 15:00	31.90	29.17	-	-	-	-	39.06	38.87
09/09/2015	15:01 - 16:00	32.11	29.36	-	-	-	-	39.32	39.14

(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

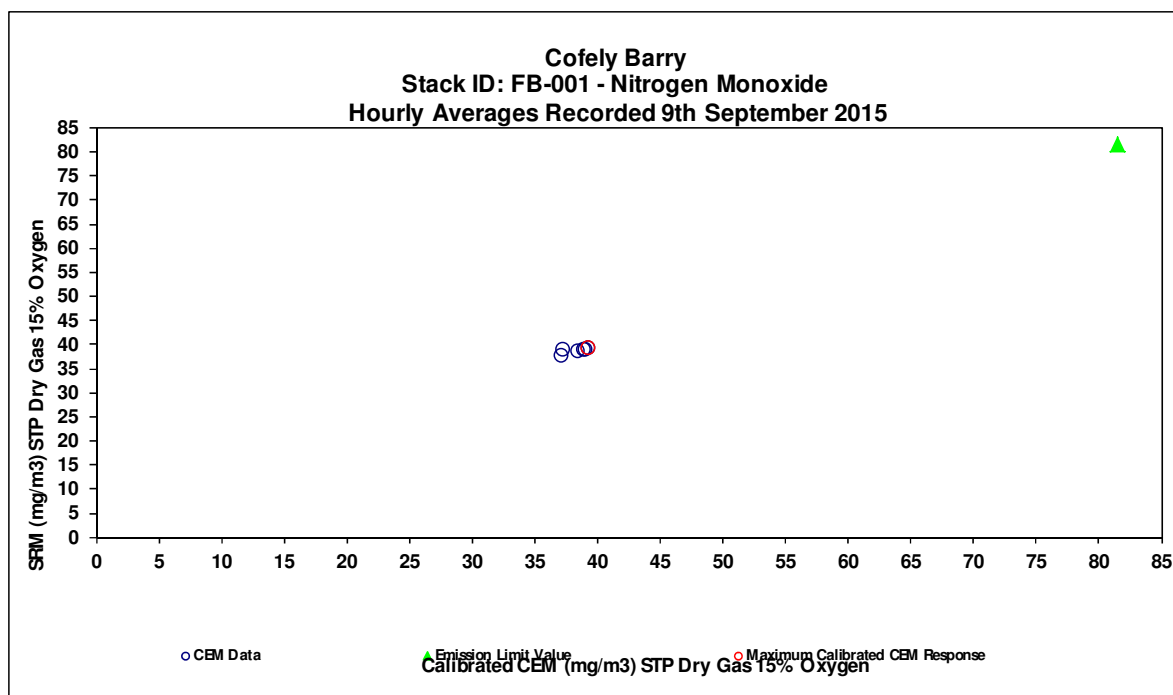
Determinand: Nitrogen Monoxide						QAL2 Calibration function: $y=0.9141x+0.0091$		
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference Conditions mg/m ³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$
40.78	38.88	37.29	38.88	40.78	37.29	1.59	1.34	1.80
40.66	37.54	37.18	37.54	40.66	37.18	0.36	0.11	0.013
42.02	38.50	38.42	38.50	42.02	38.42	0.078	-0.17	0.030
42.62	38.80	38.97	38.80	42.62	38.97	-0.17	-0.42	0.18
42.71	38.87	39.06	38.87	42.71	39.06	-0.19	-0.44	0.19
43.00	39.14	39.32	39.14	43.00	39.32	-0.18	-0.43	0.18
Sum						1.50	0.00	2.39
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 0.25$								
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0.48) = 0.69$								
$N = 6$								
$K_v = 0.93$								
$p = 20$								
$E = 82$								
$\sigma_0 = \frac{pE}{1.96} = 8.32$								
$1.5\sigma_0 k_v = 11.64$								
$S_D \leq 1.5\sigma_0 k_v = 0.69 \text{ mg/m}^3 < 11.64 \text{ mg/m}^3 - \text{Pass Variability Test}$								
$t_{0.95}(N-1) = 2.13$								
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 8.92$								
$ \bar{D} \quad 0.25 \text{ mg/m}^3 < 8.92 \text{ mg/m}^3 - \text{Calibration Remains Valid}$								

Cofely (GDF Suez)
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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	39.32	mg/m ³
Corresponding SRM @ Reference Conditions	39.14	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	30.82 - 47.46	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	mg/m ³

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

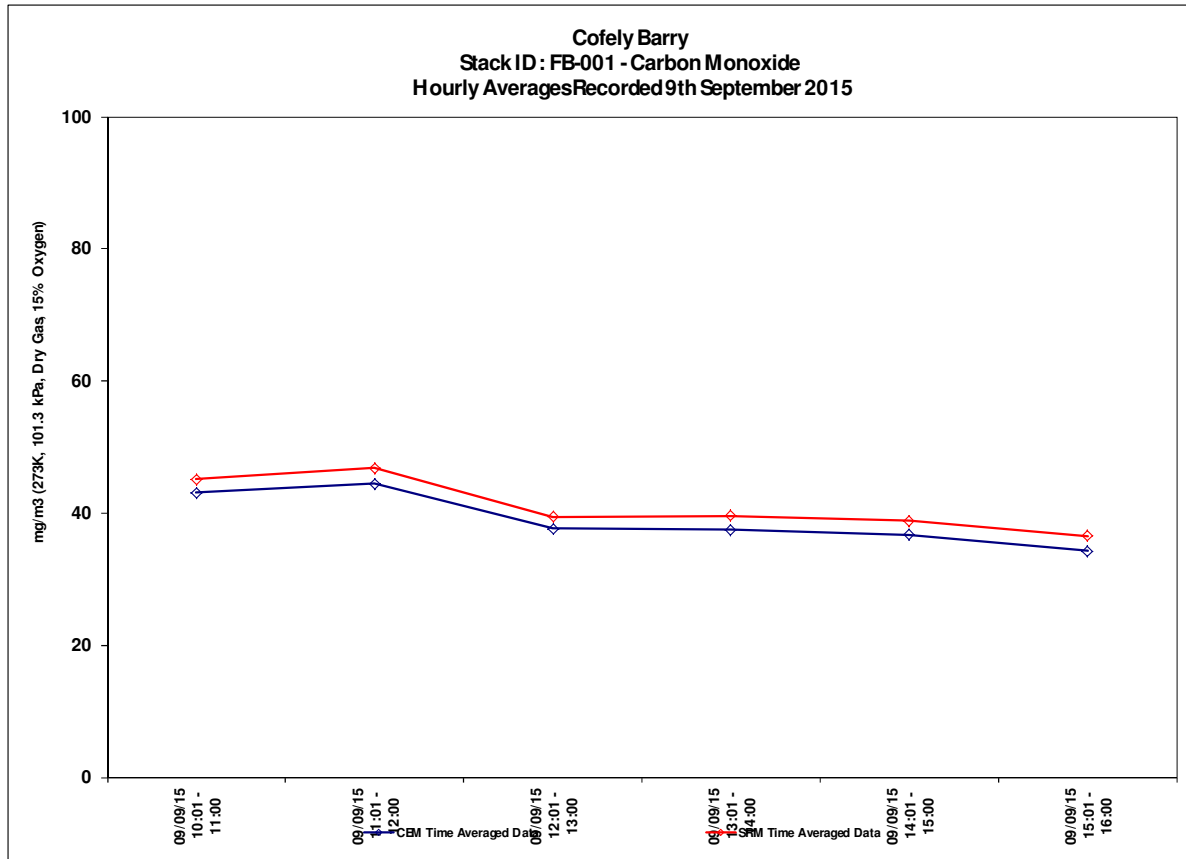
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated ⁽¹⁾	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m ³ Uncalibrated ⁽²⁾
09/09/2015	10:01 - 11:00	34.44	-	-	-	-	43.05
09/09/2015	11:01 - 12:00	35.53	-	-	-	-	44.41
09/09/2015	12:01 - 13:00	30.10	-	-	-	-	37.63
09/09/2015	13:01 - 14:00	29.98	-	-	-	-	37.47
09/09/2015	14:01 - 15:00	29.36	-	-	-	-	36.69
09/09/2015	15:01 - 16:00	27.40	-	-	-	-	34.25
(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⁾
09/09/2015	10:01 - 11:00	36.08	-	-	-	-	45.10
09/09/2015	11:01 - 12:00	37.42	-	-	-	-	46.78
09/09/2015	12:01 - 13:00	31.54	-	-	-	-	39.42
09/09/2015	13:01 - 14:00	31.65	-	-	-	-	39.57
09/09/2015	14:01 - 15:00	31.06	-	-	-	-	38.82
09/09/2015	15:01 - 16:00	29.23	-	-	-	-	36.54
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							

Cofely (GDF Suez)
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B4.3b

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



Cofely (GDF Suez)
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Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
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B4.4b**Calculation and procedure – Elimination of outliers for CO A2**

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	09/09/2015	10:01 - 11:00	36.08	34.44	1.64	0.06	YES
2	09/09/2015	11:01 - 12:00	37.42	35.53	1.90	0.20	YES
3	09/09/2015	12:01 - 13:00	31.54	30.10	1.43	0.26	YES
4	09/09/2015	13:01 - 14:00	31.65	29.98	1.68	0.02	YES
5	09/09/2015	14:01 - 15:00	31.06	29.36	1.70	0.01	YES
6	09/09/2015	15:01 - 16:00	29.23	27.40	1.83	0.13	YES

Slope	1.01	Mean	1.70
Intercept	1.40	Stdev	0.1606
R ²	1.00		

Cofely (GDF Suez)
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 Visit Details : AST – 2015
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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
09/09/2015	10:01 - 11:00	34.44	36.45	-	-	-	-	45.56	45.10
09/09/2015	11:01 - 12:00	35.53	37.60	-	-	-	-	47.00	46.78
09/09/2015	12:01 - 13:00	30.10	31.87	-	-	-	-	39.84	39.42
09/09/2015	13:01 - 14:00	29.98	31.74	-	-	-	-	39.68	39.57
09/09/2015	14:01 - 15:00	29.36	31.09	-	-	-	-	38.86	38.82
09/09/2015	15:01 - 16:00	27.40	29.02	-	-	-	-	36.28	36.54

(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

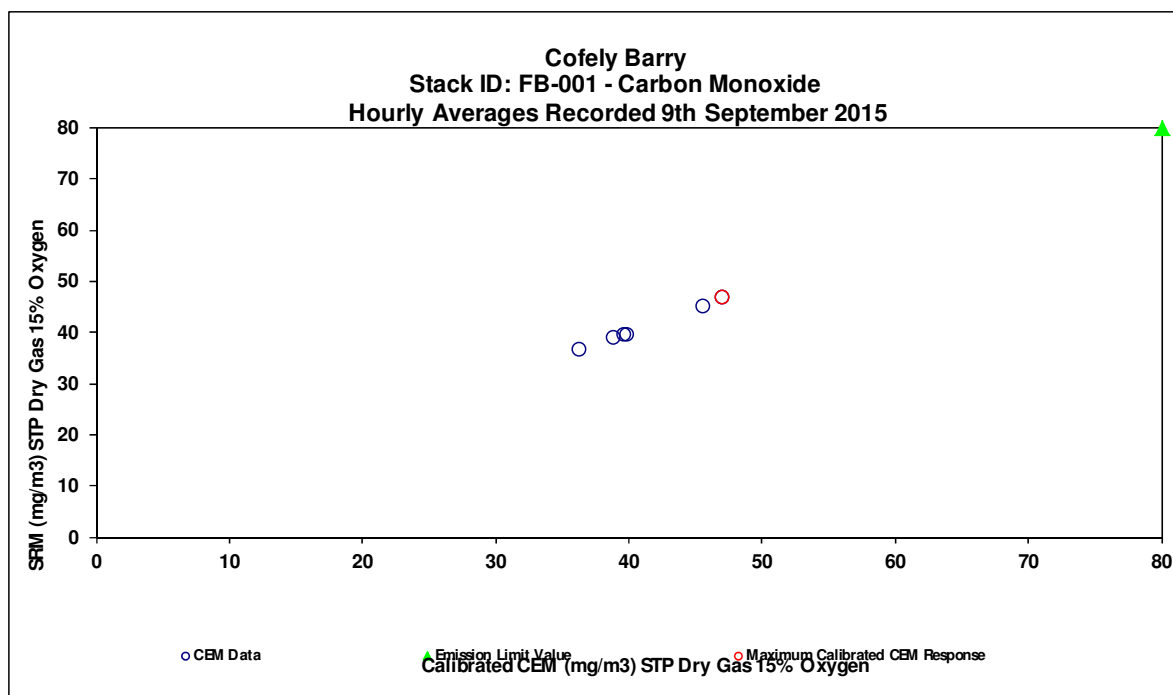
Determinand: Carbon Monoxide				QAL2 Calibration function: $y=1.0552x+0.1111$				
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference Conditions mg/m ³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$
43.05	45.10	45.56	45.10	43.05	45.56	-0.46	-0.30	0.089
44.41	46.78	47.00	46.78	44.41	47.00	-0.22	-0.056	0.0031
37.63	39.42	39.84	39.42	37.63	39.84	-0.42	-0.26	0.066
37.47	39.57	39.68	39.57	37.47	39.68	-0.11	0.057	0.0032
36.69	38.82	38.86	38.82	36.69	38.86	-0.033	0.13	0.018
34.25	36.54	36.28	36.54	34.25	36.28	0.26	0.42	0.18
Sum						-1.00	0.00	0.36
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = -0.17$								
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0.07) = 0.27$								
$N = 6$								
$K_v = 0.93$								
$p = 20$								
$E = 80$								
$\sigma_0 = \frac{pE}{1.96} = 8.16$								
$1.5\sigma_0 k_v = 11.42$								
$s_D \leq 1.5\sigma_0 k_v = 0.27 \text{ mg/m}^3 < 11.42 \text{ mg/m}^3 - \text{Pass Variability Test}$								
$t_{0.95}(N-1) = 2.13$								
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 8.40$								
$ \bar{D} \quad 0.17 \text{ mg/m}^3 < 8.4 \text{ mg/m}^3 - \text{Calibration Remains Valid}$								

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
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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	± 8.16	mg/m ³
Upper Limit of Current Valid Calibration Range	22.59	mg/m ³
Maximum Calibrated CEM @ Reference Conditions	47.00	mg/m ³
Corresponding SRM @ Reference Conditions	46.78	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.16%	38.62 - 54.94	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	NO	...
Extended Valid Calibration Range	NO	mg/m ³

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
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Installation Name : CHP
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B4.1c & B4.2c

Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A2

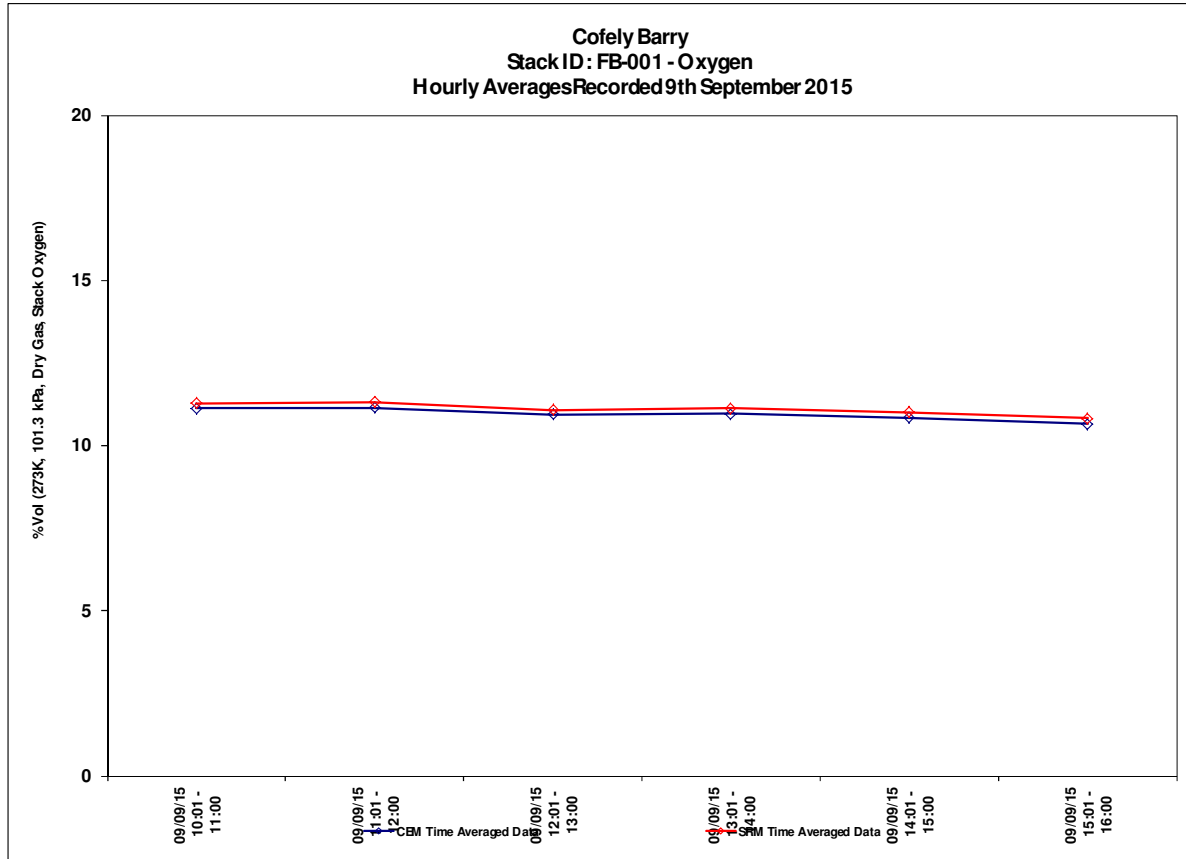
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
09/09/2015	10:01 - 11:00	11.13	-	-	-	-	11.13
09/09/2015	11:01 - 12:00	11.15	-	-	-	-	11.15
09/09/2015	12:01 - 13:00	10.95	-	-	-	-	10.95
09/09/2015	13:01 - 14:00	10.96	-	-	-	-	10.96
09/09/2015	14:01 - 15:00	10.84	-	-	-	-	10.84
09/09/2015	15:01 - 16:00	10.65	-	-	-	-	10.65
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas							
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							
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)
09/09/2015	10:01 - 11:00	11.28	-	-	-	-	11.28
09/09/2015	11:01 - 12:00	11.31	-	-	-	-	11.31
09/09/2015	12:01 - 13:00	11.08	-	-	-	-	11.08
09/09/2015	13:01 - 14:00	11.12	-	-	-	-	11.12
09/09/2015	14:01 - 15:00	11.02	-	-	-	-	11.02
09/09/2015	15:01 - 16:00	10.82	-	-	-	-	10.82
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							

Cofely (GDF Suez)
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Installation Name : CHP
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B4.3c

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



Cofely (GDF Suez)
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Installation Name : CHP
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B4.4c**Calculation and procedure – Elimination of outliers for O2 A2**

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM % Vol	CEM % Vol	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	09/09/2015	10:01 - 11:00	11.28	11.13	0.15	0.01	YES
2	09/09/2015	11:01 - 12:00	11.31	11.15	0.16	0.00	YES
3	09/09/2015	12:01 - 13:00	11.08	10.95	0.13	0.03	YES
4	09/09/2015	13:01 - 14:00	11.12	10.96	0.16	0.00	YES
5	09/09/2015	14:01 - 15:00	11.02	10.84	0.18	0.02	YES
6	09/09/2015	15:01 - 16:00	10.82	10.65	0.17	0.01	YES

Slope	0.97	Mean	0.16
Intercept	0.54	Stdev	0.0163
R ²	0.99		

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
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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⁾
09/09/2015	10:01 - 11:00	11.13	10.90	-	-	-	-	10.90	11.28
09/09/2015	11:01 - 12:00	11.15	10.92	-	-	-	-	10.92	11.31
09/09/2015	12:01 - 13:00	10.95	10.72	-	-	-	-	10.72	11.08
09/09/2015	13:01 - 14:00	10.96	10.74	-	-	-	-	10.74	11.12
09/09/2015	14:01 - 15:00	10.84	10.62	-	-	-	-	10.62	11.02
09/09/2015	15:01 - 16:00	10.65	10.44	-	-	-	-	10.44	10.82

(1) 273K, 101.3 kPa, Dry Gas

(2) 273K, 101.3 kPa, Dry Gas, Stack Oxygen

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

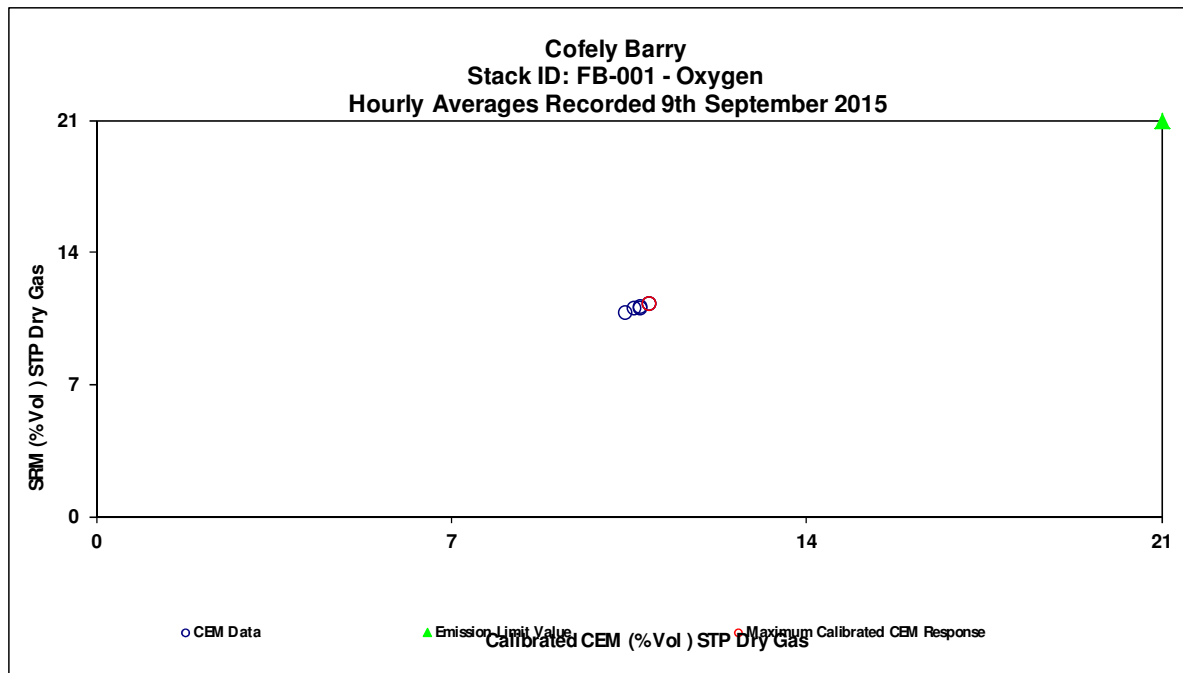
Determinand: Oxygen			QAL2 Calibration function: y=0.9788x+0.0098						
CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean		
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$	
11.13	11.28	10.90	11.28	11.13	10.90	0.38	-0.0037	0.000013	
11.15	11.31	10.92	11.31	11.15	10.92	0.39	0.0090	0.000082	
10.95	11.08	10.72	11.08	10.95	10.72	0.35	-0.029	0.00083	
10.96	11.12	10.74	11.12	10.96	10.74	0.39	0.0034	0.000011	
10.84	11.02	10.62	11.02	10.84	10.62	0.40	0.013	0.00017	
10.65	10.82	10.44	10.82	10.65	10.44	0.39	0.0071	0.000051	
Sum						2.29	1.11E-16	0.0012	
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 0.38$									
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0) = 0.015$									
$\begin{aligned} N &= 6 \\ K_v &= 0.93 \\ p &= 10 \\ E &= 21 \\ \sigma_0 &= \frac{pE}{1.96} = 1.07 \\ 1.5\sigma_0 k_v &= 1.50 \end{aligned}$									
$s_D \leq 1.5\sigma_0 k_v = 0.02 \% \text{Vol} < 1.5 \% \text{Vol} - \text{Pass Variability Test}$									
$t_{0.95}(N-1) = 2.13$									
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 1.08$									
$ \bar{D} \quad 0.38\% \text{Vol} < 1.08\% \text{Vol} - \text{Calibration Remains Valid}$									

Cofely (GDF Suez)
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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	10.92	%Vol
Corresponding SRM @ Reference Conditions	11.31	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	10.24 - 12.38	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	NO	...
Extended Valid Calibration Range	NO	%Vol

Cofely (GDF Suez)
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A3 – HR 001B

B4.1a & B4.2a

Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for NO A3

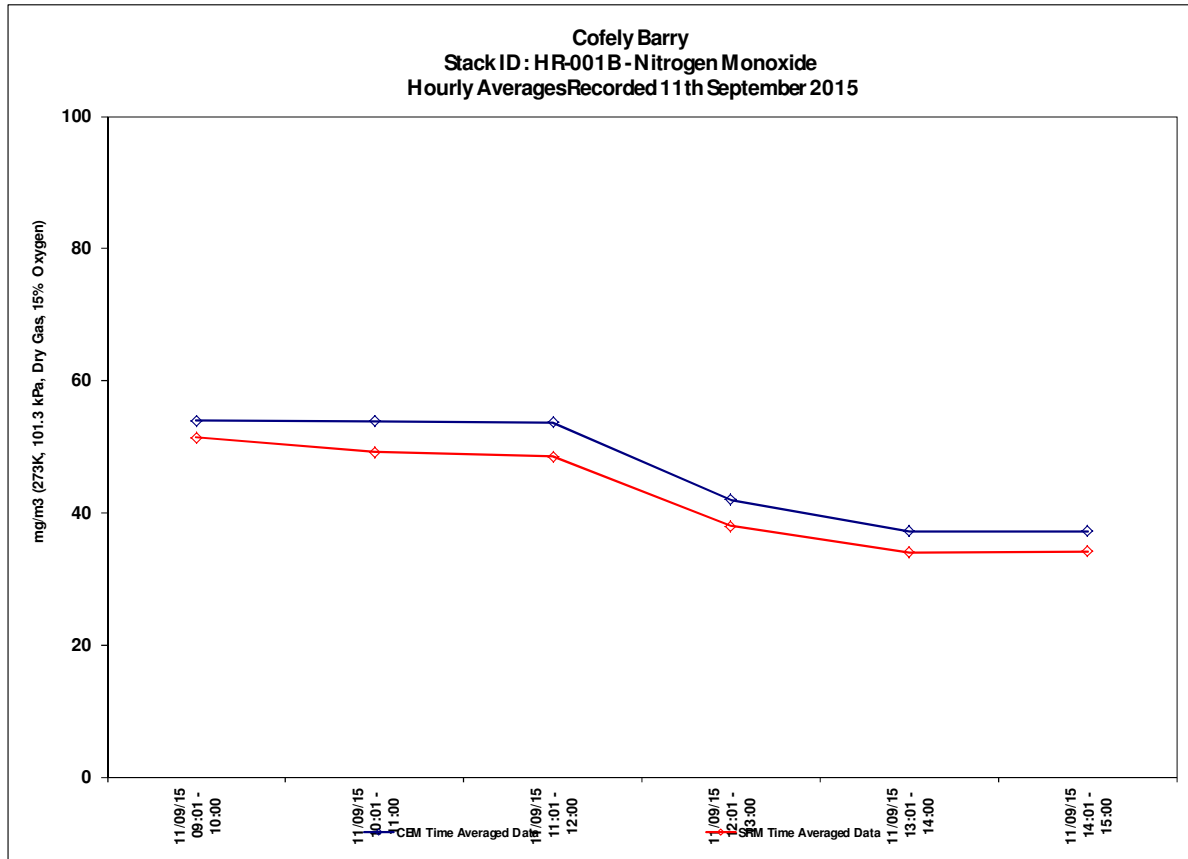
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages ppm Uncalibrated ⁽¹⁾	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages mg/m³ Uncalibrated ⁽²⁾
11/09/2015	09:01 - 10:00	40.28	-	-	-	-	53.93
11/09/2015	10:01 - 11:00	40.21	-	-	-	-	53.84
11/09/2015	11:01 - 12:00	40.13	-	-	-	-	53.73
11/09/2015	12:01 - 13:00	31.38	-	-	-	-	42.01
11/09/2015	13:01 - 14:00	27.77	-	-	-	-	37.18
11/09/2015	14:01 - 15:00	27.81	-	-	-	-	37.23
(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/m³ ⁽⁴⁾
11/09/2015	09:01 - 10:00	38.39	-	-	-	-	51.41
11/09/2015	10:01 - 11:00	36.76	-	-	-	-	49.23
11/09/2015	11:01 - 12:00	36.21	-	-	-	-	48.49
11/09/2015	12:01 - 13:00	28.36	-	-	-	-	37.98
11/09/2015	13:01 - 14:00	25.39	-	-	-	-	34.00
11/09/2015	14:01 - 15:00	25.53	-	-	-	-	34.18
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen							

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 Visit Details : AST – 2015
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B4.3a

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



Cofely (GDF Suez)
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Installation Name : CHP
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B4.4a**Calculation and procedure – Elimination of outliers for NO A3**

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	11/09/2015	09:01 - 10:00	38.39	40.28	-1.88	0.94	YES
2	11/09/2015	10:01 - 11:00	36.76	40.21	-3.44	0.63	YES
3	11/09/2015	11:01 - 12:00	36.21	40.13	-3.91	1.09	YES
4	11/09/2015	12:01 - 13:00	28.36	31.38	-3.01	0.19	YES
5	11/09/2015	13:01 - 14:00	25.39	27.77	-2.38	0.44	YES
6	11/09/2015	14:01 - 15:00	25.53	27.81	-2.28	0.54	YES

Slope	0.95	Mean	-2.82
Intercept	-1.02	Stdev	0.7728
R ²	0.99		

Cofely (GDF Suez)
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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
11/09/2015	09:01 - 10:00	40.28	38.15	-	-	-	-	51.09	51.41
11/09/2015	10:01 - 11:00	40.21	38.08	-	-	-	-	51.00	49.23
11/09/2015	11:01 - 12:00	40.13	38.00	-	-	-	-	50.89	48.49
11/09/2015	12:01 - 13:00	31.38	29.39	-	-	-	-	39.35	37.98
11/09/2015	13:01 - 14:00	27.77	25.84	-	-	-	-	34.59	34.00
11/09/2015	14:01 - 15:00	27.81	25.87	-	-	-	-	34.64	34.18

(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

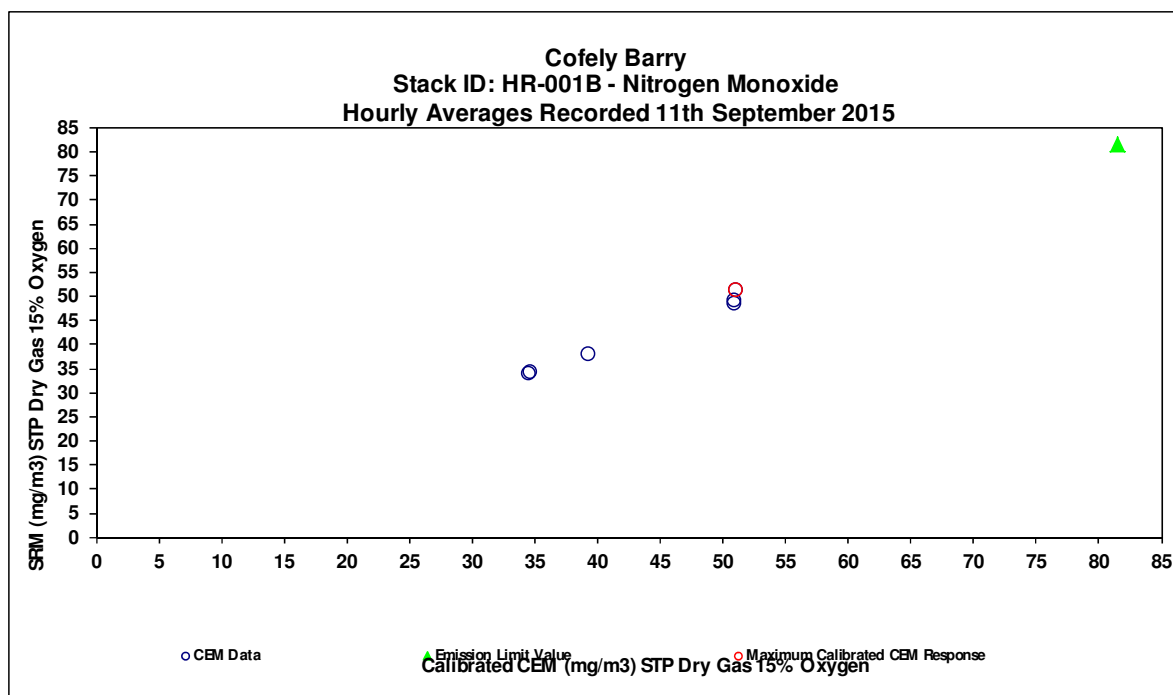
Determinand: Nitrogen Monoxide				QAL2 Calibration function: y=0.9849x-1.5148					
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference Conditions mg/m ³	Residual Value	Deviation of Residual from Mean		
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$	
53.93	51.41	51.09	51.41	53.93	51.09	0.33	1.37	1.87	
53.84	49.23	51.00	49.23	53.84	51.00	-1.77	-0.72	0.52	
53.73	48.49	50.89	48.49	53.73	50.89	-2.40	-1.35	1.83	
42.01	37.98	39.35	37.98	42.01	39.35	-1.37	-0.32	0.11	
37.18	34.00	34.59	34.00	37.18	34.59	-0.59	0.45	0.20	
37.23	34.18	34.64	34.18	37.23	34.64	-0.46	0.58	0.34	
Sum						-6.26	0.00	4.88	
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = -1.04$									
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(0.98) = 0.99$									
$N = 6$									
$K_v = 0.93$									
$p = 20$									
$E = 82$									
$\sigma_0 = \frac{pE}{1.96} = 8.32$									
$1.5\sigma_0 k_v = 11.64$									
$s_D \leq 1.5\sigma_0 k_v = 0.99 \text{ mg/m}^3 < 11.64 \text{ mg/m}^3 - \text{Pass Variability Test}$									
$t_{0.95}(N-1) = 2.13$									
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 9.18$									
$ \bar{D} \quad 1.04\text{mg/m}^3 < 9.18\text{mg/m}^3 - \text{Calibration Remains Valid}$									

Cofely (GDF Suez)
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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 A2

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	51.09	mg/m ³
Corresponding SRM @ Reference Conditions	51.41	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.32%	43.09 - 59.73	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	NO	...
Extended Valid Calibration Range	NO	mg/m ³

/

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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⁾
11/09/2015	09:01 - 10:00	9.20	-	-	-	-	11.50
11/09/2015	10:01 - 11:00	8.53	-	-	-	-	10.67
11/09/2015	11:01 - 12:00	8.85	-	-	-	-	11.07
11/09/2015	12:01 - 13:00	10.60	-	-	-	-	13.25
11/09/2015	13:01 - 14:00	0.58	-	-	-	-	0.73
11/09/2015	14:01 - 15:00	0.46	-	-	-	-	0.57

(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⁾
11/09/2015	09:01 - 10:00	15.62	-	-	-	-	19.52
11/09/2015	10:01 - 11:00	15.43	-	-	-	-	19.28
11/09/2015	11:01 - 12:00	15.25	-	-	-	-	19.07
11/09/2015	12:01 - 13:00	14.05	-	-	-	-	17.57
11/09/2015	13:01 - 14:00	2.51	-	-	-	-	3.13
11/09/2015	14:01 - 15:00	2.26	-	-	-	-	2.82

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

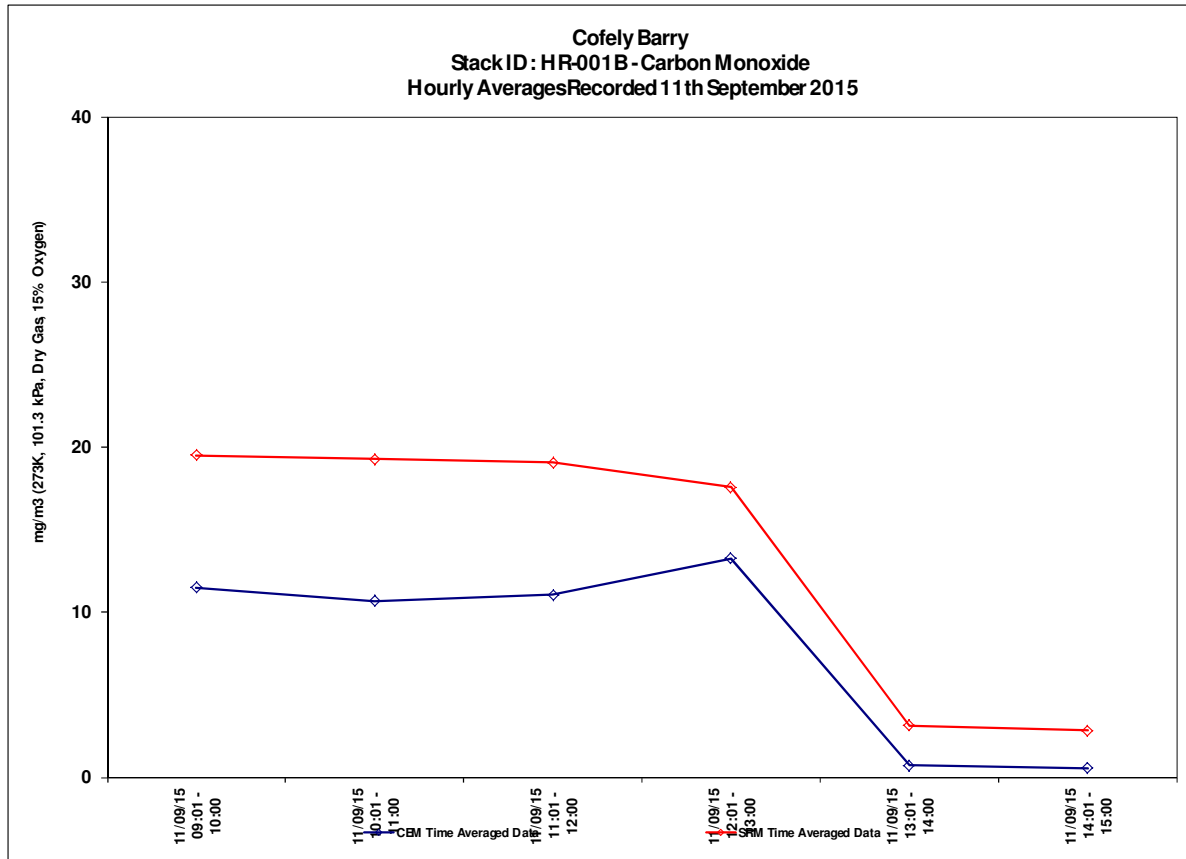
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, 15% Oxygen

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B4.3b

Plot 1 - Time Series Plot of Standardised Time Averaged SRM/CEM Monitoring Data Pairs for CO A23



Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
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B4.4b**Calculation and procedure – Elimination of outliers for CO A3**

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM mg/m ³	CEM mg/m ³	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	11/09/2015	09:01 - 10:00	15.62	9.20	6.42	1.94	YES
2	11/09/2015	10:01 - 11:00	15.43	8.53	6.89	2.41	YES
3	11/09/2015	11:01 - 12:00	15.25	8.85	6.40	1.92	YES
4	11/09/2015	12:01 - 13:00	14.05	10.60	3.45	1.03	YES
5	11/09/2015	13:01 - 14:00	2.51	0.58	1.92	2.56	YES
6	11/09/2015	14:01 - 15:00	2.26	0.46	1.80	2.68	YES

Slope	1.40	Mean	4.48
Intercept	1.95	Stdev	2.3678
R ²	0.95		

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

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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/m ³ Calibrated ⁽²⁾	SRM Hourly averages mg/m ³ ⁽²⁾
11/09/2015	09:01 - 10:00	9.20	9.19	-	-	-	-	11.49	19.52
11/09/2015	10:01 - 11:00	8.53	8.62	-	-	-	-	10.77	19.28
11/09/2015	11:01 - 12:00	8.85	8.89	-	-	-	-	11.12	19.07
11/09/2015	12:01 - 13:00	10.60	10.39	-	-	-	-	12.99	17.57
11/09/2015	13:01 - 14:00	0.58	1.77	-	-	-	-	2.21	3.13
11/09/2015	14:01 - 15:00	0.46	1.66	-	-	-	-	2.08	2.82

(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

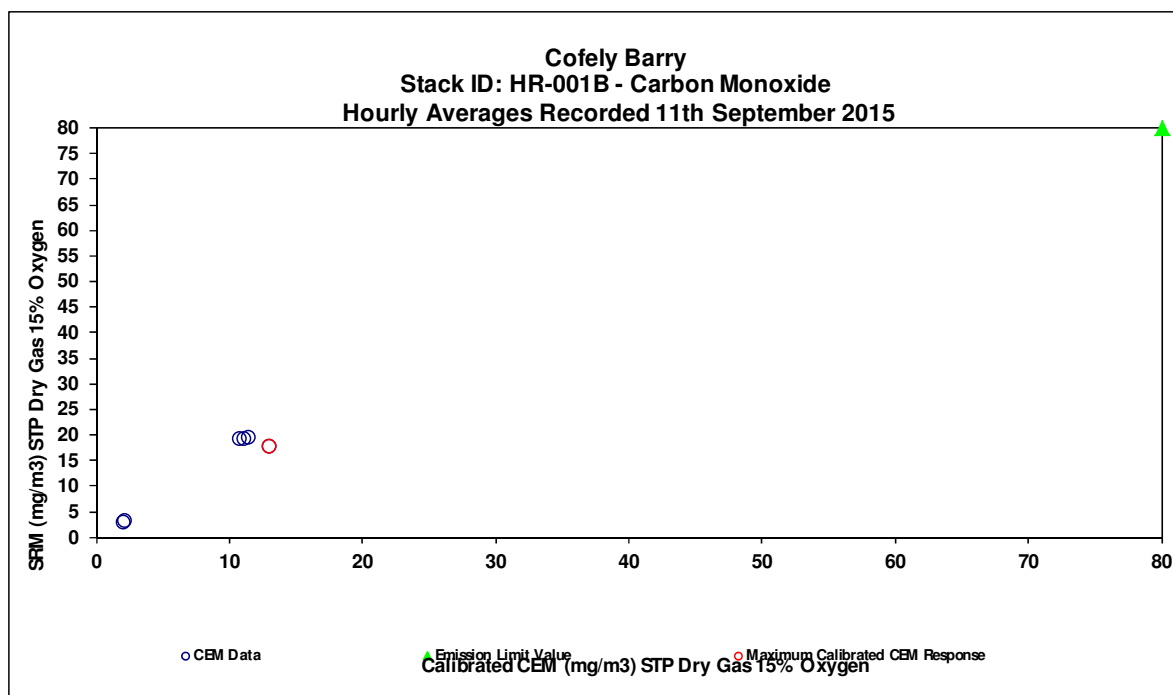
Determinand: Carbon Monoxide				QAL2 Calibration function: $y=0.8611x+1.2686$				
CEM Measured mg/m ³	SRM Measured mg/m ³	Calibrated CEM mg/m ³	SRM Measured @ Reference conditions mg/m ³	CEM Measured @ Reference conditions mg/m ³	Calibrated CEM @ Reference conditions mg/m ³	Residual Value	Deviation of Residual from Mean	
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \bar{D})$	$(D_i - \bar{D})^2$
11.50	19.52	11.49	19.52	11.50	11.49	8.04	2.91	8.49
10.67	19.28	10.77	19.28	10.67	10.77	8.51	3.39	11.49
11.07	19.07	11.12	19.07	11.07	11.12	7.95	2.83	7.99
13.25	17.57	12.99	17.57	13.25	12.99	4.57	-0.55	0.30
0.73	3.13	2.21	3.13	0.73	2.21	0.92	-4.20	17.68
0.57	2.82	2.08	2.82	0.57	2.08	0.75	-4.38	19.15
Sum						30.74	0.00	65.10
$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i = 5.12$								
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} = \text{SQRT}(13.02) = 3.61$								
$N = 6$								
$K_v = 0.93$								
$p = 20$								
$E = 80$								
$\sigma_0 = \frac{pE}{1.96} = 8.16$								
$1.5\sigma_0 k_v = 11.42$								
$s_D \leq 1.5\sigma_0 k_v = 3.61 \text{ mg/m}^3 < 11.42 \text{ mg/m}^3 - \text{Pass Variability Test}$								
$t_{0.95}(N-1) = 2.13$								
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 11.30$								
$ \bar{D} \quad 5.12 \text{ mg/m}^3 < 11.3 \text{ mg/m}^3 - \text{Calibration Remains Valid}$								

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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	± 8.16	mg/m ³
Upper Limit of Current Valid Calibration Range	15.95	mg/m ³
Maximum Calibrated CEM @ Reference Conditions	12.99	mg/m ³
Corresponding SRM @ Reference Conditions	17.57	mg/m ³
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 8.16%	9.4 - 25.73	mg/m ³
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	mg/m ³

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B4.1c & B4.2c

Incorporating: Table 4.1 Raw Monitoring Data & Table 4.2 Standardised Monitoring Data for O2 A3

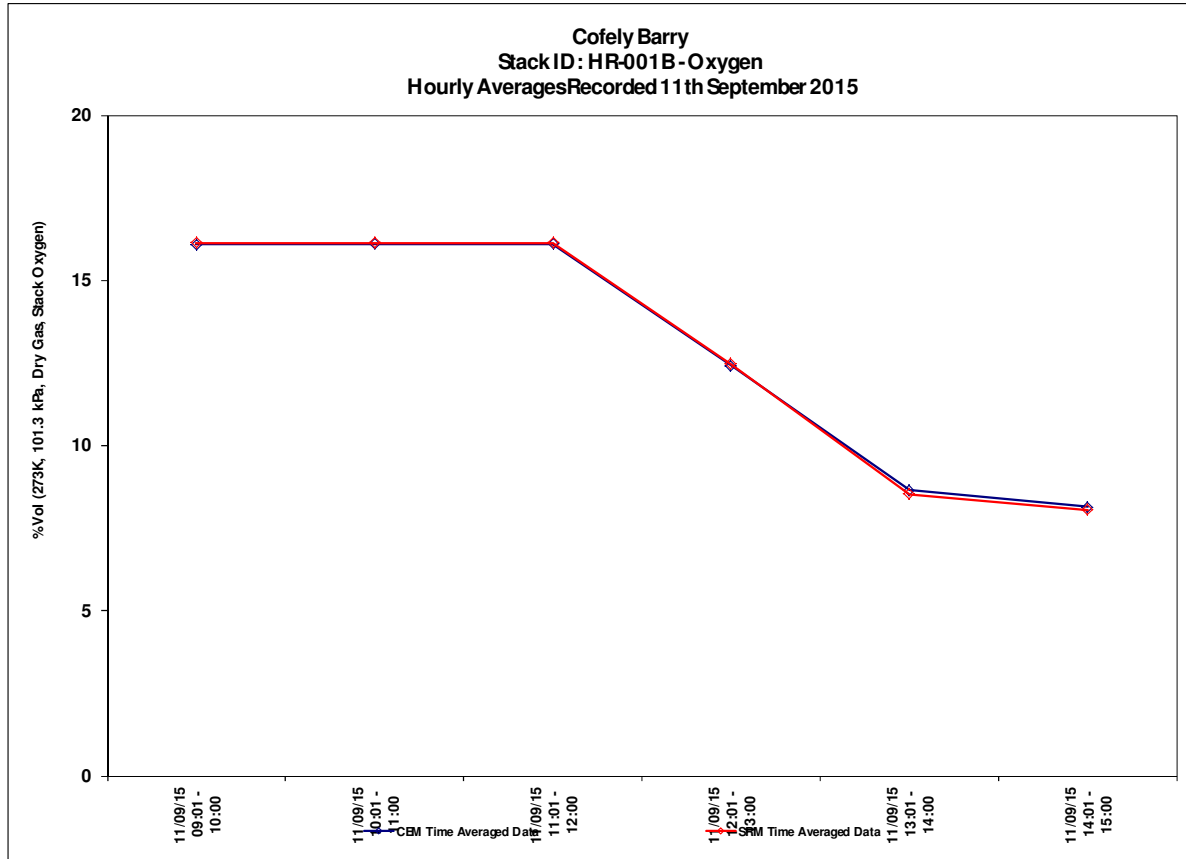
Raw Monitoring CEM Data							Standardised Data
Date	Time	CEM Hourly averages %Vol Uncalibrated (1)	Temp (K)	Pressure (kPa)	Moisture (%)	Oxygen (%) Dry	CEM Hourly averages %Vol Uncalibrated (2)
11/09/2015	09:01 - 10:00	16.10	-	-	-	-	16.10
11/09/2015	10:01 - 11:00	16.10	-	-	-	-	16.10
11/09/2015	11:01 - 12:00	16.11	-	-	-	-	16.11
11/09/2015	12:01 - 13:00	12.43	-	-	-	-	12.43
11/09/2015	13:01 - 14:00	8.64	-	-	-	-	8.64
11/09/2015	14:01 - 15:00	8.14	-	-	-	-	8.14
(1) CEM data conditions: 273K, 101.3 kPa, Dry Gas							
(2) CEM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							
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)
11/09/2015	09:01 - 10:00	16.13	-	-	-	-	16.13
11/09/2015	10:01 - 11:00	16.13	-	-	-	-	16.13
11/09/2015	11:01 - 12:00	16.14	-	-	-	-	16.14
11/09/2015	12:01 - 13:00	12.47	-	-	-	-	12.47
11/09/2015	13:01 - 14:00	8.54	-	-	-	-	8.54
11/09/2015	14:01 - 15:00	8.05	-	-	-	-	8.05
(3) SRM data conditions: 273K, 101.3 kPa, Dry Gas							
(4) SRM data conditions: 273K, 101.3 kPa, Dry Gas, Stack Oxygen							

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B4.3c

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



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

Please note: Only those averages separated by at least 1 hour have been carried forward to the outlier test. After removal of any outliers, highlighted as “outlier” below, all other averages, highlighted as “yes” below, will be taken forward to the calibration coefficient validation.

n	Date	Time	SRM % Vol	CEM % Vol	$ D_i $	$ D_i - \bar{D}_i $	$ D_i - \bar{D}_i < 2\sigma?$
1	11/09/2015	09:01 - 10:00	16.13	16.10	0.04	0.05	YES
2	11/09/2015	10:01 - 11:00	16.13	16.10	0.03	0.04	YES
3	11/09/2015	11:01 - 12:00	16.14	16.11	0.02	0.03	YES
4	11/09/2015	12:01 - 13:00	12.47	12.43	0.04	0.05	YES
5	11/09/2015	13:01 - 14:00	8.54	8.64	-0.11	0.10	YES
6	11/09/2015	14:01 - 15:00	8.05	8.14	-0.09	0.08	YES

Slope	1.02	Mean	-0.01
Intercept	-0.22	Stdev	0.0699
R ²	1.00		

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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⁾
11/09/2015	09:01 - 10:00	16.10	16.15	-	-	-	-	16.15	16.13
11/09/2015	10:01 - 11:00	16.10	16.16	-	-	-	-	16.16	16.13
11/09/2015	11:01 - 12:00	16.11	16.17	-	-	-	-	16.17	16.14
11/09/2015	12:01 - 13:00	12.43	12.43	-	-	-	-	12.43	12.47
11/09/2015	13:01 - 14:00	8.64	8.59	-	-	-	-	8.59	8.54
11/09/2015	14:01 - 15:00	8.14	8.08	-	-	-	-	8.08	8.05

(1) 273K, 101.3 kPa, Dry Gas

(2) 273K, 101.3 kPa, Dry Gas, Stack Oxygen

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

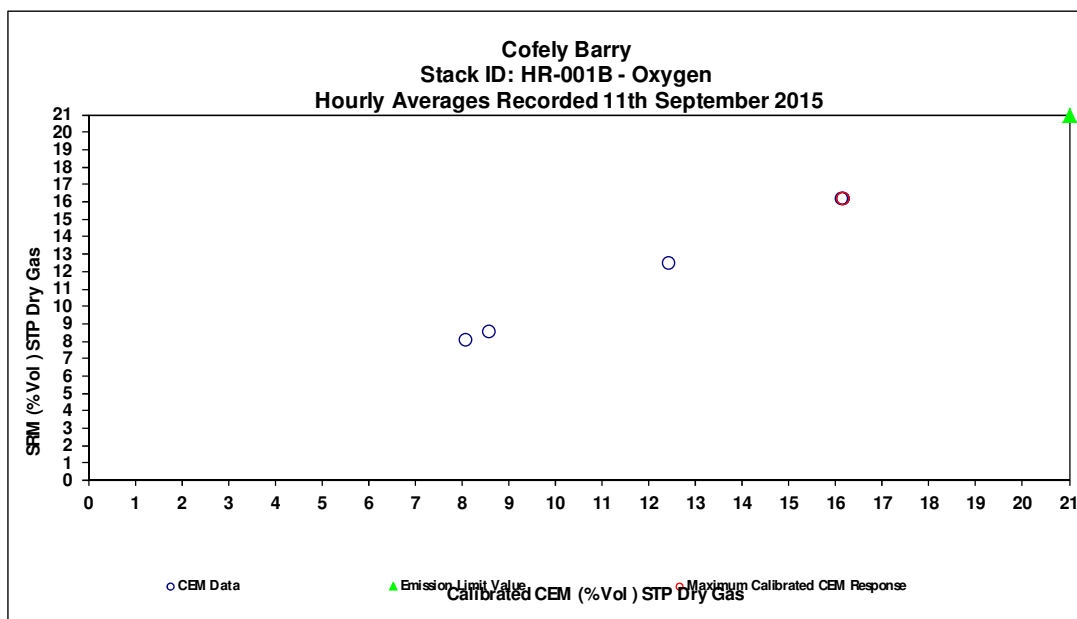
Determinand: Oxygen			QAL2 Calibration function: y=1.0149x-0.1857						
CEM Measured %Vol	SRM Measured %Vol	Calibrated CEM %Vol	SRM Measured @ Reference conditions %Vol	CEM Measured @ Reference conditions %Vol	Calibrated CEM @ Reference Conditions %Vol	Residual Value	Deviation of Residual from Mean		
x_i	y_i	$\hat{y}_i$	$y_{i,s}$	$x_{i,s}$	$\hat{y}_{i,s}$	$D_i = (y_{i,s} - \hat{y}_{i,s})$	$(D_i - \overline{D})$	$(D_i - \overline{D})^2$	
16.10	16.13	16.15	16.13	16.10	16.15	-0.015	0.0016	2.60E-06	
16.10	16.13	16.16	16.13	16.10	16.16	-0.022	-0.0052	0.000027	
16.11	16.14	16.17	16.14	16.11	16.17	-0.030	-0.013	0.00016	
12.43	12.47	12.43	12.47	12.43	12.43	0.044	0.061	0.0037	
8.64	8.54	8.59	8.54	8.64	8.59	-0.052	-0.035	0.0012	
8.14	8.05	8.08	8.05	8.14	8.08	-0.027	-0.0097	0.000095	
Sum						-0.10	0.00	0.0052	
$\overline{D} = \frac{1}{N} \sum_{i=1}^N D_i = -0.017$									
$S_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \overline{D})^2} = \text{SQRT}(0) = 0.032$									
$\begin{aligned} N &= 6 \\ K_v &= 0.93 \\ p &= 10 \\ E &= 21 \end{aligned}$									
$\sigma_0 = \frac{pE}{1.96} = 1.07$									
$1.5\sigma_0 k_v = 1.50$									
$s_D \leq 1.5\sigma_0 k_v = 0.03 \text{ \%Vol} < 1.5 \text{ \%Vol} - \text{Pass Variability Test}$									
$t_{0.95}(N-1) = 2.13$									
$t_{0.95}(N-1) \frac{S_D}{\sqrt{N}} + \sigma_0 = 1.10$									
$ \overline{D} \quad 0.02\% \text{Vol} < 1.1\% \text{Vol} - \text{Calibration Remains Valid}$									

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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	16.17	%Vol
Corresponding SRM @ Reference Conditions	16.14	%Vol
Allowable Range for Calibrated CEM Response i.e. SRM Concentration ± 1.07%	15.06 - 17.21	%Vol
Calibrated Value of CEM Response Falls Within Allowable Range?	YES	...
Maximum Calibrated CEM @ Reference Conditions plus 10% extension < 50% ELV?	N/A	...
Extended Valid Calibration Range	N/A	%Vol

5 – RESULTS OF THE FUNCTIONAL TESTS

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5.1 Functional Test Summary

Requirement	✓	Notes
1. Alignment & Cleanliness Yes ☐ No ☐ N/A ☒		
<i>A visual inspection, with reference to the CEMs manuals, shall be carried out on the following when applicable:</i>		
• Internal check of the Analyser	N/a	N/a
• Cleanliness of optical components	N/a	N/a
• Flushing air supply	N/a	N/a
• Obstructions in optical path	N/a	N/a
<i>Following re-assembly at the sampling location, the following minimum checks have been carried out:</i>		
• Alignment of the measuring system	N/a	N/a
• Contamination control (internal check of optical surfaces)	N/a	N/a
2. Sampling Systems Yes ☒ No ☐ N/A ☐		
<i>A visual inspection has been carried out and the condition of the elements of the sampling system noted (where applicable):</i>		
• Sampling probe	✓	No details on service report, but analyser detailed as "in a fully operational condition" in service by AMETEK / LAND dated 31/03/2015
• Gas conditioning systems	✓	
• Pumps	✓	
• All connections	✓	
• Sample lines	✓	System leak check performed in service by AMETEK / LAND dated 31/03/2015
• Power supplies	✓	Analyser powered off and isolated then powered back up in service by AMETEK / LAND dated 31/03/2015
• Filters	✓	No details on service report, but analyser detailed as "in a fully operational condition" in service by AMETEK / LAND dated 31/03/2015
• NOx converters – if the sampling system contains a NOx converter, then the test laboratory shall record when the last efficiency test was performed, and the result of this test	N/a	N/a
• The sampling system shall be in good condition and free of any visible faults, which may decrease the quality of data	✓	System leak check performed in service by AMETEK / LAND dated 31/03/2015
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.	✓	System leak check performed in service by AMETEK / LAND dated 31/03/2015
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.	✓	Instrument calibrated in service by AMETEK / LAND dated 31/03/2015
• 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/a
5. Linearity Yes ☒ No ☐ N/A ☐		
• During the calibration/linearity tests the applied concentrations should be logged onto the DAHS to prove the complete system (i.e. concentration applied to the instrument is represented by the	✓	Noted by ECL on site, ok

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Requirement	✓	Notes
instrument output and identical to the value logged on the DAHS). DAHS logged values should be included in the instrument service report.		
The linearity of the CEMs response shall be checked using five different reference materials, including a zero concentration.	✓	Using ECL reference gases, see Section 7.1 of this report for details
The reference material with zero concentration, as well as the reference materials with four difference concentrations, shall have a verifiable quantity and quality.¹⁸	✓	Ok
In case of gaseous reference materials, these four reference materials can be obtained from different gas cylinders or can be prepared by means of a calibrated dilution system from one single gas concentration.	✓	Different gas cylinders
The reference material concentrations shall be selected such that the measured values are at approximately 20%, 40%, 60% and 80% of a range that is at least the short-term ELV. It is necessary to know the values of the ratios of their concentrations precisely enough so that an incorrect failure of the linearity does not occur. The dry reference material shall be applied to the inlet of the CEM.	✓	See Section 5.3 of this report for details
<i>The individual CEMs are tested using the following concentrations applied in a randomised sequence:</i>		
Reference material with zero concentration;	✓	Ok
Reference material concentration approximately 20% of the range;	✓	Ok
Reference material concentration approximately 40% of the range;	✓	Ok
Reference material concentration approximately 60% of the range;	✓	Ok
Reference material concentration approximately 80% of the range;	✓	Ok
Reference material with zero concentration;	✓	Ok
After a change in concentration, the first instrument reading shall ordinarily be taken after a time period equal to at least three times the response time of the CEM.	✓	Risk based approach adopted, all verifications passed
At each reference material concentration, at least three readings shall be made, six readings shall be taken at zero.	✓	At least three stable readings at each concentration
The time period between the start of each of the three readings shall be separated by at least four times the response time.	✓	Risk based approach adopted, all verifications passed
<i>A risk-based approach to linearity testing may be applied in order to reduce the time for the tests. For example, the readings may be taken after less than 3x the response time; however, if the CEM fails the linearity test then the test shall be repeated after a period of at least 3x the response time as stated above. Alternatively, the number of repetitions of the test may be reduced if the CEM passes the required performance criteria by a factor of at least 2 (i.e. half the allowable residual). Increasing the waiting time to 5x the response time, for example, may be a means of meeting this requirement.</i>		
<i>Where no other method is possible, the linearity can also be performed with the aid of reference materials such as grating filter or gas</i>		

¹⁸ Please note: if the linearity data is to be used for Method C calibration purposes then the test gases must be accredited (Section 6.3 vii, MID 14181).

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Requirement	✓	Notes
filters.		
<i>The linearity shall be calculated and tested using the procedure as given in EN 14181, Annex B. If the CEM does not pass this test, then the problem shall be identified and rectified.</i>		

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 and there is a failure of the QAL2 or AST which could be due to interferences.	✓	No details on service report	

7. Zero and Span drift (Audit)	Yes ☒	No ☐	N/A ☐
The test laboratory shall assess whether the operator has a QAL3 procedure in place, and whether the operator has applied this procedure. The evidence would comprise (i) a document procedure, (ii) zero and span data, (iii) control charts.	✓	QAL3 in place, control charts provided by operator	

8. Response Time	Yes ☒	No ☐	N/A ☐
Please indicate the length of sample line if known.	✓	Unknown	
The response time of the CEM shall be checked. This can be performed, if appropriate, by feeding of the reference material at the end of the sampling probe. The response time shall not exceed the performance requirement applied during the QAL1 tests.	✓	No details on service report	

Requirement	✓	Notes
9. Service Report		Yes ☒ No ☐ N/A ☐
As a minimum requirement the service report should include the following:		
• Document reference for work instruction for the type of work being undertaken	✓	SRR No: SD15F
• Instrument manufacturer	✓	LAND / AMETEK
• Instrument type	✓	No details on service report but known to be extractive system
• Instrument model	✓	FGA 950E
• Instrument Serial No	✓	A1 – 0292699, A2 – 9492050, A3 - 0292697
• Operating principle	✓	No details on service report but known to be electrochemical cell
• Operating range	✓	No details on service report
• Certification details	✓	No details on service report but known to be MCERTS
• Compliance with MCERTS (including certificate no.)	✓	No details on service report but known to be MC 040019/05
• Location	✓	Noted for each analyser serial number on service report
• Date and time work was undertaken	✓	Time and date logged on service report and linearity (ECL)
• Equipment used – type, serial no’s, calibration dates	✓	ECL equipment used for linearity, see Section 7.1 of this report for gases and Section 10 for blender. AMETEK / KLAND only replaced parts in service, all detailed on report SRR No:SD15F
• Gases used – certificate numbers, expiry dates,	✓	See Section 7.3 of this report for details

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binary / mix		
• NOx converter efficiency test, if applicable	N/a	Not required
• Calibration and linearity data (as required by EN14181) where linearity testing is carried out during the service	✓	Carried out by ECL, see section 5.3 of this report for details
• Logged data for period of calibration and linearity where linearity testing is carried out during the service ¹⁹	✓	Downloaded by David Boles (ECL) when on site, ok
• Name and signature of service engineer	✓	David McGee, signed 31/03/2015
10. Comments Service carried out on 31/03/2015. A follow up service was also carried out on 29/09/2015 after AST parallel tests. Please note that the service does not include all requirements of functional tests as detailed in EN14181 and it was not carried out no more than one month prior to the parallel tests. Note: Documents and records (Annex A.4, BS EN 14181: 2014) and Serviceability (Annex A.5, BS EN 14181: 2014) are covered in ECL document ECL/QFR/114. Functional tests carried out on peripheral parameters (Section 6.2, BS EN 14181: 2014)? Yes for O2 only Details: Checks on O2, moisture not measured or reported.		

¹⁹ Note: There may be gaps in the data, however, for various reasons; for example, if the CEMs are removed from the stack for the linearity test. In such cases, the test laboratory shall state why there are gaps in the data (Appendix 1, MID 14181).

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5.2 Documentation & Records

Test	Test Component	Yes	No	Notes
Name of person(s) performing the functional tests and person(s) witnessing the functional tests		...		
The CEM is covered by a current service contract ²⁰ with the CEM manufacturer / supplier or other 3 rd party. The CEM manual / service agreement clearly indicate the elements covered at each service together with the associated service intervals.		✓		LAND 6 and 12 monthly visits.
Documentation & Records (These must be controlled, readily accessible & up to date)	Plan of the CEM ²¹	✓		Stored with Paul Gardner
	Details of performance testing and certification of the CEM	✓		In-house folder “ENV 10”
	All manuals (maintenance, users etc)	✓		In-house folder “ENV 10” and shift operator log.
	Log books to documents possible malfunctions and action taken ²²	✓		Envirosoft software
	Service Reports	✓		In-house folder “ENV 10”
	QAL3 documentation including action taken as a result of out of control situations ²³	✓		Two staff trained by LAND, see In-house folder “ENV 10”
	Management system procedures ²⁴ for maintenance, calibration & training	✓		In house SAM FM automatically generates work orders.
	Training records ²⁵	✓		Stored in control room
	Maintenance schedules	✓		Stored in control room
	Auditing plans / records ²⁶	✓		In-house folder “ENV 10”

²⁰ 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.

²¹ A generic layout plan of the probe, sample lines & system (if present) and analyser may often be found in the CEM manual.

²² Documentation of CEM performance e.g. possible malfunctions, remedial actions taken etc.

²³ 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.

²⁴ All internal procedures relating to the operation of the CEM, including maintenance, calibration and training.

²⁵ 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.

²⁶ On going assessment or review of the suitability of training, record keeping, calibration & service requirements.

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Test	Test Component	Yes	No	Notes
Serviceability (There shall be provisions for the effective management and maintenance of the CEM, to ensure quality of data)	Safe and clean working environment with sufficient space and weather protection	✓		CEM located on permanent platform but protected from weather. Platform is circular around stack approximately 1m width but there is adequate space to sample combustion gases. Linearity carried out direct to CEM.
	Easy and safe access to all elements of the CEM	✓		
	Adequate supplies of reference materials, tools and spare parts	✓		
	Please confirm whether calibration gas can be introduced via the inlet of the sampling line and at the inlet of the analyser	✓		

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5.3 Linearity Testing

Please note:

The linearity check is mandatory for both QAL2 and AST as detailed in Table A.1, Annex A, BS EN 14181: 2014.

5.3.1 Method

Dry reference gases traceable to national standards are applied to the CEM at several different concentrations²⁷ (approximately 20%, 40%, 60% & 80% of at least the short-term 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 David Boles (ECL) on the 7th to 11th September 2015 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.

²⁷ Specific concentrations used in each linearity test will be specified in the calculation details for each determinand.

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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

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Coefficient “A”

The coefficient “A” is calculated as follows:

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

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:

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

Where:

$\bar{x}_c$ 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:

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

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%.

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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:

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

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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 $\alpha/2$ 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.

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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 $\alpha/2$ with N-2 degrees of freedom.

The standard error of the intercept is calculated using:

$$S_a = S_{est} \sqrt{\frac{\sum x_i^2}{N \sum (x_i - \bar{x})^2}}$$

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 .

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5.3.6 Linearity Results

A1 – HR 001A

5.3.6.1.1 Linearity Calculations for NO

Cofely Suez, Barry
 Linearity test for Nitrogen Monoxide - 07/09/2015
 Daily ELV: 81.7 mg/m³
 Linearised Range: 163.4 mg/m³

Date	Time	% Linearised Range	Reference Concentration mg/m ³	Measured CEM Concentration mg/m ³	$\bar{Y}_c = \frac{1}{m} \sum_{i=1}^m Y_{c,i}$ mg/m ³	$(x_1 - x_2)$ mg/m ³	$(x_1 - x_2)^2$ mg/m ³	$y_i(x_1 - x_2)$ mg/m ³	$d_c = \bar{Y}_c - (A + Bx)$ mg/m ³	$d_{c,rel} = \frac{d_c}{x_u} \times 100\%$	$d_{c,rel} < 5\%?$
07/09/15	13:01	0%	0	-0.13	-0.13	-54.72	2993.91	7.33	0.92	0.57%	PASS
	13:02			-0.13				7.33			
	13:03			-0.13				7.33			
07/09/15	13:33	60%	98.2	94.20	94.92	43.48	1890.80	4096.22	-2.72	-1.67%	PASS
	13:34			95.14				4137.00			
	13:35			95.41				4148.66			
07/09/15	13:38	20%	32.8	30.02	29.35	-21.92	480.34	-657.85	-2.56	-1.57%	PASS
	13:39			28.81				-631.42			
	13:40			29.21				-640.23			
07/09/15	13:44	81%	132	133.46	133.64	77.28	5972.71	10314.54	2.03	1.24%	PASS
	13:45			133.60				10324.90			
	13:46			133.87				10345.61			
07/09/15	13:50	40%	65.3	66.20	65.84	10.58	112.01	700.57	1.27	0.78%	PASS
	13:51			66.06				699.16			
	13:52			65.26				690.65			
07/09/15	14:24	0%	0	0.00	0.00	-54.72	2993.91	0.00	1.06	0.65%	PASS
	14:25			0.00				0.00			
	14:26			0.00				0.00			

Sum	984.90	970.83
Mean ($\bar{X}_z$)	54.72	53.94
Count (n)	...	18

43331.07	43549.81
----------	----------

$$a = \frac{1}{n} \sum_{i=1}^n Y_i = 53.94$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - \bar{X}_z)}{\sum_{i=1}^n (X_i - \bar{X}_z)^2} = \frac{1.0050}{\dots} \pm 0.054$$

$$A = a - B\bar{X}_z = -1.0579 \pm 3.953$$

$$\text{Range (} X_u \text{)} = 163 \text{ mg/m}^3$$

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5.3.6.1.2 95% CI & PI Calculations for NO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
-1.06	0.854	0.00	3024.22	3.95	7.58
97.64	7.405	9643.24	1909.94	3.53	7.36
31.91	6.56	1075.84	485.20	2.89	7.08
131.61	4.138	17424.00	6033.17	4.92	8.13
64.57	1.61	4264.09	113.14	2.70	7.01
-1.06	1.12	0.00	3024.22	3.95	7.58

MSE: 5.42

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 2.3282$$

$$\sqrt{SSX} \quad 120.18$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0194$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.054$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 2.3282$$

$$n \sum (x - \bar{x})^2 \quad 86662.13$$

$$\sum x^2 \quad 32407.17$$

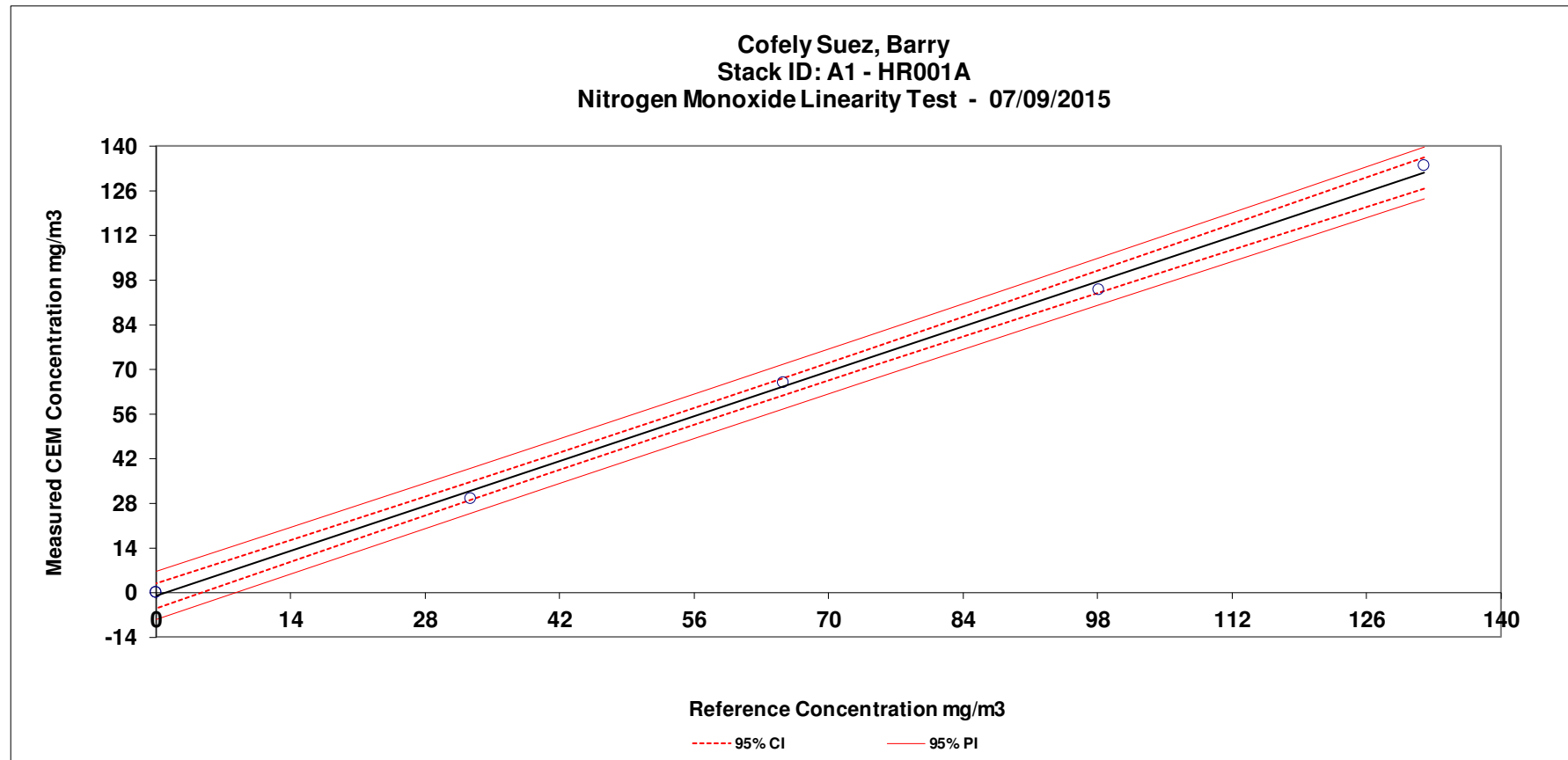
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 1.42$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 3.95$$

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



5.3.6.2.1 Linearity Calculations for CO

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Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

Cofely Suez, Barry
 Linearity test for Carbon Monoxide - 07/09/2015
 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	$d'_c = \bar{Y}_c - (A + Bx_z)$ mg/m ³	$d'_{c,rel} = \frac{d'_c}{x_u} \times 100\%$	$d'_{c,rel} < 5\%$?
07/09/15	13:01	0%	0	0.38	0.38	-53.13	2823.15	-19.93	0.75	0.47%	PASS
	13:02			0.38				-19.93			
	13:03			0.38				-19.93			
07/09/15	13:08	59%	95	99.00	99.54	41.87	1752.82	4144.80	0.43	0.27%	PASS
	13:09			99.63				4170.97			
	13:10			100.00				4186.67			
07/09/15	13:16	20%	31.9	32.13	32.17	-21.23	450.85	-682.12	-0.87	-0.54%	PASS
	13:17			32.13				-682.12			
	13:18			32.25				-684.78			
07/09/15	13:21	80%	127.9	134.00	134.08	74.77	5590.05	10018.73	0.52	0.32%	PASS
	13:22			134.13				10028.08			
	13:23			134.13				10028.08			
07/09/15	13:27	40%	64	65.63	65.42	10.87	118.08	713.13	-1.23	-0.77%	PASS
	13:28			65.38				710.41			
	13:29			65.25				709.05			
07/09/15	14:24	0%	0	0.00	0.04	-53.13	2823.15	0.00	0.41	0.26%	PASS
	14:25			0.00				0.00			
	14:26			0.13				-6.64			

Sum	956.40	994.88
Mean ($\bar{X}_z$)	53.13	55.27
Count (n)	...	18

40674.34	42594.48
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$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{55.27}$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - \bar{X}_z)}{\sum_{i=1}^n (X_i - \bar{X}_z)^2} \quad \boxed{1.0472} \quad \pm 0.022$$

$$A = a - B\bar{X}_z \quad \boxed{-0.3708} \quad \pm 1.579$$

$$\text{Range (} X_u \text{)} \quad \boxed{160} \text{ mg/m}^3$$

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5.3.6.2.2 95% CI & PI Calculations for CO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
-0.37	0.556	0.00	3095.99	1.58	3.02
99.11	0.183	9025.00	1922.22	1.40	2.94
33.04	0.75	1017.61	494.43	1.15	2.83
133.57	0.267	16358.41	6130.30	1.96	3.24
66.65	1.52	4096.00	129.50	1.08	2.80
-0.37	0.17	0.00	3095.99	1.58	3.02

MSE: 0.86

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.9290$$

$$\sqrt{SSX} \quad 116.44$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0080$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.022$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.9290$$

$$n \sum (x - \bar{x})^2 \quad 81348.68$$

$$\sum x^2 \quad 30497.02$$

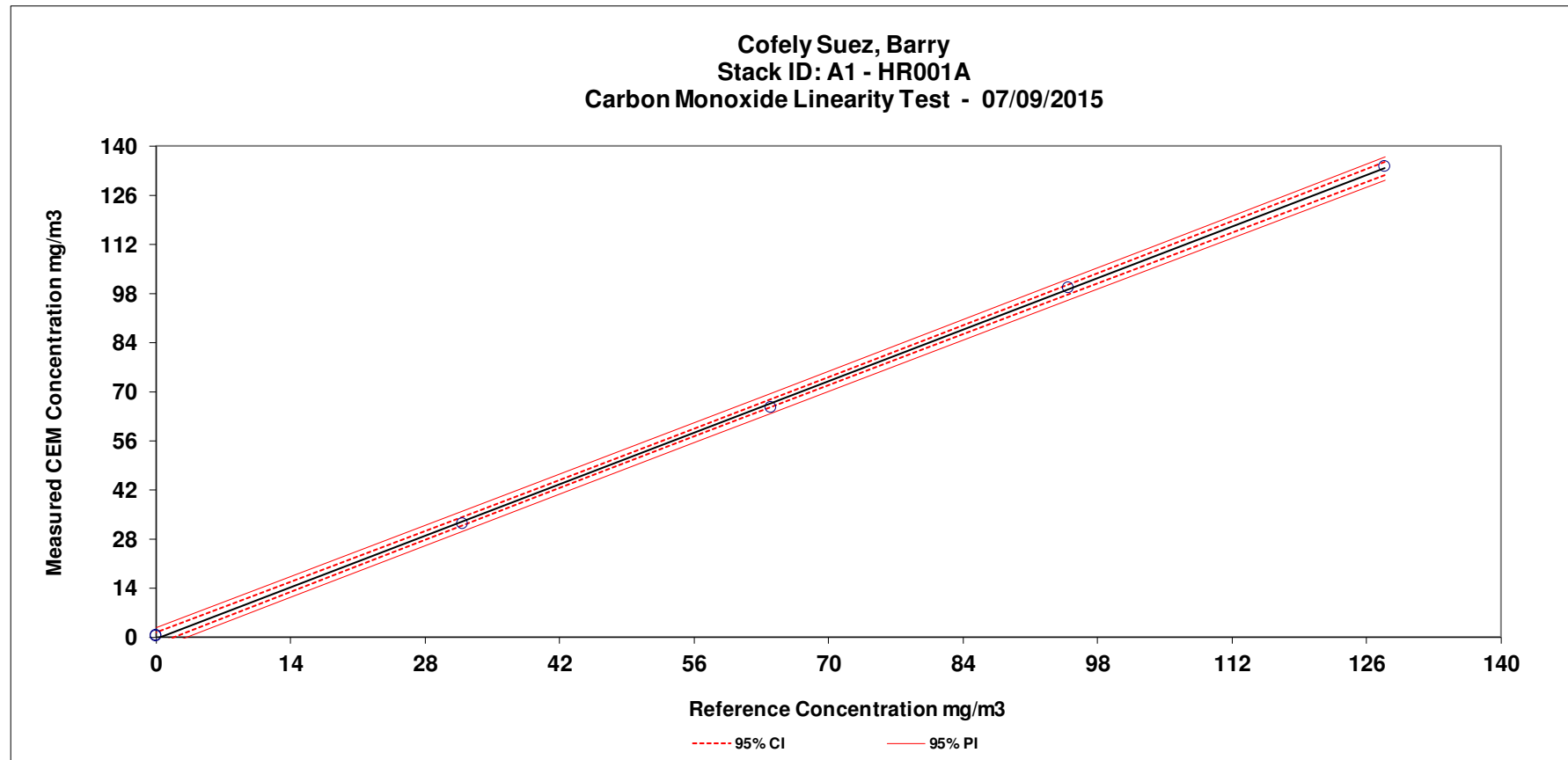
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.57$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 1.58$$

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



5.3.6.3.1 Linearity Calculations for O2

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 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
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Cofely Suez, Barry
 Linearity test for Oxygen - 07/09/2015
 Daily ELV: 21 %Vol
 Linearised Range: 21 %Vol

Date	Time	% Linearised Range	Reference Concentration %Vol	Measured CEM Concentration %Vol	$\bar{Y}_c = \frac{1}{m} \sum_{i=1}^m Y_{c,i}$ %Vol	$(x_i - x_z)$ %Vol	$(x_i - x_z)^2$ %Vol	$y_i(x_i - x_z)$ %Vol	$d_c = \bar{Y}_c - (A + Bx_z)$ %Vol	$d_{c,rel} = \frac{d_c}{x_u} \times 100\%$	$d_{c,rel} < 5\%?$
07/09/15	13:01	0%	0	-0.02	-0.02	-6.67	44.44	0.13	-0.07	-0.31%	PASS
	13:02			-0.02				0.13			
	13:03			-0.02				0.13			
07/09/15	13:58	62%	13	13.11	13.11	6.33	40.11	83.03	0.07	0.31%	PASS
	13:59			13.11				83.03			
	14:00			13.12				83.09			
07/09/15	14:05	19%	4	4.05	4.02	-2.67	7.11	-10.80	-0.03	-0.13%	PASS
	14:06			4.02				-10.72			
	14:07			3.99				-10.64			
07/09/15	14:10	71%	15	14.84	14.85	8.33	69.44	123.67	-0.20	-0.94%	PASS
	14:11			14.85				123.75			
	14:12			14.86				123.83			
07/09/15	14:17	38%	8	8.31	8.32	1.33	1.78	11.08	0.28	1.32%	PASS
	14:18			8.32				11.09			
	14:19			8.34				11.12			
07/09/15	14:26	0%	0	0.00	-0.01	-6.67	44.44	0.00	-0.05	-0.25%	PASS
	14:27			-0.01				0.07			
	14:28			-0.01				0.07			

Sum	120.00	120.84
Mean (X_z)	6.67	6.71
Count (n)	...	18

622.00	622.07
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$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{6.71}$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{1.0001} \quad \pm 0.034$$

$$A = a - B X_z \quad \boxed{0.0459} \quad \pm 0.306$$

$$\text{Range (} X_u \text{)} \quad \boxed{21} \quad \% \text{Vol}$$

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Installation Name : CHP
 Visit Details : AST – 2015
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5.3.6.3.2 95% CI & PI Calculations for O2

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
0.05	0.004	0.00	44.45	0.31	0.58
13.05	0.004	169.00	40.12	0.30	0.58
4.05	0.00	16.00	7.11	0.22	0.54
15.05	0.039	225.00	69.46	0.35	0.61
8.05	0.08	64.00	1.78	0.21	0.54
0.05	0.00	0.00	44.45	0.31	0.58

MSE: 0.03

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1787$$

$$\sqrt{SSX} \quad 14.40$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0124$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.034$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1787$$

$$n \sum (x - \bar{x})^2 \quad 1244.00$$

$$\sum x^2 \quad 474.00$$

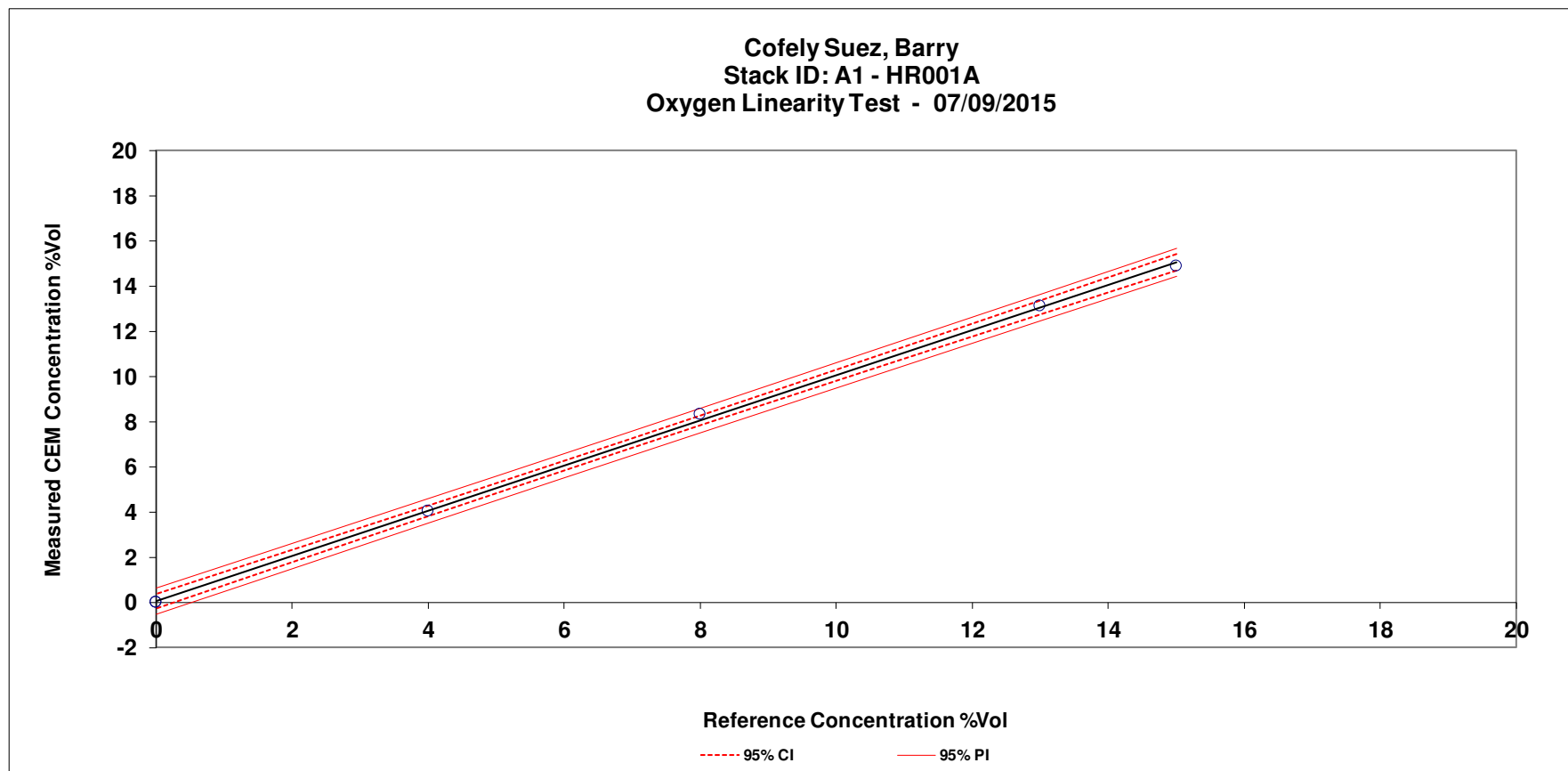
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.11$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 0.31$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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



Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.1.1 Linearity Calculations for NO

Cofely Suez, Barry

Linearity test for Nitrogen Monoxide - 07/09/2015

Daily ELV: 81.7 mg/m³

Linearised Range: 163.4 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	$d_c = \bar{Y}_c - (A + B d)$ mg/m ³	$d_{c,rel} = \frac{d_c}{X_u} \times 100\%$	$d_{c,rel} < 5\%$
07/09/15	14:49	0%	0	-0.40	-0.40	-54.67	2988.44	21.98	1.37	0.84%	PASS
	14:50			-0.40				21.98			
	14:51			-0.40				21.98			
07/09/15	15:20	60%	98.6	98.36	98.45	43.93	1930.14	4321.11	-2.45	-1.50%	PASS
	15:21			98.62				4332.88			
	15:22			98.36				4321.11			
07/09/15	15:26	20%	32.4	30.95	30.73	-22.27	495.80	-689.24	-1.23	-0.75%	PASS
	15:27			30.69				-683.27			
	15:28			30.55				-680.29			
07/09/15	15:31	81%	132	138.56	138.82	77.33	5980.44	10715.00	3.15	1.93%	PASS
	15:32			138.82				10735.72			
	15:33			139.09				10756.45			
07/09/15	15:38	40%	65	64.05	63.83	10.33	106.78	661.87	-2.08	-1.27%	PASS
	15:39			63.78				659.10			
	15:40			63.65				657.72			
07/09/15	16:10	0%	0	-0.54	-0.54	-54.67	2988.44	29.30	1.24	0.76%	PASS
	16:11			-0.54				29.30			
	16:12			-0.54				29.30			

Sum	984.00	992.67
Mean (X_z)	54.67	55.15
Count (n)	...	18

43470.16	45261.98
----------	----------

$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{55.15}$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{1.0412} \quad \pm 0.058$$

$$A = a - B X_z \quad \boxed{-1.7716} \quad \pm 4.254$$

$$\text{Range (} X_u \text{)} \quad \boxed{163} \text{ mg/m}^3$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.1.2 95% CI & PI Calculations for NO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
-1.77	1.876	0.00	3239.89	4.25	8.16
100.89	5.990	9721.96	2092.54	3.82	7.94
31.96	1.52	1049.76	537.52	3.12	7.63
135.67	9.951	17424.00	6483.63	5.30	8.76
65.91	4.32	4225.00	115.76	2.91	7.55
-1.77	1.53	0.00	3239.89	4.25	8.16

MSE: 6.30

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}} \quad 2.5093$$

$$\sqrt{SSX} \quad 120.37$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0208$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.058$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}} \quad 2.5093$$

$$n \sum (x - \bar{x})^2 \quad 86940.32$$

$$\sum x^2 \quad 32420.72$$

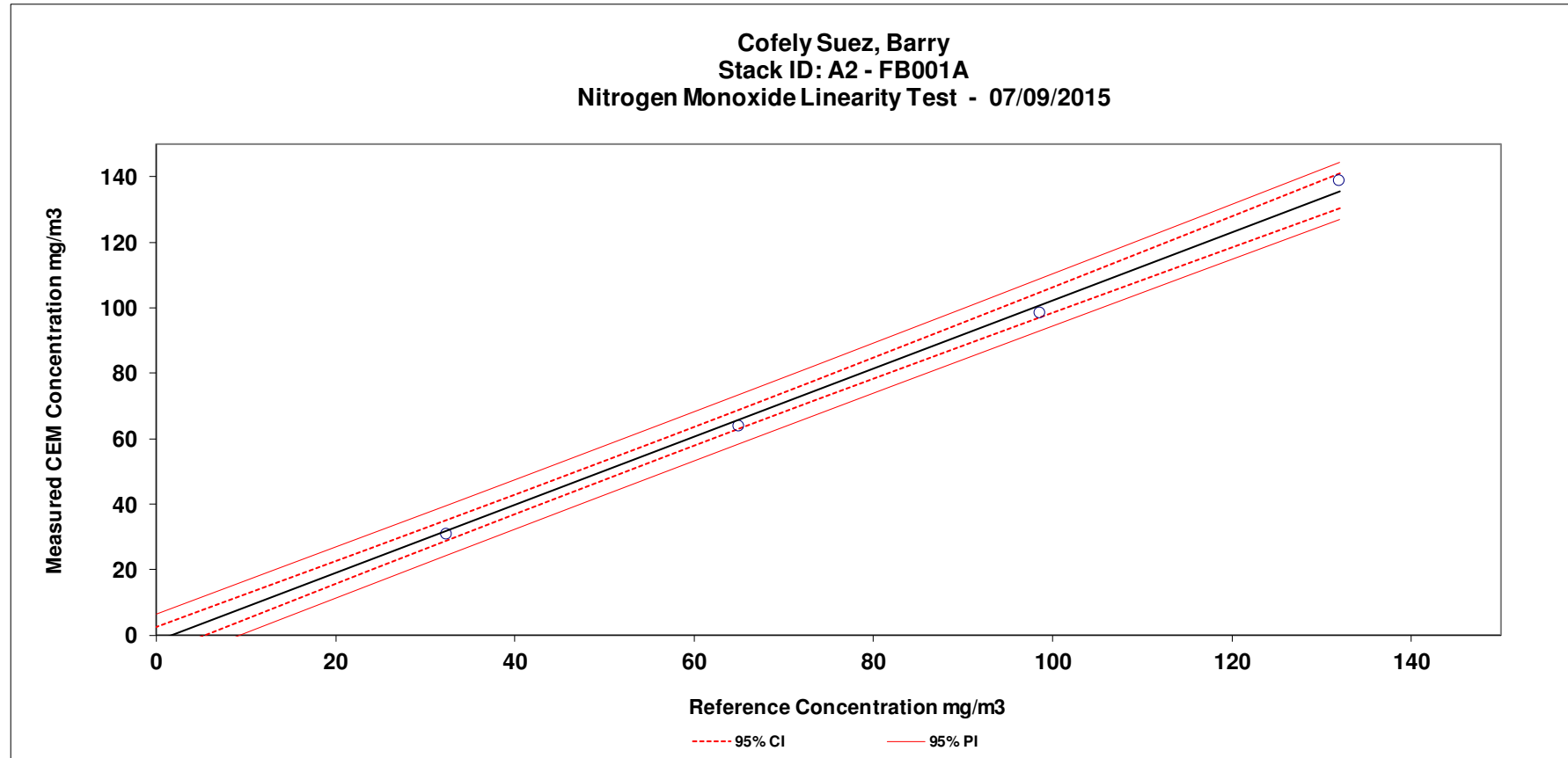
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 1.53$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 4.25$$

Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

Installation Name : CHP
Visit Details : AST – 2015
Survey Dates : 7th to 11th September 2015
Report Issue Date : 12th November 2015

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



5.3.6.2.1 Linearity Calculations for CO

Environmental Compliance Limited

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

Cofely Suez, Barry

Linearity test for Carbon Monoxide - 08/09/2015

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	$(X_1 - X_2)$ mg/m ³	$(X_1 - X_2)^2$ mg/m ³	$y_i(X_1 - X_2)$ mg/m ³	$d_c = \bar{Y}_c - (A + Bx)$ mg/m ³	$d_{c,rel} = \frac{d_c}{X_u} \times 100\%$	$d_{c,rel} < 5\%$?
08/09/15	12:09	0%	0	0.00	-0.17	-53.40	2851.56	0.00	0.40	0.25%	PASS
	12:10			-0.25				13.35			
	12:11			-0.25				13.35			
08/09/15	12:15	60%	95.8	99.88	99.88	42.40	1797.76	4234.70	-0.39	-0.24%	PASS
	12:16			99.88				4234.70			
	12:17			99.88				4234.70			
08/09/15	12:23	21%	32.8	33.38	33.25	-20.60	424.36	-687.53	-0.71	-0.44%	PASS
	12:24			33.25				-684.95			
	12:25			33.13				-682.38			
08/09/15	12:28	80%	127.5	134.50	134.54	74.10	5490.81	9966.45	0.91	0.57%	PASS
	12:29			134.50				9966.45			
	12:30			134.63				9975.71			
08/09/15	12:34	40%	64.3	66.25	66.25	10.90	118.81	722.13	-0.86	-0.54%	PASS
	12:35			66.13				720.76			
	12:36			66.38				723.49			
08/09/15	12:40	0%	0	0.25	0.08	-53.40	2851.56	-13.35	0.65	0.41%	PASS
	12:41			0.00				0.00			
	12:42			0.00				0.00			

Sum	961.20	1001.50
Mean (X_z)	53.40	55.64
Count (n)	...	18

40604.58	42737.59
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$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{55.64}$$

$$B = \frac{\sum_{i=1}^n Y_i(X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{1.0525} \quad \pm 0.02$$

$$A = a - BX_z \quad \boxed{-0.5663} \quad \pm 1.428$$

$$\text{Range (} X_u \text{)} \quad \boxed{160} \text{ mg/m}^3$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.2.2 95% CI & PI Calculations for CO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
-0.57	0.160	0.00	3159.02	1.43	2.73
100.27	0.153	9177.64	1991.60	1.27	2.65
33.96	0.50	1075.84	470.12	1.03	2.54
133.63	0.828	16256.25	6082.84	1.76	2.92
67.11	0.74	4134.49	131.62	0.97	2.52
-0.57	0.42	0.00	3159.02	1.43	2.73

MSE: 0.70

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.8374$$

$$\sqrt{SSX} \quad 116.34$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0072$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.020$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.8374$$

$$n \sum (x - \bar{x})^2 \quad 81209.16$$

$$\sum x^2 \quad 30644.22$$

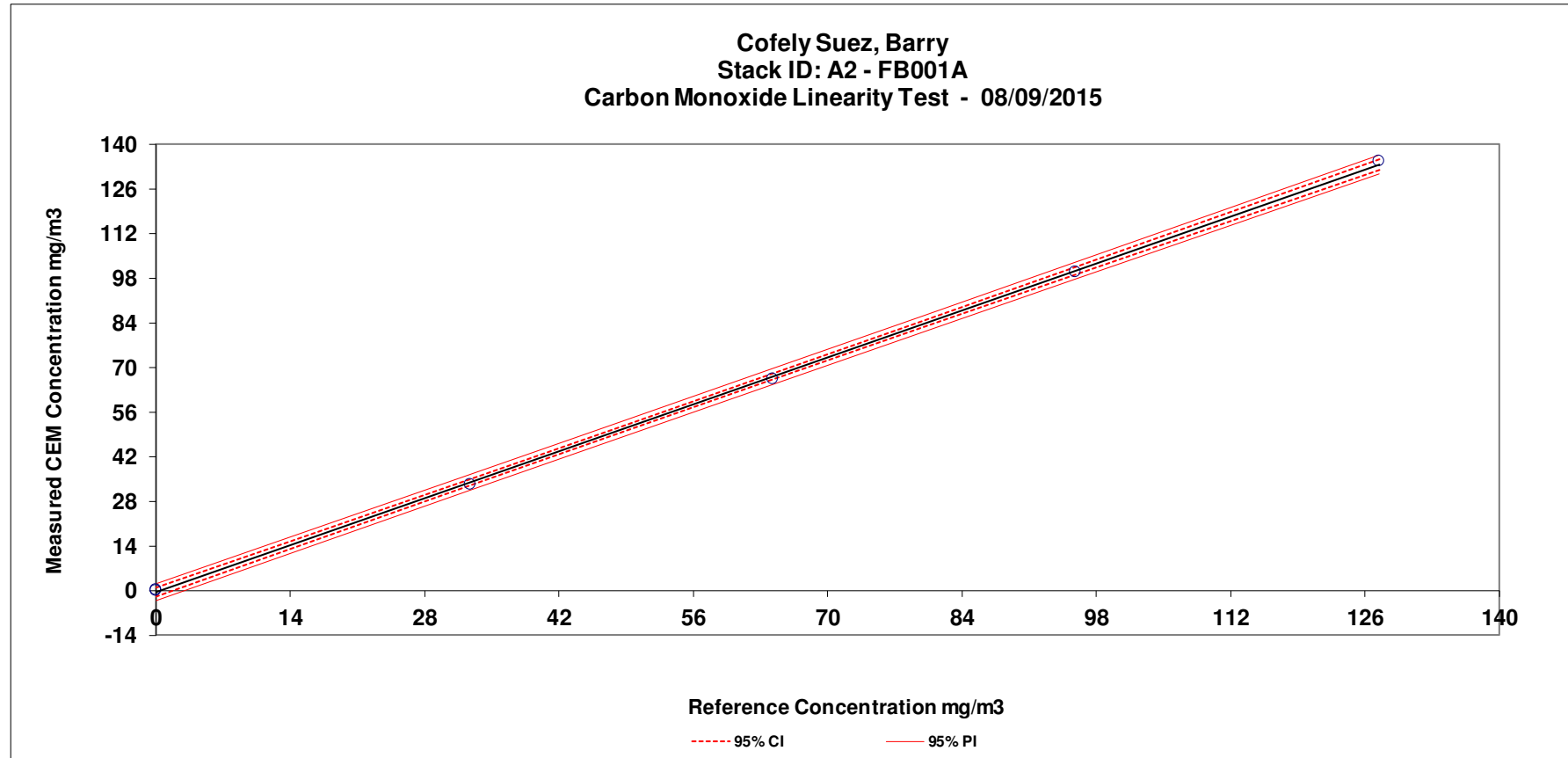
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.51$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 1.43$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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



5.3.6.3.1 Linearity Calculations for O₂

Environmental Compliance Limited

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

Cofely Suez, Barry
 Linearity test for Oxygen - 07/09/2015
 Daily ELV: 21 %Vol
 Linearised Range: 21 %Vol

Date	Time	% Linearised Range	Reference Concentration %Vol	Measured CEM Concentration %Vol	$\bar{Y}_c = \frac{1}{m} \sum_{i=1}^m Y_{c,i}$ %Vol	$(X_i - X_z)$ %Vol	$(X_i - X_z)^2$ %Vol	$y_i(X_i - X_z)$ %Vol	$d_c = \bar{Y}_c - (A + B d)$ %Vol	$d_{c,rel} = \frac{d_c}{X_u} \times 100\%$	$d_{c,rel} < 5\%$
07/09/15	14:49	0%	0	-0.01	0.00	-6.67	44.44	0.07	-0.06	-0.31%	PASS
	14:50			0.00				0.00			
	14:51			0.00				0.00			
07/09/15	15:44	62%	13	13.12	13.14	6.33	40.11	83.09	-0.03	-0.12%	PASS
	15:45			13.14				83.22			
	15:46			13.16				83.35			
07/09/15	15:50	19%	4	4.06	4.07	-2.67	7.11	-10.83	-0.02	-0.09%	PASS
	15:51			4.08				-10.88			
	15:52			4.08				-10.88			
07/09/15	15:54	71%	15	14.96	15.03	8.33	69.44	124.67	-0.15	-0.70%	PASS
	15:55			15.08				125.67			
	15:56			15.06				125.50			
07/09/15	15:59	38%	8	8.46	8.45	1.33	1.78	11.28	0.33	1.56%	PASS
	16:00			8.45				11.27			
	16:01			8.45				11.27			
07/09/15	16:10	0%	0	-0.01	-0.01	-6.67	44.44	0.07	-0.07	-0.34%	PASS
	16:11			-0.01				0.07			
	16:12			-0.01				0.07			

Sum	120.00	122.06
Mean ($\bar{X}_z$)	6.67	6.78
Count (n)	...	18

622.00	626.99
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$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{6.78}$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{1.0080} \quad \pm 0.036$$

$$A = a - B X_z \quad \boxed{0.0610} \quad \pm 0.32$$

$$\text{Range (} X_u \text{)} \quad \boxed{21} \quad \% \text{Vol}$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.3.2 95% CI & PI Calculations for O2

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
0.06	0.004	0.00	45.16	0.32	0.61
13.17	0.001	169.00	40.76	0.31	0.61
4.09	0.00	16.00	7.23	0.23	0.57
15.18	0.022	225.00	70.56	0.37	0.64
8.13	0.11	64.00	1.81	0.22	0.56
0.06	0.01	0.00	45.16	0.32	0.61

MSE: 0.03

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1869$$

$$\sqrt{SSX} \quad 14.40$$

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

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

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

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1869$$

$$n \sum (x - \bar{x})^2 \quad 1244.00$$

$$\sum x^2 \quad 474.00$$

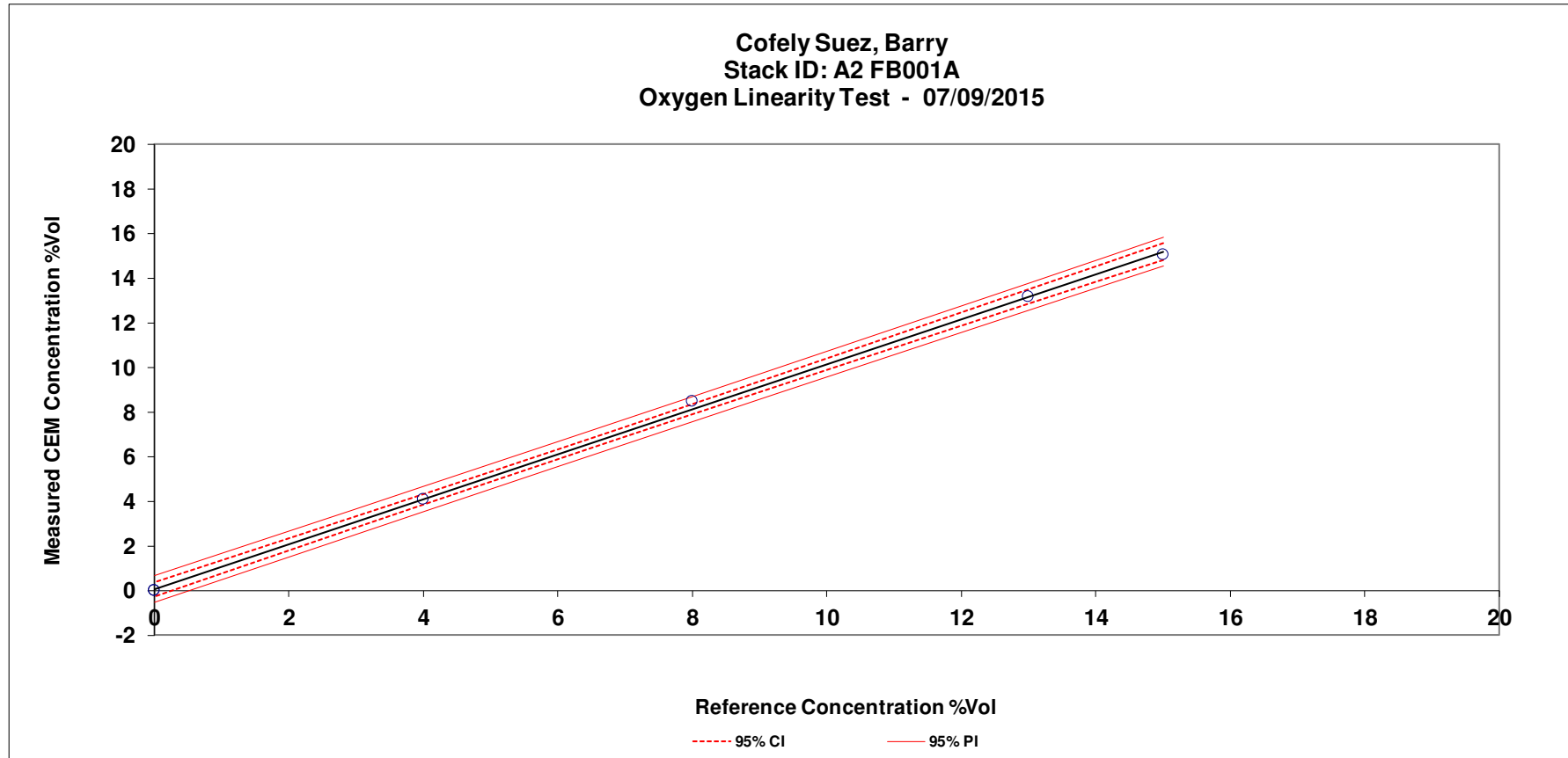
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.12$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 0.32$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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



Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.1.1 Linearity Calculations for NO

Cofely Suez, Barry

Linearity test for Nitrogen Monoxide - 07/09/2015

Daily ELV: 81.7 mg/m³

Linearised Range: 163.4 mg/m³

Date	Time	% Linearised Range	Reference Concentration mg/m ³	Measured CEM Concentration mg/m ³	$\bar{Y}_c = \frac{1}{m} \sum_{i=1}^m Y_{c,i}$ 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	$d'_c = \bar{Y}_c - (A + Bx_z)$ mg/m ³	$d_{c,rel} = \frac{d'_c}{x_u} \times 100\%$	$d_{c,rel} < 5\%$?
07/09/15	16:32	0%	0	0.00	0.00	-54.67	2988.44	0.00	0.96	0.59%	PASS
	16:33			0.00				0.00			
	16:34			0.00				0.00			
07/09/15	17:03	60%	97.4	99.29	99.25	42.73	1826.14	4243.16	-0.29	-0.18%	PASS
	17:04			99.16				4237.44			
	17:05			99.29				4243.16			
07/09/15	17:10	21%	33.9	32.83	32.61	-20.77	431.25	-681.77	-1.41	-0.86%	PASS
	17:11			32.56				-676.20			
	17:12			32.43				-673.42			
07/09/15	17:15	81%	131.7	136.14	136.28	77.03	5934.13	10487.63	1.35	0.83%	PASS
	17:16			136.41				10508.27			
	17:17			136.28				10497.95			
07/09/15	17:21	40%	65	64.86	64.54	10.33	106.78	670.18	-1.56	-0.96%	PASS
	17:22			64.45				666.02			
	17:23			64.32				664.64			
07/09/15	17:57	0%	0	0.00	0.00	-54.67	2988.44	0.00	0.96	0.59%	PASS
	17:58			0.00				0.00			
	17:59			0.00				0.00			

Sum	984.00	998.03
Mean ($\bar{X}_z$)	54.67	55.45
Count (n)	...	18

42825.58	44187.06
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$$a = \frac{1}{n} \sum_{i=1}^n Y_i = 55.45$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} = \frac{1.0318}{\dots} \pm 0.033$$

$$A = a - B X_z = -0.9584 \pm 2.435$$

$$\text{Range (} X_u \text{)} = 163 \text{ mg/m}^3$$

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

5.3.6.1.2 95% CI & PI Calculations for NO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
-0.96	0.918	0.00	3181.48	2.44	4.66
99.54	0.083	9486.76	1944.09	2.16	4.52
34.02	2.00	1149.21	459.11	1.76	4.35
134.93	1.821	17344.89	6317.44	3.03	5.00
66.11	2.45	4225.00	113.67	1.66	4.30
-0.96	0.92	0.00	3181.48	2.44	4.66

MSE: 2.05

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 1.4305$$

$$\sqrt{SSX} \quad 119.48$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0120$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.033$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 1.4305$$

$$n \sum (x - \bar{x})^2 \quad 85651.16$$

$$\sum x^2 \quad 32205.86$$

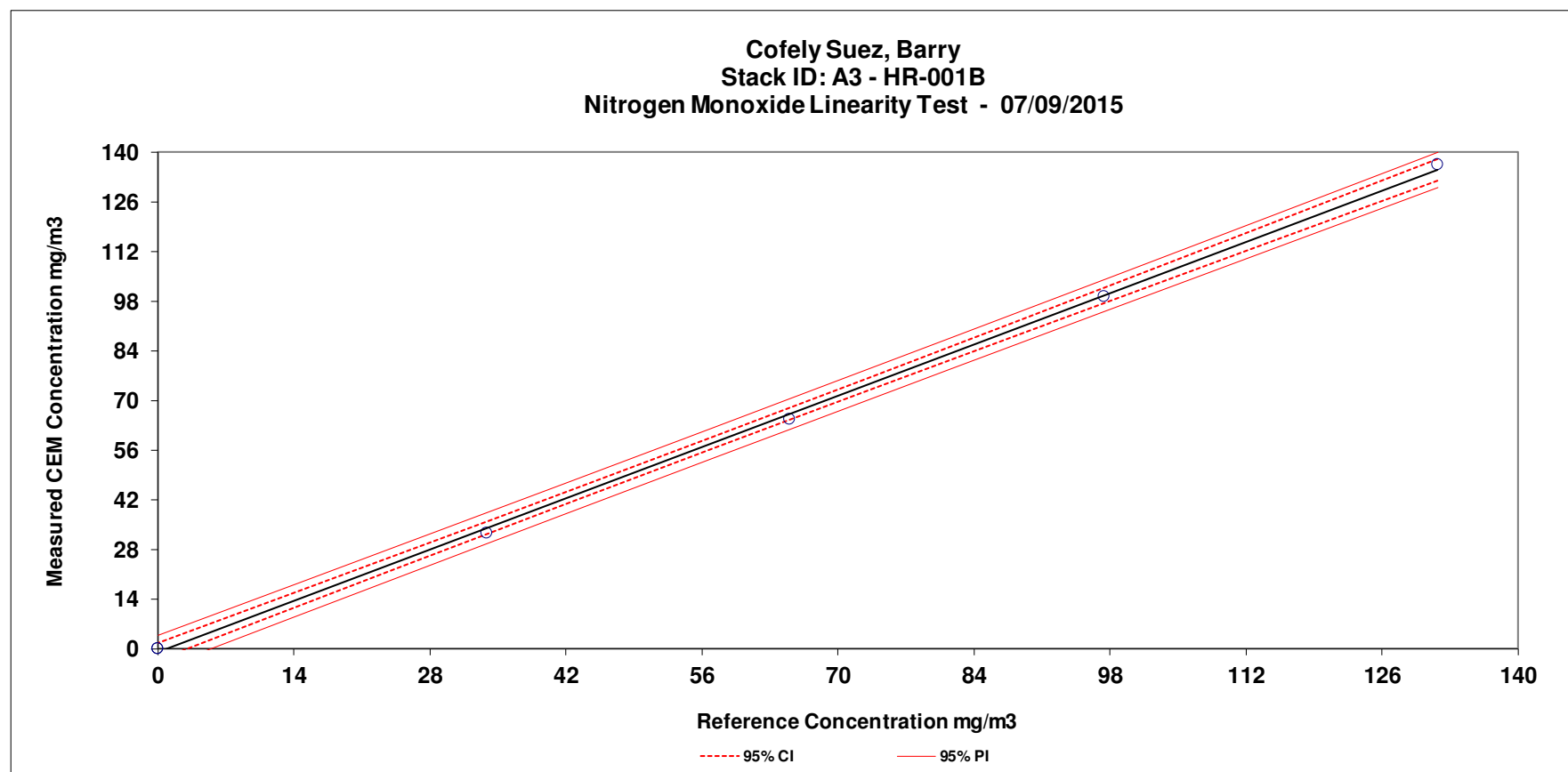
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.88$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 2.44$$

Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

Installation Name : CHP
Visit Details : AST – 2015
Survey Dates : 7th to 11th September 2015
Report Issue Date : 12th November 2015

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



5.3.6.2.1 Linearity Calculations for CO

Environmental Compliance Limited

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

Cofely Suez, Barry
 Linearity test for Carbon Monoxide - 07/09/2015
 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	$d_c = \bar{Y}_c - (A + Bx)$ mg/m ³	$d_{c,rel} = \frac{d_c}{X_u} \times 100\%$	$d_{c,rel} < 5\%$?
07/09/15	16:27	0%	0	1.00	1.25	-53.52	2864.03	-53.52	-0.15	-0.09%	PASS
	16:28			1.25				-66.90			
	16:29			1.50				-80.28			
07/09/15	16:39	60%	95.8	103.63	103.63	42.28	1787.88	4381.61	0.19	0.12%	PASS
	16:40			103.63				4381.61			
	16:41			103.63				4381.61			
07/09/15	16:45	21%	33.8	37.25	36.92	-19.72	388.75	-734.45	-0.49	-0.30%	PASS
	16:46			37.00				-729.52			
	16:47			36.50				-719.66			
07/09/15	16:50	80%	127.5	137.63	137.71	73.98	5473.53	10181.96	0.50	0.32%	PASS
	16:51			137.75				10191.20			
	16:52			137.75				10191.20			
07/09/15	16:57	40%	64	67.63	68.54	10.48	109.90	708.94	-1.03	-0.64%	PASS
	16:58			68.75				720.73			
	16:59			69.25				725.97			
07/09/15	17:56	0%	0	2.38	2.38	-53.52	2864.03	-127.10	0.97	0.61%	PASS
	17:57			2.38				-127.10			
	17:58			2.38				-127.10			

Sum	963.30	1051.25
Mean ($\bar{X}_z$)	53.52	58.40
Count (n)	...	18

40464.39	43099.22
----------	----------

$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{58.40}$$

$$B = \frac{\sum_{i=1}^n Y_i(X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{1.0651} \quad \pm 0.019$$

$$A = a - B\bar{X}_z \quad \boxed{1.4014} \quad \pm 1.365$$

$$\text{Range (} X_u \text{)} \quad \boxed{160} \text{ mg/m}^3$$

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5.3.6.2.2 95% CI & PI Calculations for CO

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
1.40	0.023	0.00	3249.16	1.36	2.60
103.44	0.034	9177.64	2028.30	1.21	2.53
37.40	0.24	1142.44	441.02	0.98	2.42
137.20	0.255	16256.25	6209.56	1.68	2.78
69.57	1.05	4096.00	124.68	0.93	2.40
1.40	0.95	0.00	3249.16	1.36	2.60

MSE: 0.64

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}} \quad 0.7986$$

$$\sqrt{SSX} \quad 116.14$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0069$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.019$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS\hat{Y}}{N-2}} \quad 0.7986$$

$$n \sum (x - \bar{x})^2 \quad 80928.77$$

$$\sum x^2 \quad 30672.33$$

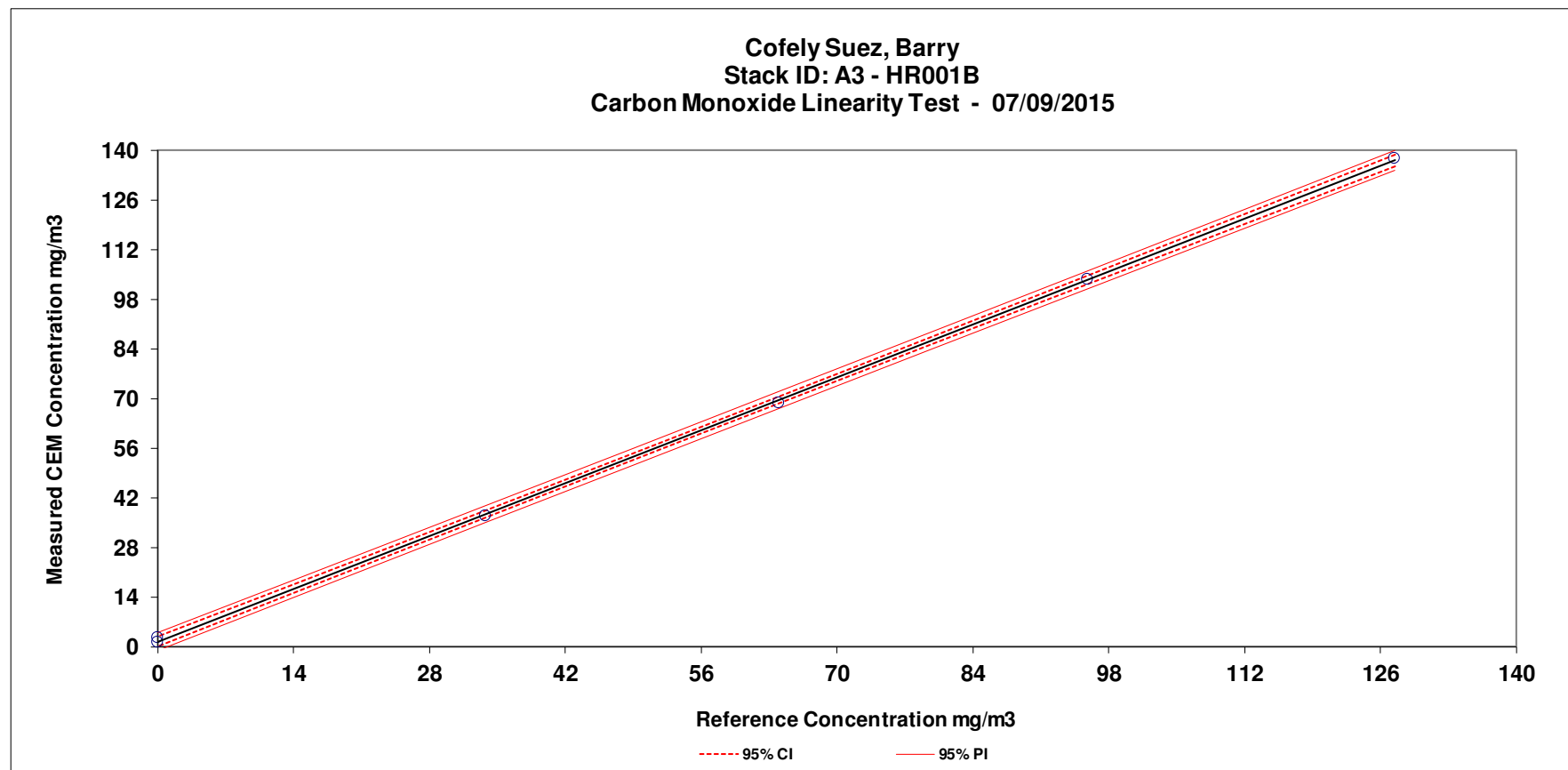
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.49$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 1.36$$

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



5.3.6.3.1 Linearity Calculations for O2

Environmental Compliance Limited

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Cofely Suez, Barry
Linearity test for Oxygen - 07/09/2015
Daily ELV: 21 %Vol
Linearised Range: 21 %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	$d_c = \bar{Y}_c - (A + Bx)$ %Vol	$d_{c,rel} = \frac{d_c}{x_u} \times 100\%$	$d_{c,rel} < 5\%$?
07/09/15	16:32	0%	0	0.01	0.00	-6.66	44.31	-0.07	-0.08	-0.37%	PASS
	16:33			0.00				0.00			
	16:34			0.00				0.00			
07/09/15	17:27	62%	12.93	13.00	13.02	6.27	39.35	81.55	0.06	0.27%	PASS
	17:28			13.02				81.68			
	17:29			13.04				81.80			
07/09/15	17:34	19%	4	4.11	4.11	-2.66	7.06	-10.92	0.04	0.19%	PASS
	17:35			4.11				-10.92			
	17:36			4.10				-10.89			
07/09/15	17:40	71%	15	14.82	14.83	8.34	69.61	123.65	-0.20	-0.94%	PASS
	17:41			14.83				123.73			
	17:42			14.83				123.73			
07/09/15	17:46	38%	8.01	8.32	8.32	1.35	1.83	11.26	0.26	1.23%	PASS
	17:47			8.32				11.26			
	17:48			8.32				11.26			
07/09/15	17:57	0%	0	0.00	0.00	-6.66	44.31	0.00	-0.08	-0.39%	PASS
	17:58			0.00				0.00			
	17:59			0.00				0.00			

Sum	119.82	120.83
Mean (X_z)	6.66	6.71
Count (n)	...	18

619.43	617.13
--------	--------

$$a = \frac{1}{n} \sum_{i=1}^n Y_i \quad \boxed{6.71}$$

$$B = \frac{\sum_{i=1}^n Y_i (X_i - X_z)}{\sum_{i=1}^n (X_i - X_z)^2} \quad \boxed{0.9963} \quad \pm 0.034$$

$$A = a - B X_z \quad \boxed{0.0809} \quad \pm 0.302$$

$$\text{Range (} X_u \text{)} \quad \boxed{21} \text{ %Vol}$$

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5.3.6.3.2 95% CI & PI Calculations for O2

95% Confidence Intervals

$\hat{y}$	$(y - \hat{y})^2$	x^2	$(\hat{y} - \bar{y})^2$	95% CI	95% PI
0.08	0.006	0.00	43.98	0.30	0.57
12.96	0.003	167.18	39.06	0.29	0.57
4.07	0.00	16.00	7.01	0.22	0.54
15.03	0.039	225.00	69.09	0.35	0.60
8.06	0.07	64.16	1.82	0.20	0.53
0.08	0.01	0.00	43.98	0.30	0.57

MSE: 0.03

95% Confidence Interval of Slope

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1760$$

$$\sqrt{SSX} \quad 14.37$$

$$s_b = \frac{s_{est}}{\sqrt{SSX}} \quad 0.0122$$

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

$$95\% CI = s_b \times t_{\alpha/2, N-2} \quad 0.034$$

95% Confidence Interval of Intercept

$$s_{est} = \sqrt{\frac{SS \hat{Y}}{N - 2}} \quad 0.1760$$

$$n \sum (x - \bar{x})^2 \quad 1238.87$$

$$\sum x^2 \quad 472.35$$

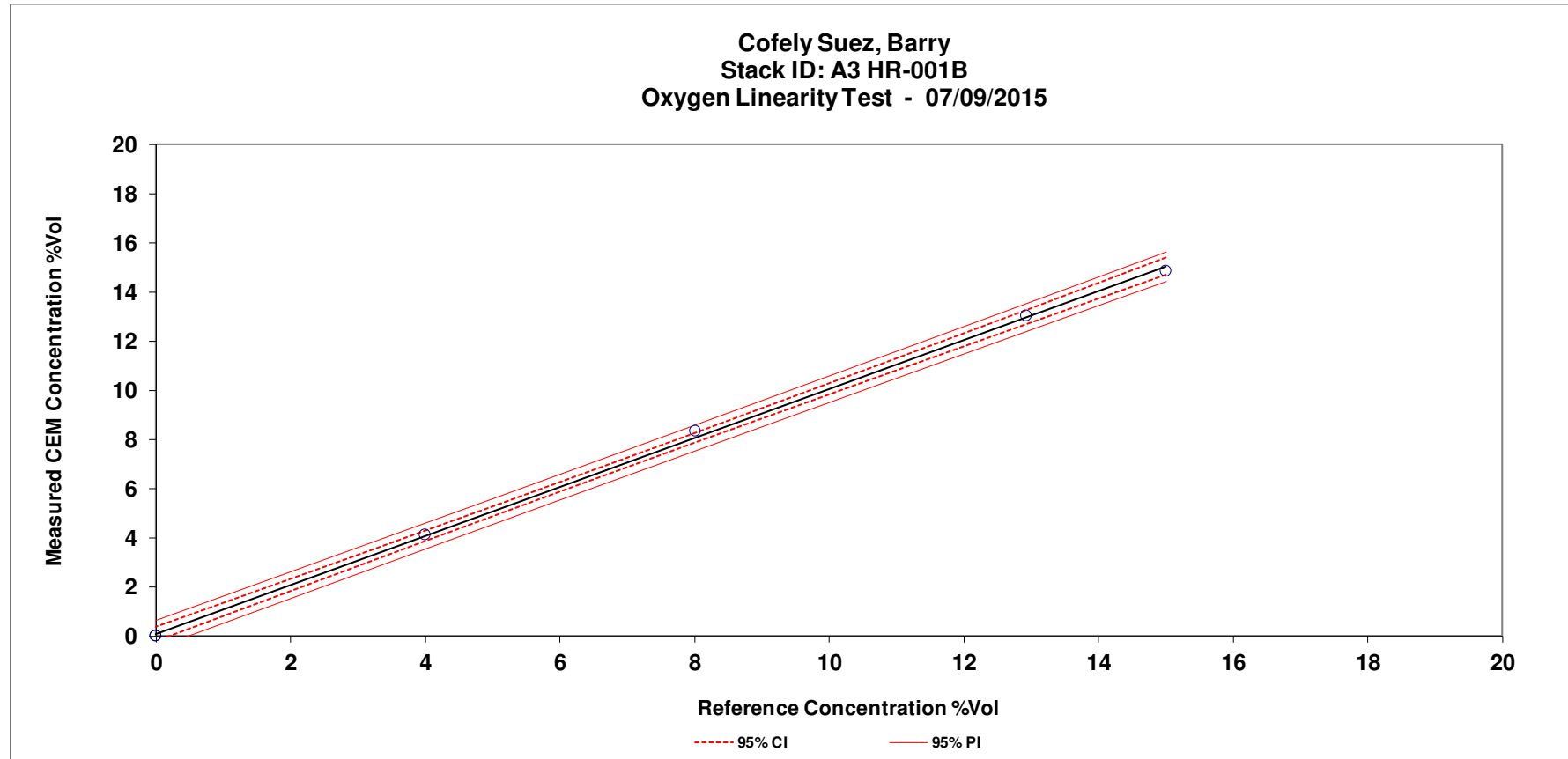
$$s_a = s_{est} \sqrt{\frac{\sum x^2}{n \sum (x - \bar{x})^2}} \quad 0.11$$

$$95\% CI = s_a \times t_{\alpha/2, N-2} \quad 0.30$$

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



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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}	²⁸ $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
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}	²⁹ $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$
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}	$u(x_i) = \Delta x_i$
³⁰ Effect of Voltage Fluctuation See Note	u_v	$u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,max} - x_{i,adj})^2 + (x_{i,min} - x_{i,adj})(x_{i,max} - x_{i,adj}) + (x_{i,min} - x_{i,adj})^2}{3}}$
³¹ 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 $|x_{i,max} - x_{i,adj}| = |x_{i,min} - x_{i,adj}|$, $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

²⁸ Where Δx_i is the percent of range in mg/m³ (or %Vol).

²⁹ Where Δx_i is the percent of the measured value in mg/m³ (or %Vol).

³⁰ Applies to TOC analyser only.

³¹ Applies to TOC analyser only.

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6.1.2 Combustion Gas Uncertainty

Measurement Uncertainty 08/09/2015

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributioun	Minimum Certified Range (R _i)		
			NO 0 - 125 mg/m ³	CO 0 - 95 mg/m ³	O ₂ 0 - 25 %Vol
Lack of fit ⁽¹⁾	u_{lof}	Rectangular (Divisor = $\sqrt{3}$)	0.40	0.40	0.13
Span drift ⁽²⁾	$u_{d,s}$	Rectangular (Divisor = $\sqrt{3}$)	0.27	0.29	0.029
Repeatability Standard Deviation (span) ⁽³⁾	u_r	Normal (Divisor = 1)	1.18	0.69	0.19
Losses / leakage in the sample system ⁽⁴⁾	u_{loss}	Rectangular (Divisor = $\sqrt{3}$)	1.21	1.52	0.39
Temperature dependant span drift ⁽⁵⁾	u_t	Rectangular (Divisor = $\sqrt{3}$)	0.18	0.050	0.070
Interferents ⁽¹⁾	u_i	Rectangular (Divisor = $\sqrt{3}$)	1.20	2.90	0.56
Uncertainty of Reference Gas ⁽⁶⁾	u_{ref}	Rectangular (Divisor = $\sqrt{3}$)	2.13	2.60	0.15

Note:

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

- 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/m ³	CO 0 - 95 mg/m ³	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	$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} =$	1.18	0.69	0.19
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	0.88	0.83	0.06
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{i,adj})^2 + (x_{i,min} - x_{i,adj})^2 + (x_{i,max} - x_{i,min})^2}{3}} =$	0.13	0.027	0.010
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}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	1.23	1.50	0.087
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	2.13	2.46	0.23
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	4.27	4.91	0.46
Applied Span Concentration			123.00	150.00	15.00
Measured Span Concentration, STP Dry Gas			125.91	151.70	15.07
Expanded measurement uncertainty as % of Applied Span			3%	3%	3%

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Measurement Uncertainty 09/09/2015

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributioun	Minimum Certified Range (R _i)		
			NO 0 - 125 mg/m ³	CO 0 - 95 mg/m ³	O ₂ 0 - 25 %Vol
Lack of fit ⁽¹⁾	u_{lof}	Rectangular (Divisor = $\sqrt{3}$)	0.40	0.40	0.13
Span drift ⁽²⁾	$u_{d,s}$	Rectangular (Divisor = $\sqrt{3}$)	0.27	0.29	0.029
Repeatability Standard Deviation (span) ⁽³⁾	u_r	Normal (Divisor = 1)	0.57	2.15	0.13
Losses / leakage in the sample system ⁽⁴⁾	u_{loss}	Rectangular (Divisor = $\sqrt{3}$)	1.64	2.16	0.13
Temperature dependant span drift ⁽⁵⁾	u_t	Rectangular (Divisor = $\sqrt{3}$)	0.18	0.050	0.070
Interferents ⁽¹⁾	u_i	Rectangular (Divisor = $\sqrt{3}$)	1.20	2.90	0.56
Uncertainty of Reference Gas ⁽⁶⁾	u_{ref}	Rectangular (Divisor = $\sqrt{3}$)	2.13	2.60	0.15

Note:

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

- 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/m ³	CO 0 - 95 mg/m ³	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	$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} =$	0.57	2.15	0.13
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	1.18	1.19	0.02
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t \times R_i}{100} \times \sqrt{\frac{(x_{i,\max} - x_{i,\text{adj}})^2 + (x_{i,\min} - x_{i,\text{adj}})^2 + (x_{i,\max} - x_{i,\text{adj}})(x_{i,\min} - x_{i,\text{adj}})}{3}}$	0.13	0.027	0.010
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}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	1.23	1.50	0.087
Combined Standard Uncertainty			2.03	3.30	0.18
Expanded measurement uncertainty (at 95% confidence)			4.06	6.60	0.36
Applied Span Concentration			123.00	150.00	15.00
Measured Span Concentration, STP Dry Gas			125.23	150.17	15.02
Expanded measurement uncertainty as % of Applied Span			3%	4%	2%

Measurement Uncertainty 11/09/2015

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Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributioun	Minimum Certified Range (R _i)		
			NO 0 - 125 mg/m ³	CO 0 - 95 mg/m ³	O ₂ 0 - 25 %Vol
Lack of fit ⁽¹⁾	u_{lof}	Rectangular (Divisor = $\sqrt{3}$)	0.40	0.40	0.13
Span drift ⁽²⁾	$u_{d,s}$	Rectangular (Divisor = $\sqrt{3}$)	0.27	0.29	0.029
Repeatability Standard Deviation (span) ⁽³⁾	u_r	Normal (Divisor = 1)	1.84	1.39	0.09
Losses / leakage in the sample system ⁽⁴⁾	u_{loss}	Rectangular (Divisor = $\sqrt{3}$)	1.95	0.41	0.13
Temperature dependant span drift ⁽⁵⁾	u_t	Rectangular (Divisor = $\sqrt{3}$)	0.18	0.050	0.070
Interferents ⁽¹⁾	u_i	Rectangular (Divisor = $\sqrt{3}$)	1.20	2.90	0.56
Uncertainty of Reference Gas ⁽⁶⁾	u_{ref}	Rectangular (Divisor = $\sqrt{3}$)	2.13	2.60	0.15

Note:

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

- 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/m ³	CO 0 - 95 mg/m ³	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	$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} =$	1.84	1.39	0.09
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	1.41	0.22	0.02
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{i,adj})^2 + (x_{i,min} - x_{i,adj})^2 + (x_{i,max} - x_{i,adj})(x_{i,min} - x_{i,adj})}{3}}$	0.52	0.110	0.040
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}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	1.23	1.50	0.087
Combined Standard Uncertainty			2.83	2.62	0.16
Expanded measurement uncertainty (at 95% confidence)			5.66	5.24	0.31
Applied Span Concentration			123.00	150.00	15.00
Measured Span Concentration, STP Dry Gas			126.84	149.14	14.95
Expanded measurement uncertainty as % of Applied Span			5%	3%	2%

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7.1

SRM Reference Materials

Calibration Gas	Concentration ³²	Supplier	Cylinder Solution ID.	Expiry Date	Uncertainty
NO	255.2 ppm	Air Liquide	Gas / 1446	19/11/2016	± 1%
CO	201.6 ppm	Air Liquide	Gas / 1389	15/01/2017	± 1%
O ₂	15.00 % Vol	Air Liquide	Gas / 1488	21/05/2018	± 1%

³² Please note that this is the cylinder bottle concentration. Mass flow controllers were used to blend these concentrations down to a suitable range for calibration as detailed in Section 7.2 of this report.

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
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 Report Issue Date : 12th November 2015

7.2 SRM Calibration Validation Summary

Field Calibration 08/09/2015

Units

Mean Initial Direct Zero
 Mean Confirmation Direct Zero
 Difference in Direct Zero
 Repeatability at Zero
 <2 x Repeatability at Zero?

Mean Pre Test Zero
 % of Measurement Range?
 Detection Limit (LOD)

Actual Applied Span Concentration

Mean Pre Test System Zero
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test Zero
 % of Certified Range?
 Zero Drift $\leq \pm 5\%$ of Applied Span?

Mean Pre Test System Span
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test System Span
 Span Drift $\leq \pm 5\%$ Span Value?

Horiba PG 250 Measurement Ranges:		
NO as NO ₂	CO	O ₂
205	250	25
mg/m ³	mg/m ³	%Vol
Zero Values (Direct)		
0.03	0.48	-0.09
0.13	0.71	-0.07
0.10	0.23	0.02
2.05	2.50	0.20
YES	YES	YES
Pre Zero Values (System)		
0.09	0.42	-0.05
0.05%	0.17%	-0.22%
0.10	0.33	0.20
Applied Span:		
NO	CO	O ₂
123.00	150.00	15.00
Pre Test System Zero Values		
0.09	0.42	-0.05
0.08%	0.28%	0.36%
Post Zero Values (System)		
0.16	0.69	-0.05
0.08%	0.28%	-0.21%
0.06%	0.18%	0.02%
Pre Test System Span Values		
124.52	151.45	15.10
1.23%	0.96%	0.65%
Post Test System Span Values		
127.30	152.02	15.04
2.24%	0.38%	0.36%

2.24% 0.38% 0.36%

See Note 2 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.

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
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Field Calibration 09/09/2015

Units

Mean Initial Direct Zero
 Mean Confirmation Direct Zero
 Difference in Direct Zero
 Repeatability at Zero
 <2 x Repeatability at Zero?

Mean Pre Test Zero
 % of Measurement Range?
 Detection Limit (LOD)

Actual Applied Span Concentration

Mean Pre Test System Zero
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test Zero
 % of Certified Range?
 Zero Drift $\leq \pm 5\%$ of Applied Span?

Mean Pre Test System Span
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test System Span
 Span Drift $\leq \pm 5\%$ Span Value?

Horiba PG 250 Measurement Ranges:		
NO as NO ₂	CO	O ₂
205 mg/m ³	250 mg/m ³	25 %Vol
Zero Values (Direct)		
0.03	0.48	-0.09
0.13	0.71	-0.07
0.10	0.23	0.02
2.05	2.50	0.20
YES	YES	YES
Pre Zero Values (System)		
0.03	0.71	-0.05
0.01%	0.28%	-0.20%
0.07	0.10	0.20
Applied Span:		
NO	CO	O ₂
123.00	150.00	15.00
Pre Test System Zero Values		
0.03	0.71	-0.05
0.02%	0.47%	0.33%
Post Zero Values (System)		
0.21	0.72	-0.04
0.10%	0.29%	-0.17%
0.15%	0.00%	0.04%
Pre Test System Span Values		
125.05	152.05	15.03
1.67%	1.37%	0.22%
Post Test System Span Values		
125.45	148.29	15.01
0.32%	2.47%	0.18%

0.32% 2.47% 0.18%

See Note 3

See Note 2

See Note 3

NOTE 1: Data Invalid! Contact Quality Manager!

NOTE 2: Correct test data for drift!

NOTE 3: No drift correction required.

Cofely (GDF Suez)
 Permit No : JP3632ZH
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Installation Name : CHP
 Visit Details : AST – 2015
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Units

Mean Initial Direct Zero
 Mean Confirmation Direct Zero
 Difference in Direct Zero
 Repeatability at Zero
 <2 x Repeatability at Zero?

Mean Pre Test Zero
 % of Measurement Range?
 Detection Limit (LOD)

Actual Applied Span Concentration

Mean Pre Test System Zero
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test Zero
 % of Certified Range?
 Zero Drift $\leq \pm 5\%$ of Applied Span?

Mean Pre Test System Span
 Difference $\leq \pm 2\%$ of Span Value (5% for SO₂)?

Mean Post Test System Span
 Span Drift $\leq \pm 5\%$ Span Value?

Horiba PG 250 Measurement Ranges:		
NO as NO ₂	CO	O ₂
205	250	25
mg/m ³	mg/m ³	% Vol
Zero Values (Direct)		
0.03	0.48	-0.09
0.13	0.71	-0.07
0.10	0.23	0.02
2.05	2.50	0.20
YES	YES	YES
Pre Zero Values (System)		
0.03	0.46	-0.05
0.01%	0.18%	-0.20%
0.17	0.21	0.20
Applied Span:		
NO	CO	O ₂
123.00	150.00	15.00
Pre Test System Zero Values		
0.03	0.46	-0.05
0.02%	0.31%	0.33%
Post Zero Values (System)		
0.09	0.42	-0.07
0.04%	0.17%	-0.28%
0.05%	0.03%	0.14%
Pre Test System Span Values		
125.44	150.39	14.97
1.99%	0.26%	0.21%
Post Test System Span Values		
127.40	147.90	14.94
1.56%	1.66%	0.22%
1.56%	1.66%	0.22%
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.

Cofely (GDF Suez)
 Permit No : JP3632ZH
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7.3

CEM Reference Materials

Calibration Gas	Concentration	Supplier	Cylinder Solution ID.	Expiry Date	Uncertainty
NO	196.8 ppm	Air Products	040005197656	2016	± 0.05%
CO	200.5 ppm	Air Products	040005295599	2016	± 2%
O ₂	Ambient				

Cofely (GDF Suez)
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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 ($\bar{D}$) and standard deviation (σ) of the differences D_i . If the difference between D_i and $\bar{D}$ 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 ($\bar{D}_i$) and the standard deviation of the residuals are calculated as follows:

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

Where:

n = Number of half hourly averages

The magnitude of the difference between each residual (D_i) and the mean residual ($\bar{D}_i$) is calculated and compared with $S_{residuals}$. Where $|D_i - \bar{D}_i| > 2 \times S_{residuals}$ (i.e. $2 \times$ standard deviation $\sim$ 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.

Cofely (GDF Suez)
 Permit No : JP3632ZH
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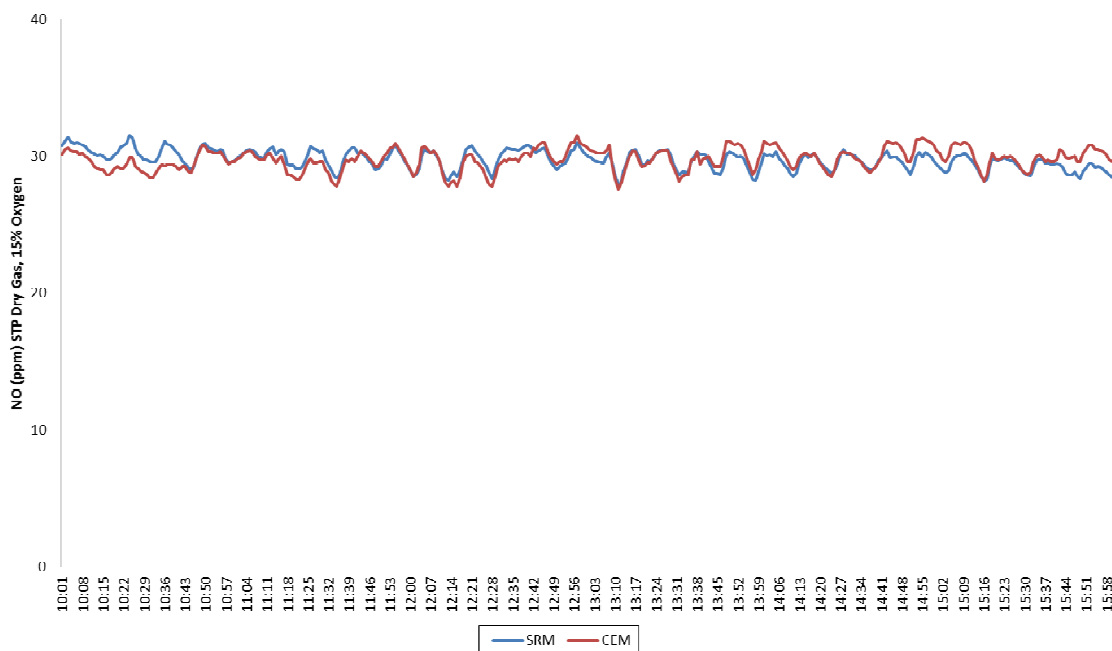
Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

8.2 Time Series Plots of Minute Averages

A1

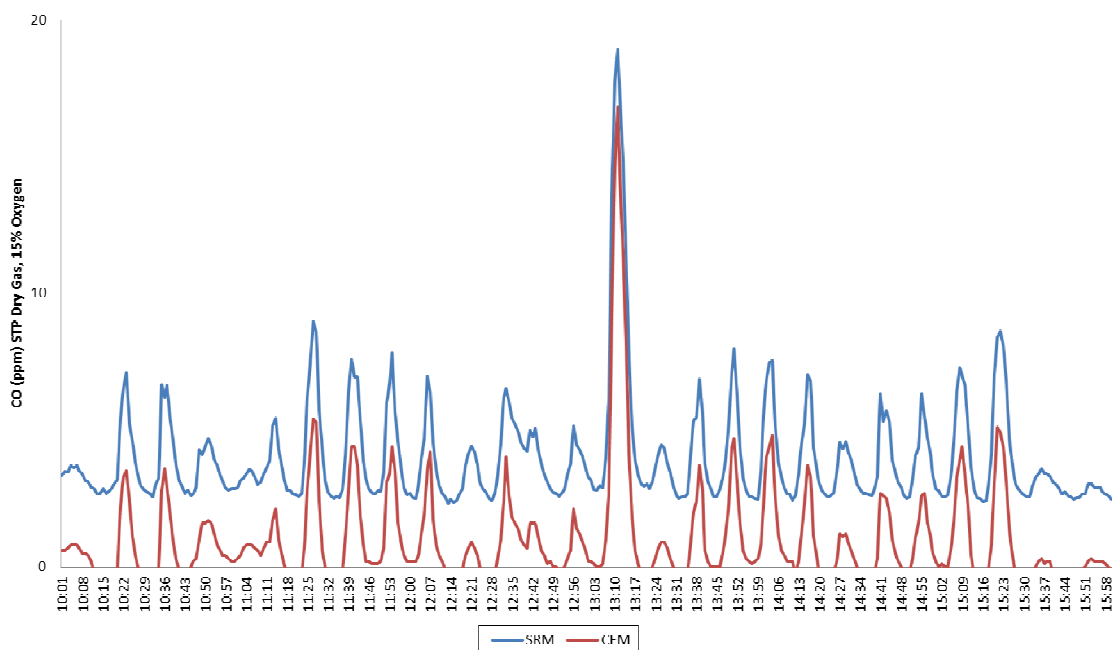
NO

Time Series Plot of SRM and CEM NO Readings
 A1 HR-001A on 08/09/2015



CO

Time Series Plot of SRM and CEM CO Readings
 A1 HR-001A on 08/09/2015

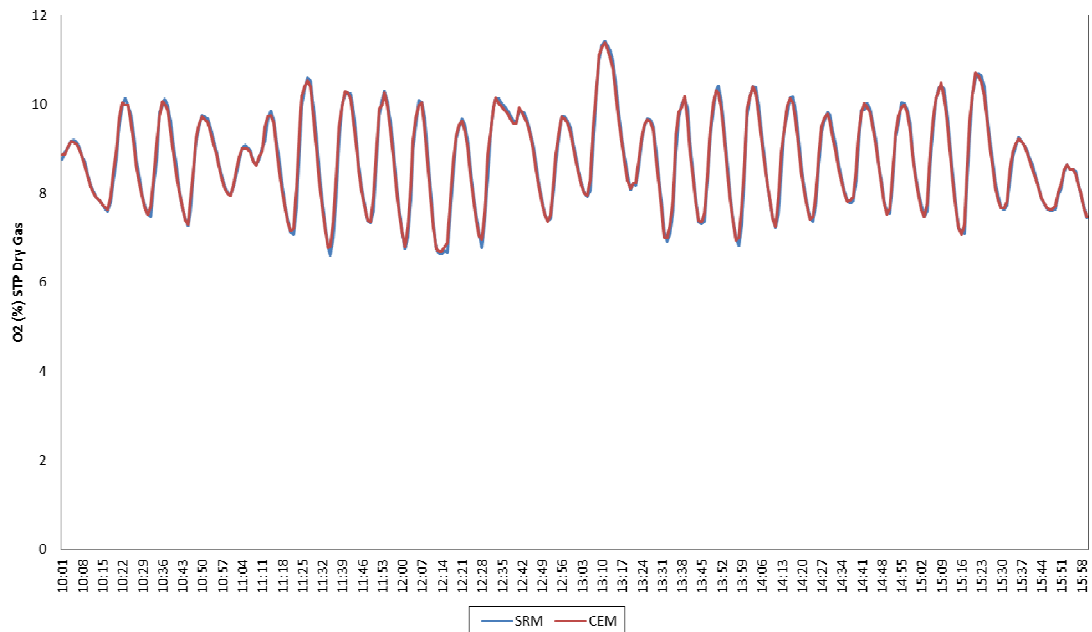


Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

O₂

Time Series Plot of SRM and CEM O₂ Readings
 A1 HR-001A on 08/09/2015



A₂

NO

Time Series Plot of SRM and CEM NO Readings
 A2 FB-001 on 09/09/2015

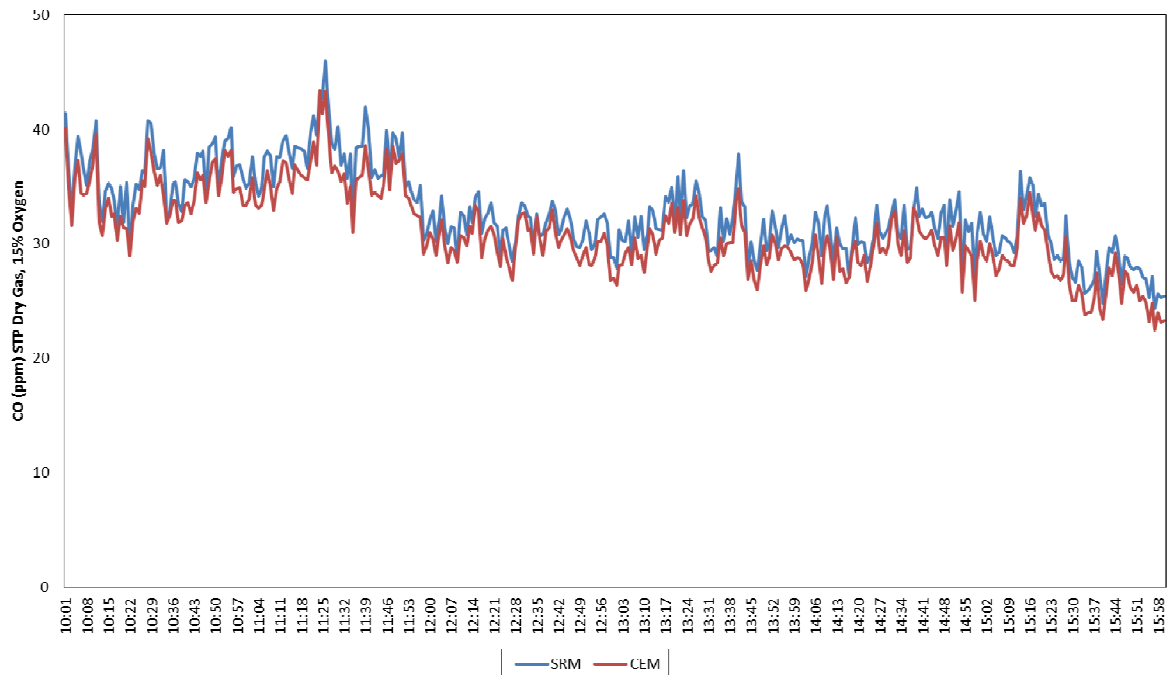


CO

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

**Time Series Plot of SRM and CEM CO Readings
 A2 FB-001 on 09/09/2015**



O2

**Time Series Plot of SRM and CEM O2 Readings
 A2 FB-001 on 09/09/2015**



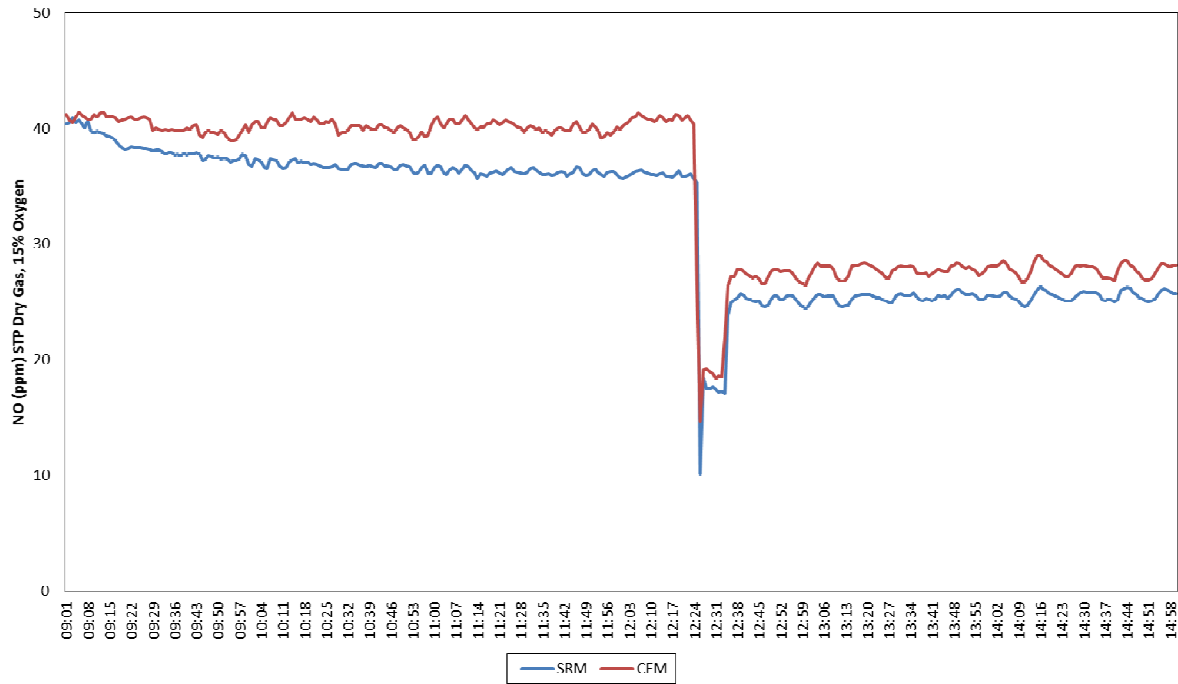
A3

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

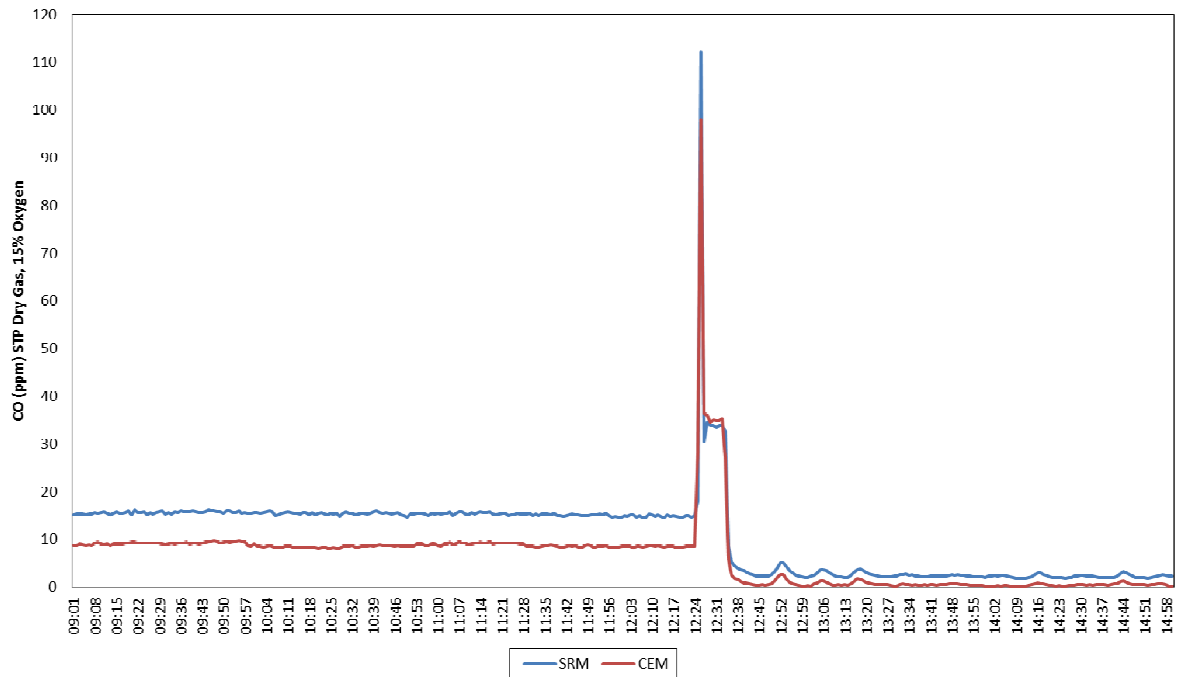
NO

Time Series Plot of SRM and CEM NO Readings
 A3 HR-001B on 11/09/2015



CO

Time Series Plot of SRM and CEM CO Readings
 A3 HR-001B on 11/09/2015

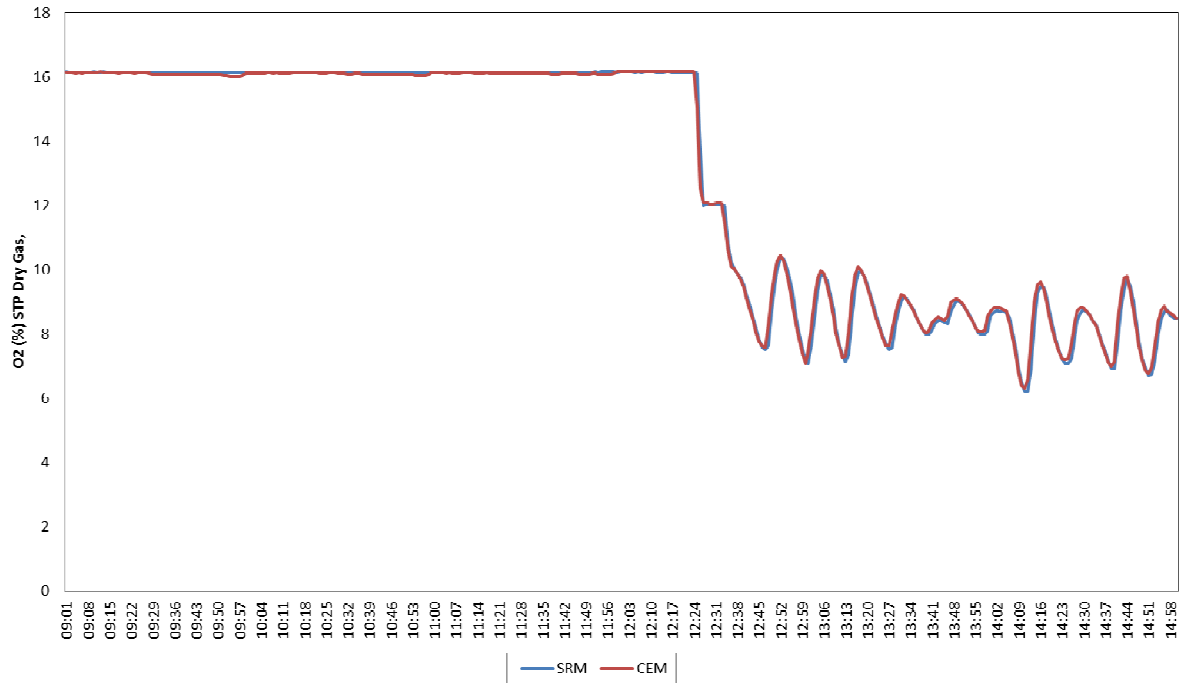


O2

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

Time Series Plot of SRM and CEM O2 Readings A3 HR-001B on 11/09/2015



Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

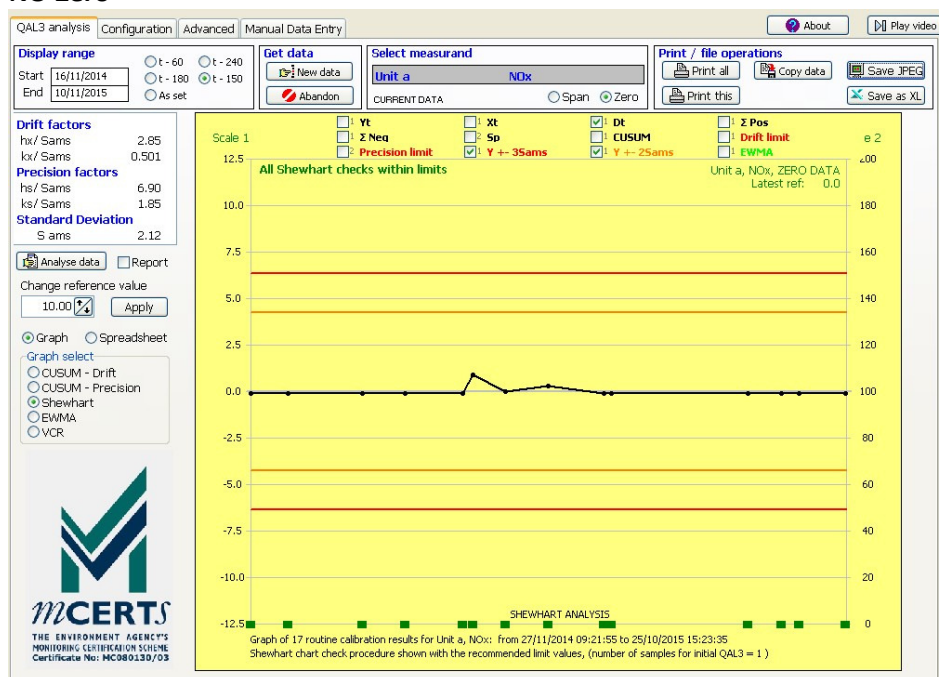
Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

9 CEM QAL3 DATA

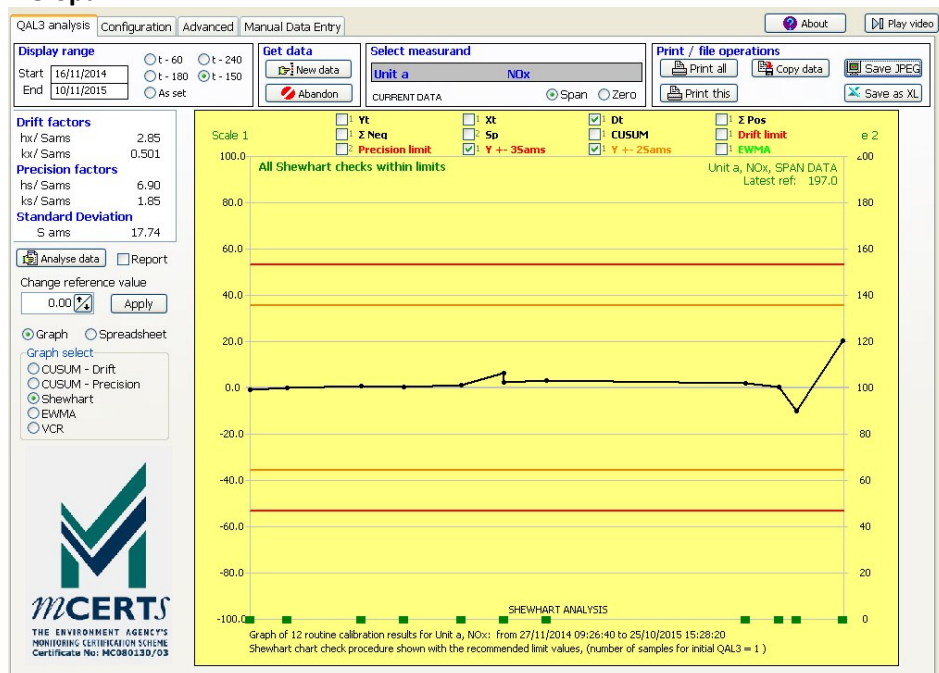
9.1 QAL3 Control Charts

A1

NO Zero



NO Span

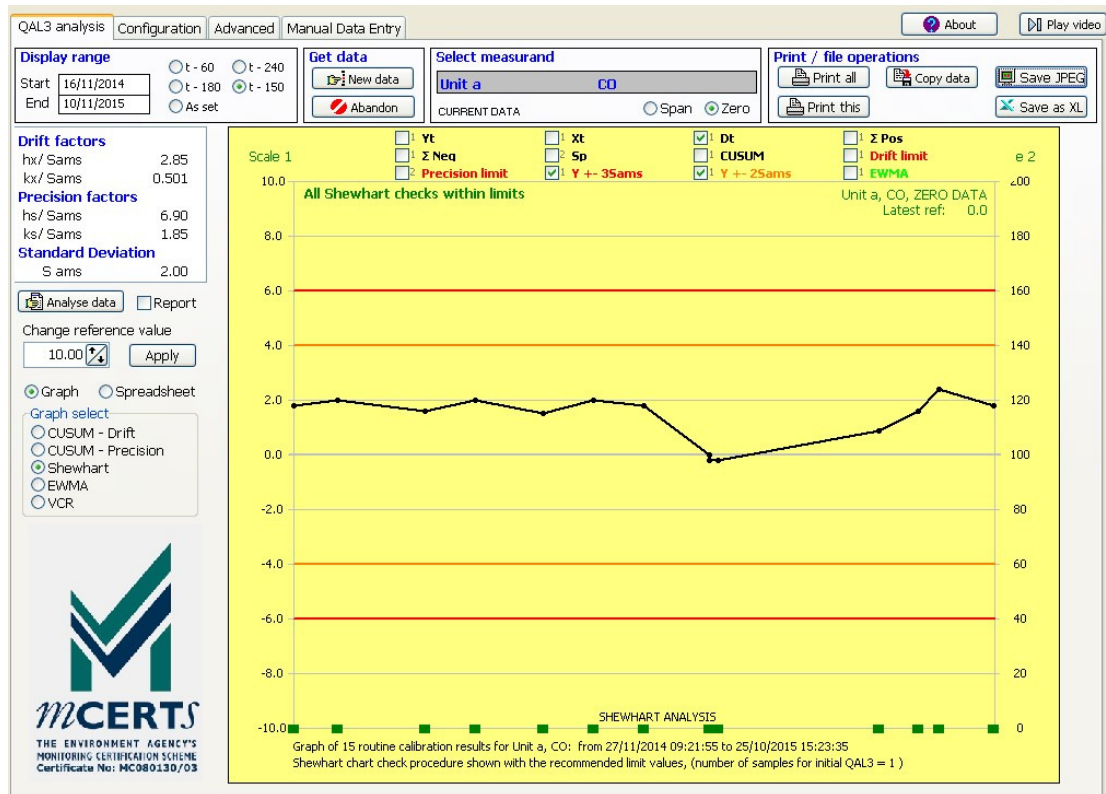


Environmental Compliance Limited

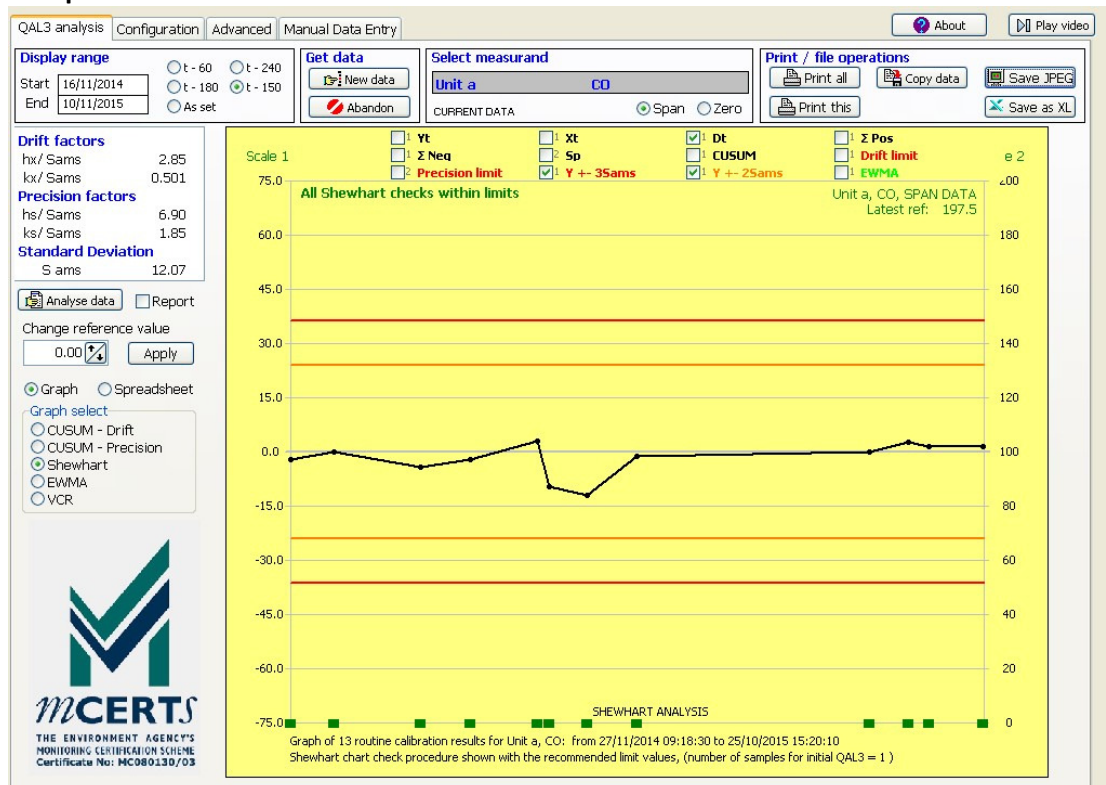
Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
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CO Zero



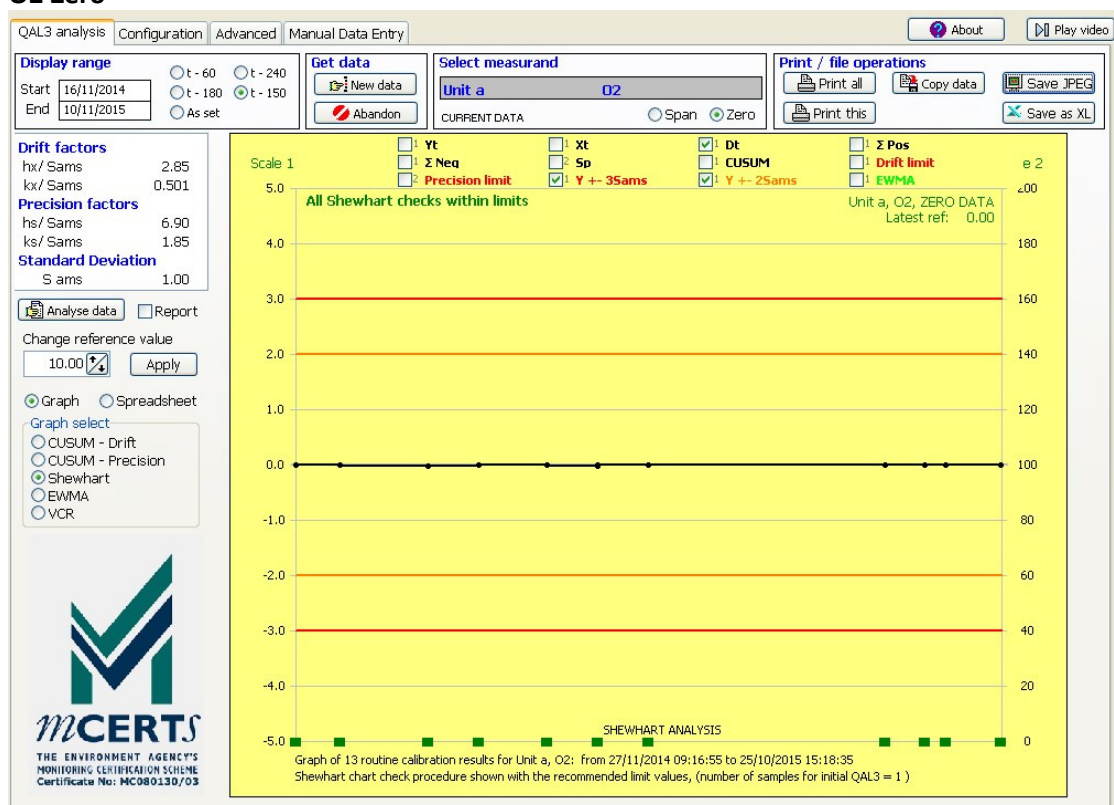
CO Span



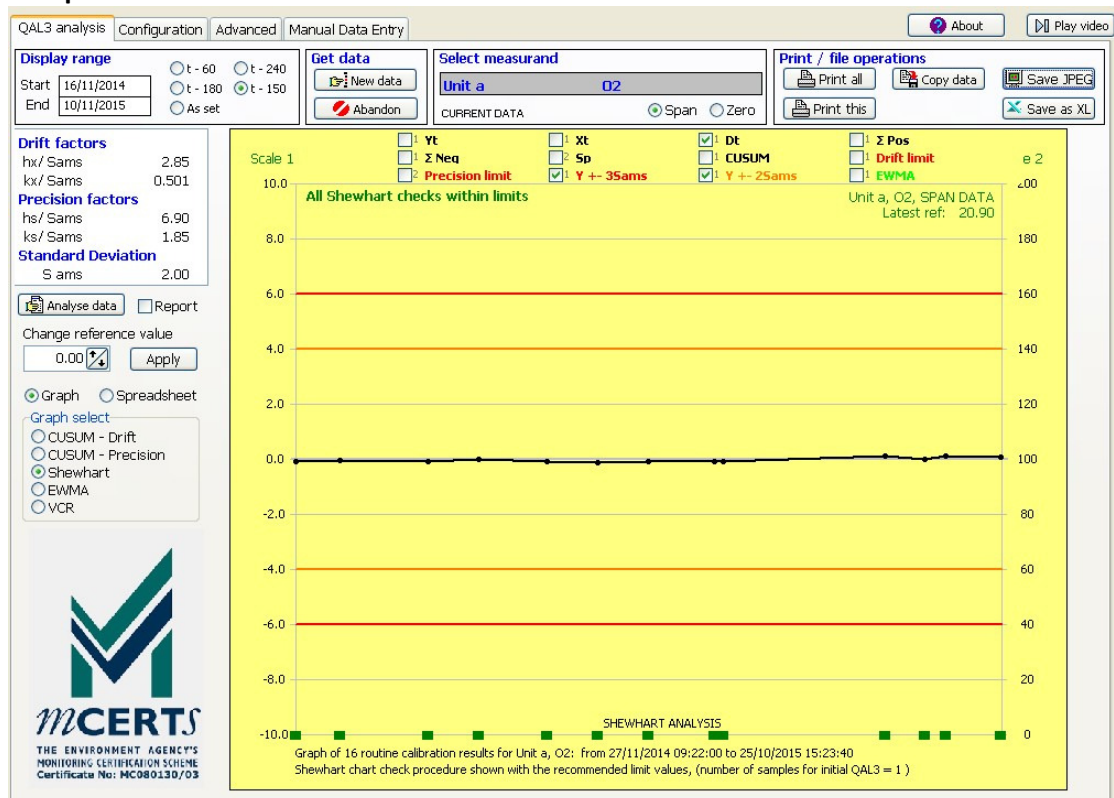
Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

O2 Zero



O2 Span



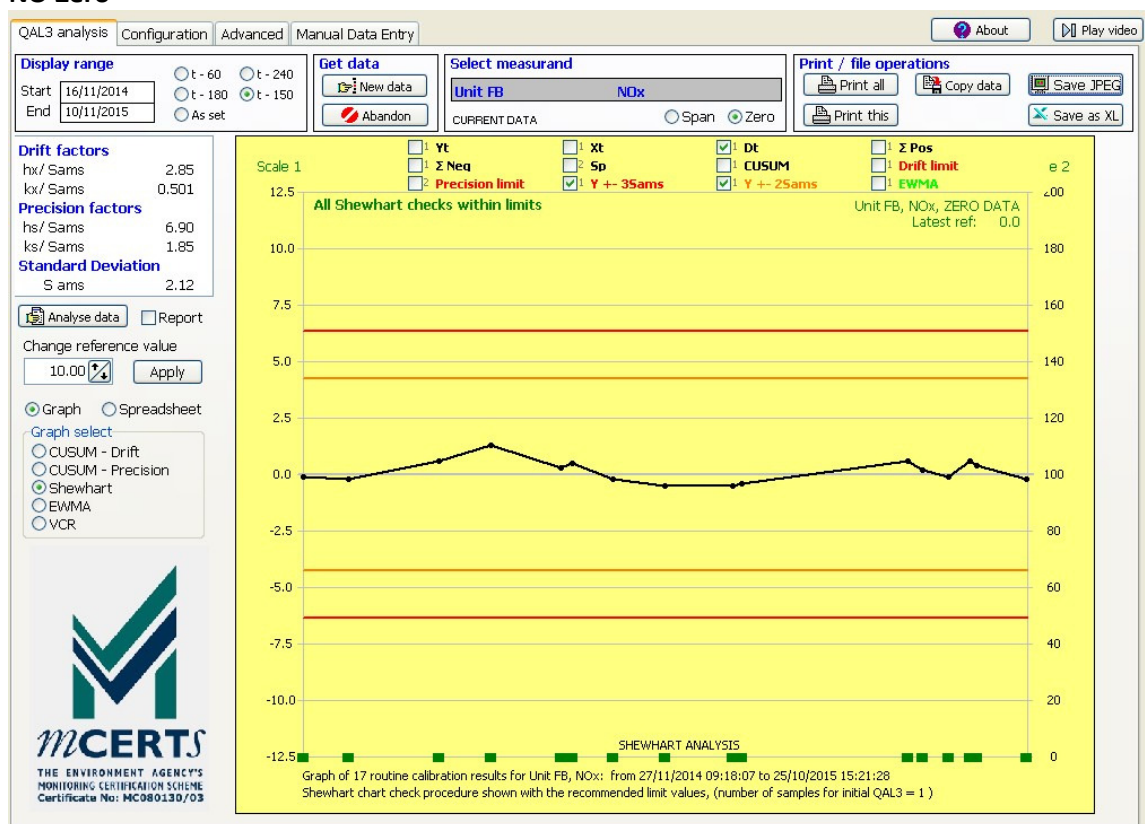
Environmental Compliance Limited

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

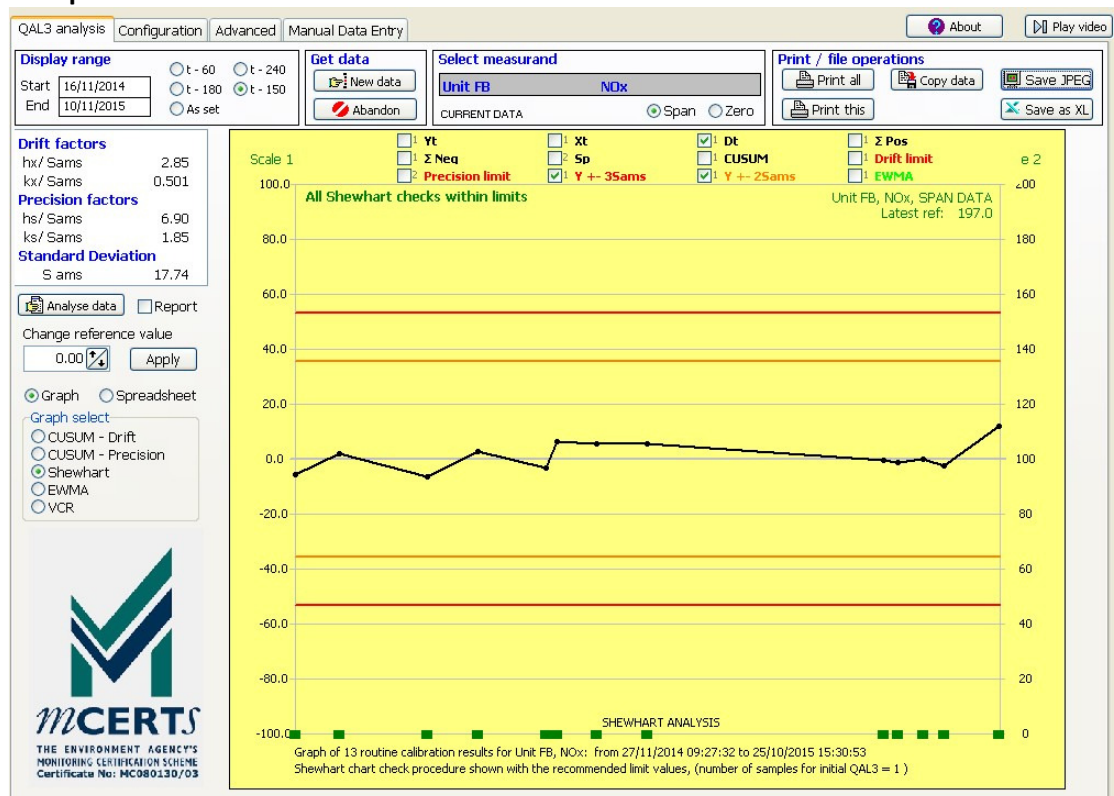
Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

A2

NO Zero



NO Span

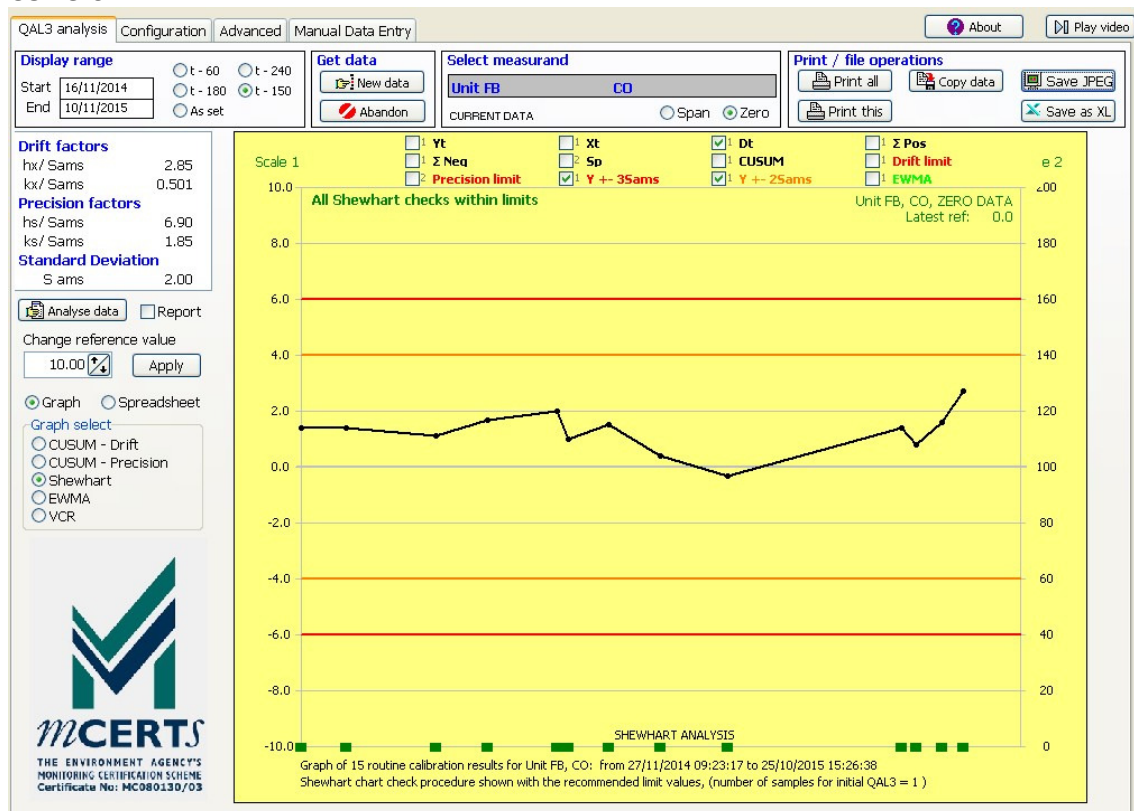


Environmental Compliance Limited

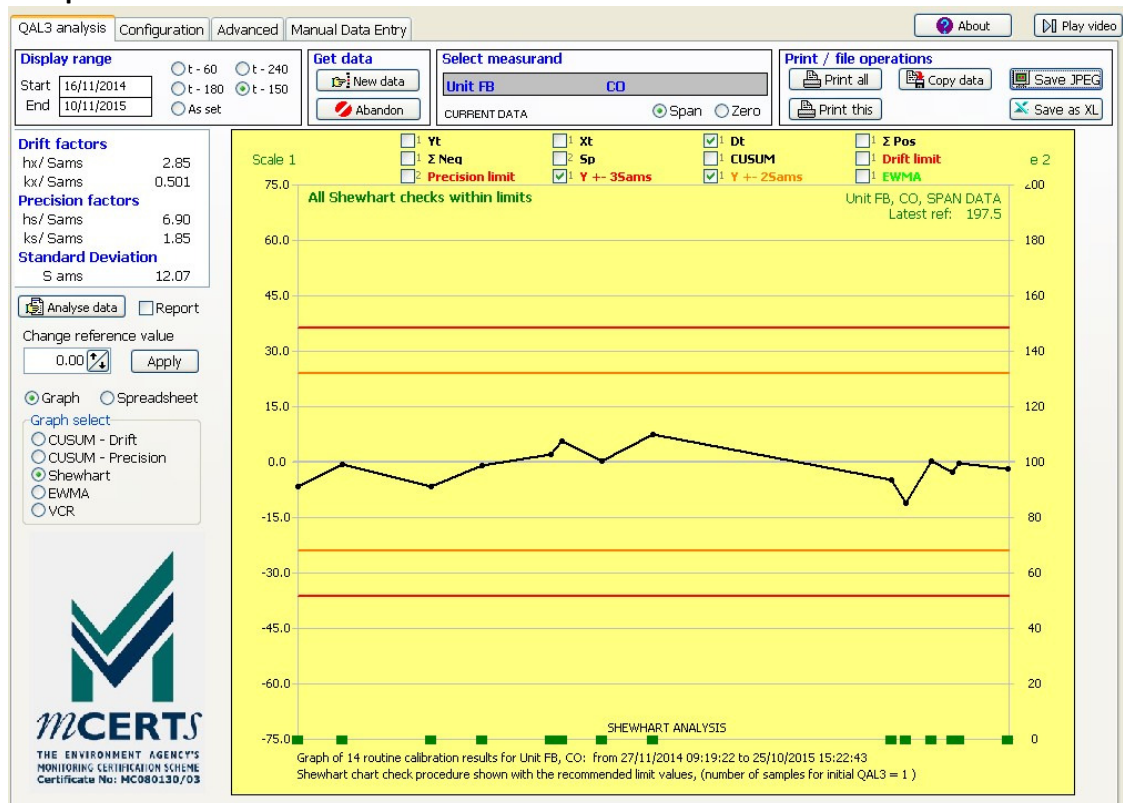
Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

CO Zero



CO Span

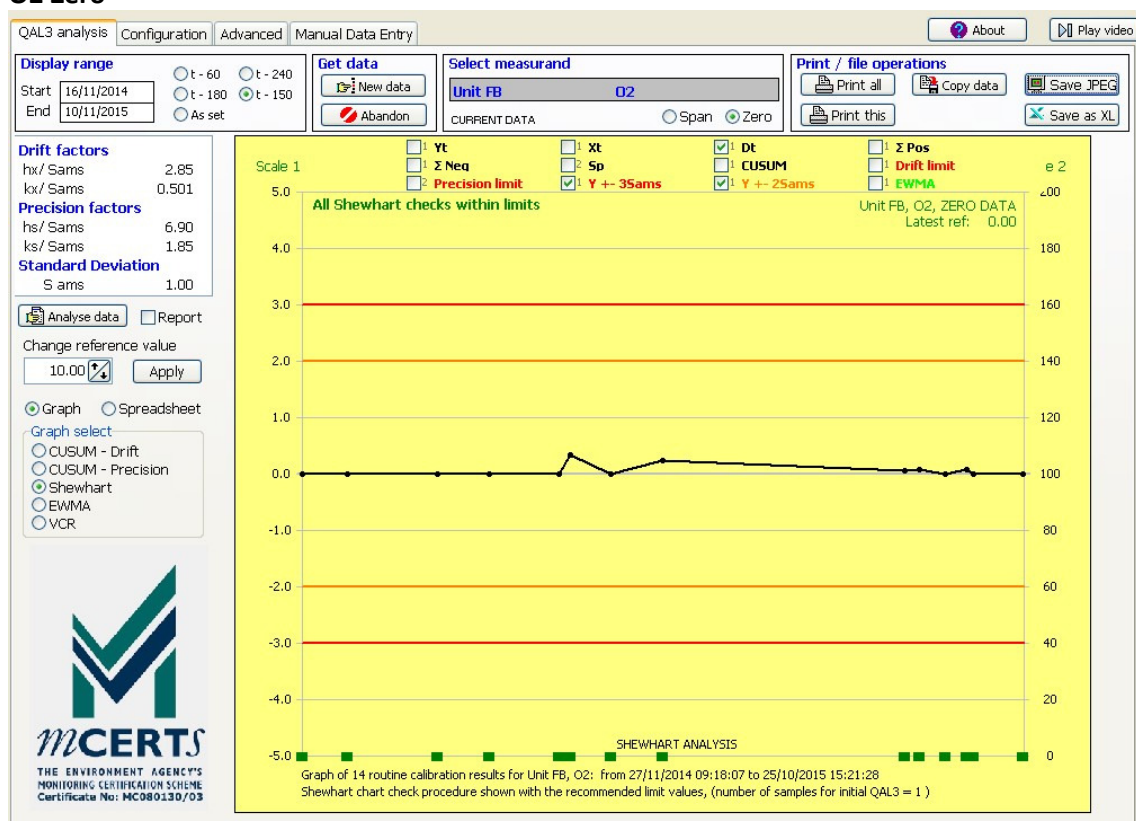


Environmental Compliance Limited

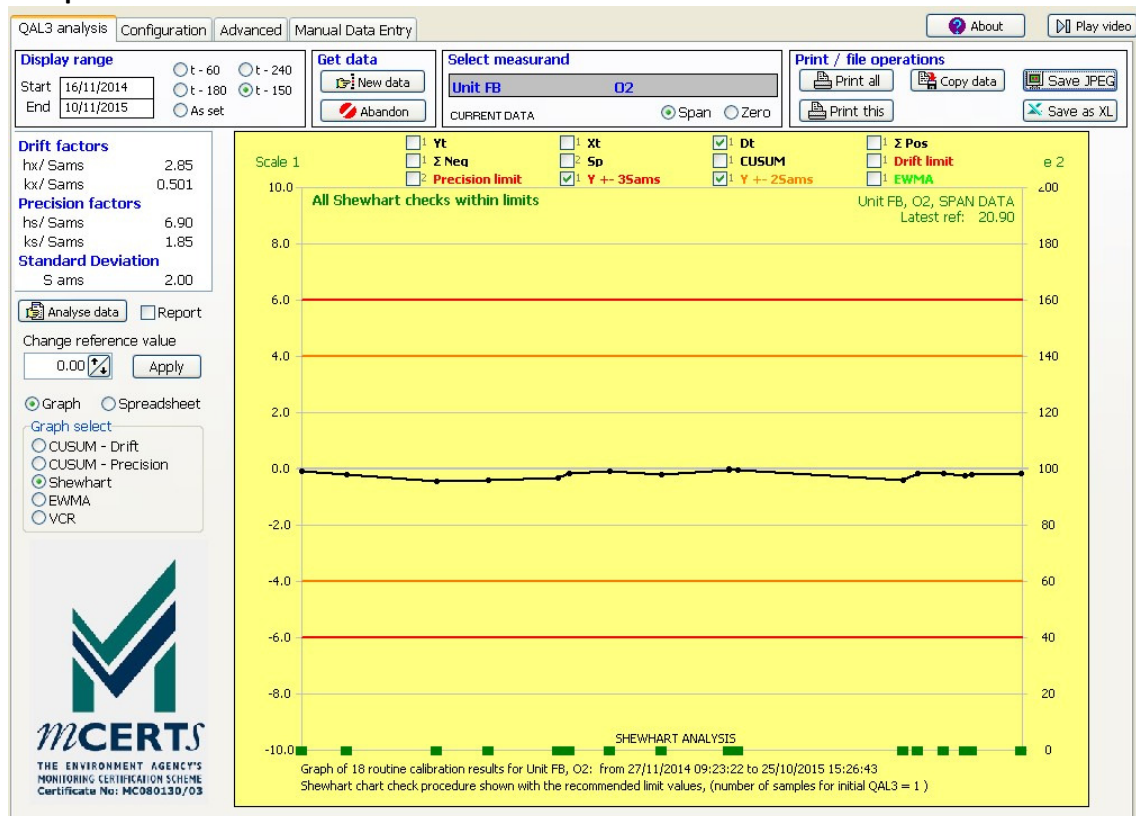
Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

Installation Name : CHP
Visit Details : AST - 2015
Survey Dates : 7th to 11th September 2015
Report Issue Date : 12th November 2015

O2 Zero

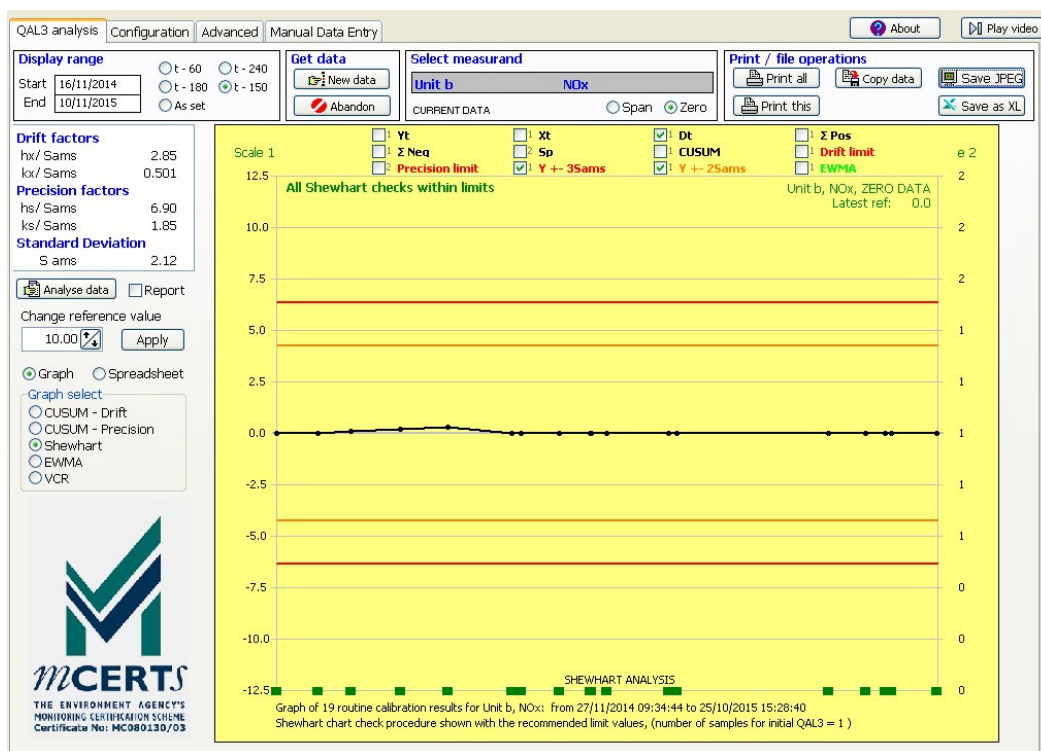
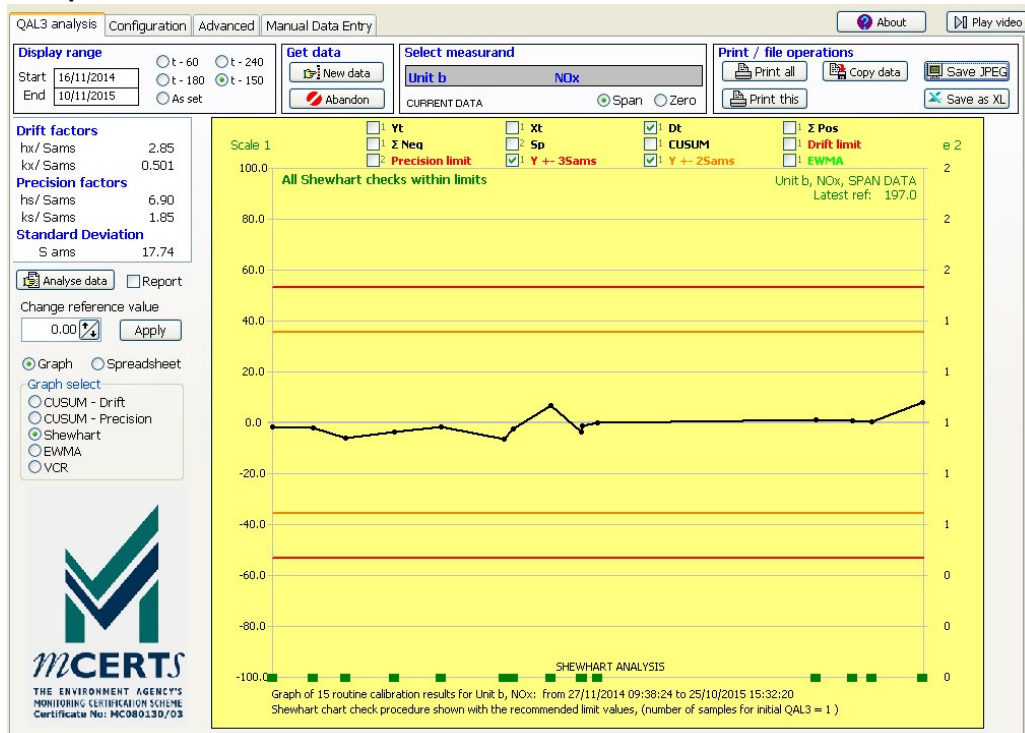


O2 Span



Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

Installation Name : CHP
Visit Details : AST – 2015
Survey Dates : 7th to 11th September 2015
Report Issue Date : 12th November 2015

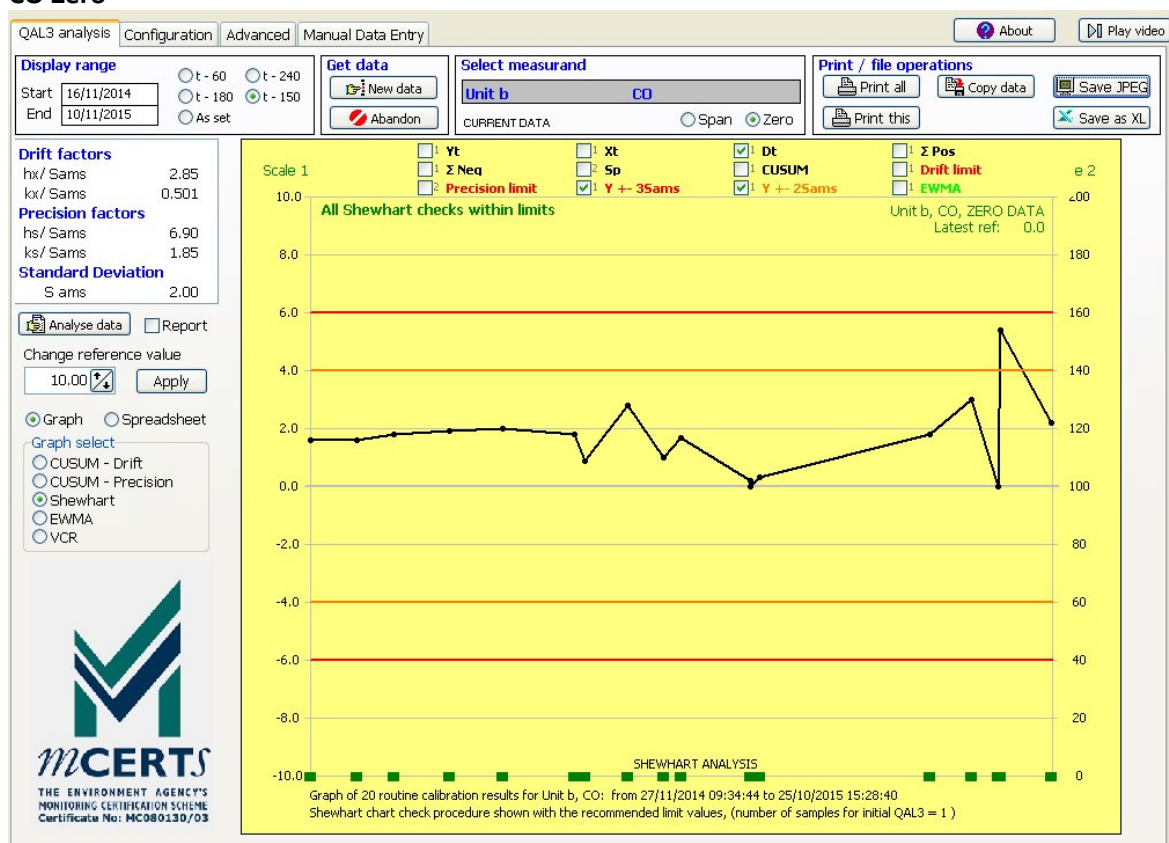
A3**NO Zero****NO Span**

Environmental Compliance Limited

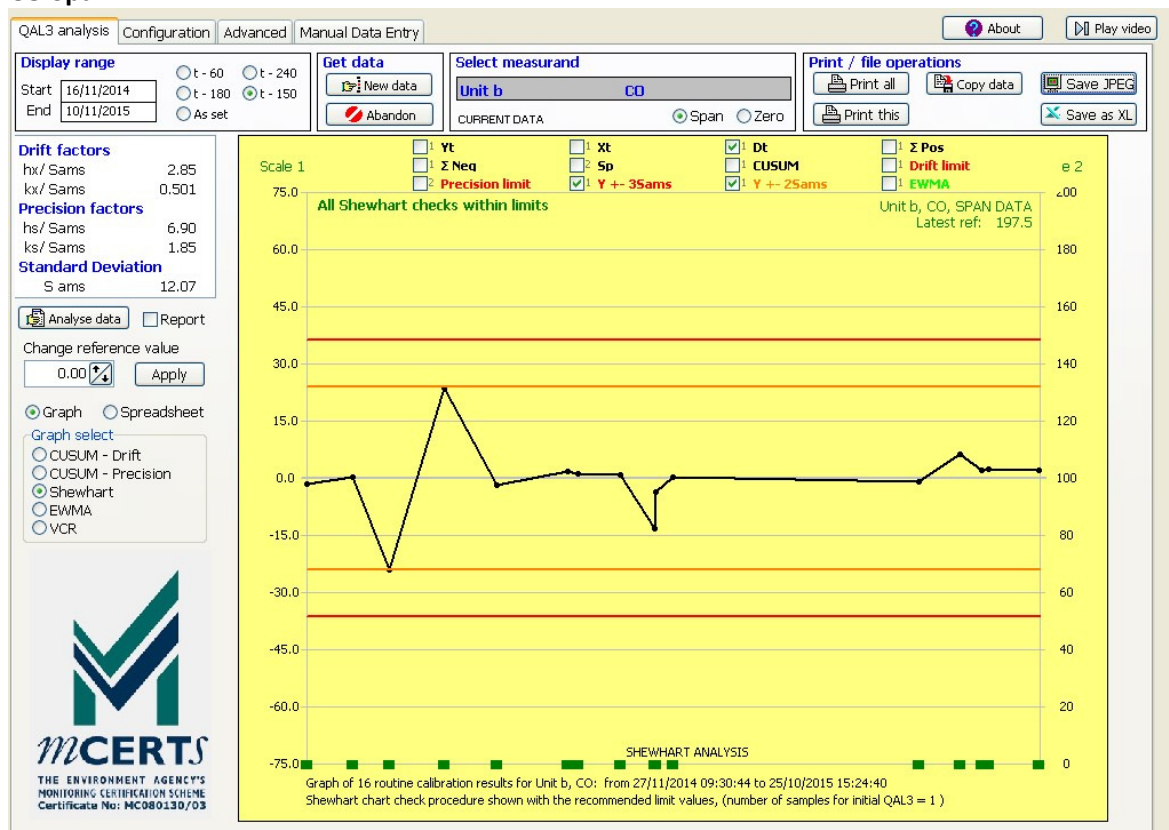
Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

CO Zero



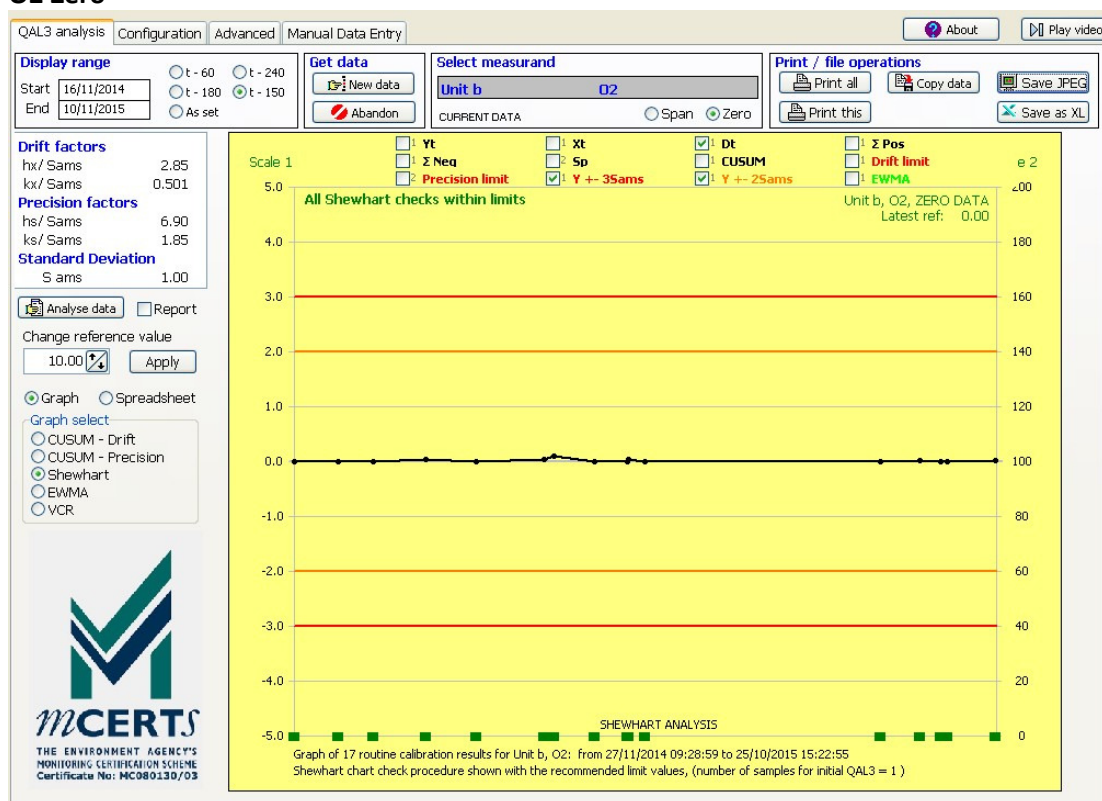
CO Span



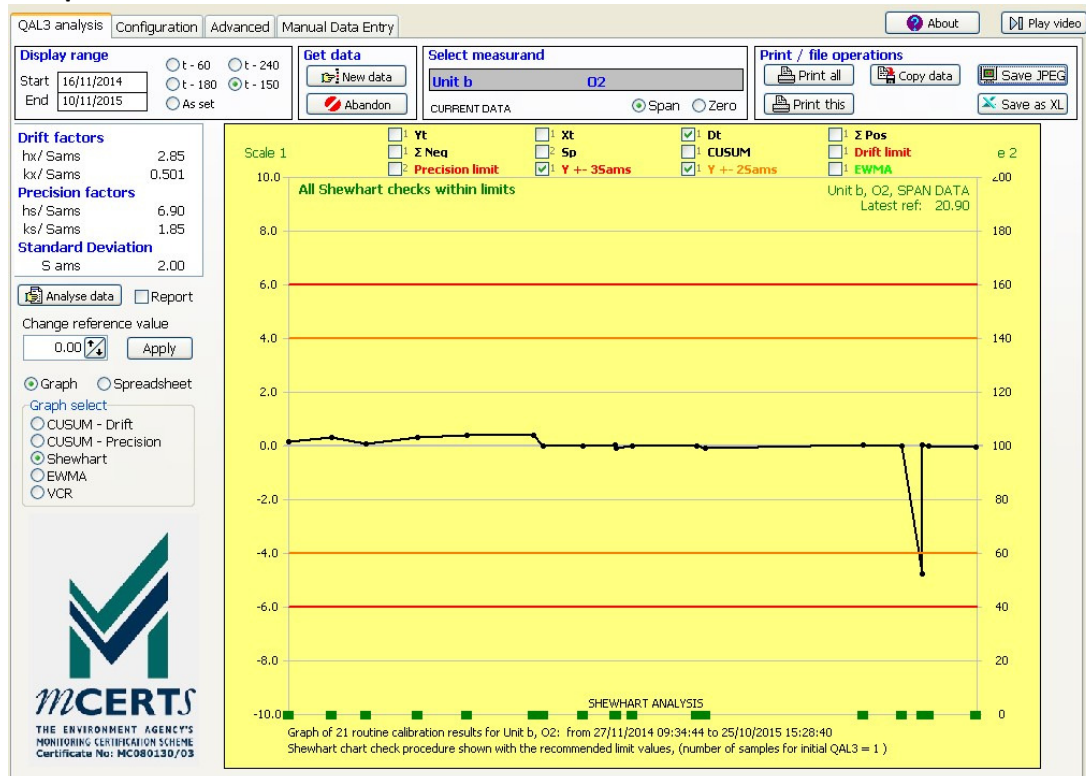
Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

O2 Zero



O2 Span



Cofely (GDF Suez)
Permit No : JP3632ZH
Variation No : ...
Report Ref : P2522 : R001

Installation Name : CHP
Visit Details : AST – 2015
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9.2 QAL3 CEM Logged Data

Operator can be provide Excel spreadsheets from Envirosoft for A1, A2 and A3 upon request.

Cofely (GDF Suez)
 Permit No : JP3632ZH
 Variation No : ...
 Report Ref : P2522 : R001

Installation Name : CHP
 Visit Details : AST – 2015
 Survey Dates : 7th to 11th September 2015
 Report Issue Date : 12th November 2015

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		626			
Site Balance					
Site Check weights					
Horiba	E002	511			
Heated Probe Filter		806			
Chiller		970			
Sonimix / MFC		754	755		
Heated Line		1011	1012		
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: Not required