enviroDAT
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Report for the Periodic Monitoring of Emissions to Air from the Landfill Gas Engine and Flare Stack Located at Brookhill Landfill Site, Buckley.

Part 1: **Executive Summary**

Permit Number: BV7273

Operator: Flintshire County Council

Installation: Brookhill Landfill Site (Engine & Flare)

MCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

UKAS TESTING
4251

Monitoring dates:	6th May 2016
Job Number:	**R16221**
Version:	1
Address:	**Flintshire County Council**
	Alltami Depot
	Mold Road - Alltami
	Flintshire, CH7 6LG
Monitoring Organisation:	**EnviroDat Ltd**
Address:	Science & Technology Centre
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Date of Report:	1st June 2016
Report Approved By:	David Littlewood
MCERTS Registration Number:	MM 06 772 (Level II, TE1, 2, 3 & 4)
Function:	Operations Manager (Team Leader)
Signed:	

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PART 1: EXECUTIVE SUMMARY

1.1 Monitoring Objectives

Flintshire County Council operates a landfill gas engine and a flare stack at its facility located at Brookhill Landfill site. This combustion plant has the potential to pollute the atmosphere. Consequently, these processes are subject to regulation and periodic environmental monitoring is necessary under this regulation.

Methane is produced as a by-product of the decomposition of organic waste that is buried within the site (methanogenesis). This methane is extracted and pumped through inert piping to the engine or flare for combustion, the scale of which is dictated according to local engineering, operational requirements and methanogenic rate. The flare is designed to operate when excess gas is produced or for periods of engine maintenance.

EnviroDat Limited was requested to undertake a monitoring campaign on the engine and flare stacks. This work forms part of the annual compliance test. The pollutants monitored within the engine and flare emissions, as required under permit BV7273 are summarised below:

Substances to be monitored	**Emission Point Identification**	**Emission Point Identification**
	Engine	Flare Stack
Oxides of Nitrogen (as NO2)	✓	✓
Carbon Monoxide	✓	✓
Volatile Organic Compounds (VOCs)	✓	✓
Oxygen (for correction)	✓	✓
Moisture (for correction)	✓	✓
Special requirements	None requested	None requested

1.2 Monitoring Results

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Estimate of Uncertainty (2σ at 95% confidence)	Units	Reference Conditions	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation for use of Method (see note below)	Operating Status
Engine	Oxides of Nitrogen (as NO_2)	650	**265**	±17	$mg(N)m^{-3}$	101.3kPa, 273K, dry gas, 5% Oxygen	06/05/2016	10:22-11:22	BS EN 14792	A	At 44% MCR
	Carbon Monoxide	1500	**1648**	±65	$mg(N)m^{-3}$				BS EN 15058	A	
	Volatile Organic Compounds (VOCs as carbon)	1750	**1835**	±57	$mg(N)m^{-3}$				BS EN 12619	A	
	Moisture	-	**12.3**	n/a	%	101.3kPa, 273K, dry gas			BS EN 14790	A	
	Oxygen	-	**7.36**	±0.45	%				BS EN 14789	A	

NOTE:

A. EnviroDat Ltd MCerts/UKAS Accredited for sampling and analysis.

B. EnviroDat Ltd Mcerts/UKAS Accredited for sampling only, UKAS Accredited analysis conducted by sub-contract laboratory.

C. EnviroDat Ltd UKAS Accredited for sampling only (further clarification is given in section 1.4). Analysis of this component is not UKAS Accredited.

D. The method for sampling and analysis is not UKAS or MCerts Accredited, method follows documented in-house procedure (further clarification is given in section 1.4).

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Estimate of Uncertainty (2σ at 95% confidence)	Units	Reference Conditions	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation for use of Method (see note below)	Operating Status
Flare Stack	Oxides of Nitrogen (as NO_2)	150	**86.2**	±3.2	$mg(N)m^{-3}$	101.3kPa, 273K, dry gas, 3% Oxygen	06/05/2016	12:51-13:51	BS EN 14792	A	At 60% MCR
	Carbon Monoxide	50	**17.1**	±2.7	$mg(N)m^{-3}$				BS EN 15058	A	
	Volatile Organic Compounds (VOCs as carbon)	10	**4.4**	±0.3	$mg(N)m^{-3}$				BS EN 12619	A	
	Moisture	-	**7.8**	n/a	%	101.3kPa, 273K, dry gas			BS EN 14790	A	
	Oxygen	-	**13.22**	±0.63	%				BS EN 14789	A	

NOTE:

A. EnviroDat Ltd MCerts/UKAS Accredited for sampling and analysis.

B. EnviroDat Ltd Mcerts/UKAS Accredited for sampling only, UKAS Accredited analysis conducted by sub-contract laboratory.

C. EnviroDat Ltd UKAS Accredited for sampling only (further clarification is given in section 1.4). Analysis of this component is not UKAS Accredited.

D. The method for sampling and analysis is not UKAS or MCerts Accredited, method follows documented in-house procedure (further clarification is given in section 1.4).

1.3 Operating Information

Emission Point Reference	Date	Process Type	Process Duration	Fuel	Feedstock	Abatement	Load	Comparison of Operator CEMS and Periodic Monitoring Results			
								Substance	CEMS Results	Periodic Monitoring Results	Units
Engine	06/05/2016	Combustion	Continuous	Landfill Gas	N/A	None	Producing 500kWe (44% MCR)	N/A	N/A	N/A	N/A
Flare Stack	06/05/2016	Combustion	Continuous	Landfill Gas	N/A	None	Burning 600m^3/hr (60% MCR)	N/A	N/A	N/A	N/A

1.4 Monitoring Deviations

Emission Point Reference	Substance Deviations	Monitoring Deviations	Other Relevant Issues
Engine	None	None	None
Flare Stack	None	None	None

PART 2: SUPPORTING INFORMATION

2.1 Appendix I: General Information

2.1.1 Monitoring organisation staff details

Monitoring at Brookhill Landfill Site was conducted by the following EnviroDat Engineers:

Team Leader, David Littlewood – Mcerts Level II (TE1, 2, 3 & 4)	MM06 772
Assistant, Dean Kyle – Mcerts Level I	MM12 1188

2.1.2 Monitoring organisation method details

2.1.2.1 Standard Reference Conditions

All pollutant concentrations measured have been expressed at standard reference conditions of 273K, 101.3kPa, dry gas and 5% O_2 for the engine and 3% O_2 for the flare.

2.1.2.2 NO_x (as NO_2)

A sample of the duct gas was passed via a short high temperature, titanium probe and down a heated PTFE line to a gas conditioner used to remove moisture. The conditioned (dry) gas then passed to a Horiba PG250 analyser, which, following specific pre-treatment of the NO_x within the sample, measured the concentration of NOx (as NO_2) by chemiluminescent detector, in accordance with EnviroDat Ltd. documented procedure SP14792, which implements the requirements of the standard reference method (SRM) BSEN14792. The detector and sampling system was checked prior to, and immediately following, testing to ensure operational conformity. This involved ensuring the absence of sample egress or air ingress, span and zero gas checks and system response times as necessary. All raw data was logged at 60-second intervals via a Grant Instruments Squirrel Datalogger and these are presented in Appendix II. An estimate of the uncertainty associated with the monitoring is also presented, as Appendix III.

2.1.2.3 CO

A sample of the duct gas was passed via a short high temperature, titanium probe and down a heated PTFE line to a gas conditioner used to remove moisture. The conditioned (dry) gas then passed to a Horiba PG250 analyser, which measured the concentration of CO by non-dispersive infrared (NDIR) detector, in accordance with EnviroDat Ltd. documented procedure SP15058 which implements the requirements of the SRM BSEN15058. The detector and sampling system was checked prior to, and immediately following, testing to ensure operational conformity. This involved ensuring the absence of sample egress or air ingress, span and zero gas checks and system response times as necessary. All raw data was logged at 60-second intervals via a Grant Instruments Squirrel Datalogger and these raw data are presented in Appendix II. An estimate of the uncertainty associated with the monitoring is also presented, as Appendix III.

2.1.2.4 Total VOCs

VOC sampling was performed using a Signal 3010HM analyser that measures by use of a heated flame ionisation detector (FID) in accordance with SP12619, which implements the requirements of the SRM BSEN12619:2013. The VOC analyser was positioned prior to the gas conditioner and measured the sample gas 'hot and wet.' The result was subsequently corrected to dry values. The detector and sampling system was checked prior to, and immediately following, testing to ensure operational conformity. This involved ensuring the absence of sample egress or air ingress, span and zero gas checks and system response times as necessary. All raw data was logged at 60-second intervals via a Grant Instruments Squirrel Datalogger and these raw data are presented in Appendix II. An estimate of the uncertainty associated with the monitoring is also presented, as Appendix III.

2.1.2.5 O_2

A sample of the duct gas was passed via a short high temperature, titanium probe and down a heated PTFE line to a gas conditioner used to remove moisture. The conditioned (dry) gas then passed to a Horiba PG250 analyser, which measured the concentration of O_2 by was measured by a zirconia cell, as detailed in documented procedure SP14789, which implements the requirements of the SRM BSEN14789. The detector and sampling system was checked prior to, and immediately following, testing to ensure operational conformity. This involved ensuring the absence of sample egress or air ingress, span and zero gas checks and system response times as necessary. All raw data was logged at 60-second intervals via a Grant Instruments Squirrel Datalogger and the raw data are presented in Appendix II. An estimate of the uncertainty associated with the monitoring is also presented, as Appendix III.

Determination of oxygen is essential for adjusting the prescribed pollutants to reference oxygen levels as detailed in the sites permit. This was performed in the following manner:

$$Conc_{ref} = Conc_{meas} \times \frac{(20.95-O_{2ref})}{(20.95-O_{2meas})}$$

Whereby, $Conc_{ref}$ was the concentration at reference conditions and $Conc_{meas}$ was the measured concentration, O_{2ref} is the oxygen reference conditions and O_{2meas} is the measured oxygen value.

2.1.2.6 Moisture

Moisture levels in the stack were determined gravimetrically to the requirements of BSEN14790, which implements the requirements of the SRM BSEN14790. The equipment consisted of an Apex Instruments USEPA Method Five apparatus. This consisted of a heated probe, heated filter and impinger bucket, connected to the sampling console. The console contained a calibrated dry gas meter. The data obtained from this system combined with the gravimetric increases allowed water content to be calculated. The moisture correction factor was calculated in the following manner:

$$\frac{(100-[H_2O]reference)}{(100-[H_2O]measured)}$$

This correction factor is only applied to the VOC result and was not applied to the combustion gases as the sample train for combustion gases uses a gas conditioner to remove moisture and introduces dried gas to the analyser. The raw data relating to the moisture test is presented as Appendix IV.

2.1.3 Monitoring organisation equipment and gas check list references

EQUIPMENT			
Item	**Reference**	**Calibration Due**	**PAT Due**
Portable Gas Analyser	PGA#02	25-Jan-17	Oct-16
Flame Ionisation Detector Analyser	FID#02	19-Apr-17	Oct-16
Gas Conditioner	COND#02	07-Mar-17	Oct-16
Data Logger	DL#05	04-Nov-16	-
Digital Barometer	DB#15	27-Feb-17	-
Digital Barometer	DB#17	05-Feb-17	
Balance	BAL#03	03-Apr-17	-
Heated Line[1]	HL#03B	04-Jan-17	-
Heated Line[2]	HL#05	04-Jan-17	-
Heated Line Controller[1]	HLC#06	04-Jan-17	Oct-16
Heated Line Controller[2]	HLC#04	04-Jan-17	Oct-16
Heated Filter Holder	HFH#01	31-Jan-17	Oct-16
'Apex' Kit	APEX#03	See each item	Oct-16
Dry Gas Meter ('Apex')	DGM#06	03-Sep-16	-
Timepiece[1] ('Apex')	TP#12	03-Sep-16	-
Timepiece[2]	TP#08	22-Dec-16	-
Thermocouple[1]	TC#28	08-Oct-16	-
Thermocouple[2] ('Apex' Dogleg Exit)	TC#20	03-Sep-16	-
Thermocouple[3] ('Apex' Dry Gas Meter)	TC#30	03-Sep-16	-
Thermocouple[4]	TC#43	08-Oct-16	-
Thermocouple Reader ('Apex')[1]	TCR#12	03-Sep-16	-
Thermocouple Reader[2]	TCR#09	08-Oct-16	-
Flow meter[1]	FM05	21-Dec-16	-

Flow meter[2]	FM08	21-Dec-16	-
Transformer[1]	-	-	Oct-16
Transformer[2]	-	-	Oct-16
Cable Reel/Splitter[1]	-	-	Oct-16
Cable Reel/Splitter[2]	-	-	Oct-16

GAS CYLINDERS			
	Certificate No.	**Level (ppm)**	**Validity**
'Zero' Gas (%)[1]	D909084	99.999%	-
'Zero' Gas (%)[2]	N10000018	8.11% O_2 in N2	-
Carbon Monoxide Span Gas[1]	VCD116940	1158	09-Jul-16
Nitrogen Dioxide Span Gas[1]	VCD116940	264	09-Jul-16
Oxygen Span Gas (%)[1]	11787910	7.94	01-Jul-16
VOC Span Gas[1]	11787910	565	01-Jul-16
Carbon Monoxide Span Gas[2]	VCD115689	184.1	13-Dec-16
Nitrogen Dioxide Span Gas[2]	VCD115689	85.7	13-Dec-16
Oxygen Span Gas (%)[2]	7700651	8.01	07-May-17
VOC Span Gas[2]	7700651	7.94	07-May-17

2.2 Appendix II: Emission Point Reference Data & Results

2.2.1 Photograph of Sampling Location on Engine

Engine sampled from 3 inch BSP port on vertical section of approx. 0.4m diameter stack. Accessed via permanent platform.

2.2.2 Photograph of Sampling Location on Flare

Flare sampled from flanged port on vertical section of approx. 1.5m diameter stack. Accessed via Aluminium Tower Scaffolding erected by PASMA Trained staff.

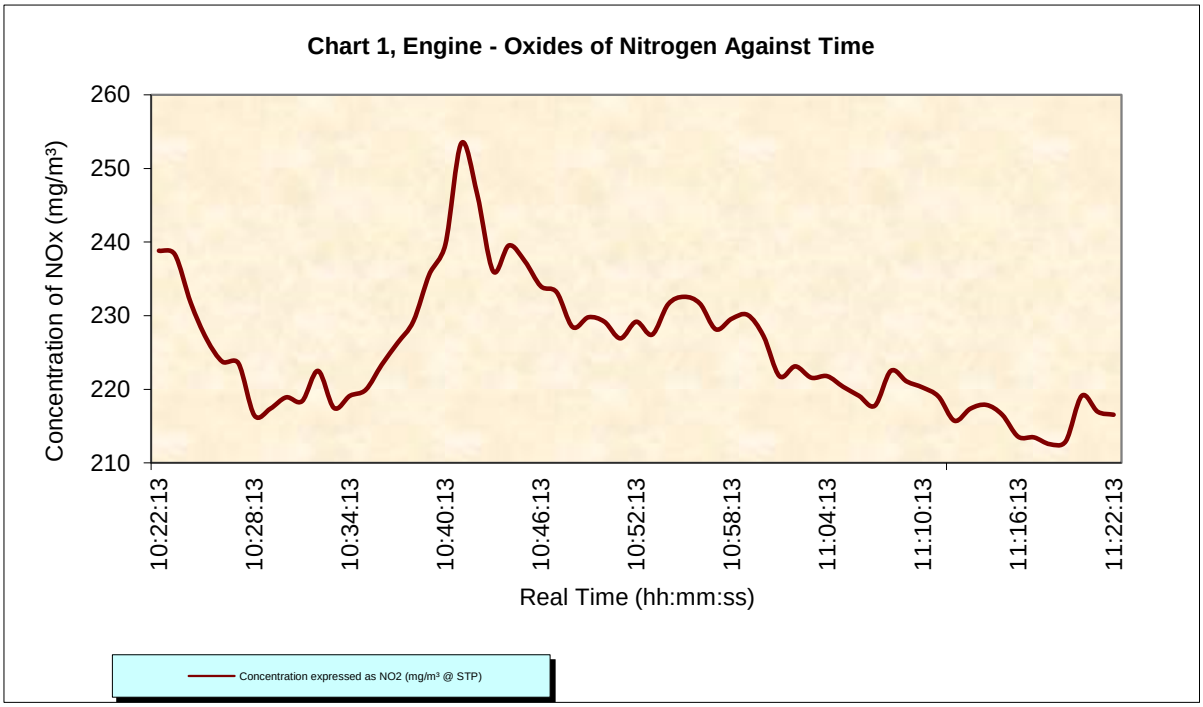
2.2.3 Homogeneity testing

BS EN 15259 stipulates that the exhaust gases emitted from combustion processes are tested to ensure homogeneity and that a representative sample is obtained during the monitoring, subject to a number of caveats as elucidated in Environment Agency guidance MID15259. The details of the testing at each emission point are summarised below:

Stack	Result of Homogeneity Testing
Engine	N/A –homogeneity testing only required on stacks exceeding 1.13 m diameter, as specified in MID 15259. Homogeneity assumed and single point sampling acceptable
Flare Stack	N/A – Due to the health & safety implications of working on a live flare, homogeneity assumed and single point sampling acceptable.

2.2.4 Gas analyser site measurements and calibrations

The data in Charts 1 to 6 and Tables 1 & 2 are expressed in mgm^{-3} @ STP and is uncorrected for O_2. In addition, VOC results are expressed as methane equivalent. This data was subsequently converted to reference oxygen concentrations (Section 1.2) with the addition of moisture correction for VOCs. Analyser calibration data is shown in Tables 3 & 4.



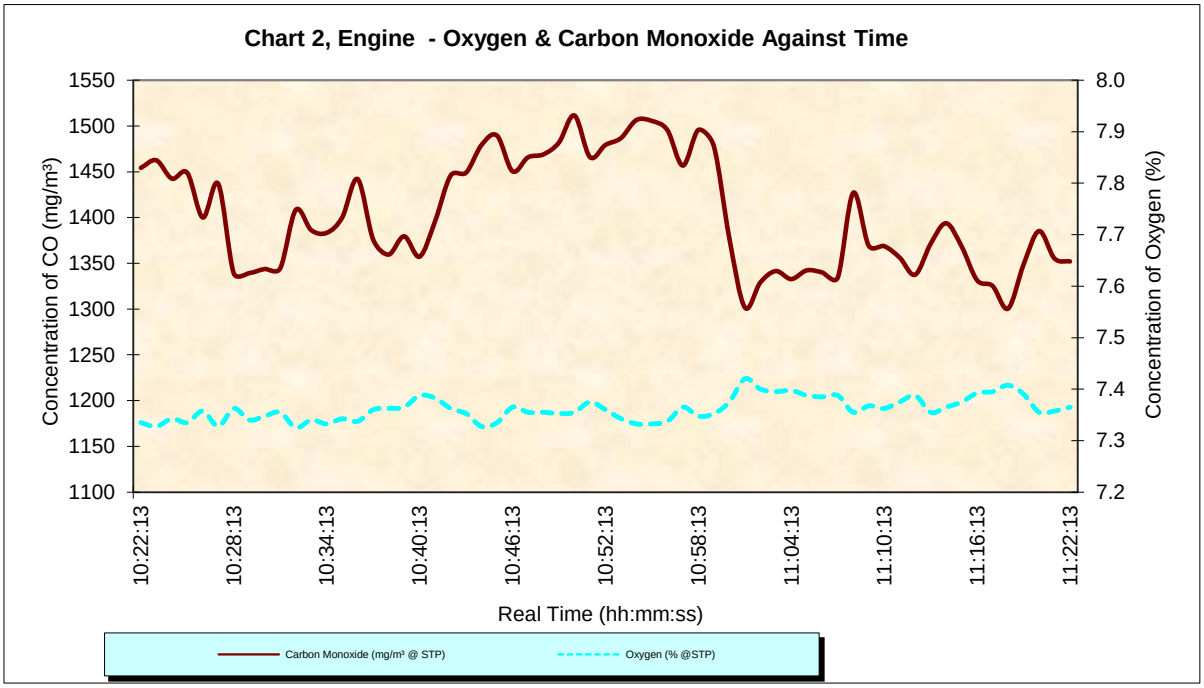


Chart 2, Engine - Oxygen & Carbon Monoxide Against Time
Concentration of CO (mg/m³)
1550
1500
1450
1400
1350
1300
1250
1200
1150
1100
Concentration of Oxygen (%)
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
10:22:13
10:28:13
10:34:13
10:40:13
10:46:13
10:52:13
10:58:13
11:04:13
11:10:13
11:16:13
11:22:13
Real Time (hh:mm:ss)
Carbon Monoxide (mg/m³ @ STP)
Oxygen (% @STP)

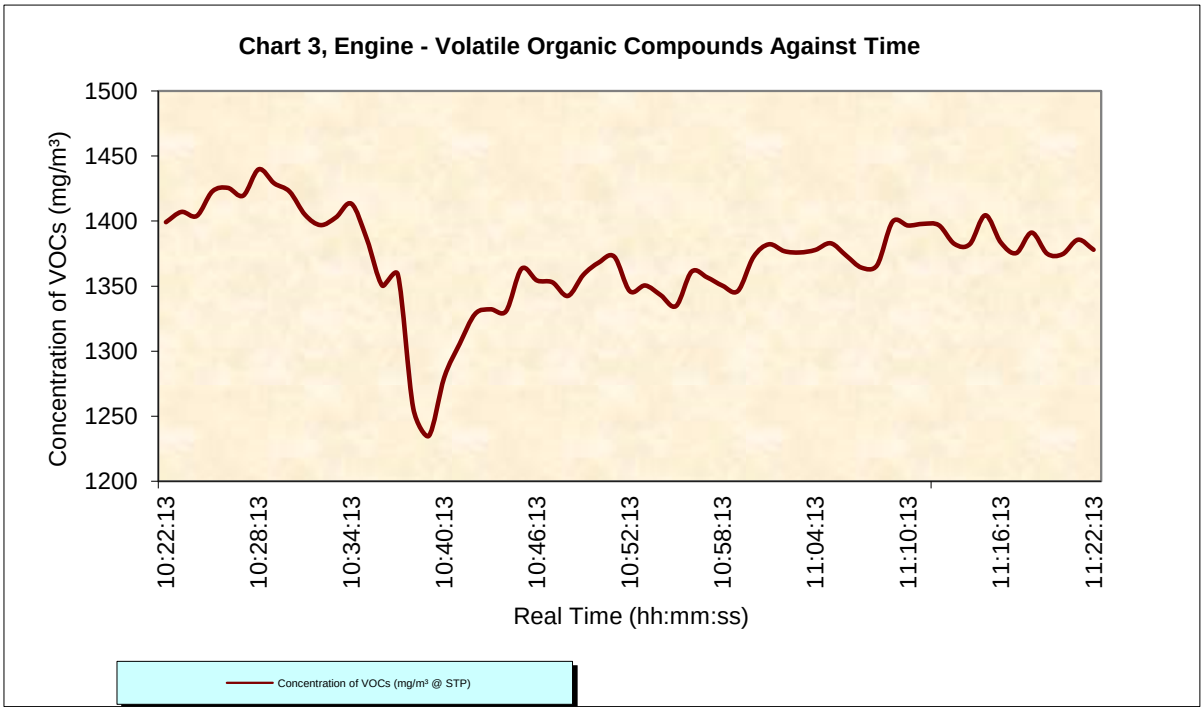


Chart 3, Engine - Volatile Organic Compounds Against Time
Concentration of VOCs (mg/m³)
1500
1450
1400
1350
1300
1250
1200
10:22:13
10:28:13
10:34:13
10:40:13
10:46:13
10:52:13
10:58:13
11:04:13
11:10:13
11:16:13
11:22:13
Real Time (hh:mm:ss)
Concentration of VOCs (mg/m³ @ STP)

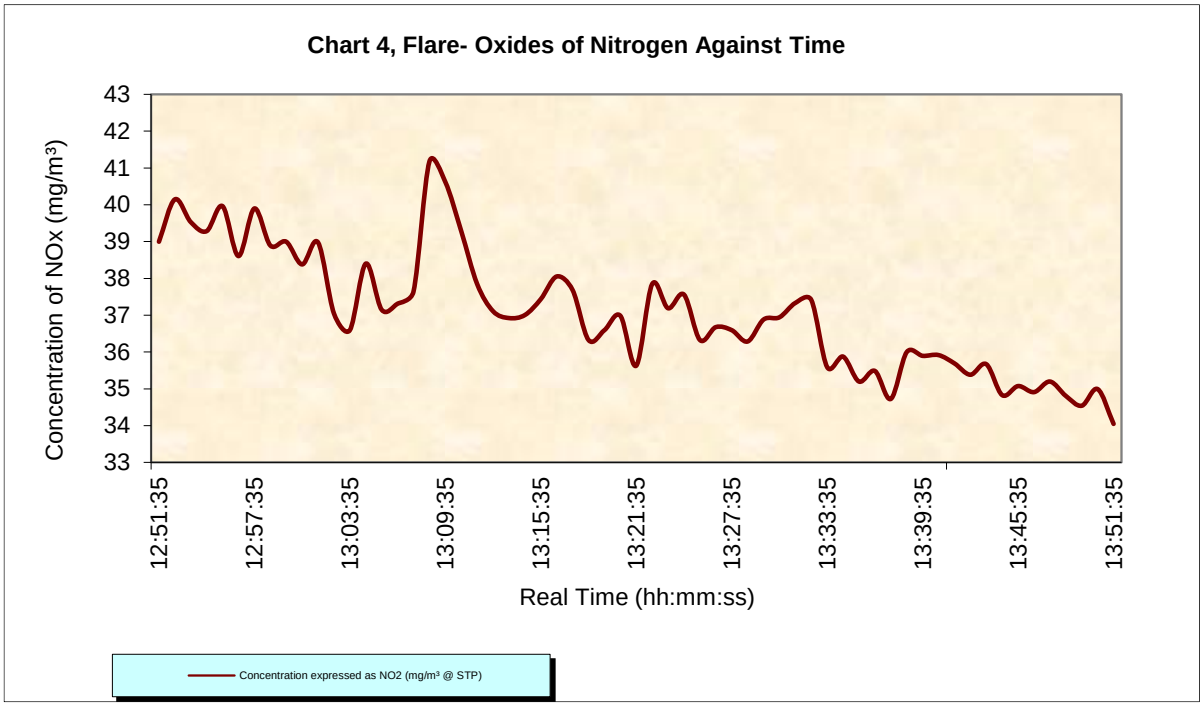


Chart 4, Flare- Oxides of Nitrogen Against Time
Concentration of NOx (mg/m³)
43
42
41
40
39
38
37
36
35
34
33
12:51:35
12:57:35
13:03:35
13:09:35
13:15:35
13:21:35
13:27:35
13:33:35
13:39:35
13:45:35
13:51:35
Real Time (hh:mm:ss)
Concentration expressed as NO2 (mg/m³ @ STP)

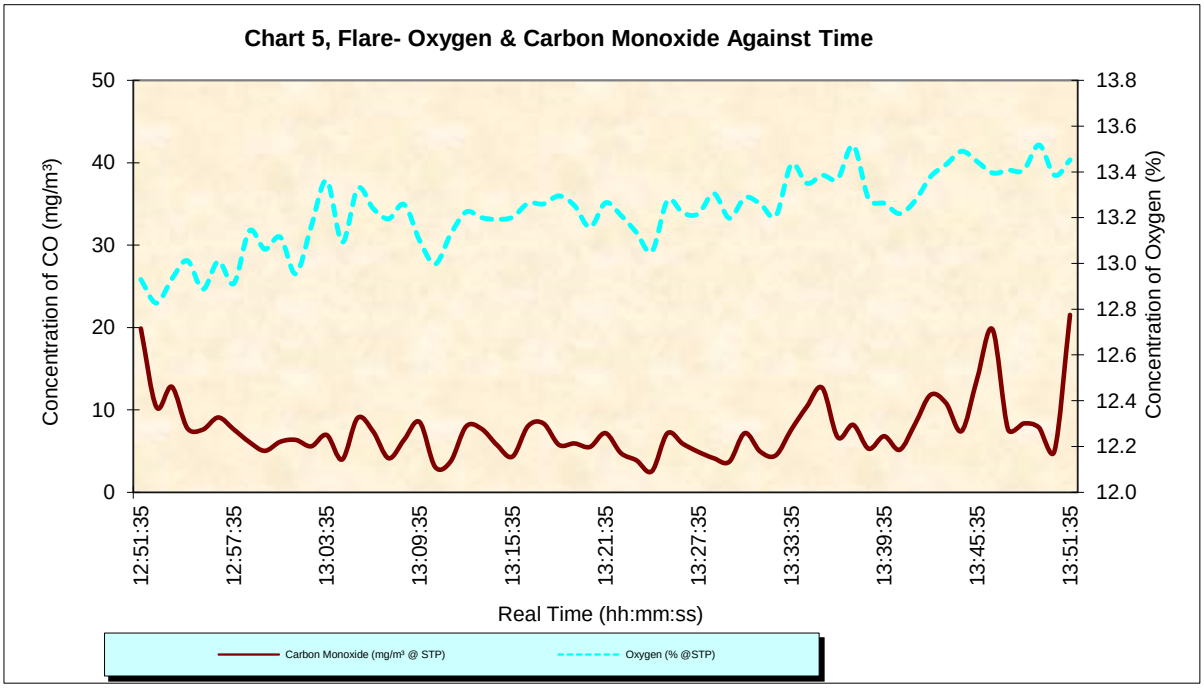


Chart 5, Flare- Oxygen & Carbon Monoxide Against Time
Concentration of CO (mg/m³)
50
40
30
20
10
0
Concentration of Oxygen (%)
13.8
13.6
13.4
13.2
13.0
12.8
12.6
12.4
12.2
12.0
12:51:35
12:57:35
13:03:35
13:09:35
13:15:35
13:21:35
13:27:35
13:33:35
13:39:35
13:45:35
13:51:35
Real Time (hh:mm:ss)
Carbon Monoxide (mg/m³ @ STP)
Oxygen (% @STP)

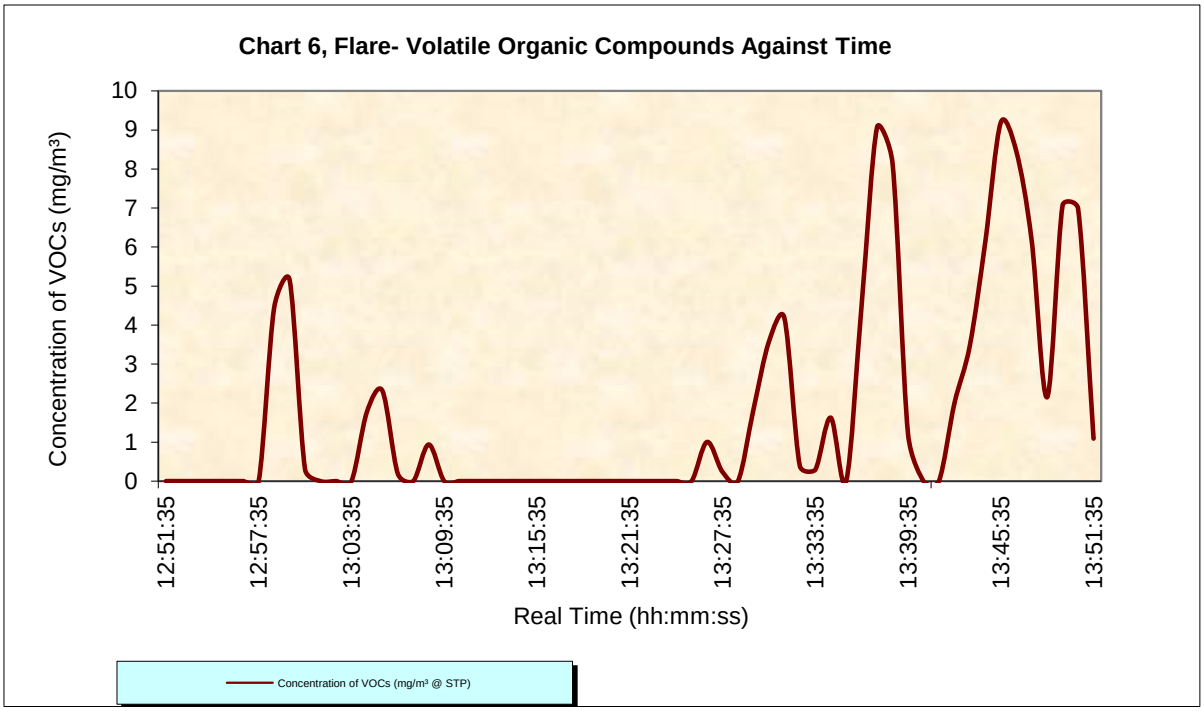


Table 1 – Engine, Raw Data

Time	Oxygen (%)	VOC (mgC/m³)	CO (mg/m³)	Nox (mg/m³)	Comment
10:22:13	7.3	1399.2	1454.3	238.8	
10:23:13	7.3	1407.1	1462.5	238.3	
10:24:13	7.3	1404.0	1442.5	231.7	
10:25:13	7.3	1422.8	1448.8	226.8	
10:26:13	7.4	1425.5	1400.0	223.7	
10:27:13	7.3	1419.6	1436.8	223.5	
10:28:13	7.4	1439.8	1339.0	216.4	
10:29:13	7.3	1429.1	1339.3	217.4	
10:30:13	7.3	1422.6	1343.8	218.9	
10:31:13	7.4	1404.8	1344.5	218.4	
10:32:13	7.3	1396.9	1408.3	222.5	
10:33:13	7.3	1402.9	1386.3	217.5	
10:34:13	7.3	1413.3	1383.3	219.1	
10:35:13	7.3	1386.0	1400.0	219.9	
10:36:13	7.3	1350.3	1442.0	223.3	
10:37:13	7.4	1358.8	1376.0	226.3	
10:38:13	7.4	1255.8	1359.5	229.3	
10:39:13	7.4	1234.8	1379.5	235.6	
10:40:13	7.4	1279.8	1357.3	239.7	
10:41:13	7.4	1305.6	1396.0	253.4	
10:42:13	7.4	1328.6	1445.8	246.5	
10:43:13	7.4	1332.2	1449.0	236.1	
10:44:13	7.3	1330.7	1479.3	239.5	

Time	Oxygen (%)	VOC (mgC/m³)	CO (mg/m³)	Nox (mg/m³)	Comment
10:45:13	7.3	1363.3	1489.5	237.4	
10:46:13	7.4	1354.3	1450.5	234.0	
10:47:13	7.4	1352.9	1465.8	233.2	
10:48:13	7.4	1342.4	1469.0	228.5	
10:49:13	7.4	1358.7	1482.0	229.8	
10:50:13	7.4	1368.2	1511.5	229.2	
10:51:13	7.4	1372.7	1466.0	226.9	
10:52:13	7.4	1346.1	1479.3	229.2	
10:53:13	7.3	1350.5	1486.8	227.4	
10:54:13	7.3	1343.1	1506.5	231.5	
10:55:13	7.3	1334.7	1505.5	232.6	
10:56:13	7.3	1361.1	1495.5	231.6	
10:57:13	7.4	1356.8	1456.8	228.2	
10:58:13	7.3	1350.3	1495.8	229.6	
10:59:13	7.4	1346.3	1478.0	230.1	
11:00:13	7.4	1372.3	1377.5	227.2	
11:01:13	7.4	1382.1	1301.8	221.8	
11:02:13	7.4	1376.8	1329.0	223.1	
11:03:13	7.4	1375.9	1341.5	221.6	
11:04:13	7.4	1377.8	1332.8	221.8	
11:05:13	7.4	1382.9	1342.3	220.3	
11:06:13	7.4	1373.5	1340.0	219.1	
11:07:13	7.4	1364.1	1334.3	217.8	
11:08:13	7.4	1366.1	1427.0	222.5	
11:09:13	7.4	1399.5	1369.3	221.1	
11:10:13	7.4	1396.6	1368.8	220.2	
11:11:13	7.4	1397.9	1356.3	219.0	
11:12:13	7.4	1396.8	1337.5	215.7	
11:13:13	7.4	1382.5	1371.3	217.4	
11:14:13	7.4	1382.3	1393.8	217.9	
11:15:13	7.4	1404.5	1368.5	216.5	
11:16:13	7.4	1383.6	1331.5	213.6	
11:17:13	7.4	1375.4	1325.3	213.5	
11:18:13	7.4	1391.1	1300.5	212.5	
11:19:13	7.4	1374.9	1348.5	213.0	
11:20:13	7.4	1374.6	1385.3	219.1	
11:21:13	7.4	1385.7	1355.3	217.0	
11:22:13	7.4	1378.0	1352.0	216.5	

Table 2 – Flare, Raw Data

Time	Oxygen (%)	VOC (mgC/m³)	CO (mg/m³)	Nox (mg/m³)	Comment
12:51:35	12.9	0.0	19.9	39.0	
12:52:35	12.8	0.0	10.4	40.1	
12:53:35	12.9	0.0	12.8	39.5	
12:54:35	13.0	0.0	7.8	39.3	
12:55:35	12.9	0.0	7.6	40.0	
12:56:35	13.0	0.0	9.1	38.6	
12:57:35	12.9	0.0	7.6	39.9	
12:58:35	13.1	4.4	6.1	38.9	
12:59:35	13.1	5.2	5.0	39.0	
13:00:35	13.1	0.3	6.1	38.4	
13:01:35	13.0	0.0	6.4	39.0	
13:02:35	13.2	0.0	5.6	37.0	
13:03:35	13.4	0.0	7.0	36.6	
13:04:35	13.1	1.8	4.0	38.4	
13:05:35	13.3	2.3	9.0	37.1	
13:06:35	13.2	0.2	7.4	37.3	
13:07:35	13.2	0.0	4.1	37.6	
13:08:35	13.3	0.9	6.4	41.2	
13:09:35	13.1	0.0	8.5	40.6	
13:10:35	13.0	0.0	3.1	39.3	
13:11:35	13.1	0.0	3.7	37.8	
13:12:35	13.2	0.0	8.0	37.1	
13:13:35	13.2	0.0	7.7	36.9	
13:14:35	13.2	0.0	5.7	37.0	
13:15:35	13.2	0.0	4.3	37.4	
13:16:35	13.3	0.0	8.0	38.1	
13:17:35	13.3	0.0	8.4	37.7	
13:18:35	13.3	0.0	5.8	36.3	
13:19:35	13.3	0.0	5.9	36.6	
13:20:35	13.2	0.0	5.5	37.0	
13:21:35	13.3	0.0	7.2	35.6	
13:22:35	13.2	0.0	4.8	37.8	
13:23:35	13.1	0.0	3.9	37.2	
13:24:35	13.1	0.0	2.6	37.6	
13:25:35	13.3	0.0	7.2	36.3	
13:26:35	13.2	1.0	5.9	36.7	
13:27:35	13.2	0.2	4.9	36.6	
13:28:35	13.3	0.0	4.1	36.3	
13:29:35	13.2	1.8	3.7	36.9	
13:30:35	13.3	3.6	7.2	36.9	
13:31:35	13.3	4.2	4.9	37.3	
13:32:35	13.2	0.4	4.5	37.4	
13:33:35	13.4	0.3	7.6	35.6	
13:34:35	13.4	1.6	10.4	35.9	
13:35:35	13.4	0.0	12.7	35.2	

Time	Oxygen (%)	VOC (mgC/m³)	CO (mg/m³)	Nox (mg/m³)	Comment
13:36:35	13.4	4.5	6.7	35.5	
13:37:35	13.5	9.1	8.2	34.7	
13:38:35	13.3	8.1	5.3	36.0	
13:39:35	13.3	1.2	6.8	35.9	
13:40:35	13.2	0.0	5.2	35.9	
13:41:35	13.3	0.0	8.3	35.7	
13:42:35	13.4	2.0	11.8	35.4	
13:43:35	13.4	3.5	10.8	35.7	
13:44:35	13.5	6.1	7.4	34.8	
13:45:35	13.4	9.2	13.8	35.1	
13:46:35	13.4	8.5	19.8	34.9	
13:47:35	13.4	6.2	7.6	35.2	
13:48:35	13.4	2.2	8.4	34.8	
13:49:35	13.5	7.1	7.9	34.5	
13:50:35	13.4	7.0	5.0	35.0	
13:51:35	13.5	1.1	21.5	34.0	

Table 3 – Engine, Analyser Calibration Data

ANALYSER CALIBRATION DATA					
Pre Sampling Check					
		NO (ppm)	**CO (ppm)**	**O2 (%)**	**VOC's (ppm)**
Range		500	2000	25	1000
Zero Gas	**Cylinder No.**	D909084			Scrubbed Air/ N10000018
Span Gas	**Cylinder No.**	VCD116940	VCD116940	VC1981886	VC1981886
	Certified Value	264	1158	7.43	800
Zero Check	**Value**	0.4	2	0	0
<2 x repeatability (Yes/No)		YES	YES	YES	YES
Down Line Zero & Span Check					
Zero Gas	**Value**	0.4	1	0.08	0
	<2% of span	**YES**	**YES**	**YES**	**YES**
Span Gas	**Value**	263.7	1158	7.42	803
	Within 2% of span	YES	YES	YES	YES
Post Sampling Drift Check					
Zero Gas	**Value**	4.9	6	0.03	0
	Drift (%)	1.7	0.4	0.7	0.0
	Validation	**No Correction Required**	**No Correction Required**	**No Correction Required**	**No Correction Required**
Span Gas	**Value**	259.8	1149	7.41	799
	Drift (%)	1.5	0.8	0.1	0.5
	Validation	**No Correction Required**	**No Correction Required**	**No Correction Required**	**No Correction Required**

Table 4 – Flare, Analyser Calibration Data

ANALYSER CALIBRATION DATA					
Pre Sampling Check					
		NO (ppm)	**CO (ppm)**	**O2 (%)**	**VOC's (ppm)**
Range		100	200	25	10
Zero Gas	**Cylinder No.**	D909084			Scrubbed Air/ N10000018
Span Gas	**Cylinder No.**	VCD115689	VCD115690	7700651	7700651
	Certified Value	85.7	184.1	8.01	7.94
Zero Check	**Value**	0.3	0.8	-0.01	0
<2 x repeatability (Yes/No)		YES	YES	YES	YES
Down Line Zero & Span Check					
Zero Gas	**Value**	0.8	0.4	0.07	0.02
	<2% of span	**YES**	**YES**	**YES**	**YES**
Span Gas	**Value**	85.6	184.2	8	7.97
	Within 2% of span	YES	YES	YES	YES
Post Sampling Drift Check					
Zero Gas	**Value**	0.2	-1.4	0.07	-0.12
	Drift (%)	0.7	1.0	0.0	1.8
	Validation	**No Correction Required**	**No Correction Required**	**No Correction Required**	**No Correction Required**
Span Gas	**Value**	85.6	182.4	8.11	7.97
	Drift (%)	0.0	1.0	1.4	0.0
	Validation	**No Correction Required**	**No Correction Required**	**No Correction Required**	**No Correction Required**

2.3 Appendix III: Uncertainty Calculation

2.3.1 Engine, Uncertainties

NOx - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	2.37
Drift	u_{Odr}	7.22
volume or pressure flow dependence	u_{spres}	0.06
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.69
NH3 (20 mg/m3)	u_{interf}	0.14
CO2 (15%)	-	0.02
H2O (30%)	-	0.01
Error in logger voltage	-	0.50
Dependence on voltage	u_{volt}	0.03
Converter efficiency	u_{ceff}	1.04
losses in the line (leak)	u_{leak}	2.60
Uncertainty of calibration gas	u_{calib}	2.60

NOx Measurement uncertainty		Result	225.56	mg/m^3
Combined uncertainty			8.55	mg/m^3
Expanded uncertainty	k =	2	17.11	mg/m^3
Uncertainty corrected to std conds			17.11	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.63**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**17.11**	**mg.m^{-3} of result**

CO - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	5.77
Drift	u_{Odr}	22.54
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
CO2 (15%)	u_{interf}	0.00
N2O (40mgm3)	-	0.00
CH4 (57mgm3)	-	0.00
H2O (1%)	-	0.00
Dependence on voltage	u_{volt}	0.03
Error in Logger reading	-	2.00
losses in the line (leak)	u_{leak}	16.21
Uncertainty of calibration gas	u_{calib}	16.21

CO Measurement uncertainty		Result	1404.09	mg/m^3
Combined uncertainty			32.73	mg/m^3
Expanded uncertainty	k =	2	65.46	mg/m^3
Uncertainty corrected to std conds			65.46	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.36**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**65.46**	**mg.m^{-3} of result**

VOC - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	3.74
Drift	u_{0dr}	17.27
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
NH3 (20 mg/m3)	u_{interf}	0.00
CO2 (15%)	-	0.00
H2O (30%)	-	0.00
Error on Logger voltage	-	1.00
Dependence on voltage	u_{volt}	0.03
losses in the line (leak)	u_{leak}	15.83
Uncertainty of calibration gas	u_{calib}	15.83

VOC Measurement uncertainty		Result	1371.14	mg/m^3
Combined uncertainty			28.54	mg/m^3
Expanded uncertainty	k =	2	57.08	mg/m^3
Uncertainty corrected to std conds			57.08	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.26**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**57.08**	**$mg.m^{-3}$ of result**

Oxygen - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.20
Standard deviation of repeatability at span level	u_{rs}	0.03
Lack of fit	u_{fit}	0.08
Drift	u_{0dr}	0.11
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.10
CO2 (15%)	-	0.00
NO(300)	-	0.06
NO2(30)	-	0.00
dependence on voltage	u_{volt}	0.02
losses in the line (leak)	u_{leak}	0.08
Error in Logger voltage	-	0.03
Uncertainty of calibration gas	u_{calib}	0.08

O2 Measurement uncertainty		Result	7.36	%vol
Combined uncertainty			0.23	%vol
% of value			3.07	%
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.15**	**% of value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.45**	**% vol**

2.3.2 Flare, Uncertainties

NOx - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	0.47
Drift	u_{0dr}	1.40
volume or pressure flow dependence	u_{spres}	0.01
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
NH3 (20 mg/m3)	u_{interf}	0.14
CO2 (15%)	-	0.02
H2O (30%)	-	0.01
Error in logger voltage	-	0.10
Dependence on voltage	u_{volt}	0.03
Converter efficiency	u_{ceff}	0.17
losses in the line (leak)	u_{leak}	0.43
Uncertainty of calibration gas	u_{calib}	0.43

NOx Measurement uncertainty		Result	37.11	mg/m^3
Combined uncertainty			1.62	mg/m^3
Expanded uncertainty	k =	2	3.24	mg/m^3
Uncertainty corrected to std conds			3.24	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.16**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.24**	**$mg.m^{-3}$ of result**

CO - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	0.58
Drift	u_{0dr}	1.20
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
CO2 (15%)	u_{interf}	0.00
N2O (40mgm3)	-	0.00
CH4 (57mgm3)	-	0.00
H2O (1%)	-	0.00
Dependence on voltage	u_{volt}	0.03
Error in Logger reading	-	0.20
losses in the line (leak)	u_{leak}	0.08
Uncertainty of calibration gas	u_{calib}	0.08

CO Measurement uncertainty		Result	7.36	mg/m^3
Combined uncertainty			1.35	mg/m^3
Expanded uncertainty	k =	2	2.71	mg/m^3
Uncertainty corrected to std conds			2.71	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.42**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.71**	**$mg.m^{-3}$ of result**

VOC - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.80
Standard deviation of repeatability at span level	u_{rs}	0.10
Lack of fit	u_{fit}	0.04
Drift	u_{0dr}	0.10
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
NH3 (20 mg/m3)	u_{interf}	0.00
CO2 (15%)	-	0.00
H2O (30%)	-	0.00
Error on Logger voltage	-	0.01
Dependence on voltage	u_{volt}	0.03
losses in the line (leak)	u_{leak}	0.02
Uncertainty of calibration gas	u_{calib}	0.02

VOC Measurement uncertainty		Result	1.75	mg/m^3
Combined uncertainty			0.16	mg/m^3
Expanded uncertainty	k =	2	0.31	mg/m^3
Uncertainty corrected to std conds			0.31	mg.m-3 (corrected)
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.14**	**% ELV**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.31**	**$mg.m^{-3}$ of result**

Oxygen - Measurement performance related to stationary conditions		
Performance characteristic	**Uncertainty**	**Value of uncertainty quantity**
Standard deviation of repeatability at zero	u_{r0}	0.20
Standard deviation of repeatability at span level	u_{rs}	0.03
Lack of fit	u_{fit}	0.15
Drift	u_{0dr}	0.15
volume or pressure flow dependence	u_{spres}	0.00
atmopsheric pressure dependence	u_{apres}	0.00
ambient temperature dependence	u_{temp}	0.00
CO2 (15%)	-	0.00
NO(300)	-	0.06
NO2(30)	-	0.00
dependence on voltage	u_{volt}	0.02
losses in the line (leak)	u_{leak}	0.15
Error in Logger voltage	-	0.03
Uncertainty of calibration gas	u_{calib}	0.15

O2 Measurement uncertainty		Result	13.22	%vol
Combined uncertainty			0.31	%vol
% of value			2.38	%
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.76**	**% of value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.63**	**% vol**

2.4 Appendix IV: Moisture Calculations

2.4.1 Engine, Moisture

Test No	T1		Site	Flintshire CC	
Date	6-5-16			Brookhill	
pbar (mbar)	996		Stack	Engine	
pbar (mnHg)	747		Job Number:	R16221	
Nozzle Diameter (mm)	n/a		Site Team:		DL + DK
Temp of Meter (in)/(out) deg. C	21		Data Entered By:		DL
ΔH ave (mmH 2 0)	10.0				
DGM Cal Factor (Y)	0.9706		Enter Data into coloured cells only		

Start Volume Reading	0.0000	m³	Start time	10:22	hr:min
End Volume Reading	0.5095	m³	End time	11:22	hr:min
Volume Sampled	0.4945	m³	Total time	01:00	hr:min

IMPINGER	1	2	3	4	Initials of Analyst
Absorber Solution (Type):	H2O	H2O	KO IMP	SILICA	
Sample No:	n/a	n/a	n/a	n/a	
Analysis Required:	n/a	n/a	n/a	n/a	
Initial Weight of Impingers plus absorber (g)	785.2	787.9	551.0	728.4	DK
Final Weight of Impingers plus absorber (g)	827.3	790.2	551.2	734.7	DK
Weight Gain (g)	42.1	2.3	0.2	6.3	

Total Weight Gain (1+2+3+4) (g)	50.9

Gas Volume of water at 0 °C (l)	63.37
Gas Meter volume at 0 °C (l)	451.94

Moisture content of Gases (%)	12.3

2.4.2 Flare, Moisture

Test No	T2		Site	Flintshire CC		
Date	6-5-16			Brookhill		
pbar (mbar)	992		Stack	Flare		
pbar (mnHg)	744		Job Number:	R16221		
Nozzle Diameter (mm)	n/a		Site Team:		DL + DK	
Temp of Meter (in)/(out) deg. C	21		Data Entered By:		DL	
ΔH_{ave} (mmH_2O)	10.0					
DGM Cal Factor (Y)	0.9706		Enter Data into coloured cells only			

Start Volume Reading	0.0000	m^3	Start time	12:51	hr:min
End Volume Reading	0.4881	m^3	End time	13:51	hr:min
Volume Sampled	0.4737	m^3	Total time	01:00	hr:min

IMPINGER	1	2	3	4	Initials of Analyst
Absorber Solution (Type):	H2O	H2O	KO IMP	SILICA	
Sample No:	n/a	n/a	n/a	n/a	
Analysis Required:	n/a	n/a	n/a	n/a	
Initial Weight of Impingers plus absorber (g)	827.3	790.2	551.2	734.7	DK
Final Weight of Impingers plus absorber (g)	850.4	791.2	551.3	739.8	DK
Weight Gain (g)	23.1	1.0	0.1	5.1	

Total Weight Gain (1+2+3+4) (g)	29.3

Gas Volume of water at 0 °C (l)	36.48
Gas Meter volume at 0 °C (l)	431.22

Moisture content of Gases (%)	7.8