

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

**Part 1: Executive Summary**

Permit Number: 37073

Operator: Flintshire County Council

Installation: Standard Landfill Site (Engine & Flare)



4251

Monitoring dates: 17<sup>th</sup> March 2015

Job Number: **R15099**

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: 2<sup>nd</sup> April 2015

Report Approved By: Yu Shen

MCERTS Registration Number: MM 06 727 (Level II, TE1, 2, 3 & 4)

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 Standard 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 37073 are summarised below:

| Substances to be monitored               | Emission Point Identification |  |             |
|------------------------------------------|-------------------------------|--|-------------|
|                                          | Engine                        |  | Flare Stack |
| Oxides of Nitrogen (as NO <sub>2</sub> ) | ✓                             |  | ✓           |
| 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 <sub>2</sub> )    | 650                  | 278                        | ±18                                            | mg(N)m <sup>-3</sup> | 101.3kPa, 273K, dry gas, 5% Oxygen | 17/03/2015       | 12:30-13:30         | BS EN 14792                 | A                                                | At 65% MCR       |
|                          | Carbon Monoxide                             | 1500                 | 628                        | ±42                                            | mg(N)m <sup>-3</sup> |                                    |                  |                     | BS EN 15058                 | A                                                |                  |
|                          | Volatile Organic Compounds (VOCs as carbon) | 1750                 | 1435                       | ±51                                            | mg(N)m <sup>-3</sup> |                                    |                  |                     | BS EN 12619                 | A                                                |                  |
|                          | Moisture                                    | -                    | 12.0                       | n/a                                            | %                    | 101.3kPa, 273K, dry gas            |                  | 12:30-13:30         | BS EN 14790                 | A                                                |                  |
|                          | Oxygen                                      | -                    | 6.15                       | ±0.37                                          | %                    |                                    |                  | 12:30-13:30         | 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 <sub>2</sub> )    | 150                  | 43.6                       | ±3.1                                           | mg(N)m <sup>3</sup> | 101.3kPa, 273K, dry gas, 3% Oxygen | 17/03/2015       | 12:07-13:07         | BS EN 14792                 | A                                                | At 50% MCR       |
|                          | Carbon Monoxide                             | 50                   | 49.7                       | ±3.6                                           | mg(N)m <sup>3</sup> |                                    |                  |                     | BS EN 15058                 | A                                                |                  |
|                          | Volatile Organic Compounds (VOCs as carbon) | 10                   | 0.01                       | ±0.3                                           | mg(N)m <sup>3</sup> |                                    |                  |                     | BS EN 12619                 | A                                                |                  |
|                          | Moisture                                    | -                    | 10.1                       | n/a                                            | %                   | 101.3kPa, 273K, dry gas            |                  | 12:02-13:02         | BS EN 14790                 | A                                                |                  |
|                          | Oxygen                                      | -                    | 9.67                       | ±0.49                                          | %                   |                                    |                  | 12:07-13:07         | BS EN 14789                 | A                                                |                  |

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### 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      | 650kWe Output<br>@ 1000kWe unit                         | N/A                                                         | N/A          | N/A                         | N/A   |
| Flare Stack              | 17/03/2015 | When required | N/A              | Landfill Gas | N/A       | None      | 250m <sup>3</sup> /hr<br>Rated at 500m <sup>3</sup> /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

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### 2.1 Appendix I: General Information

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#### 2.1.1 Monitoring organisation staff details

Monitoring at Standard 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% O<sub>2</sub> for the engine and 3% O<sub>2</sub> for the flare.

##### 2.1.2.2 NO<sub>x</sub> (as NO<sub>2</sub>)

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<sub>x</sub> within the sample, measured the concentration of NO<sub>x</sub> (as NO<sub>2</sub>) 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 O<sub>2</sub>

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 O<sub>2</sub> 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,  $\text{Conc}_{\text{ref}}$  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 Photos of Sampling Location on Engine



Engine sampled from  
10mm turbo port on  
vertical section of approx.  
0.25m diameter stack.



Engine Stack

### 2.2.2 Photo of Sampling Location on Flare

Flare sampled from a TOP EXIT on vertical section of approx. 1m diameter stack. Accessed via portable MAST.



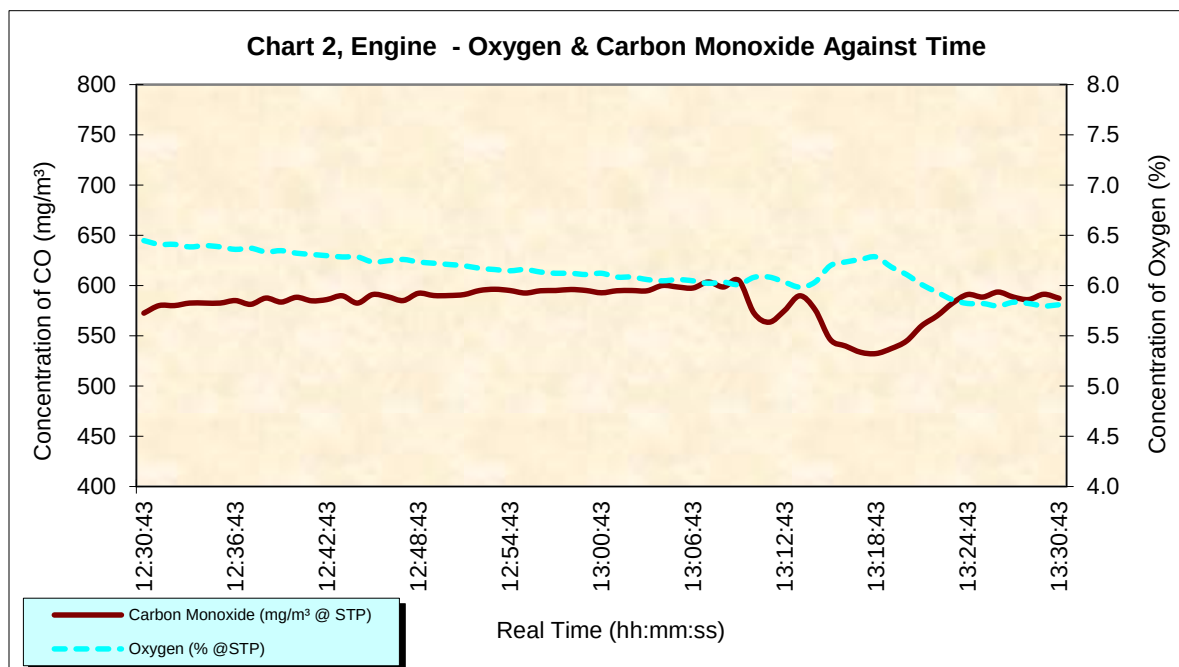
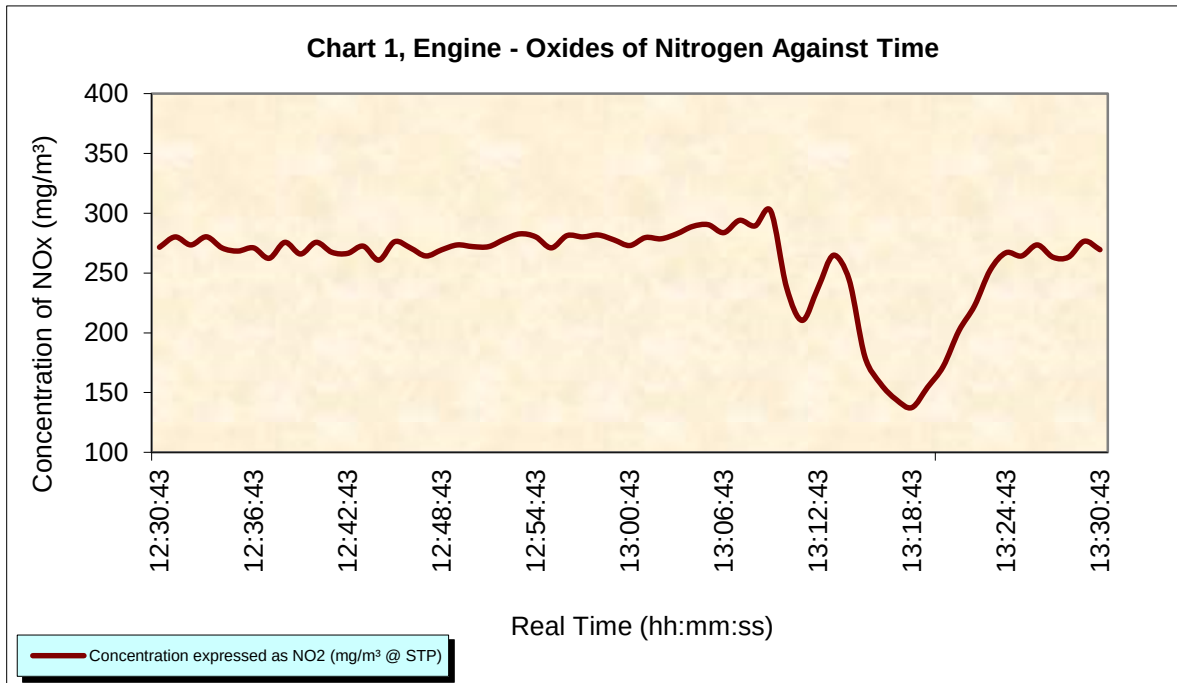
### 2.2.3 Homogeneity testing

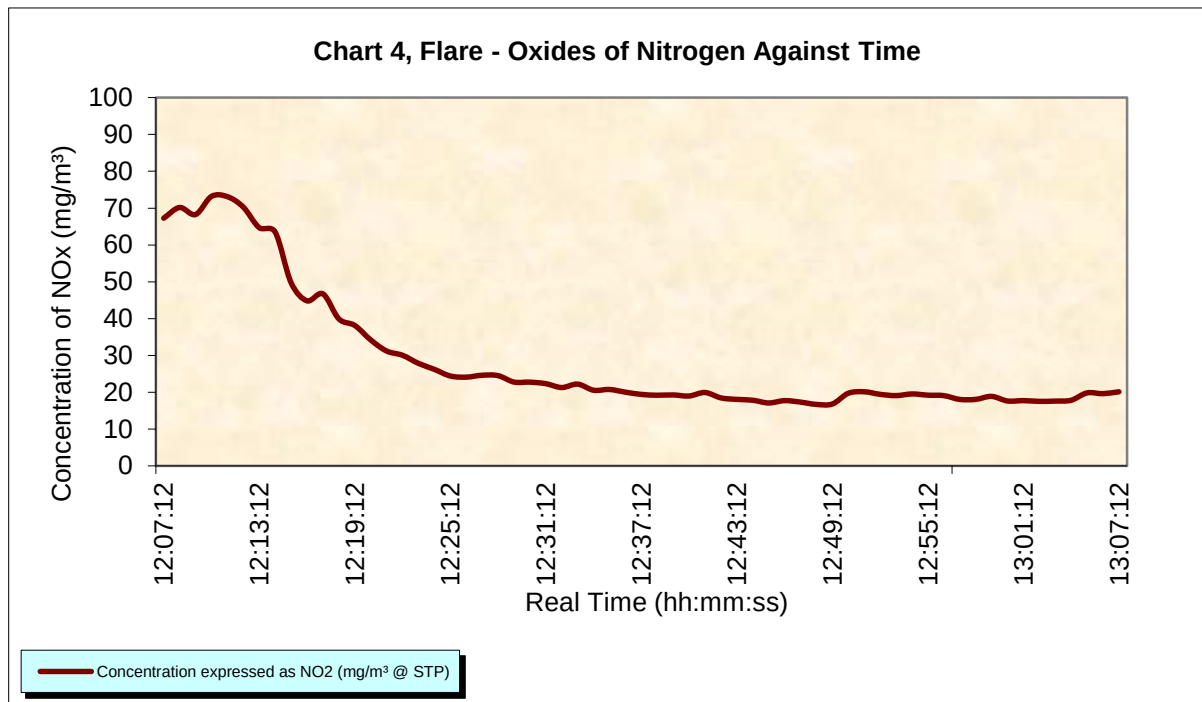
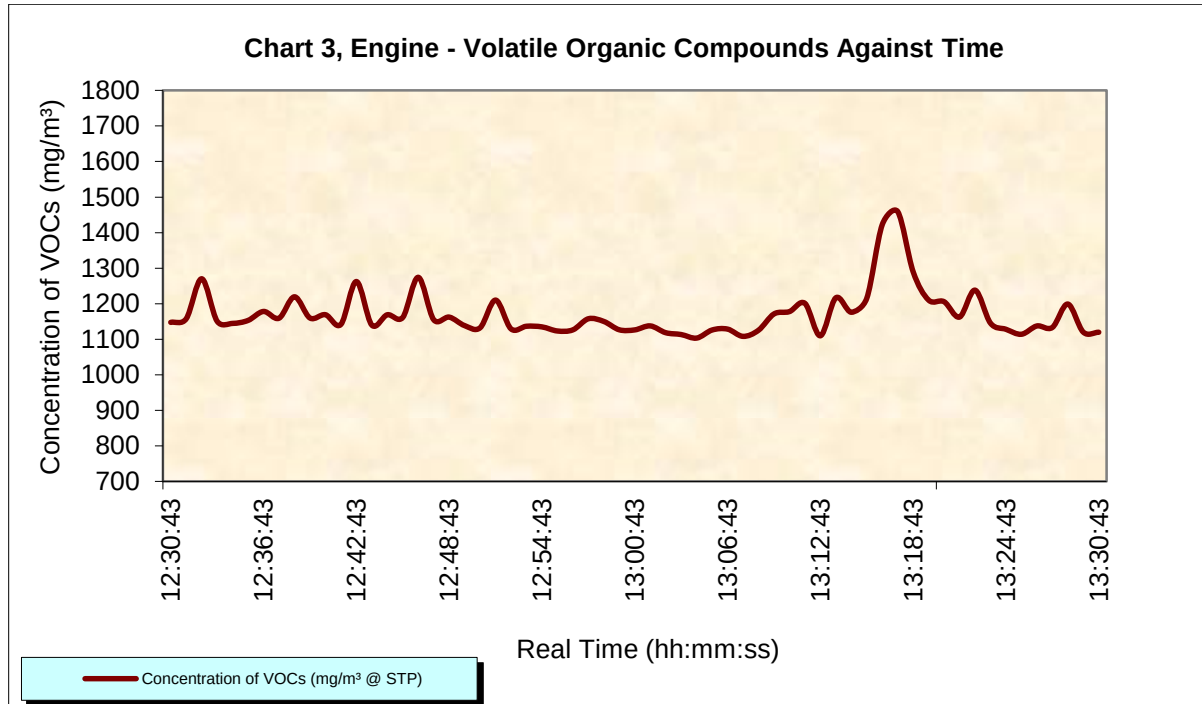
BS EN 15259 stipulates that the exhaust gases emitted from combustion processes are tested to ensure homogeneity and that a representative sample is obtained during the monitoring, subject to a number of caveats as elucidated in Environment Agency guidance MID15259. The details of the testing at each 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  $\text{mgm}^{-3}$  @ STP and is uncorrected for  $\text{O}_2$ . 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.





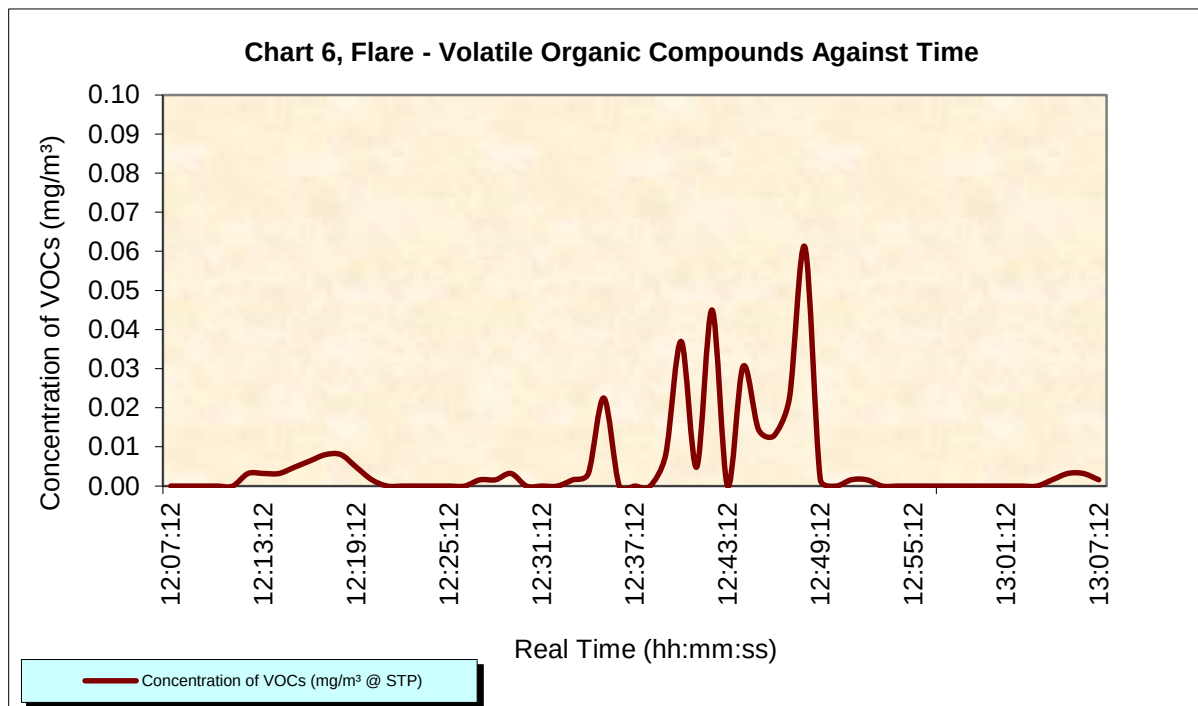
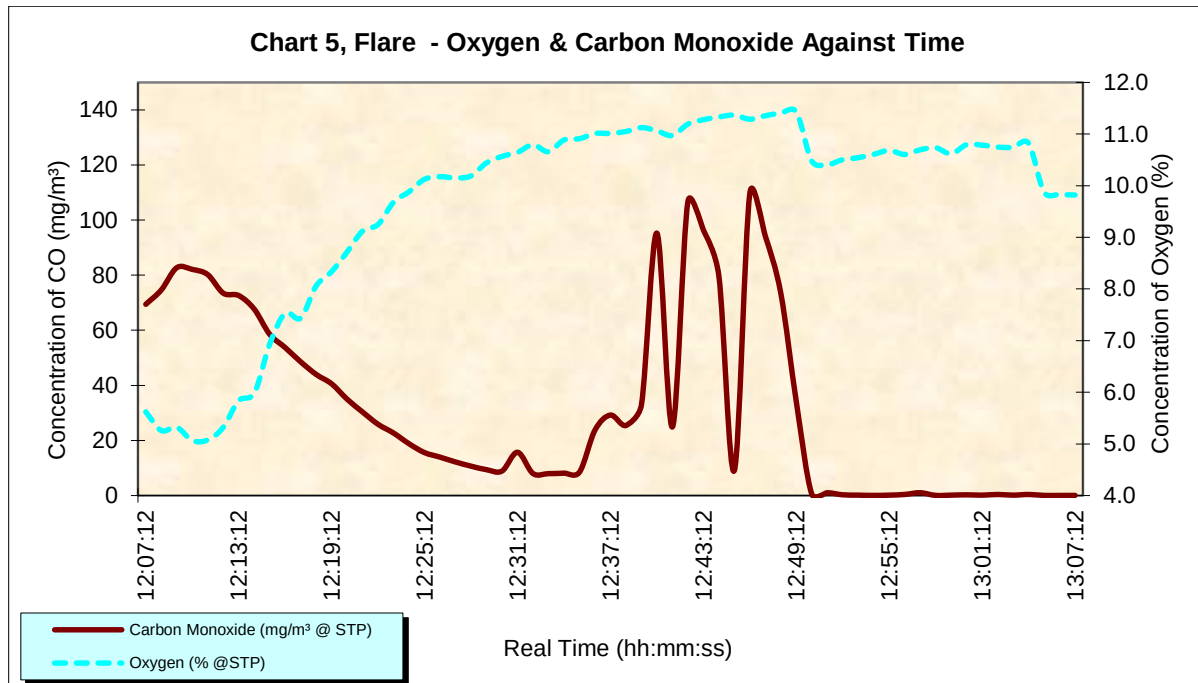


**Table 1 – Engine, Raw Data**

| Time     | Oxygen (%)<br>(Dry Gas) | VOC (mgC/m <sup>3</sup> )<br>(Wet Gas) | CO (mg/m <sup>3</sup> )<br>(Dry Gas) | Nox (mg/m <sup>3</sup> )<br>(Dry Gas) | Comment                |
|----------|-------------------------|----------------------------------------|--------------------------------------|---------------------------------------|------------------------|
| 12:30:43 | 6.4                     | 1147.98                                | 572.5                                | 271.6                                 | Engine Sampling Starts |
| 12:31:43 | 6.4                     | 1158.11                                | 580.0                                | 280.2                                 |                        |
| 12:32:43 | 6.4                     | 1270.45                                | 580.0                                | 273.5                                 |                        |
| 12:33:43 | 6.4                     | 1151.04                                | 582.5                                | 280.3                                 |                        |
| 12:34:43 | 6.4                     | 1145.09                                | 582.5                                | 271.0                                 |                        |
| 12:35:43 | 6.4                     | 1153.45                                | 582.5                                | 268.4                                 |                        |
| 12:36:43 | 6.4                     | 1178.68                                | 585.0                                | 271.1                                 |                        |
| 12:37:43 | 6.4                     | 1159.71                                | 581.3                                | 262.3                                 |                        |
| 12:38:43 | 6.3                     | 1219.82                                | 587.5                                | 275.7                                 |                        |
| 12:39:43 | 6.3                     | 1160.20                                | 583.5                                | 265.9                                 |                        |
| 12:40:43 | 6.3                     | 1169.52                                | 588.3                                | 275.7                                 |                        |
| 12:41:43 | 6.3                     | 1142.20                                | 584.8                                | 267.4                                 |                        |
| 12:42:43 | 6.3                     | 1262.73                                | 586.0                                | 266.5                                 |                        |
| 12:43:43 | 6.3                     | 1140.27                                | 589.8                                | 272.5                                 |                        |
| 12:44:43 | 6.3                     | 1169.36                                | 582.5                                | 260.8                                 |                        |
| 12:45:43 | 6.2                     | 1161.80                                | 591.0                                | 276.2                                 |                        |
| 12:46:43 | 6.2                     | 1274.63                                | 588.8                                | 271.1                                 |                        |
| 12:47:43 | 6.3                     | 1155.38                                | 585.0                                | 264.3                                 |                        |
| 12:48:43 | 6.2                     | 1162.77                                | 592.3                                | 269.4                                 |                        |
| 12:49:43 | 6.2                     | 1138.82                                | 590.0                                | 273.5                                 |                        |
| 12:50:43 | 6.2                     | 1132.71                                | 590.0                                | 272.1                                 |                        |
| 12:51:43 | 6.2                     | 1210.50                                | 591.0                                | 272.1                                 |                        |
| 12:52:43 | 6.2                     | 1129.66                                | 595.0                                | 278.2                                 |                        |
| 12:53:43 | 6.2                     | 1137.05                                | 596.3                                | 282.8                                 |                        |
| 12:54:43 | 6.1                     | 1135.29                                | 595.0                                | 280.3                                 |                        |
| 12:55:43 | 6.2                     | 1123.71                                | 592.5                                | 271.1                                 |                        |
| 12:56:43 | 6.1                     | 1126.93                                | 594.8                                | 281.3                                 |                        |
| 12:57:43 | 6.1                     | 1158.11                                | 595.0                                | 280.2                                 |                        |
| 12:58:43 | 6.1                     | 1150.55                                | 596.0                                | 281.9                                 |                        |
| 12:59:43 | 6.1                     | 1127.09                                | 595.0                                | 277.7                                 |                        |
| 13:00:43 | 6.1                     | 1126.77                                | 592.8                                | 273.0                                 |                        |
| 13:01:43 | 6.1                     | 1138.02                                | 594.8                                | 279.7                                 |                        |
| 13:02:43 | 6.1                     | 1118.89                                | 595.0                                | 278.7                                 |                        |
| 13:03:43 | 6.1                     | 1113.75                                | 594.8                                | 282.8                                 |                        |
| 13:04:43 | 6.0                     | 1103.79                                | 600.0                                | 288.9                                 |                        |
| 13:05:43 | 6.1                     | 1126.45                                | 598.5                                | 290.5                                 |                        |
| 13:06:43 | 6.0                     | 1129.02                                | 597.5                                | 283.8                                 |                        |
| 13:07:43 | 6.0                     | 1108.61                                | 603.5                                | 294.1                                 |                        |

| Time     | Oxygen (%)<br>(Dry Gas) | VOC (mgC/m <sup>3</sup> )<br>(Wet Gas) | CO (mg/m <sup>3</sup> )<br>(Dry Gas) | Nox (mg/m <sup>3</sup> )<br>(Dry Gas) | Comment              |
|----------|-------------------------|----------------------------------------|--------------------------------------|---------------------------------------|----------------------|
| 13:08:43 | 6.0                     | 1125.80                                | 598.5                                | 289.5                                 |                      |
| 13:09:43 | 6.0                     | 1171.61                                | 605.0                                | 301.8                                 |                      |
| 13:10:43 | 6.1                     | 1178.20                                | 572.5                                | 238.2                                 |                      |
| 13:11:43 | 6.1                     | 1201.50                                | 563.5                                | 210.4                                 |                      |
| 13:12:43 | 6.0                     | 1110.21                                | 575.0                                | 237.2                                 |                      |
| 13:13:43 | 6.0                     | 1216.93                                | 589.8                                | 264.9                                 |                      |
| 13:14:43 | 6.0                     | 1176.43                                | 576.0                                | 244.4                                 |                      |
| 13:15:43 | 6.2                     | 1215.48                                | 546.3                                | 180.1                                 |                      |
| 13:16:43 | 6.2                     | 1422.48                                | 539.8                                | 157.5                                 |                      |
| 13:17:43 | 6.3                     | 1459.45                                | 533.5                                | 144.2                                 |                      |
| 13:18:43 | 6.3                     | 1290.05                                | 532.3                                | 137.5                                 |                      |
| 13:19:43 | 6.2                     | 1210.50                                | 537.3                                | 154.4                                 |                      |
| 13:20:43 | 6.1                     | 1206.00                                | 544.8                                | 171.9                                 |                      |
| 13:21:43 | 6.0                     | 1162.93                                | 560.0                                | 201.7                                 |                      |
| 13:22:43 | 5.9                     | 1238.46                                | 569.8                                | 222.7                                 |                      |
| 13:23:43 | 5.9                     | 1145.73                                | 582.3                                | 252.5                                 |                      |
| 13:24:43 | 5.8                     | 1128.54                                | 591.0                                | 267.0                                 |                      |
| 13:25:43 | 5.8                     | 1114.55                                | 588.5                                | 264.3                                 |                      |
| 13:26:43 | 5.8                     | 1137.86                                | 593.5                                | 273.5                                 |                      |
| 13:27:43 | 5.8                     | 1133.68                                | 588.5                                | 263.3                                 |                      |
| 13:28:43 | 5.8                     | 1199.41                                | 586.0                                | 263.4                                 |                      |
| 13:29:43 | 5.8                     | 1120.50                                | 591.3                                | 276.6                                 |                      |
| 13:30:43 | 5.8                     | 1120.18                                | 587.3                                | 269.5                                 | Engine Sampling Ends |

**Table 2 – Flare, Raw Data**

| Time     | Oxygen (%)<br>(Dry Gas) | VOC (mgC/m <sup>3</sup> )<br>(Wet Gas) | CO (mg/m <sup>3</sup> )<br>(Dry Gas) | Nox (mg/m <sup>3</sup> )<br>(Dry Gas) | Comment               |
|----------|-------------------------|----------------------------------------|--------------------------------------|---------------------------------------|-----------------------|
| 12:07:12 | 5.6                     | 0.00                                   | 69.4                                 | 67.3                                  | Flare Sampling Starts |
| 12:08:12 | 5.3                     | 0.00                                   | 74.6                                 | 70.2                                  |                       |
| 12:09:12 | 5.3                     | 0.00                                   | 82.7                                 | 68.2                                  |                       |
| 12:10:12 | 5.1                     | 0.00                                   | 82.1                                 | 73.2                                  |                       |
| 12:11:12 | 5.1                     | 0.00                                   | 80.2                                 | 73.1                                  |                       |
| 12:12:12 | 5.3                     | 0.00                                   | 73.5                                 | 70.3                                  |                       |
| 12:13:12 | 5.8                     | 0.00                                   | 72.6                                 | 64.7                                  |                       |
| 12:14:12 | 6.0                     | 0.00                                   | 67.7                                 | 63.5                                  |                       |
| 12:15:12 | 6.9                     | 0.00                                   | 58.5                                 | 49.8                                  |                       |
| 12:16:12 | 7.5                     | 0.01                                   | 53.7                                 | 44.8                                  |                       |
| 12:17:12 | 7.4                     | 0.01                                   | 48.5                                 | 46.7                                  |                       |
| 12:18:12 | 8.1                     | 0.01                                   | 44.0                                 | 39.9                                  |                       |
| 12:19:12 | 8.3                     | 0.00                                   | 40.5                                 | 38.2                                  |                       |

| Time     | Oxygen (%)<br>(Dry Gas) | VOC (mgC/m <sup>3</sup> )<br>(Wet Gas) | CO (mg/m <sup>3</sup> )<br>(Dry Gas) | Nox (mg/m <sup>3</sup> )<br>(Dry Gas) | Comment |
|----------|-------------------------|----------------------------------------|--------------------------------------|---------------------------------------|---------|
| 12:20:12 | 8.7                     | 0.00                                   | 35.0                                 | 34.2                                  |         |
| 12:21:12 | 9.1                     | 0.00                                   | 30.3                                 | 31.2                                  |         |
| 12:22:12 | 9.2                     | 0.00                                   | 25.8                                 | 30.1                                  |         |
| 12:23:12 | 9.7                     | 0.00                                   | 22.7                                 | 27.9                                  |         |
| 12:24:12 | 9.9                     | 0.00                                   | 18.8                                 | 26.2                                  |         |
| 12:25:12 | 10.1                    | 0.00                                   | 15.6                                 | 24.4                                  |         |
| 12:26:12 | 10.2                    | 0.00                                   | 13.9                                 | 24.1                                  |         |
| 12:27:12 | 10.1                    | 0.00                                   | 12.2                                 | 24.6                                  |         |
| 12:28:12 | 10.2                    | 0.00                                   | 10.6                                 | 24.5                                  |         |
| 12:29:12 | 10.4                    | 0.00                                   | 9.4                                  | 22.8                                  |         |
| 12:30:12 | 10.6                    | 0.00                                   | 8.9                                  | 22.8                                  |         |
| 12:31:12 | 10.6                    | 0.00                                   | 15.7                                 | 22.4                                  |         |
| 12:32:12 | 10.8                    | 0.00                                   | 8.0                                  | 21.3                                  |         |
| 12:33:12 | 10.7                    | 0.00                                   | 7.9                                  | 22.2                                  |         |
| 12:34:12 | 10.9                    | 0.00                                   | 8.1                                  | 20.6                                  |         |
| 12:35:12 | 10.9                    | 0.02                                   | 8.5                                  | 20.8                                  |         |
| 12:36:12 | 11.0                    | 0.00                                   | 23.7                                 | 20.1                                  |         |
| 12:37:12 | 11.0                    | 0.00                                   | 29.2                                 | 19.4                                  |         |
| 12:38:12 | 11.0                    | 0.00                                   | 25.4                                 | 19.2                                  |         |
| 12:39:12 | 11.1                    | 0.01                                   | 32.9                                 | 19.3                                  |         |
| 12:40:12 | 11.1                    | 0.04                                   | 95.3                                 | 19.0                                  |         |
| 12:41:12 | 11.0                    | 0.00                                   | 24.9                                 | 20.0                                  |         |
| 12:42:12 | 11.2                    | 0.05                                   | 106.7                                | 18.5                                  |         |
| 12:43:12 | 11.3                    | 0.00                                   | 96.5                                 | 18.1                                  |         |
| 12:44:12 | 11.3                    | 0.03                                   | 79.7                                 | 17.9                                  |         |
| 12:45:12 | 11.4                    | 0.01                                   | 9.1                                  | 17.1                                  |         |
| 12:46:12 | 11.3                    | 0.01                                   | 109.7                                | 17.8                                  |         |
| 12:47:12 | 11.4                    | 0.02                                   | 94.2                                 | 17.4                                  |         |
| 12:48:12 | 11.4                    | 0.06                                   | 73.4                                 | 16.7                                  |         |
| 12:49:12 | 11.4                    | 0.00                                   | 34.1                                 | 16.8                                  |         |
| 12:50:12 | 10.5                    | 0.00                                   | 0.5                                  | 19.8                                  |         |
| 12:51:12 | 10.4                    | 0.00                                   | 1.0                                  | 20.2                                  |         |
| 12:52:12 | 10.5                    | 0.00                                   | 0.2                                  | 19.5                                  |         |
| 12:53:12 | 10.5                    | 0.00                                   | 0.1                                  | 19.1                                  |         |
| 12:54:12 | 10.6                    | 0.00                                   | 0.0                                  | 19.6                                  |         |
| 12:55:12 | 10.7                    | 0.00                                   | 0.1                                  | 19.2                                  |         |
| 12:56:12 | 10.6                    | 0.00                                   | 0.4                                  | 19.1                                  |         |
| 12:57:12 | 10.7                    | 0.00                                   | 1.0                                  | 18.1                                  |         |
| 12:58:12 | 10.7                    | 0.00                                   | 0.0                                  | 18.1                                  |         |
| 12:59:12 | 10.6                    | 0.00                                   | 0.1                                  | 18.9                                  |         |
| 13:00:12 | 10.8                    | 0.00                                   | 0.2                                  | 17.7                                  |         |
| 13:01:12 | 10.8                    | 0.00                                   | 0.1                                  | 17.8                                  |         |
| 13:02:12 | 10.7                    | 0.00                                   | 0.4                                  | 17.6                                  |         |
| 13:03:12 | 10.7                    | 0.00                                   | 0.1                                  | 17.6                                  |         |
| 13:04:12 | 10.8                    | 0.00                                   | 0.4                                  | 17.9                                  |         |
| 13:05:12 | 9.9                     | 0.00                                   | 0.0                                  | 19.9                                  |         |

| Time     | Oxygen (%)<br>(Dry Gas) | VOC (mgC/m <sup>3</sup> )<br>(Wet Gas) | CO (mg/m <sup>3</sup> )<br>(Dry Gas) | Nox (mg/m <sup>3</sup> )<br>(Dry Gas) | Comment             |
|----------|-------------------------|----------------------------------------|--------------------------------------|---------------------------------------|---------------------|
| 13:06:12 | 9.8                     | 0.00                                   | 0.0                                  | 19.7                                  |                     |
| 13:07:12 | 9.8                     | 0.00                                   | 0.0                                  | 20.2                                  | 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             | 0.5                    | 3                      | 0.03                   | 0                      |
| <2 x repeatability (Yes/No)        |                   | YES                    | YES                    | YES                    | YES                    |
| Down Line Zero & Span Check        |                   |                        |                        |                        |                        |
| Zero Gas                           | Value             | 0.2                    | 1                      | 0.14                   | -2                     |
|                                    | <2% of span       | YES                    | YES                    | YES                    | YES                    |
| Span Gas                           | Value             | 269.2                  | 1156                   | 7.97                   | 794                    |
|                                    | Within 2% of span | YES                    | YES                    | YES                    | YES                    |
| Post Sampling Drift Check          |                   |                        |                        |                        |                        |
| Zero Gas                           | Value             | 4.4                    | 5                      | 0.13                   | 6                      |
|                                    | Drift (%)         | 1.6                    | 0.3                    | 0.1                    | 1.0                    |
|                                    | Validation        | No Correction Required | No Correction Required | No Correction Required | No Correction Required |
| Span Gas                           | Value             | 269.3                  | 1162                   | 7.9                    | 796                    |
|                                    | Drift (%)         | 0.0                    | 0.5                    | 0.9                    | 0.2                    |
|                                    | Validation        | No Correction Required | No Correction Required | No Correction Required | No Correction Required |

**Table 4 – Flare, Analyser Calibration Data**

| <b>ANALYSER CALIBRATION DATA (Flare)</b> |                          |                        |                        |                        |                        |
|------------------------------------------|--------------------------|------------------------|------------------------|------------------------|------------------------|
| <b>Pre Sampling Check</b>                |                          |                        |                        |                        |                        |
|                                          |                          | <b>NO (ppm)</b>        | <b>CO (ppm)</b>        | <b>O2 (%)</b>          | <b>VOC's (ppm)</b>     |
| <b>Range</b>                             |                          | 100                    | 200                    | 25                     | 10                     |
| <b>Zero Gas</b>                          | <b>Cylinder No.</b>      | DV98PHI                |                        |                        |                        |
| <b>Span Gas</b>                          | <b>Cylinder No.</b>      | D530838                | D530838                | AC48FDG                | AC48FDG                |
|                                          | <b>Certified Value</b>   | 89.9                   | 160.5                  | 7.97                   | 10.03                  |
| <b>Zero Check</b>                        | <b>Value</b>             | 0.2                    | 0.2                    | 0.02                   | 0.03                   |
| <b>&lt;2 x repeatability (Yes/No)</b>    |                          | YES                    | YES                    | YES                    | YES                    |
| <b>Down Line Zero &amp; Span Check</b>   |                          |                        |                        |                        |                        |
| <b>Zero Gas</b>                          | <b>Value</b>             | 0.2                    | 0.2                    | 0.02                   | 0.04                   |
|                                          | <b>&lt;2% of span</b>    | YES                    | YES                    | YES                    | YES                    |
| <b>Span Gas</b>                          | <b>Value</b>             | 89                     | 159.4                  | 7.98                   | 10.07                  |
|                                          | <b>Within 2% of span</b> | YES                    | YES                    | YES                    | YES                    |
| <b>Post Sampling Drift Check</b>         |                          |                        |                        |                        |                        |
| <b>Zero Gas</b>                          | <b>Value</b>             | -0.2                   | -0.2                   | 0.04                   | -0.02                  |
|                                          | <b>Drift (%)</b>         | 0.4                    | 0.2                    | 0.3                    | 0.6                    |
|                                          | <b>Validation</b>        | No Correction Required | No Correction Required | No Correction Required | No Correction Required |
| <b>Span Gas</b>                          | <b>Value</b>             | 89.1                   | 157.4                  | 7.98                   | 9.99                   |
|                                          | <b>Drift (%)</b>         | 0.1                    | 1.2                    | 0.0                    | 0.8                    |
|                                          | <b>Validation</b>        | 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 <sub>r0</sub>                    | 0.80                          |
| Standard deviation of repeatability at span level              |       |                                             | U <sub>rs</sub>                    | 0.10                          |
| Lack of fit                                                    |       |                                             | U <sub>rit</sub>                   | 2.37                          |
| Drift                                                          |       |                                             | U <sub>odr</sub>                   | 7.41                          |
| volume or pressure flow dependence                             |       |                                             | U <sub>spres</sub>                 | 0.06                          |
| atmosphseric pressure dependence                               |       |                                             | U <sub>apres</sub>                 | 0.59                          |
| ambient temperature dependence                                 |       |                                             | U <sub>temp</sub>                  | 0.35                          |
| NH3 (20 mg/m3)                                                 |       |                                             | U <sub>interf</sub>                | 0.14                          |
| CO2 (15%)                                                      |       |                                             | -                                  | 0.02                          |
| H2O (30%)                                                      |       |                                             | -                                  | 0.01                          |
| Error in logger voltage                                        |       |                                             | -                                  | 0.50                          |
| Dependence on voltage                                          |       |                                             | U <sub>vdt</sub>                   | 0.03                          |
| Converter efficiency                                           |       |                                             | U <sub>ceff</sub>                  | 1.19                          |
| losses in the line (leak)                                      |       |                                             | U <sub>leak</sub>                  | 2.98                          |
| Uncertainty of calibration gas                                 |       |                                             | U <sub>calib</sub>                 | 2.98                          |
|                                                                |       |                                             |                                    |                               |
| NOx Measurement uncertainty                                    |       | Result                                      | 258.07                             | mg/m <sup>3</sup>             |
| Combined uncertainty                                           |       |                                             | 8.97                               | mg/m <sup>3</sup>             |
| Expanded uncertainty                                           | k = 2 |                                             | 17.94                              | mg/m <sup>3</sup>             |
| Uncertainty corrected to std conds                             |       |                                             | 17.94                              | mg.m-3 (corrected)            |
| Expanded uncertainty                                           |       | expressed with a level of confidence of 95% | 2.76 % ELV                         |                               |
| Expanded uncertainty                                           |       | expressed with a level of confidence of 95% | 17.94 mg.m <sup>-3</sup> of result |                               |

| CO - Measurement performance related to stationary conditions |       |                                             |                                    |                    |
|---------------------------------------------------------------|-------|---------------------------------------------|------------------------------------|--------------------|
| Performance characteristic                                    |       | Uncertainty                                 | Value of uncertainty quantity      |                    |
| Standard deviation of repeatability at zero                   |       | U <sub>r0</sub>                             | 0.80                               |                    |
| Standard deviation of repeatability at span level             |       | U <sub>rs</sub>                             | 0.10                               |                    |
| Lack of fit                                                   |       | U <sub>fit</sub>                            | 5.77                               |                    |
| Drift                                                         |       | U <sub>odr</sub>                            | 17.80                              |                    |
| volume or pressure flow dependence                            |       | U <sub>spres</sub>                          | 0.00                               |                    |
| atmosphseric pressure dependence                              |       | U <sub>apres</sub>                          | 1.15                               |                    |
| ambient temperature dependence                                |       | U <sub>temp</sub>                           | 0.00                               |                    |
| CO2 (15%)                                                     |       | U <sub>interf</sub>                         | 0.00                               |                    |
| N2O (40mgm3)                                                  |       | -                                           | 0.00                               |                    |
| CH4 (57mgm3)                                                  |       | -                                           | 0.00                               |                    |
| H2O (1%)                                                      |       | -                                           | 0.00                               |                    |
| Dependence on voltage                                         |       | U <sub>volt</sub>                           | 0.03                               |                    |
| Error in Logger reading                                       |       | -                                           | 2.00                               |                    |
| losses in the line (leak)                                     |       | U <sub>leak</sub>                           | 6.73                               |                    |
| Uncertainty of calibration gas                                |       | U <sub>calib</sub>                          | 6.73                               |                    |
|                                                               |       |                                             |                                    |                    |
| CO Measurement uncertainty                                    |       | Result                                      | 582.99                             | mg/m <sup>3</sup>  |
| Combined uncertainty                                          |       |                                             | 21.12                              | mg/m <sup>3</sup>  |
| Expanded uncertainty                                          | k = 2 |                                             | 42.24                              | mg/m <sup>3</sup>  |
| Uncertainty corrected to std conds                            |       |                                             | 42.24                              | mg.m-3 (corrected) |
| Expanded uncertainty                                          |       | expressed with a level of confidence of 95% | 2.82 % ELV                         |                    |
| Expanded uncertainty                                          |       | expressed with a level of confidence of 95% | 42.24 mg.m <sup>-3</sup> of result |                    |

| VOC - Measurement performance related to stationary conditions |                                             |        |                                    |                               |
|----------------------------------------------------------------|---------------------------------------------|--------|------------------------------------|-------------------------------|
| Performance characteristic                                     |                                             |        | Uncertainty                        | Value of uncertainty quantity |
| Standard deviation of repeatability at zero                    |                                             |        | U <sub>i0</sub>                    | 0.80                          |
| Standard deviation of repeatability at span level              |                                             |        | U <sub>rs</sub>                    | 0.10                          |
| Lack of fit                                                    |                                             |        | U <sub>fit</sub>                   | 3.74                          |
| Drift                                                          |                                             |        | U <sub>odr</sub>                   | 16.12                         |
| volume or pressure flow dependence                             |                                             |        | U <sub>spres</sub>                 | 0.00                          |
| atmosphseric pressure dependence                               |                                             |        | U <sub>apres</sub>                 | 0.75                          |
| ambient temperature dependence                                 |                                             |        | U <sub>temp</sub>                  | 0.00                          |
| NH3 (20 mg/m3)                                                 |                                             |        | U <sub>interf</sub>                | 0.00                          |
| CO2 (15%)                                                      |                                             |        | -                                  | 0.00                          |
| H2O (30%)                                                      |                                             |        | -                                  | 0.00                          |
| Error on Logger voltage                                        |                                             |        | -                                  | 1.00                          |
| Dependence on voltage                                          |                                             |        | U <sub>volt</sub>                  | 0.03                          |
| losses in the line (leak)                                      |                                             |        | U <sub>leak</sub>                  | 13.53                         |
| Uncertainty of calibration gas                                 |                                             |        | U <sub>calib</sub>                 | 13.53                         |
|                                                                |                                             |        |                                    |                               |
| VOC Measurement uncertainty                                    |                                             | Result | 1171.78                            | mg/m <sup>3</sup>             |
| Combined uncertainty                                           |                                             |        | 25.33                              | mg/m <sup>3</sup>             |
| Expanded uncertainty                                           | k = 2                                       |        | 50.66                              | mg/m <sup>3</sup>             |
| Uncertainty corrected to std conds                             |                                             |        | 50.66                              | mg.m-3 (corrected)            |
| Expanded uncertainty                                           | expressed with a level of confidence of 95% |        | 2.89 % ELV                         |                               |
| Expanded uncertainty                                           | expressed with a level of confidence of 95% |        | 50.66 mg.m <sup>-3</sup> 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                                                       |  |                                             | $U_{fit}$       | 0.07                          |
| Drift                                                             |  |                                             | $U_{odr}$       | 0.10                          |
| volume or pressure flow dependence                                |  |                                             | $U_{spres}$     | 0.00                          |
| atmopsheric pressure dependence                                   |  |                                             | $U_{apres}$     | 0.01                          |
| ambient temperature dependence                                    |  |                                             | $U_{temp}$      | 0.05                          |
| CO2 (15%)                                                         |  |                                             | -               | 0.00                          |
| NO(300)                                                           |  |                                             | -               | 0.06                          |
| NO2(30)                                                           |  |                                             | -               | 0.00                          |
| dependence on voltage                                             |  |                                             | $U_{volt}$      | 0.02                          |
| losses in the line (leak)                                         |  |                                             | $U_{leak}$      | 0.07                          |
| Error in Logger voltage                                           |  |                                             | -               | 0.03                          |
| Uncertainty of calibration gas                                    |  |                                             | $U_{calib}$     | 0.07                          |
|                                                                   |  |                                             |                 |                               |
| O2 Measurement uncertainty                                        |  | Result                                      | 6.15            | %vol                          |
| Combined uncertainty                                              |  |                                             | 0.18            | %vol                          |
| % of value                                                        |  |                                             | 2.99            | %                             |
| Expanded uncertainty                                              |  | expressed with a level of confidence of 95% | 5.98 % of value |                               |
| Expanded uncertainty                                              |  | expressed with a level of confidence of 95% | 0.37 % 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 <sub>r0</sub>                   | 0.80                          |
| Standard deviation of repeatability at span level              |       |                                             | U <sub>rs</sub>                   | 0.10                          |
| Lack of fit                                                    |       |                                             | U <sub>fit</sub>                  | 0.47                          |
| Drift                                                          |       |                                             | U <sub>odr</sub>                  | 1.34                          |
| volume or pressure flow dependence                             |       |                                             | U <sub>spres</sub>                | 0.01                          |
| atmosphseric pressure dependence                               |       |                                             | U <sub>apres</sub>                | 0.12                          |
| ambient temperature dependence                                 |       |                                             | U <sub>temp</sub>                 | 0.23                          |
| NH3 (20 mg/m3)                                                 |       |                                             | U <sub>interf</sub>               | 0.14                          |
| CO2 (15%)                                                      |       |                                             | -                                 | 0.02                          |
| H2O (30%)                                                      |       |                                             | -                                 | 0.01                          |
| Error in logger voltage                                        |       |                                             | -                                 | 0.10                          |
| Dependence on voltage                                          |       |                                             | U <sub>volt</sub>                 | 0.03                          |
| Converter efficiency                                           |       |                                             | U <sub>ceff</sub>                 | 0.13                          |
| losses in the line (leak)                                      |       |                                             | U <sub>leak</sub>                 | 0.32                          |
| Uncertainty of calibration gas                                 |       |                                             | U <sub>calib</sub>                | 0.32                          |
|                                                                |       |                                             |                                   |                               |
| NOx Measurement uncertainty                                    |       | Result                                      | 27.42                             | mg/m <sup>3</sup>             |
| Combined uncertainty                                           |       |                                             | 1.54                              | mg/m <sup>3</sup>             |
| Expanded uncertainty                                           | k = 2 |                                             | 3.07                              | mg/m <sup>3</sup>             |
| Uncertainty corrected to std conds                             |       |                                             | 3.07                              | mg.m-3 (corrected)            |
| Expanded uncertainty                                           |       | expressed with a level of confidence of 95% | 2.05 % ELV                        |                               |
| Expanded uncertainty                                           |       | expressed with a level of confidence of 95% | 3.07 mg.m <sup>-3</sup> of result |                               |

| CO - Measurement performance related to stationary conditions |       |                                             |                                   |                    |
|---------------------------------------------------------------|-------|---------------------------------------------|-----------------------------------|--------------------|
| Performance characteristic                                    |       | Uncertainty                                 | Value of uncertainty quantity     |                    |
| Standard deviation of repeatability at zero                   |       | U <sub>r0</sub>                             | 0.80                              |                    |
| Standard deviation of repeatability at span level             |       | U <sub>rs</sub>                             | 0.10                              |                    |
| Lack of fit                                                   |       | U <sub>fit</sub>                            | 0.58                              |                    |
| Drift                                                         |       | U <sub>odr</sub>                            | 1.62                              |                    |
| volume or pressure flow dependence                            |       | U <sub>spres</sub>                          | 0.00                              |                    |
| atmosphseric pressure dependence                              |       | U <sub>apres</sub>                          | 0.12                              |                    |
| ambient temperature dependence                                |       | U <sub>temp</sub>                           | 0.00                              |                    |
| CO2 (15%)                                                     |       | U <sub>interf</sub>                         | 0.00                              |                    |
| N2O (40mgm3)                                                  |       | -                                           | 0.00                              |                    |
| CH4 (57mgm3)                                                  |       | -                                           | 0.00                              |                    |
| H2O (1%)                                                      |       | -                                           | 0.00                              |                    |
| Dependence on voltage                                         |       | U <sub>volt</sub>                           | 0.03                              |                    |
| Error in Logger reading                                       |       | -                                           | 0.20                              |                    |
| losses in the line (leak)                                     |       | U <sub>leak</sub>                           | 0.36                              |                    |
| Uncertainty of calibration gas                                |       | U <sub>calib</sub>                          | 0.36                              |                    |
|                                                               |       |                                             |                                   |                    |
| CO Measurement uncertainty                                    |       | Result                                      | 31.24                             | mg/m <sup>3</sup>  |
| Combined uncertainty                                          |       |                                             | 1.82                              | mg/m <sup>3</sup>  |
| Expanded uncertainty                                          | k = 2 |                                             | 3.63                              | mg/m <sup>3</sup>  |
| Uncertainty corrected to std conds                            |       |                                             | 3.63                              | mg.m-3 (corrected) |
| Expanded uncertainty                                          |       | expressed with a level of confidence of 95% | 7.26 % ELV                        |                    |
| Expanded uncertainty                                          |       | expressed with a level of confidence of 95% | 3.63 mg.m <sup>-3</sup> of result |                    |

| VOC - Measurement performance related to stationary conditions |     |                                             |                                   |                               |
|----------------------------------------------------------------|-----|---------------------------------------------|-----------------------------------|-------------------------------|
| Performance characteristic                                     |     |                                             | Uncertainty                       | Value of uncertainty quantity |
| Standard deviation of repeatability at zero                    |     |                                             | U <sub>r0</sub>                   | 0.80                          |
| Standard deviation of repeatability at span level              |     |                                             | U <sub>rs</sub>                   | 0.10                          |
| Lack of fit                                                    |     |                                             | U <sub>fit</sub>                  | 0.04                          |
| Drift                                                          |     |                                             | U <sub>odr</sub>                  | 0.09                          |
| volume or pressure flow dependence                             |     |                                             | U <sub>spres</sub>                | 0.00                          |
| atmospheric pressure dependence                                |     |                                             | U <sub>apres</sub>                | 0.01                          |
| ambient temperature dependence                                 |     |                                             | U <sub>temp</sub>                 | 0.00                          |
| NH3 (20 mg/m3)                                                 |     |                                             | U <sub>interf</sub>               | 0.00                          |
| CO2 (15%)                                                      |     |                                             | -                                 | 0.00                          |
| H2O (30%)                                                      |     |                                             | -                                 | 0.00                          |
| Error on Logger voltage                                        |     |                                             | -                                 | 0.01                          |
| Dependence on voltage                                          |     |                                             | U <sub>vdt</sub>                  | 0.03                          |
| losses in the line (leak)                                      |     |                                             | U <sub>leak</sub>                 | 0.00                          |
| Uncertainty of calibration gas                                 |     |                                             | U <sub>calib</sub>                | 0.00                          |
|                                                                |     |                                             |                                   |                               |
| VOC Measurement uncertainty                                    |     | Result                                      | 0.01                              | mg/m <sup>3</sup>             |
| Combined uncertainty                                           |     |                                             | 0.15                              | mg/m <sup>3</sup>             |
| Expanded uncertainty                                           | k = | 2                                           | 0.30                              | mg/m <sup>3</sup>             |
| Uncertainty corrected to std conds                             |     |                                             | 0.30                              | mg.m-3 (corrected)            |
| Expanded uncertainty                                           |     | expressed with a level of confidence of 95% | 2.97 % ELV                        |                               |
| Expanded uncertainty                                           |     | expressed with a level of confidence of 95% | 0.30 mg.m <sup>-3</sup> of result |                               |

| Oxygen - Measurement performance related to stationary conditions |  |                                             |                    |                               |
|-------------------------------------------------------------------|--|---------------------------------------------|--------------------|-------------------------------|
| Performance characteristic                                        |  |                                             | Uncertainty        | Value of uncertainty quantity |
| Standard deviation of repeatability at zero                       |  |                                             | U <sub>r0</sub>    | 0.20                          |
| Standard deviation of repeatability at span level                 |  |                                             | U <sub>rs</sub>    | 0.03                          |
| Lack of fit                                                       |  |                                             | U <sub>fit</sub>   | 0.11                          |
| Drift                                                             |  |                                             | U <sub>odr</sub>   | 0.13                          |
| volume or pressure flow dependence                                |  |                                             | U <sub>spres</sub> | 0.00                          |
| atmospheric pressure dependence                                   |  |                                             | U <sub>apres</sub> | 0.01                          |
| ambient temperature dependence                                    |  |                                             | U <sub>temp</sub>  | 0.03                          |
| CO2 (15%)                                                         |  |                                             | -                  | 0.00                          |
| NO(300)                                                           |  |                                             | -                  | 0.06                          |
| NO2(30)                                                           |  |                                             | -                  | 0.00                          |
| dependence on voltage                                             |  |                                             | U <sub>volt</sub>  | 0.02                          |
| losses in the line (leak)                                         |  |                                             | U <sub>leak</sub>  | 0.11                          |
| Error in Logger voltage                                           |  |                                             | -                  | 0.03                          |
| Uncertainty of calibration gas                                    |  |                                             | U <sub>calib</sub> | 0.11                          |
|                                                                   |  |                                             |                    |                               |
| O2 Measurement uncertainty                                        |  | Result                                      | 9.67               | %vol                          |
| Combined uncertainty                                              |  |                                             | 0.25               | %vol                          |
| % of value                                                        |  |                                             | 2.54               | %                             |
| Expanded uncertainty                                              |  | expressed with a level of confidence of 95% | 5.09 % of value    |                               |
| Expanded uncertainty                                              |  | expressed with a level of confidence of 95% | 0.49 % vol         |                               |

## 2.4 Appendix IV: Moisture Calculations

### 2.4.1 Engine, Uncertainties

|                                               |          |                |        |                                     |                     |        |  |
|-----------------------------------------------|----------|----------------|--------|-------------------------------------|---------------------|--------|--|
| Test No                                       | T1       |                |        | Site                                | Flintshire CC       |        |  |
| Date                                          | 17-3-15  |                |        |                                     | Standard LFS        |        |  |
| pbar (mbar)                                   | 1001     |                |        | Stack                               | Engine              |        |  |
| pbar (mmHg)                                   | 751      |                |        | Job Number:                         | R15099              |        |  |
| Nozzle Diameter (mm)                          | n/a      |                |        | Site Team:                          | BK, YS, TB          |        |  |
| Temp of Meter (in)/(out) deg. C               | 14       |                |        | Data Entered By:                    | Yu Shen             |        |  |
| $\Delta H_{ave}$ (mmH <sub>2</sub> O)         | 10.0     |                |        |                                     |                     |        |  |
| DGM Cal Factor (Y)                            | 0.9272   |                |        |                                     |                     |        |  |
|                                               |          |                |        | Enter Data into coloured cells only |                     |        |  |
| Start Volume Reading                          | 748.6930 | m <sup>3</sup> |        | Start time                          | 12:30               | hr:min |  |
| End Volume Reading                            | 749.1290 | m <sup>3</sup> |        | End time                            | 13:30               | hr:min |  |
| Volume Sampled                                | 0.4043   | m <sup>3</sup> |        | 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) | 749.8    | 768.7          | 564.9  | 798.1                               | YS                  |        |  |
| Final Weight of Impingers plus absorber (g)   | 777.2    | 774.5          | 565.9  | 805.6                               | YS                  |        |  |
| Weight Gain (g)                               | 27.4     | 5.8            | 1.0    | 7.5                                 |                     |        |  |
| Total Weight Gain (1+2+3+4) (g)               | 41.7     |                |        |                                     |                     |        |  |
| Gas Volume of water at 0 °C (l)               | 51.92    |                |        |                                     |                     |        |  |
| Gas Meter volume at 0 °C (l)                  | 380.36   |                |        |                                     |                     |        |  |
| Moisture content of Gases (%)                 | 12.0     |                |        |                                     |                     |        |  |

**2.4.2 Flare, Uncertainties**

|                                               |          |                |                                     |               |                     |  |
|-----------------------------------------------|----------|----------------|-------------------------------------|---------------|---------------------|--|
| Test No                                       | T2       |                | Site                                | Flintshire CC |                     |  |
| Date                                          | 17-3-15  |                |                                     | Standard LFS  |                     |  |
| pbar (mbar)                                   | 1001     |                | Stack                               | Flare         |                     |  |
| pbar (mmHg)                                   | 751      |                | Job Number:                         | R15099        |                     |  |
| Nozzle Diameter (mm)                          | n/a      |                | Site Team:                          | BK, YS, TB    |                     |  |
| Temp of Meter (in)/(out) deg. C               | 12       |                | Data Entered By:                    | BK            |                     |  |
| $\Delta H_{ave}$ (mmH <sub>2</sub> O)         | 10.0     |                | Enter Data into coloured cells only |               |                     |  |
| DGM Cal Factor (Y)                            | 1.0103   |                |                                     |               |                     |  |
| Start Volume Reading                          | 658.8490 | m <sup>3</sup> | Start time                          | 12:02         | hr:min              |  |
| End Volume Reading                            | 659.4202 | m <sup>3</sup> | End time                            | 13:02         | hr:min              |  |
| Volume Sampled                                | 0.5771   | m <sup>3</sup> | 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) | 777.2    | 774.5          | 565.9                               | 805.6         | BK                  |  |
| Final Weight of Impingers plus absorber (g)   | 818.2    | 778.5          | 566.1                               | 809.6         | BK                  |  |
| Weight Gain (g)                               | 41.0     | 4.0            | 0.2                                 | 4.0           |                     |  |
| Total Weight Gain (1+2+3+4) (g)               | 49.2     |                |                                     |               |                     |  |
| Gas Volume of water at 0 °C (l)               | 61.25    |                |                                     |               |                     |  |
| Gas Meter volume at 0 °C (l)                  | 546.77   |                |                                     |               |                     |  |
| Moisture content of Gases (%)                 | 10.1     |                |                                     |               |                     |  |