

**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: AP3739KS

Operator: Flintshire County Council

Installation: Brookhill Landfill Site (Engine & Flare)



4251

Monitoring dates: 17th March 2015

Job Number: **R15100**

Version: 1

Address: **Flintshire County Council**

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Monitoring Organisation: **EnviroDat Ltd**

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Date of Report: 7th April 2015

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Function: Project 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 release pollution to the atmosphere. As a result of this, the site is subject to authorisation under the Environmental Permitting Regulations and is regulated by the Environment Agency.

Methane is produced as a by-product of the decomposition of waste that is buried, and is collected and piped to flare stack for destruction.

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 AP3739KS are summarised below:

Substances to be monitored	Emission Point Identification		
	Engine		Flare Stack
Oxides of Nitrogen (as NO ₂)	✓		✓
Carbon Monoxide	✓		✓
Oxygen (for correction)	✓		✓
Volatile Organic Compounds (VOCs)	✓		✓
Moisture (for correction)	✓		✓
Special requirements	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	147	±15	mg(N)m ³	101.3kPa, 273K, dry gas, 5% Oxygen	17/03/2015	15:15-16:15	BS EN 14792	A	At 49% MCR
	Carbon Monoxide	1500	1386	±60	mg(N)m ³				BS EN 15058	A	
	Volatile Organic Compounds (VOCs as carbon)	1750	1933	±61	mg(N)m ³				BS EN 12619	A	
	Moisture	-	12.3	n/a	%	101.3kPa, 273K, dry gas		15:15-16:15	BS EN 14790	A	
	Oxygen	-	6.89	±0.41	%			15:15-16:15	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	Oxides of Nitrogen (as NO ₂)	150	80.9	±3.7	mg(N)m ⁻³	101.3kPa, 273K, dry gas, 3% Oxygen	17/03/2015	14:58-15:58	BS EN 14792	A	At 77% MCR
	Carbon Monoxide	50	58.5	±3.7	mg(N)m ⁻³				BS EN 15058	A	
	Volatile Organic Compounds (VOCs as carbon)	10	2.8	±0.3	mg(N)m ⁻³				BS EN 12619	A	
	Moisture	-	10.2	n/a	%	101.3kPa, 273K, dry gas		14:58-15:58	BS EN 14790	A	
	Oxygen	-	10.31	±0.54	%			14:58-15:58	BS EN 14789	A	

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- 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	17/03/2015	When required	N/A	Landfill Gas	N/A	None	560kWe Output @ 1136kWe unit	N/A	N/A	N/A	N/A
Flare Stack	17/03/2015	When required	N/A	Landfill Gas	N/A	None	770m ³ /hr Rated at 1000m ³ /hr	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, Yu Shen – Mcerts Level II (TE1, 2, 3 & 4)	MM06 727
Team Leader, Bruce Kester – Mcerts Level II (TE1, 2, 3 & 4)	MM03 190
Assistant, Tom Bonham – Mcerts Level I	MM10 1076

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% O₂ for the engine and 3% O₂ for the flare.

2.1.2.2 NO_x (as NO₂)

A sample of the duct gas was passed via a short high temperature, stainless steel 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 NO_x (as NO₂) 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, stainless steel 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 O₂

A sample of the duct gas was passed via a short high temperature, stainless steel 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 O₂ 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:

$$\text{Conc}_{\text{ref}} = \text{Conc}_{\text{meas}} \times \frac{(20.95 - \text{O}_{2\text{ref}})}{(20.95 - \text{O}_{2\text{meas}})}$$

Whereby, Conc_{ref} was the concentration at reference conditions and $\text{Conc}_{\text{meas}}$ was the measured concentration, $\text{O}_{2\text{ref}}$ is the oxygen reference conditions and $\text{O}_{2\text{meas}}$ 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:

$$\frac{(100 - [\text{H}_2\text{O}]_{\text{reference}})}{(100 - [\text{H}_2\text{O}]_{\text{measured}})}$$

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	27-Jul-15	Oct-15
Flame Ionisation Detector Analyser	FID#01	24-Apr-15	Oct-15
Portable Gas Analyser	PGA#04	02-Nov-15	Oct-15
Flame Ionisation Detector Analyser	FID#02	24-Apr-15	Oct-15
Data Logger	DL#03	02-Nov-15	-
Data Logger	DL#04	24-Nov-15	-
Gas Conditioner	COND#02	06-Feb-16	Oct-15
Gas Conditioner	COND#03	23-Nov-15	Oct-15
NOx Converter	CONV#01	05-Feb-16	Oct-15
Digital Barometer	DB#07	29-Mar-15	-
Digital Barometer	DB#10	09-Jul-15	-
Balance	BAL#02	05-Apr-15	-
Heated Filter Head	HFH#02	14-Jan-16	
Heated Line	HL#18 & HL#11	14-Jan-16	-
Thermocouple (Stack Temperature Check)	TC#38	23-Nov-15	-
Thermocouple (HFH#02 Temperature Check)	TC#37	14-Jan-16	-
Timepiece	TP#10	29-Apr-15	-
Timepiece	TP#16	04-Jan-16	-
'Apex' Kit	APEX#02	Various	Oct-15
'Apex' Kit	APEX#04	Various	Oct-15

GAS CYLINDERS			
	Certificate No.	Level (ppm)	Validity
'Zero' Gas (%)	DV98PHI	99.9995%	N/A
Oxygen Span Gas (%)	VC80253	8.01%	22-Jan-16
VOC Span Gas	VC80253	801	22-Jan-16
Carbon Monoxide Span Gas	D666204	1154	11-Feb-16
Nitrogen Dioxide Span Gas	D666204	268.1	11-Feb-16
Oxygen Span Gas (%)	AC48FDG	7.97%	14-Dec-15
VOC Span Gas	AC48FDG	10.03	14-Dec-15
Carbon Monoxide Span Gas	D530838	160.5	29-Jul-15
Nitrogen Dioxide Span Gas	D530838	160.5	29-Jul-15

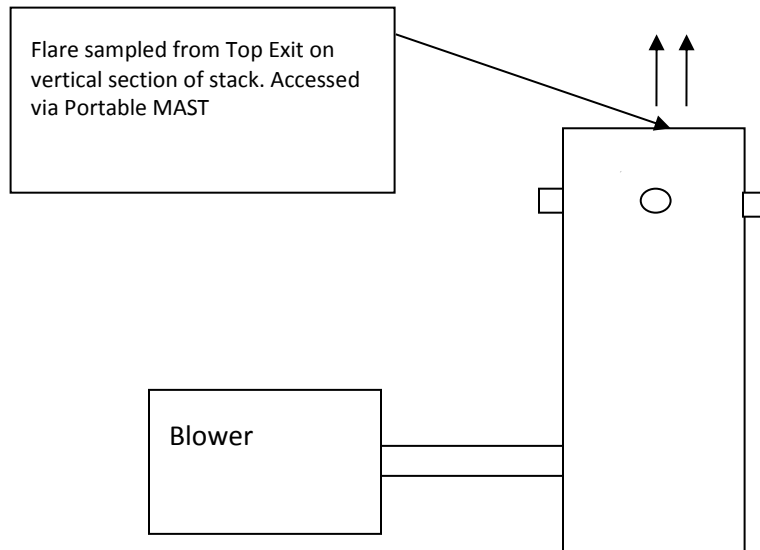
2.2 Appendix II: Emission Point Reference Data & Results

2.2.1 Photo of Sampling Location on Engine



Engine sampled from 3 inch BSP port on vertical section of approx. 0.30m diameter stack. Accessed via permanent platform.

2.2.2 Diagram of Sampling Location on Flare



Flare sampled from Top Exit on vertical section of stack. Accessed via Portable MAST

Blower

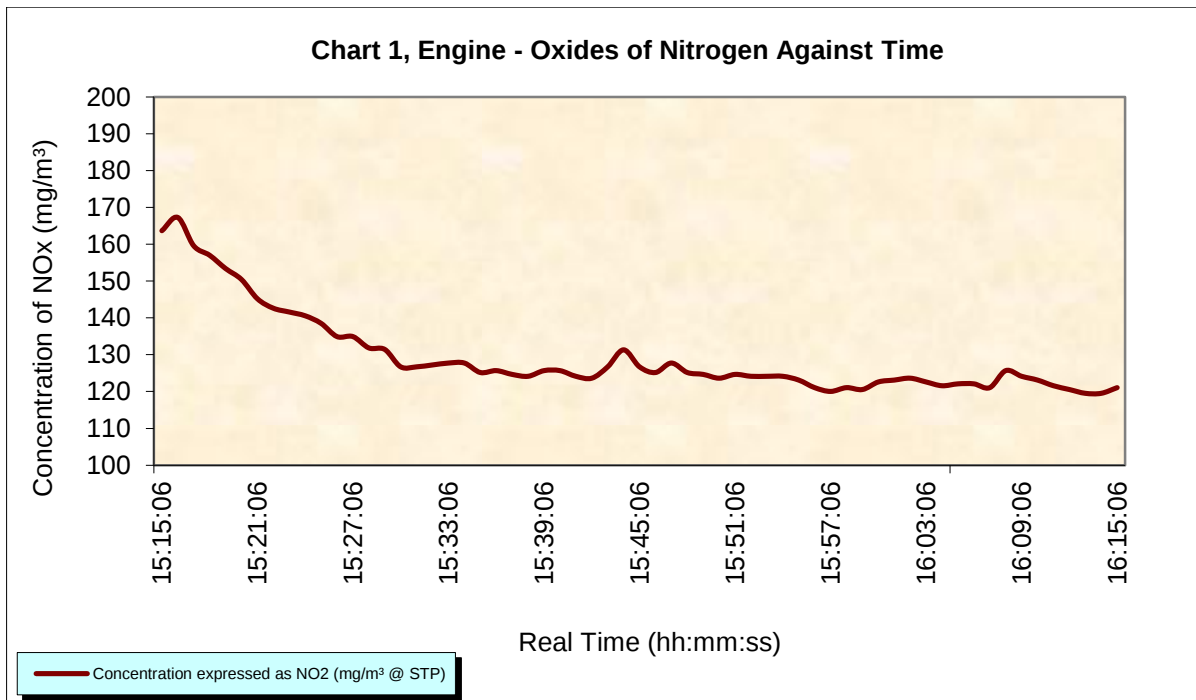
2.2.3 Homogeneity testing

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 to 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.



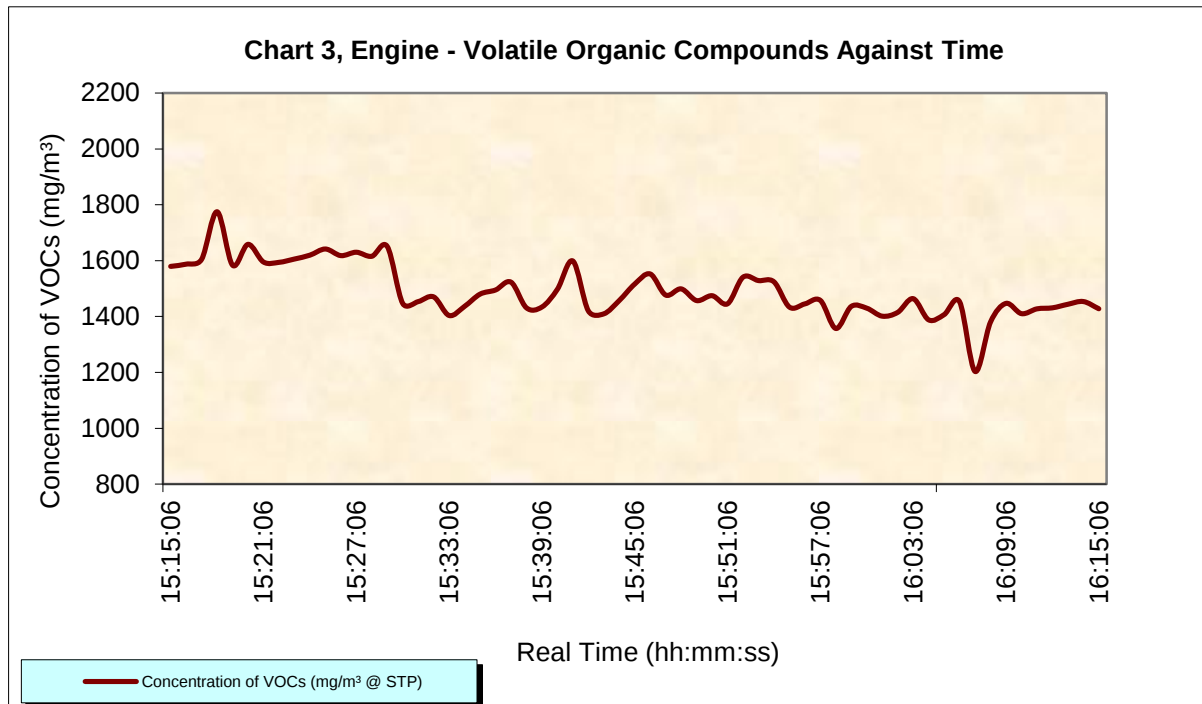
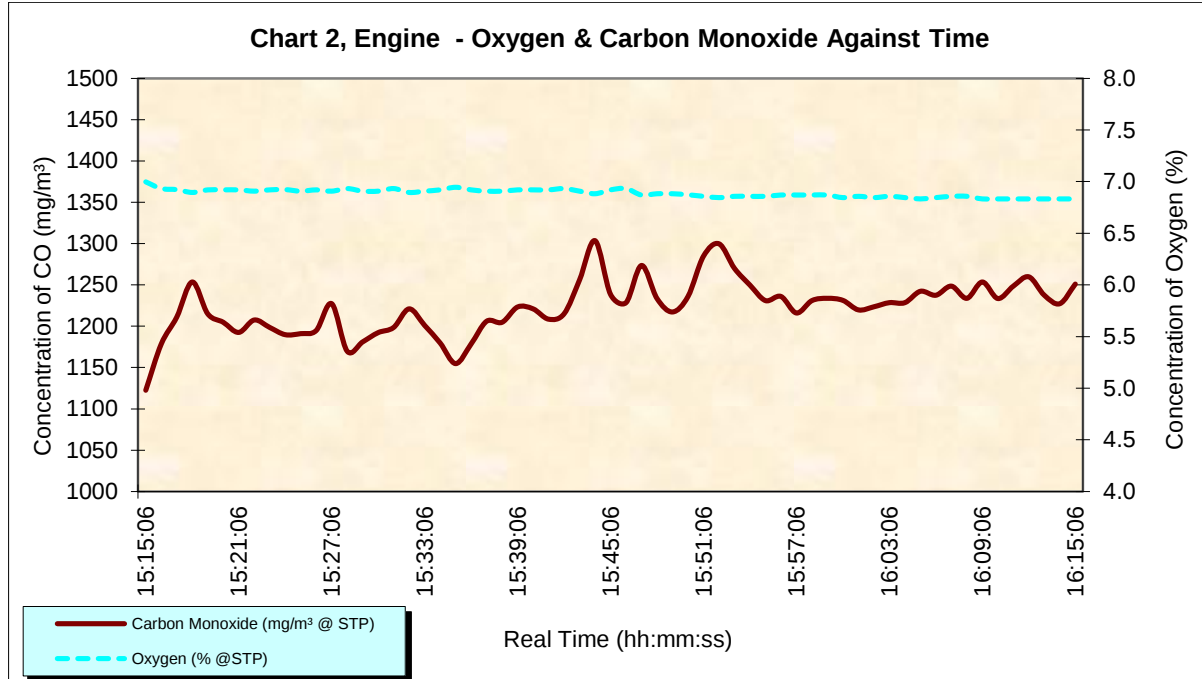


Chart 4, Flare - Oxides of Nitrogen Against Time

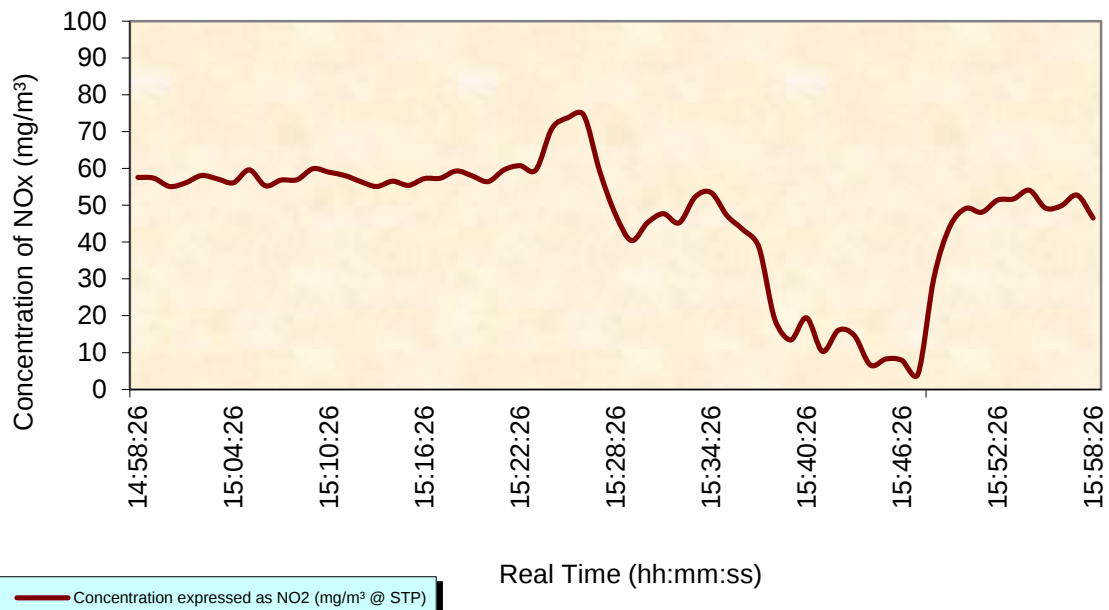
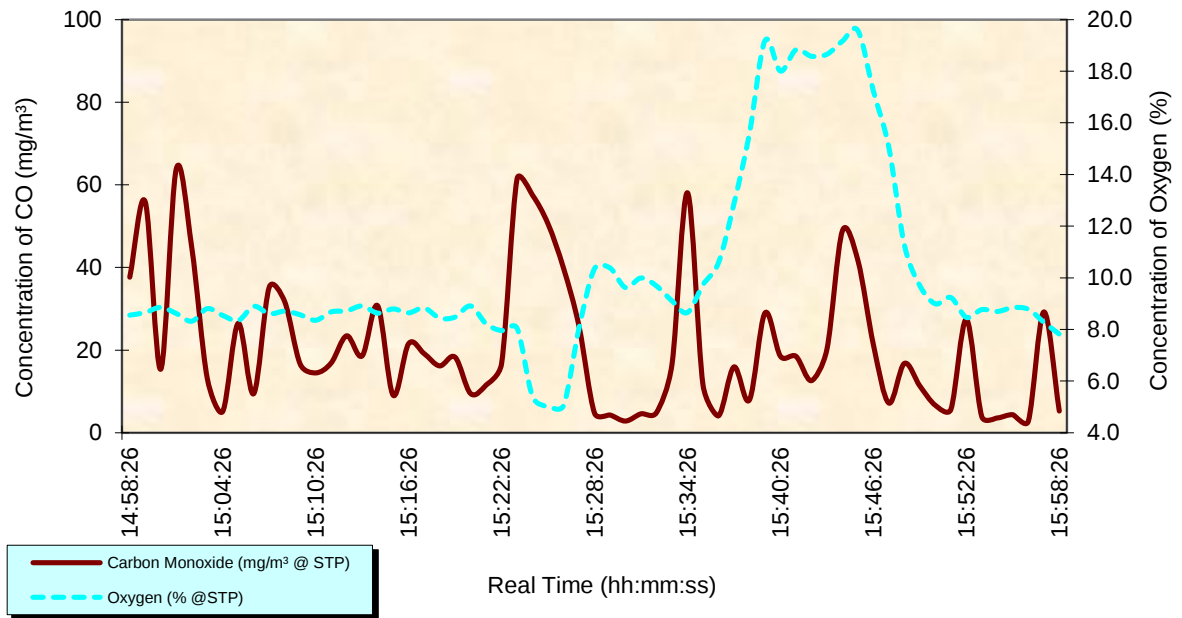
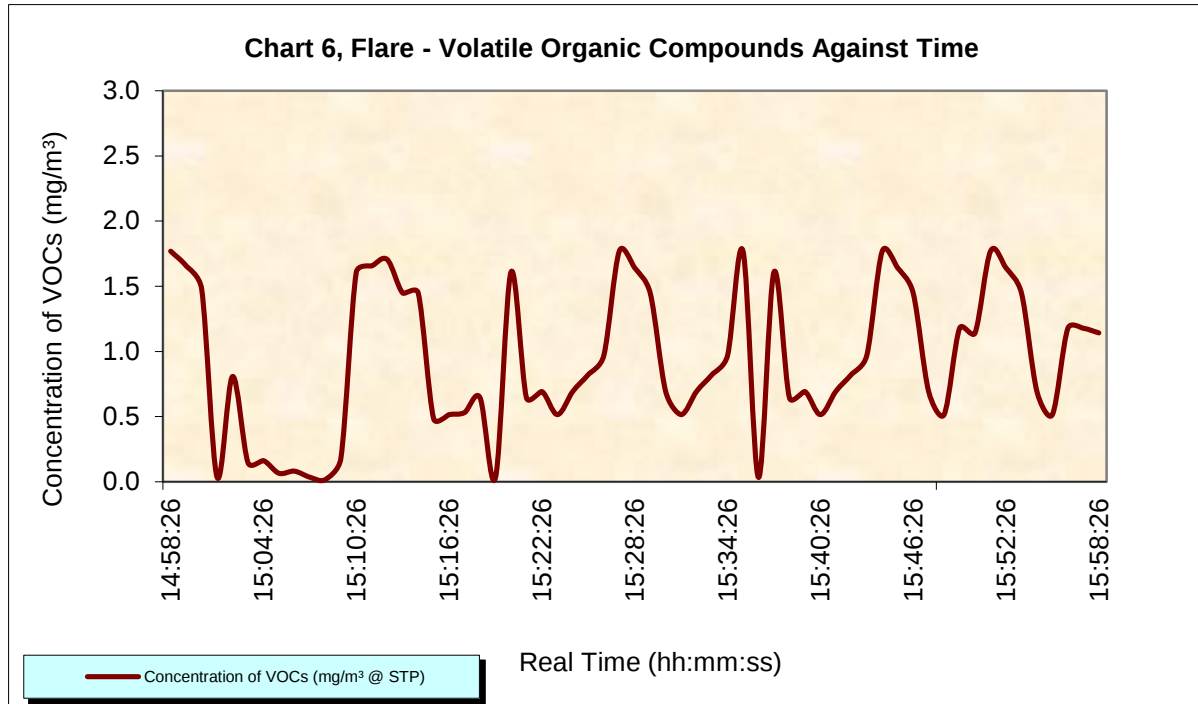


Chart 5, Flare - Oxygen & Carbon Monoxide Against Time



**Table 1 – Engine, Raw Data**

Time	Oxygen (%) (Dry Gas)	VOC (mgC/m³) (Wet Gas)	CO (mg/m³) (Dry Gas)	Nox (mg/m³) (Dry Gas)	Comment
15:15:06	7.0	1579.50	1122.5	163.7	Engine Sampling Starts
15:16:06	6.9	1587.54	1178.5	167.3	
15:17:06	6.9	1604.89	1211.0	159.6	
15:18:06	6.9	1775.09	1253.5	157.0	
15:19:06	6.9	1583.68	1215.0	153.4	
15:20:06	6.9	1658.41	1204.8	150.4	
15:21:06	6.9	1595.09	1192.5	145.2	
15:22:06	6.9	1593.96	1207.5	142.6	
15:23:06	6.9	1605.86	1198.5	141.6	
15:24:06	6.9	1619.68	1189.8	140.6	
15:25:06	6.9	1641.70	1191.0	138.5	
15:26:06	6.9	1618.07	1194.8	134.9	
15:27:06	6.9	1630.13	1227.3	134.9	
15:28:06	6.9	1615.66	1169.8	131.8	
15:29:06	6.9	1650.86	1181.0	131.4	
15:30:06	6.9	1446.75	1192.3	126.7	
15:31:06	6.9	1453.50	1198.5	126.7	
15:32:06	6.9	1470.21	1221.0	127.2	
15:33:06	6.9	1403.68	1201.0	127.7	

Time	Oxygen (%) (Dry Gas)	VOC (mgC/m ³) (Wet Gas)	CO (mg/m ³) (Dry Gas)	Nox (mg/m ³) (Dry Gas)	Comment
15:34:06	6.9	1436.46	1179.8	127.7	
15:35:06	6.9	1480.18	1154.8	125.2	
15:36:06	6.9	1494.96	1178.5	125.7	
15:37:06	6.9	1523.09	1206.0	124.7	
15:38:06	6.9	1431.16	1204.8	124.1	
15:39:06	6.9	1434.05	1223.3	125.7	
15:40:06	6.9	1497.54	1221.0	125.7	
15:41:06	6.9	1598.79	1208.5	124.1	
15:42:06	6.9	1420.23	1215.0	123.6	
15:43:06	6.9	1409.63	1256.0	126.7	
15:44:06	6.9	1457.36	1303.5	131.3	
15:45:06	6.9	1516.34	1238.5	126.7	
15:46:06	6.9	1552.34	1228.5	125.2	
15:47:06	6.9	1476.80	1273.5	127.7	
15:48:06	6.9	1498.98	1233.5	125.2	
15:49:06	6.9	1457.04	1217.3	124.7	
15:50:06	6.9	1474.55	1236.0	123.6	
15:51:06	6.9	1445.63	1284.8	124.7	
15:52:06	6.8	1540.93	1299.8	124.1	
15:53:06	6.9	1528.71	1270.0	124.1	
15:54:06	6.9	1524.21	1249.8	124.1	
15:55:06	6.9	1433.73	1231.0	123.1	
15:56:06	6.9	1445.30	1236.0	121.1	
15:57:06	6.9	1457.68	1216.0	120.0	
15:58:06	6.9	1357.23	1231.0	121.1	
15:59:06	6.9	1436.30	1233.8	120.5	
16:00:06	6.8	1429.88	1231.3	122.6	
16:01:06	6.9	1401.27	1219.8	123.1	
16:02:06	6.8	1414.93	1223.5	123.6	
16:03:06	6.9	1463.95	1228.5	122.6	
16:04:06	6.8	1388.09	1228.5	121.6	
16:05:06	6.8	1406.73	1242.3	122.1	
16:06:06	6.8	1452.86	1237.5	122.1	
16:07:06	6.9	1203.43	1248.5	121.1	
16:08:06	6.9	1380.54	1233.8	125.7	
16:09:06	6.8	1447.07	1253.5	124.1	
16:10:06	6.8	1410.27	1233.5	123.1	
16:11:06	6.8	1427.46	1248.5	121.6	
16:12:06	6.8	1431.16	1259.8	120.5	

Time	Oxygen (%) (Dry Gas)	VOC (mgC/m ³) (Wet Gas)	CO (mg/m ³) (Dry Gas)	Nox (mg/m ³) (Dry Gas)	Comment
16:13:06	6.8	1443.86	1237.5	119.5	
16:14:06	6.8	1453.66	1227.3	119.5	
16:15:06	6.8	1427.79	1251.0	121.1	Engine Sampling Ends

Table 2 – Flare, Raw Data

Time	Oxygen (%) (Dry Gas)	VOC (mgC/m ³) (Wet Gas)	CO (mg/m ³) (Dry Gas)	Nox (mg/m ³) (Dry Gas)	Comment
14:58:26	8.55	1.8	37.7	57.6	Flare Sampling Starts
14:59:26	8.66	1.7	55.9	57.4	
15:00:26	8.86	1.5	15.4	55.1	
15:01:26	8.62	0.0	63.8	56.1	
15:02:26	8.32	0.8	44.9	58.1	
15:03:26	8.81	0.1	13.2	57.2	
15:04:26	8.54	0.2	5.2	56.1	
15:05:26	8.34	0.1	26.5	59.6	
15:06:26	8.89	0.1	9.5	55.3	
15:07:26	8.61	0.0	35.2	56.8	
15:08:26	8.71	0.0	31.7	56.9	
15:09:26	8.57	0.2	16.6	59.9	
15:10:26	8.36	1.6	14.5	59.0	
15:11:26	8.68	1.7	16.9	58.1	
15:12:26	8.72	1.7	23.5	56.4	
15:13:26	8.91	1.4	18.6	55.1	
15:14:26	8.63	1.4	30.7	56.5	
15:15:26	8.79	0.5	9.1	55.4	
15:16:26	8.64	0.5	21.6	57.3	
15:17:26	8.83	0.5	19.2	57.4	
15:18:26	8.44	0.6	16.2	59.3	
15:19:26	8.48	0.0	18.3	58.0	
15:20:26	8.91	1.6	9.5	56.4	
15:21:26	8.22	0.6	11.5	59.6	
15:22:26	7.96	0.7	16.7	60.7	
15:23:26	8.05	0.5	61.5	59.6	
15:24:26	5.40	0.7	57.5	70.8	
15:25:26	5.01	0.8	50.5	73.8	
15:26:26	5.06	1.0	39.8	74.5	
15:27:26	8.05	1.8	25.8	59.3	
15:28:26	10.36	1.6	4.7	47.5	
15:29:26	10.38	1.4	4.3	40.4	
15:30:26	9.62	0.7	2.8	45.2	
15:31:26	9.99	0.5	4.6	47.7	
15:32:26	9.68	0.7	4.9	45.2	
15:33:26	9.11	0.8	16.6	52.2	
15:34:26	8.66	1.0	58.1	53.5	

Time	Oxygen (%) (Dry Gas)	VOC (mgC/m ³) (Wet Gas)	CO (mg/m ³) (Dry Gas)	Nox (mg/m ³) (Dry Gas)	Comment
15:35:26	9.73	1.8	11.6	47.2	
15:36:26	10.58	0.0	4.1	43.4	
15:37:26	12.87	1.6	15.9	38.7	
15:38:26	15.59	0.6	8.0	19.1	
15:39:26	19.18	0.7	29.0	13.4	
15:40:26	18.01	0.5	18.5	19.4	
15:41:26	18.83	0.7	18.5	10.3	
15:42:26	18.58	0.8	12.6	16.1	
15:43:26	18.66	1.0	20.2	14.6	
15:44:26	19.17	1.8	48.9	6.6	
15:45:26	19.57	1.6	41.7	8.3	
15:46:26	17.23	1.4	21.3	7.9	
15:47:26	15.05	0.7	7.2	4.2	
15:48:26	11.27	0.5	16.8	30.3	
15:49:26	9.69	1.2	11.3	44.2	
15:50:26	8.99	1.1	6.6	49.1	
15:51:26	9.23	1.8	5.6	48.1	
15:52:26	8.47	1.6	27.4	51.4	
15:53:26	8.77	1.4	3.9	51.7	
15:54:26	8.70	0.7	3.6	54.1	
15:55:26	8.84	0.5	4.4	49.2	
15:56:26	8.78	1.2	2.8	49.9	
15:57:26	8.28	1.2	29.2	52.7	
15:58:26	7.82	1.1	5.3	46.5	Flare Sampling Ends

Table 3 – Engine, Analyser Calibration Data

ANALYSER CALIBRATION DATA (Engine)					
Pre Sampling Check					
		NO (ppm)	CO (ppm)	O2 (%)	VOC's (ppm)
Range		500	2000	25	1000
Zero Gas	Cylinder No.	DV98PHI			
Span Gas	Cylinder No.	D666204	D666204	VC80253	VC80253
	Certified Value	268.1	1154	8.01	801
Zero Check	Value	0.4	2	0.02	0
<2 x repeatability (Yes/No)		YES	YES	YES	YES
Down Line Zero & Span Check					
Zero Gas	Value	0.1	1	0.13	-1
	<2% of span	YES	YES	YES	YES
Span Gas	Value	269.2	1158	7.99	798
	Within 2% of span	YES	YES	YES	YES
Post Sampling Drift Check					
Zero Gas	Value	4.7	7	0.02	-7
	Drift (%)	1.7	0.5	1.4	0.7
	Validation	No Correction Required	No Correction Required	No Correction Required	No Correction Required
Span Gas	Value	266.6	1171	7.9	799
	Drift (%)	1.0	1.1	1.1	0.1
	Validation	No Correction Required	No Correction Required	No Correction Required	No Correction Required

Table 4 – Flare, Analyser Calibration Data

ANALYSER CALIBRATION DATA (Flare)					
Pre Sampling Check					
		NO (ppm)	CO (ppm)	O2 (%)	VOC's (ppm)
Range		100	200	25	10
Zero Gas	Cylinder No.	DV98PHI			
Span Gas	Cylinder No.	D530838	D530838	AD48FDG	AD48FDG
	Certified Value	89.9	160.5	7.97	10.03
Zero Check	Value	0.01	0.2	0.03	0.02
<2 x repeatability (Yes/No)		YES	YES	YES	YES
Down Line Zero & Span Check					
Zero Gas	Value	-0.2	0.1	0.02	0.02
	<2% of span	YES	YES	YES	YES
Span Gas	Value	89.2	160	7.97	10
	Within 2% of span	YES	YES	YES	YES
Post Sampling Drift Check					
Zero Gas	Value	0.2	-0.2	-0.03	0.04
	Drift (%)	0.4	0.2	0.6	0.2
	Validation	No Correction Required	No Correction Required	No Correction Required	No Correction Required
Span Gas	Value	89.2	162	7.98	10.01
	Drift (%)	0.0	1.2	0.1	0.1
	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 _{rit}	2.37
Drift			U _{odr}	6.67
volume or pressure flow dependence			U _{spres}	0.06
atmosphseric pressure dependence			U _{apres}	0.59
ambient temperature dependence			U _{temp}	0.52
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}	0.60
losses in the line (leak)			U _{leak}	1.50
Uncertainty of calibration gas			U _{calib}	1.50
NOx Measurement uncertainty		Result	129.59	mg/m ³
Combined uncertainty			7.47	mg/m ³
Expanded uncertainty	k = 2		14.94	mg/m ³
Uncertainty corrected to std conds			14.94	mg.m-3 (corrected)
Expanded uncertainty		expressed with a level of confidence of 95%	2.30 % ELV	
Expanded uncertainty		expressed with a level of confidence of 95%	14.94 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 _{rit}	5.77	
Drift		U _{odr}	21.49	
volume or pressure flow dependence		U _{spres}	0.00	
atmospheric pressure dependence		U _{apres}	1.15	
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}	14.11	
Uncertainty of calibration gas		U _{calib}	14.11	
CO Measurement uncertainty		Result	1222.18	mg/m ³
Combined uncertainty			29.98	mg/m ³
Expanded uncertainty	k = 2		59.96	mg/m ³
Uncertainty corrected to std conds			59.96	mg.m-3 (corrected)
Expanded uncertainty		expressed with a level of confidence of 95%		4.00 % ELV
Expanded uncertainty		expressed with a level of confidence of 95%		59.96 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 _{odr}	17.98
volume or pressure flow dependence			U _{spres}	0.00
atmosphseric pressure dependence			U _{apres}	0.75
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}	17.25
Uncertainty of calibration gas			U _{calib}	17.25
VOC Measurement uncertainty		Result	1493.78	mg/m ³
Combined uncertainty			30.56	mg/m ³
Expanded uncertainty	k = 2		61.12	mg/m ³
Uncertainty corrected to std conds			61.12	mg.m-3 (corrected)
Expanded uncertainty	expressed with a level of confidence of 95%		3.49 % ELV	
Expanded uncertainty	expressed with a level of confidence of 95%		61.12 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_{odr}	0.11
volume or pressure flow dependence			U_{spres}	0.00
atmopsheric pressure dependence			U_{apres}	0.01
ambient temperature dependence			U_{temp}	0.08
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	6.89	%vol
Combined uncertainty			0.21	%vol
% of value			2.98	%
Expanded uncertainty		expressed with a level of confidence of 95%	5.96 % of value	
Expanded uncertainty		expressed with a level of confidence of 95%	0.41 % 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 _{odr}	1.46
volume or pressure flow dependence			U _{spres}	0.01
atmospheric pressure dependence			U _{apres}	0.12
ambient temperature dependence			U _{temp}	0.58
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}	0.22
losses in the line (leak)			U _{leak}	0.55
Uncertainty of calibration gas			U _{calib}	0.55
NOx Measurement uncertainty		Result	47.99	mg/m ³
Combined uncertainty			1.85	mg/m ³
Expanded uncertainty	k = 2		3.70	mg/m ³
Uncertainty corrected to std conds			3.70	mg.m-3 (corrected)
Expanded uncertainty		expressed with a level of confidence of 95%	2.47 % ELV	
Expanded uncertainty		expressed with a level of confidence of 95%	3.70 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 _{odr}	1.64	
volume or pressure flow dependence		U _{spres}	0.00	
atmosphseric pressure dependence		U _{apres}	0.12	
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}	0.40	
Uncertainty of calibration gas		U _{calib}	0.40	
CO Measurement uncertainty		Result	34.70	mg/m ³
Combined uncertainty			1.85	mg/m ³
Expanded uncertainty	k = 2		3.70	mg/m ³
Uncertainty corrected to std conds			3.70	mg.m-3 (corrected)
Expanded uncertainty		expressed with a level of confidence of 95%		7.40 % ELV
Expanded uncertainty		expressed with a level of confidence of 95%		3.70 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 _{odr}	0.10
volume or pressure flow dependence			U _{spres}	0.00
atmosphseric pressure dependence			U _{apres}	0.01
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	1.47	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%		3.11 % 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}	0.12
Drift			U _{odr}	0.13
volume or pressure flow dependence			U _{spres}	0.00
atmospheric pressure dependence			U _{apres}	0.01
ambient temperature dependence			U _{temp}	0.09
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}	0.12
Error in Logger voltage			-	0.03
Uncertainty of calibration gas			U _{calib}	0.12
O2 Measurement uncertainty		Result	10.31	%vol
Combined uncertainty			0.27	%vol
% of value			2.62	%
Expanded uncertainty		expressed with a level of confidence of 95%	5.25 % of value	
Expanded uncertainty		expressed with a level of confidence of 95%	0.54 % vol	

2.4 Appendix IV: Moisture Calculations

2.4.1 Engine, Uncertainties

Test No	T1			Site	Flintshire CC		
Date	17-3-15				Brookhill		
pbar (mbar)	1002			Stack	Engine		
pbar (mmHg)	752			Job Number:	R15100		
Nozzle Diameter (mm)	n/a			Site Team:	BK, YS, TB		
Temp of Meter (in)/(out) deg. C	15			Data Entered By:	Yu Shen		
ΔH_{ave} (mmH ₂ O)	10.0						
DGM Cal Factor (Y)	1.0103						
				Enter Data into coloured cells only			
Start Volume Reading	660.1970	m ³		Start time	15:15	hr:min	
End Volume Reading	660.7220	m ³		End time	16:15	hr:min	
Volume Sampled	0.5304	m ³		Total time	01:00	hr:min	
IMPINGER	1	2	3	4	Initials of Analyst		
Absorber Solution (Type):	H ₂ O	H ₂ O	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)	777.3	775.3	566.2	806.2	YS		
Final Weight of Impingers plus absorber (g)	817.5	781.9	567.3	814.6	YS		
Weight Gain (g)	40.2	6.6	1.1	8.4			
Total Weight Gain (1+2+3+4) (g)	56.3						
Gas Volume of water at 0 °C (l)	70.09						
Gas Meter volume at 0 °C (l)	498.67						
Moisture content of Gases (%)	12.3						

2.4.2 Flare, Uncertainties

Test No	T2		Site	Flintshire CC		
Date	17-3-15			Brookhill LFS		
pbar (mbar)	1002		Stack	FLARE		
pbar (mmHg)	752		Job Number:	R15100		
Nozzle Diameter (mm)	n/a		Site Team:	YS + TB + BK		
Temp of Meter (in)/(out) deg. C	14		Data Entered By:	Yu Shen		
ΔH_{ave} (mmH ₂ O)	10.0		Enter Data into coloured cells only			
DGM Cal Factor (Y)	0.9272					
Start Volume Reading	749.1305	m ³	Start time	14:58	hr:min	
End Volume Reading	749.7212	m ³	End time	15:58	hr:min	
Volume Sampled	0.5477	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)	778.2	774.7	565.0	805.6	YS	
Final Weight of Impingers plus absorber (g)	815.2	776.5	565.5	813.5	YS	
Weight Gain (g)	37.0	1.8	0.5	7.9		
Total Weight Gain (1+2+3+4) (g)	47.2					
Gas Volume of water at 0 °C (l)	58.76					
Gas Meter volume at 0 °C (l)	515.83					
Moisture content of Gases (%)	10.2					