

# STACK EMISSIONS MONITORING REPORT



**SOCOTEC**

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#### Operator & Address:

Medite Smartply  
Redmonstown  
Clonmel  
Co. Tipperary  
Ireland

#### Permit Reference:

IE Licence: P0027-04

#### Release Point:

A2-6

#### Sampling Date(s):

03 - 05 May 2022

|                         |                              |
|-------------------------|------------------------------|
| SOCOTEC Job Number:     | LEK 13247 / Q2               |
| Report Date:            | 07-Jun-22                    |
| Version:                | 1                            |
| Report By:              | Aidan Whitney                |
| MCERTS Number:          | MM20 1603                    |
| MCERTS Level:           | MCERTS Level 1 Technician    |
| Technical Endorsements: | 1                            |
| Report Approved By:     | Brian Walsh                  |
| MCERTS Number:          | MM 17 1414                   |
| Business Title:         | MCERTS Level 2 - Team Leader |
| Technical Endorsements: | 1, 2, 3 & 4                  |
| Signature:              |                              |



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## EXECUTIVE SUMMARY

### MONITORING OBJECTIVES

Medite Smartply operates a wood fibre board manufacturing process at Clonmel which is subject to IE Licence P0027-04, under the EPA Act 1992.

SOCOTEC LTD were commissioned by Medite Europe Ltd to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's IE Licence, P0027-04.

#### Plant

A2-6

#### Operator

Medite Smartply  
Redmonstown  
Clonmel  
Co. Tipperary  
Ireland

IE Licence: P0027-04

#### Stack Emissions Monitoring Test House

SOCOTEC - East Kilbride Laboratory  
2-4 Langlands Place  
Kelvin South Business Park  
East Kilbride  
G75 0YF  
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.  
The results of this testing relate only to the emission release point(s) listed in the report.  
MCERTS accredited results will only be claimed where both the sampling and analytical stages are MCERTS accredited.  
This test report shall not be reproduced, except in full, without written approval of SOCOTEC LTD.

## EXECUTIVE SUMMARY

| EMISSIONS SUMMARY                                      |                    |          |                            |                            |               |
|--|--------------------|----------|----------------------------|----------------------------|---------------|
| Parameter  | Units              | Result   | Calculated Uncertainty +/- | Emission Limit Value (ELV) | Accreditation |
| Total Particulate Matter                               | mg/m <sup>3</sup>  | 2.16     | 2.48                       | 20                         | MCERTS        |
| Particulate Emission Rate                              | g/hr               | 440.43   | 506.93                     | -                          |               |
| Isocyanates  | mg/m <sup>3</sup>  | 0.0013   | 0.0007                     | 0.06                       | MCERTS        |
| Isocyanates Emission Rate                              | g/hr               | 0.2984   | 0.1692                     | -                          |               |
| Oxides of Nitrogen (as NO <sub>2</sub> )               | mg/m <sup>3</sup>  | 62.3     | 5.3                        | 110                        | MCERTS        |
| Oxides of Nitrogen (as NO <sub>2</sub> ) Emission Rate | g/hr               | 9821.4   | 833.5                      | -                          |               |
| Carbon Monoxide  | mg/m <sup>3</sup>  | 26.9     | 1.9                        | 600                        | MCERTS        |
| Carbon Monoxide Emission Rate                          | g/hr               | 4235.8   | 303.9                      | -                          |               |
| Moisture   | %                  | 11.9     | 13.2                       | -                          | MCERTS        |
| Stack Gas Temperature                                  | °C                 | 57.5     | -                          | -                          | MCERTS        |
| Stack Gas Velocity                                     | m/s                | 14.5     | 0.35                       | -                          |               |
| Gas Volumetric Flow Rate (Actual)                      | m <sup>3</sup> /hr | 217614.3 | 11180.8                    | -                          |               |
| Gas Volumetric Flow Rate (STP, Wet)                    | m <sup>3</sup> /hr | 178756.7 | 9184.4                     | -                          |               |
| Gas Volumetric Flow Rate (STP, Dry)                    | m <sup>3</sup> /hr | 157566.2 | 8095.6                     | -                          |               |
| Gas Volumetric Flow Rate at Reference Conditions       | m <sup>3</sup> /hr | 157566.2 | 8095.6                     | 174400                     |               |
|  |                    |          |                            |                            |               |

ND = None Detected,

Results at or below the limit of detection are highlighted by bold italic text.

The above volumetric flow rate is an average of the data collected during the isokinetic tests. Mass emissions for non isokinetic tests are also calculated using these values.

Reference conditions are 273K, 101.3kPa, dry gas .

## EXECUTIVE SUMMARY

| MONITORING TIMES               |                  |                |                   |
|--------------------------------|------------------|----------------|-------------------|
| Parameter                      | Sampling Date(s) | Sampling Times | Sampling Duration |
| Total Particulate Matter Run 1 | 03 May 2022      | 13:35 - 14:05  | 30 minutes        |
| Isocyanates Run 1              | 03 May 2022      | 14:26 - 14:56  | 30 minutes        |
| Combustion Gases               | 03 May 2022      | 13:45 - 14:45  | 60 minutes        |
| Preliminary Stack Traverse     | 03 May 2022      | 13:20 - 13:30  | -                 |

## EXECUTIVE SUMMARY

### PROCESS DETAILS

| Parameter                                     | Process Details                |
|---|--------------------------------|
| Description of process                        | Wood Fibre Board Manufacturing |
| Continuous or batch                           | Continuous                     |
| Product Details                               | Wood Fibre Board               |
| Part of batch to be monitored (if applicable) | Normal Operation               |
| Normal load, throughput or continuous rating  | Normal Load                    |
| Fuel used during monitoring                   | N/A                            |
| Abatement                                     | Cyclone                        |
| Plume Appearance                              | Heavy Moisture Plume           |

## EXECUTIVE SUMMARY

### Monitoring Methods

The selection of standard reference / alternative methods employed by SOCOTEC is determined, wherever possible by the hierarchy of method selection outlined in Environmental Protection Agency Technical Guidance Note (Monitoring) AG2.

| MONITORING METHODS       |   |                                   |                    |                         |                                |                                  |                               |
|--------------------------|---|-----------------------------------|--------------------|-------------------------|--------------------------------|----------------------------------|-------------------------------|
| Species                  | Method<br>Standard Reference Method /<br>Alternative Method | SOCOTEC<br>Technical<br>Procedure | UKAS Lab<br>Number | Method<br>Accreditation | Limit of<br>Detection<br>(LOD) | Calculated<br>MU<br>+/- % Result | Calculated<br>MU<br>+/- % ELV |
| Total Particulate Matter | SRM - EN 13284-1  | AE 104                            | 1015               | MCERTS                  | 0.32 mg/m <sup>3</sup>         | 115.1%                           | 12.43%                        |
| Isocyanates              | SRM - US EPA CTM 036  | AE 116                            | 1015               | MCERTS                  | 0.0013 mg/m <sup>3</sup>       | 56.7%                            | 1.24%                         |
| Oxides of Nitrogen       | SRM - EN 14792:2017   | AE 102                            | 1015               | MCERTS                  | 0.51 mg/m <sup>3</sup>         | 8.5%                             | 4.81%                         |
| Carbon Monoxide          | SRM - EN 15058:2017   | AE 102                            | 1015               | MCERTS                  | 0.28 mg/m <sup>3</sup>         | 7.2%                             | 0.3%                          |
| Moisture                 | EN 14790  | AE 105                            | 1015               | MCERTS                  | 0.02%                          | 111.2%                           | N/A - No ELV                  |
| Velocity                 | SRM - EN ISO 16911-1  | AE 154                            | 1015               | MCERTS                  | 5 Pa                           | 2.4%                             | N/A - No ELV                  |
| Volumetric Flow Rate     | SRM - EN ISO 16911-1  | AE 154                            | 1015               | MCERTS                  | -                              | 5.1%                             | 4.64%                         |

## EXECUTIVE SUMMARY

### Analytical Methods

The following tables list the analytical methods employed together with the custody details. Unless otherwise stated the samples are archived at the analysis lab location.

| SAMPLING METHODS WITH SUBSEQUENT ANALYSIS |   |                      |                 |                        |                         |                        |                |
|---|---|----------------------|-----------------|------------------------|-------------------------|------------------------|----------------|
| Species                                   | Analytical Technique                                  | Analytical Procedure | UKAS Lab Number | Analysis Accreditation | Analysis Lab            | Analysis Report number | Archive Period |
| Total Particulate Matter                  | Gravimetric   | AE 106               | 1015            | MCERTS                 | SOCOTEC (East Kilbride) | N/A                    | 8 Weeks        |
| Isocyanates                               | High performance Liquid Chromatography - Ultra Violet | AE 104               | 0605            | MCERTS                 | 30                      | 22-05664-1             | 8 Weeks        |

| ON-SITE TESTING    |                          |                      |                 |               |                         |                         |                |
|--------------------|--------------------------|----------------------|-----------------|---------------|-------------------------|-------------------------|----------------|
| Species            | Analytical Technique     | Analytical Procedure | UKAS Lab Number | Accreditation | Laboratory              | Data Archive Location   | Archive Period |
| -                  | -                        | -                    | -               | -             | -                       | -                       | -              |
| Oxides of Nitrogen | Chemiluminescence        | AE 102               | 1015            | MCERTS        | SOCOTEC (East Kilbride) | SOCOTEC (East Kilbride) | 5 years        |
| Carbon Monoxide    | Non Dispersive Infra Red | AE 102               | 1015            | MCERTS        | SOCOTEC (East Kilbride) | SOCOTEC (East Kilbride) | 5 years        |
| Moisture           | Gravimetric              | AE 105               | 1015            | MCERTS        | SOCOTEC (East Kilbride) | -                       | -              |



## EXECUTIVE SUMMARY

| SAMPLING LOCATION                              |       |       |             |           |          |
|--|-------|-------|-------------|-----------|----------|
| Sampling Plane Validation Criteria             | Value | Units | Requirement | Compliant | Method   |
| Lowest Differential Pressure                   | 54    | Pa    | >= 5 Pa     | Yes       | EN 15259 |
| Lowest Gas Velocity                            | 10.2  | m/s   | -           | -         | -        |
| Highest Gas Velocity                           | 19.9  | m/s   | -           | -         | -        |
| Ratio of Gas Velocities                        | 1.9   | : 1   | < 3 : 1     | Yes       | EN 15259 |
| Mean Velocity                                  | 14.5  | m/s   | -           | -         | -        |
| Maximum angle of flow with regard to duct axis | <15   | °     | < 15°       | Yes       | EN 15259 |
| No local negative flow                         | Yes   | -     | -           | Yes       | EN 15259 |

| DUCT CHARACTERISTICS |          |                |
|----------------------|----------|----------------|
|                      | Value    | Units          |
| Shape                | Circular | -              |
| Depth                | 2.30     | m              |
| Width                | -        | m              |
| Area                 | 4.16     | m <sup>2</sup> |
| Port Depth           | 90       | mm             |

| SAMPLING LINES & POINTS |            |                 |
|-------------------------|------------|-----------------|
|                         | Isokinetic | Non-Iso & Gases |
| Sample port size        | 4" BSP     | 4" BSP          |
| Number of lines used    | 2          | 1               |
| Number of points / line | 9          | 1               |
| Duct orientation        | Vertical   | Vertical        |
| Filtration              | In Stack   | Out Stack       |
| Filtration for TPM      | In Stack   | -               |

| SAMPLING PLATFORM  |           |
|--|-----------|
| General Platform Information                                       |           |
| Permanent / Temporary Platform / Ground level / Floor Level / Roof | Permanent |
| Inside / Outside   | Outside   |

| AG1 Platform requirements   |     |
|---|-----|
| Is there a sufficient working area so work can be performed in a compliant manner | Yes |
| Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)             | Yes |
| Platform has vertical base boards (approximately 0.25 m high)                     | Yes |
| Platform has removable chains / self closing gates at the top of ladders          | Yes |
| Handrail / obstructions do not hamper insertion of sampling equipment             | Yes |
| Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m      | Yes |

### Sampling Platform Improvement Recommendations (if applicable)

Although the monitoring position doesn't comply with most of the sampling plane validation criteria described in AG1, it is the safest and only real means of access practically possible in order to undertake extractive sampling.

## EXECUTIVE SUMMARY

### Sampling & Analytical Method Deviations

#### **Nozzle Size**

Due to the high velocities at the sampling point selected in the stack a 4mm nozzle was required to achieve isokinetic monitoring, this does not completely adhere to EN 13284-1.

#### **Sampling lines**

It was only possible to sample from one representative sampling point for all isokinetic monitoring due to a number of factors i.e. flow being excessively high, swirl being greater than 15° & negative flow experienced throughout sample point locations. This sampling location does not therefore comply with all the requirements of AG1 & IS EN 16911-1.

#### **Velocity traverse**

As this sampling location shows high levels of turbulence throughout the results from the standard flow traverse are only indicative. In the past, reports detailing the volumetric flow rate according to fan rating have been used to calculate mass emission rates for this stack.

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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

| MONITORING SCHEDULE      |   |                                   |                    |                                |                      |
|--------------------------|---|-----------------------------------|--------------------|--------------------------------|----------------------|
| Species                  | Method<br>Standard Reference Method /<br>Alternative Method | SOCOTEC<br>Technical<br>Procedure | UKAS Lab<br>Number | MCERTS<br>Accredited<br>Method | Number of<br>Samples |
| Total Particulate Matter | SRM - EN 13284-1  | AE 104                            | 1015               | MCERTS                         | 1                    |
| Isocyanates              | SRM - US EPA CTM 036  | AE 116                            | 1015               | MCERTS                         | 1                    |
| Oxides of Nitrogen       | SRM - EN 14792:2017   | AE 102                            | 1015               | MCERTS                         | 1                    |
| Carbon Monoxide          | SRM - EN 15058:2017   | AE 102                            | 1015               | MCERTS                         | 1                    |
| Moisture                 | EN 14790  | AE 105                            | 1015               | MCERTS                         | 1                    |
| Velocity                 | SRM - EN ISO 16911-1  | AE 154                            | 1015               | MCERTS                         | 1                    |

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

| CALIBRATEABLE EQUIPMENT CHECKLIST |                |                                 |                |                           |                |
|-----------------------------------|----------------|---------------------------------|----------------|---------------------------|----------------|
| Extractive Sampling               |                | Instrumental Analyser/s         |                | Miscellaneous             |                |
| Equipment                         | Equipment I.D. | Equipment                       | Equipment I.D. | Equipment                 | Equipment I.D. |
| Control Box DGM                   | LEK 9.49       | Horiba PG-250 Analyser          | LEK 12.18      | Laboratory Balance        | LEK 15.21      |
| Box Thermocouples                 | LEK 17.77      | FT-IR Gasmet                    | -              | Tape Measure              | LEK 20.2       |
| Meter In Thermocouple             | LEK 17.78      | FT-IR Oven Box                  | -              | Stopwatch                 | -              |
| Meter Out Thermocouple            | LEK 17.79      | Bernath 3006 FID                | LEK 8.4        | Protractor                | -              |
| Control Box Timer                 | LEK 9.50       | Signal 3030 FID                 | -              | Barometer                 | LEK 16.8       |
| Oven Box                          | LEK 13.25      | Servomex                        | -              | Digital Micromanometer    | LEK 1.20       |
| Probe                             | LEK 6.53       | JCT Heated Head Filter          | LEK 13.32a     | Digital Temperature Meter | LEK 2.11       |
| Probe Thermocouple                | LEK 3.187      | Thermo FID                      | -              | Stack Thermocouple        | -              |
| Probe                             | LEK 6.17       | Stackmaster                     | -              | Mass Flow Controller      | -              |
| Probe Thermocouple                | LEK 6.17       | FTIR Heater Box for Heated Line | -              | MFC Display module        | -              |
| S-Pitot                           | LEK 6.77       | Anemometer                      | -              | 1m Heated Line (1)        | -              |
| L-Pitot                           | -              | Ecophysics NOx Analyser         | -              | 1m Heated Line (2)        | -              |
| Site Balance                      | LEK 23.16      | Chiller (JCT/MAK 10)            | LEK 12.12      | 1m Heated Line (3)        | -              |
| Last Impinger Arm                 | LEK 3.109      | Heated Line Controller (1)      | LEK 8.49       | 5m Heated Line (1)        | -              |
| Dioxins Cond. Thermocouple        | LEK 10.93      | Heated Line Controller (2)      | -              | 10m Heated Line (1)       | -              |
| Callipers                         | LEK 15.1X      | Site temperature Logger         | -              | 10m Heated Line (2)       | -              |
| Small DGM                         | -              |                                 |                | 15m Heated Line (1)       | -              |
| Heater Controller                 | -              |                                 |                | 20m Heated Line (1)       | LEK 8.49       |
| Inclinometer (Swirl Device)       | LEK 24.10      |                                 |                | 20m Heated Line (2)       | -              |

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

| CALIBRATION GASES            |                     |          |     |       |                            |
|------------------------------|---------------------|----------|-----|-------|----------------------------|
| Gas (traceable to ISO 17025) | Cylinder I.D Number | Supplier | ppm | %     | Analytical Tolerance +/- % |
| Nitric Oxide                 | LEK 262             | BOC      | 202 | -     | 2.0                        |
| Carbon Monoxide              | LEK 262             | BOC      | 167 | -     | 2.0                        |
| Carbon Dioxide               | LEK 262             | BOC      | -   | 16.08 | 2.0                        |
| -                            | -                   | -        | -   | -     | -                          |

**STACK EMISSIONS MONITORING TEAM**

| MONITORING TEAM |               |                |        |   |        |        |        |        |
|-----------------|---------------|----------------|--------|---|--------|--------|--------|--------|
| Personnel       | MCERTS Number | MCERTS         |        | TE / H&S Qualifications and Expiry Date |        |        |        |        |
|                 |               | Level          | Expiry | TE1                                     | TE2    | TE3    | TE4    | H&S    |
| Brian Walsh     | MM 17 1414    | MCERTS Level 2 | Jan-23 | Jan-23                                  | Nov-23 | Nov-23 | May-23 | Sep-23 |
| Aidan Whitney   | MM20 1603     | MCERTS Level 1 | Sep-25 | Nov-26                                  | -      | -      | -      | Sep-25 |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| TOTAL PARTICULATE MATTER SUMMARY |                              |                                    |                                  |                          |                       |
|----------------------------------|------------------------------|------------------------------------|----------------------------------|--------------------------|-----------------------|
| Parameter                        | Sampling Times               | Concentration<br>mg/m <sup>3</sup> | Uncertainty<br>mg/m <sup>3</sup> | ELV<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
| Run 1                            | 13:35 - 14:05<br>03 May 2022 | 2.16                               | 2.49                             | 20                       | 440.43                |
| Blank                            | -                            | 0.32                               | -                                | -                        | -                     |

Reference conditions are 273K, 101.3kPa, dry gas .

| Acetone Blank Value<br>mg/l | Acceptable Value<br>mg/l |
|-----------------------------|--------------------------|
| 0.3                         | 10                       |

**FILTER INFORMATION**

| SAMPLES |                                |                        |                      |                          |                             |                           |                         |                               |
|---------|--------------------------------|------------------------|----------------------|--------------------------|-----------------------------|---------------------------|-------------------------|-------------------------------|
| Test    | Filter & Probe<br>Rinse Number | Filter Start<br>Weight | Filter End<br>Weight | Mass Gained<br>on Filter | Probe Rinse<br>Start Weight | Probe Rinse<br>End Weight | Mass Gained on<br>Probe | Combined Total<br>Mass Gained |
|         |                                | g                      | g                    | g                        | g                           | g                         | g                       | g                             |
| Run 1   | AC 3119                        | 0.09695                | 0.09885              | 0.00190                  | 161.14270                   | 161.14200                 | -0.00070                | 0.00120                       |

If total mass gained is less than the LOD then the LOD is reported

| BLANKS |                          |                        |                      |                       |                       |                     |                      |                               |
|--------|--------------------------|------------------------|----------------------|-----------------------|-----------------------|---------------------|----------------------|-------------------------------|
| Test   | Filter & Probe<br>Number | Filter Start<br>Weight | Filter End<br>Weight | Mass Gained<br>Filter | Probe Start<br>Weight | Probe End<br>Weight | Mass Gained<br>Probe | Combined Total<br>Mass Gained |
|        |                          | g                      | g                    | g                     | g                     | g                   | g                    | g                             |
| Run 1  | AC 3099                  | 0.09664                | 0.09669              | 0.00005               | 177.35010             | 177.35000           | -0.00010             | 0.00018                       |

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| ISOKINETIC SAMPLING EQUATIONS - RUN 1   |                    |           | TPM  |                               |
|---|--------------------|-----------|--|-------------------------------|
| <b>Absolute pressure of stack gas, P<sub>s</sub></b>                              |                    |           | <b>Molecular weight of dry gas, M<sub>d</sub></b>                                      |                               |
| Barometric pressure, P <sub>b</sub>   | Kpa                | 101.9     | CO <sub>2</sub>  | % 0.66                        |
| Stack static pressure, P <sub>static</sub>  | pa                 | -164.0    | O <sub>2</sub>   | % 20.30                       |
| P <sub>s</sub> = P <sub>b</sub> + P <sub>static</sub>                             | Kpa                | 101.7     | Total  | % 20.96                       |
|   |                    |           | N <sub>2</sub> (100 -Total)  | % 79.04                       |
| <b>Vol. of water vapour collected, V<sub>wstd</sub></b>                           |                    |           | <b>Molecular weight of wet gas, M<sub>s</sub></b>                                      |                               |
| Moisture trap weight increase, V <sub>lc</sub>                                    | g                  | 60.0      | M <sub>d</sub> = 0.44(%CO <sub>2</sub> )+0.32(%O <sub>2</sub> )+0.28(%N <sub>2</sub> ) | 28.92                         |
| V <sub>wstd</sub> = (0.001246)(V <sub>lc</sub> )                                  | m <sup>3</sup>     | 0.07476   | M <sub>s</sub> = M <sub>d</sub> (1 - B <sub>w0</sub> ) + 18(B <sub>w0</sub> )          | g/gmol 27.62                  |
| <b>Volume of gas metered dry, V<sub>mstd</sub></b>                                |                    |           | <b>Actual flow of stack gas, Q<sub>a</sub></b>   |                               |
| Volume of gas sample through gas meter, V <sub>m</sub>                            |                    | 0.618     | Area of stack, A <sub>s</sub>  | m <sup>2</sup> 4.16           |
| Gas meter correction factor, Y <sub>d</sub>                                       |                    | 0.959     | Q <sub>a</sub> = (60)(A <sub>s</sub> )(V <sub>d</sub> )                                | m <sup>3</sup> /min 4560.4    |
| Mean dry gas meter temperature, T <sub>m</sub>                                    |                    | 294       | <b>Total flow of stack gas, Q</b>  |                               |
| Mean pressure drop across orifice, DH   | mmH <sub>2</sub> O | 36.355    | Conversion factor (K/mm.Hg)  | 0.3592                        |
| V <sub>mstd</sub> = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m}$             | m <sup>3</sup>     | 0.556     | Q <sub>std</sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{w0})}{(T_s)}$                          | Dry 3400.4                    |
| <b>Volume of gas metered wet, V<sub>mstw</sub></b>                                |                    |           | Q <sub>stdO2</sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{w0})(O_2REF)}{(T_s)}$                |                               |
| V <sub>mstw</sub> = V <sub>mstd</sub> + V <sub>wstd</sub>                         | m <sup>3</sup>     | 0.6307    |  | @O <sub>2</sub> ref No O2 Ref |
| <b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., V<sub>mstd@X%O2</sub></b>     |                    |           | Q <sub>stw</sub> = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$                                    |                               |
| Is the process burning hazardous waste? (If yes, no favourable oxygen correction) | No                 |           | <b>Percent isokinetic, %I</b>  |                               |
| % oxygen measured in gas stream, act%O <sub>2</sub>                               | 20.3               |           | Nozzle diameter, D <sub>n</sub>  | mm 5.02                       |
| % oxygen reference condition  | 21                 |           | Nozzle area, A <sub>n</sub>  | mm <sup>2</sup> 19.77         |
| O <sub>2</sub> Reference O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub>           | No O2 Ref          |           | Total sampling time, q   | min 30                        |
| Factor $\frac{21.0 - ref\%O_2}{21.0 - act\%O_2}$                                  | No O2 Ref          |           | %I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{w0})}$                  | % 114.5                       |
| V <sub>mstd@X%oxygen</sub> = (V <sub>mstd</sub> ) (O <sub>2</sub> Ref)            | m <sup>3</sup>     | No O2 Ref | Acceptable isokinetic range 95% to 115%  |                               |
| <b>Moisture content, B<sub>w0</sub></b>   |                    |           | <b>Particulate Concentration, C</b>  |                               |
| B <sub>w0</sub> = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$                          | %                  | 11.85     | Mass collected on filter, M <sub>f</sub>   | g 0.00190                     |
| <b>Moisture by FTIR</b>   |                    |           | Mass collected in probe, M <sub>p</sub>  |                               |
|   | %                  | -         | Total mass collected, M <sub>n</sub>   | g 0.00120                     |
| <b>Velocity of stack gas, V<sub>s</sub></b>                                       |                    |           | C <sub>wet</sub> = $\frac{M_n}{V_{mstw}}$  |                               |
| Velocity pressure coefficient, C <sub>p</sub>                                     |                    | 0.84      |  | mg/m <sup>3</sup> 1.903       |
| Mean of velocity heads, DP <sub>avg</sub>   | Pa                 | 245.00    | C <sub>dry</sub> = $\frac{M_n}{V_{mstd}}$  | mg/m <sup>3</sup> 2.159       |
| Mean stack gas temperature, T <sub>s</sub>  | K                  | 324       | C <sub>dry@X%O2</sub> = $\frac{M_n}{V_{mstd@X\%oxygen}}$                               | mg/m <sup>3</sup> No O2 Ref   |
| Gas density (wet, ambient), p   | kg/m <sup>3</sup>  | 1.043     | <b>Particulate Emission Rates, E</b>   |                               |
| p = (Ms*Ps)/(8.314*Ts)  | kg/m <sup>3</sup>  | 1.043     | E = [(C <sub>wet</sub> )(Q <sub>stw</sub> )(60)] / 1000                                |                               |
| Stack Velocity, V <sub>s</sub> $V_s = C_p \sqrt{\frac{\Delta DP_{avg}}{p}}$       | m/s                | 18.29     | 440.43   |                               |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST**

| LEAK RATE |                                 |                                     |                                      |                         |                                   |                        |
|-----------|---------------------------------|-------------------------------------|--------------------------------------|-------------------------|-----------------------------------|------------------------|
| Run       | Mean Sampling Rate<br>litre/min | Pre-sampling Leak Rate<br>litre/min | Post-sampling Leak Rate<br>litre/min | Maximum Vacuum<br>mm Hg | Acceptable Leak Rate<br>litre/min | Leak Tests Acceptable? |
| Run 1     | 19.74                           | -19.00                              | -19.00                               | -482.6                  | 0.39                              | Yes                    |

| ISOKINETICITY |                           |                          |
|---------------|---------------------------|--------------------------|
| Run           | Isokinetic Variation<br>% | Acceptable Isokineticity |
| Run 1         | 114.54                    | Yes                      |

Acceptable isokinetic range 95% to 115%

| WEIGHING BALANCE UNCERTAINTY |                             |                             |              |
|------------------------------|-----------------------------|-----------------------------|--------------|
| Run                          | Result<br>mg/m <sup>3</sup> | 5% ELV<br>mg/m <sup>3</sup> | LOD - 5% ELV |
| Run 1                        | 0.32                        | 1.0                         | Yes          |

The above is based on both the Filter and rinse uncertainty

| BLANK VALUE |  |   |   |   |
|-------------|--|---|---|---|
| Run         | Overall Blank Value<br>mg/m <sup>3</sup> | Daily Emission Limit Value<br>mg/m <sup>3</sup> | Acceptable Blank Value<br>mg/m <sup>3</sup> | Overall Blank Acceptable<br>mg/m <sup>3</sup> |
| Blank 1     | 0.32                                     | 20  | 2.0   | Yes   |

| FILTERS |                 |                   |                                  |   |  |
|---------|-----------------|-------------------|----------------------------------|---|--|
| Run     | Filter Material | Filter Size<br>mm | Max Filtration Temperature<br>°C | Pre-use Filter Conditioning Temperature<br>°C | Post-use Filter Conditioning Temperature<br>°C |
| Run 1   | 47              | GF                | 51                               | 180   | 160  |



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| ISOCYANATES SUMMARY |                              |                                    |                          |                          |                       |
|---------------------|------------------------------|------------------------------------|--------------------------|--------------------------|-----------------------|
| Test                | Sampling Times               | Concentration<br>mg/m <sup>3</sup> | LOD<br>mg/m <sup>3</sup> | ELV<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
| Run 1               | 14:26 - 14:56<br>03 May 2022 | 0.0013                             | 0.0013                   | 0.06                     | 0.30                  |
| Field Blank         | -                            | 0.0013                             | -                        | -                        | -                     |

Reference conditions are 273K, 101.3kPa, dry gas .

| INDIVIDUAL ISOCYANATES SUMMARY |     |                  |                                    |                          |                       |
|--------------------------------|-----|------------------|------------------------------------|--------------------------|-----------------------|
| Test                           |     | Lab Result<br>ug | Concentration<br>mg/m <sup>3</sup> | LOD<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
| Run 1                          | MDI | 0.70             | 0.00132                            | 0.00132                  | 0.29841               |
| Blank 1                        | MDI | 0.70             | 0.00132                            | 0.00132                  | 0.29841               |

Reference conditions are 273K, 101.3kPa, dry gas .

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| ISOKINETIC SAMPLING EQUATIONS 1  |  |                       | ISOCYANATES  |                       |
|--|--|-----------------------|--|-----------------------|
| <b>Absolute pressure of stack gas, P<sub>s</sub></b>                                       |  |                       | <b>Velocity of stack gas, V<sub>s</sub></b>  |                       |
| Barometric pressure, P <sub>b</sub>  | kPa  | 102                   | Velocity pressure coefficient, C <sub>p</sub>  | 0.84                  |
| Stack static pressure, P <sub>static</sub>   | Pa   | -180                  | Mean of velocity heads, DP <sub>avg</sub>  | Pa                    |
| P <sub>s</sub> = P <sub>b</sub> + (P <sub>static</sub> )                                   | KPa  | 102                   | Mean stack gas temperature, T <sub>s</sub>   | K                     |
|  |  | 13.6                  | Gas density (wet, ambient), ρ  |                       |
| <b>Vol. of water vapour collected, V<sub>wstd</sub></b>                                    |  |                       | p = (M <sub>s</sub> *P <sub>s</sub> )/(8.314*T <sub>s</sub> )                            |                       |
| Moisture trap weight increase, V <sub>lc</sub>   | g  | -                     | kg/m <sup>3</sup>  | 1.040                 |
| V <sub>wstd</sub> = (0.001246)(V <sub>lc</sub> )   | m <sup>3</sup>                                 | -                     | Stack Velocity, V <sub>s</sub>   |                       |
|  |  |                       | $V_s = C_p \sqrt{\frac{\Delta DP_{avg}}{\rho}}$  | m/s                   |
|  |  |                       |  | 20.40                 |
| <b>Volume of gas metered dry, V<sub>mstd</sub></b>   |  |                       | <b>Actual flow of stack gas, Q<sub>a</sub></b>   |                       |
| Volume of gas sample through gas meter, V <sub>m</sub>                                     | m <sup>3</sup>                                 | 0.5927                | Area of stack, A <sub>s</sub>  | 4.16                  |
| Gas meter correction factor, V <sub>d</sub>  |  | 0.9588                | Q <sub>a</sub> = (60)(A <sub>s</sub> )(V <sub>s</sub> )                                  | m <sup>3</sup> /min   |
| Mean dry gas meter temperature, T <sub>m</sub>   | K  | 295                   |  | 5086                  |
| Mean pressure drop across orifice, DH  | mmH <sub>2</sub> O                             | 45.933                | <b>Dry total flow of stack gas, Q<sub>std</sub></b>                                      |                       |
| V <sub>mstd</sub> = $\frac{(0.3592)(V_m)(P_s + (DH/13.6))(V_d)}{T_m + 273}$                |  | 0.532                 | Conversion factor (K/mm.Hg)  | 0.3592                |
|  |  |                       | Q <sub>std</sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) + 273}$                      | m <sup>3</sup> /min   |
|  |  |                       |  | 3780.41               |
| <b>Volume of gas metered wet, V<sub>mstw</sub></b>   |  |                       | <b>Wet total flow of stack gas, Q<sub>stw</sub></b>                                      |                       |
| V <sub>mstw</sub> = V <sub>mstd</sub> + V <sub>wstd</sub>                                  | m <sup>3</sup>                                 | 0.6036                | Q <sub>stw</sub> = $\frac{(Q_a)P_s(0.3592)}{(T_s) + 273}$                                | m <sup>3</sup> /min   |
|  |  |                       |  | 4288.8                |
| <b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., V<sub>mstd@X%O<sub>2</sub></sub></b>   |  |                       | <b>Dry total flow of stack gas at X% O<sub>2</sub>, Q<sub>stdO<sub>2</sub></sub></b>     |                       |
| Is the process burning hazardous waste? (If yes, no favourable oxygen correction)          |  | No                    | Q <sub>stdO<sub>2</sub></sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) + 273}$ | m <sup>3</sup> /min   |
| % oxygen measured in gas stream, act%O <sub>2</sub>  |  | 20.3                  |  | No O <sub>2</sub> Ref |
| % oxygen reference condition   |  | 21                    | <b>Percent isokinetic, %I</b>  |                       |
| O <sub>2</sub> Reference   | O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub> | No O <sub>2</sub> Ref | Nozzle diameter, D <sub>n</sub>  | mm                    |
| Factor   | 21.0 - ref%O <sub>2</sub>                      | No O <sub>2</sub> Ref | Nozzle area, A <sub>n</sub>  | mm <sup>2</sup>       |
| V <sub>mstd@X%oxygen</sub> = (V <sub>mstd</sub> )(O <sub>2</sub> Ref)                      | m <sup>3</sup>                                 | No O <sub>2</sub> Ref | Total sampling time, q   | min                   |
|  |  |                       | %I = $\frac{(4.6398E6)(T_s)(V_{mstw})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$                    | %                     |
|  |  |                       | Acceptable isokinetic range 95% to 115%  | Yes                   |
| <b>Moisture content, B<sub>wo</sub></b>  |  |                       | <b>Isocyanates Concentration, C</b>  |                       |
| B <sub>wo</sub> = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$                                   | %  | 11.85                 | Mass of isocyanates collected, I   | ug                    |
|  |  |                       | C <sub>wet</sub> = $\frac{M_n}{V_{mstw}}$  | mg/m <sup>3</sup>     |
| <b>Moisture by FTIR</b>  |  |                       |  |                       |
|  |  |                       | C <sub>dry</sub> = $\frac{M_n}{V_{mstd}}$  | mg/m <sup>3</sup>     |
| <b>Molecular weight of dry gas, M<sub>d</sub></b>  |  |                       | C <sub>dry@X%O<sub>2</sub></sub> = $\frac{M_n}{V_{mstd@X\%oxygen}}$                      | mg/m <sup>3</sup>     |
| CO <sub>2</sub>  | %  | 0.66                  |  | No O <sub>2</sub> Ref |
| O <sub>2</sub>   | %  | 20.30                 | <b>Isocyanates Emission Rates, E</b>   |                       |
| Total  | %  | 20.96                 | E = [(C <sub>wet</sub> )(Q <sub>stw</sub> )(60)] / 1000                                  | g/hr                  |
| N <sub>2</sub> (100 - Total)   | %  | 79.04                 |  | 0.30                  |
| M <sub>d</sub> = 0.44(%CO <sub>2</sub> ) + 0.32(%O <sub>2</sub> ) + 0.28(%N <sub>2</sub> ) |  | 28.92                 |  |                       |
| <b>Molecular weight of wet gas, M<sub>s</sub></b>  |  |                       |  |                       |
| M <sub>s</sub> = M <sub>d</sub> (1 - B <sub>wo</sub> ) + 18(B <sub>wo</sub> )              | g/gmol   | 27.6                  |  |                       |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**ISOCYANATES QUALITY ASSURANCE CHECKLIST**

| Leak Test Results | Mean Sampling Rate<br>litre/min | Pre-sampling Leak Rate<br>litre/min | Post-sampling Leak Rate<br>litre/min | Maximum Vacuum<br>mm Hg | Acceptable Leak Rate<br>litre/min | Leak Tests Acceptable |
|-------------------|---------------------------------|-------------------------------------|--------------------------------------|-------------------------|-----------------------------------|-----------------------|
| Run 1             | 18.9                            | 0.19                                | 0.16                                 | -304.8                  | 0.38                              | Yes                   |

| Isokinetic Criterion Compliance | Isokinetic Variation % | Acceptable Isokineticity |
|---------------------------------|------------------------|--------------------------|
| Run 1                           | 111.9                  | Yes                      |

| Filtration | Filter Material | Filter Size<br>mm | Maximum Filtration Temperature<br>°C | Filters Coated with     |
|------------|-----------------|-------------------|--------------------------------------|-------------------------|
| Run 1      | Glass Fibre     | 47                | 120                                  | 1-(2-pyridyl)piperazine |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**COMBUSTION GASES SUMMARY**

| Test               | Sampling Time and Date       | Concentration<br>mg/m <sup>3</sup> | LOD<br>mg/m <sup>3</sup> | ELV<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
|--------------------|------------------------------|------------------------------------|--------------------------|--------------------------|-----------------------|
| Oxides of Nitrogen | 13:45 - 14:45<br>03 May 2022 | 62.3                               | 0.51                     | 110                      | 9821                  |
| Carbon Monoxide    | 13:45 - 14:45<br>03 May 2022 | 26.9                               | 0.28                     | 600                      | 4235.80               |

Reference conditions are 273K, 101.3kPa, dry gas .

**PRE-SAMPLING CALIBRATION DATA**

|            |             |
|------------|-------------|
| Date       | 03 May 2022 |
| Start Time | 12:00       |
| End Time   | 12:38       |

|                          |       |
|--------------------------|-------|
| Chiller Temperature (°C) | 3.0   |
| Requirement              | < 4°C |
| Compliant                | Yes   |

| Gas             | Range<br>(ppm / %) | Zero Reading<br>at analyser | Span Reading<br>at analyser | Zero Check<br>at analyser | Zero Check<br>down line | Span Check<br>down line | Response<br>Time (Secs) | Leak Rate<br>% |
|-----------------|--------------------|-----------------------------|-----------------------------|---------------------------|-------------------------|-------------------------|-------------------------|----------------|
| Nitric Oxide    | 250                | 0.00                        | 201.9                       | 0.00                      | 0.20                    | 201.9                   | 23                      | 0.00           |
| Carbon Monoxide | 200                | 0.10                        | 167.0                       | 0.00                      | 0.10                    | 166.8                   | 29                      | 0.12           |

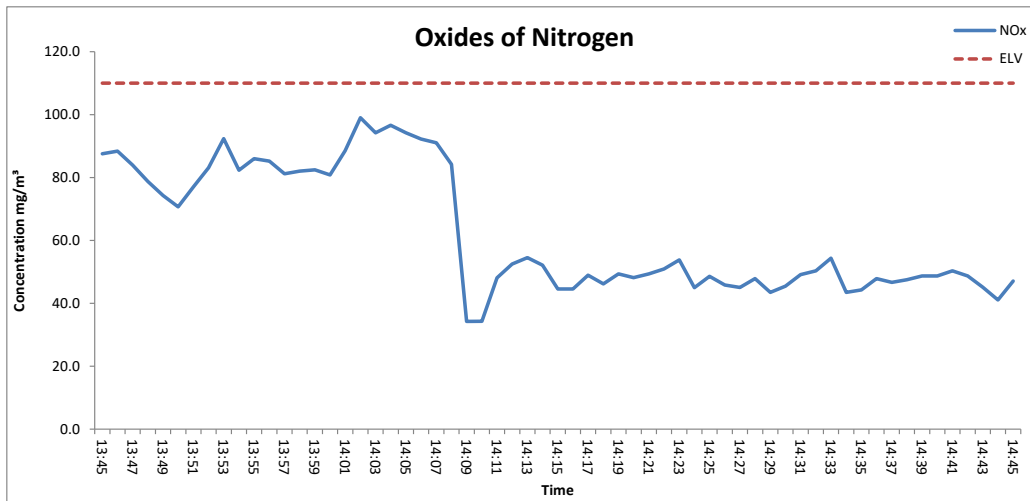
**POST-SAMPLING CALIBRATION DATA**

|            |             |
|------------|-------------|
| Date       | 03 May 2022 |
| Start Time | 15:20       |
| End Time   | 15:35       |

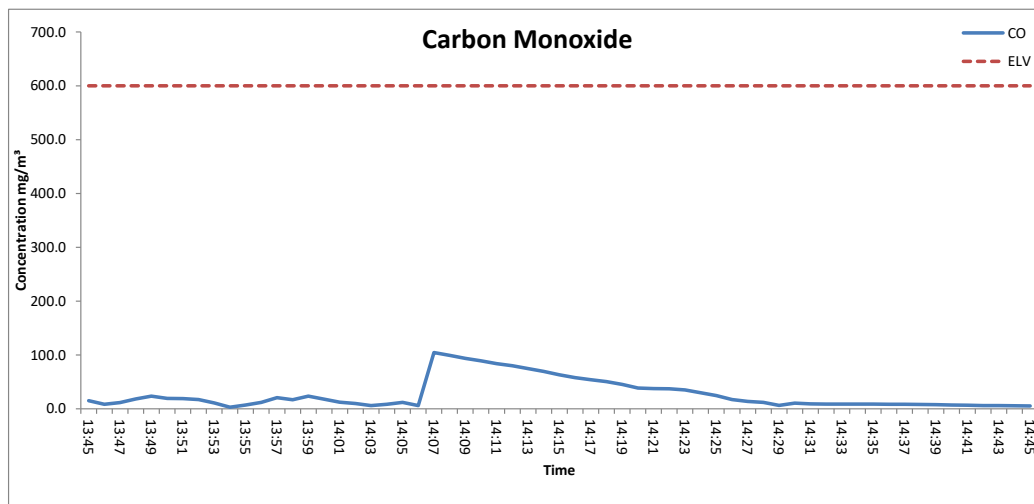
|                          |       |
|--------------------------|-------|
| Chiller Temperature (°C) | 3.0   |
| Requirement              | < 4°C |
| Compliant                | Yes   |

| Gas             | Zero Check<br>at Analyser | Span Check<br>at Analyser | Zero Drift<br>(%) | Span Drift<br>(%) | Corrected for<br>Zero Drift | Corrected for<br>Span Drift | Corrected Values<br>ppm / % |
|-----------------|---------------------------|---------------------------|-------------------|-------------------|-----------------------------|-----------------------------|-----------------------------|
| Nitric Oxide    | 0.00                      | 200.1                     | 0.00              | -0.89             | x                           | x                           | N/A - not corrected         |
| Carbon Monoxide | -0.10                     | 165.5                     | -0.06             | -0.84             | x                           | x                           | N/A - not corrected         |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts  
**OXIDES OF NITROGEN (as NO<sub>2</sub>) EMISSIONS CHART**



**CARBON MONOXIDE EMISSIONS CHART**



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**MOISTURE CALCULATIONS**

| Moisture Determination - Isokinetic |                              |                    |                  |                  |                    |          |                  |
|-------------------------------------|------------------------------|--------------------|------------------|------------------|--------------------|----------|------------------|
| Test Number                         | Sampling Time and Date       | Start Weight<br>kg | End Weight<br>kg | Total gain<br>kg | Concentration<br>% | LOD<br>% | Uncertainty<br>% |
| Run 1                               | 13:35 - 14:05<br>03 May 2022 | 1.8305             | 1.8905           | 0.0600           | 11.9               | 0.02     | 111.2            |

| Moisture Quality Assurance |                           |                           |                        |                          |                        |                               |                        |
|----------------------------|---------------------------|---------------------------|------------------------|--------------------------|------------------------|-------------------------------|------------------------|
| Test Number                | Sampling Duration<br>mins | Total Volume Sampled<br>l | Sampling Rate<br>l/min | Start Leak Rate<br>l/min | End Leak Rate<br>l/min | Acceptable Leak Rate<br>l/min | Leak Tests Acceptable? |
| Run 1                      | 30                        | 631                       | 19.7                   | -19.00                   | -19.00                 | 0.39                          | Yes                    |

**PRELIMINARY STACK SURVEY**

| Stack Characteristics         |        |                |
|-------------------------------|--------|----------------|
| Stack Diameter / Depth, D     | 2.30   | m              |
| Stack Width, W                | -      | m              |
| Stack Area, A                 | 4.16   | m <sup>2</sup> |
| Average stack gas temperature | 58     | °C             |
| Stack static pressure         | -0.162 | kPa            |
| Barometric Pressure           | 100.9  | kPa            |

| Stack Gas Composition & Molecular Weights |                 |                                   |                   |                          |                                     |                   |                          |                                     |
|---|-----------------|-----------------------------------|-------------------|--------------------------|-------------------------------------|-------------------|--------------------------|-------------------------------------|
| Component                                 | Molar Mass<br>M | Density<br>kg/m <sup>3</sup><br>p | Conc Dry<br>% Vol | Dry Volume Fraction<br>r | Dry Conc<br>kg/m <sup>3</sup><br>pi | Conc Wet<br>% Vol | Wet Volume Fraction<br>r | Wet Conc<br>kg/m <sup>3</sup><br>pi |
| CO <sub>2</sub>                           | 44              | 1.963059                          | 0.656667          | 0.006567                 | 0.012891                            | 0.578823          | 0.005788                 | 0.011363                            |
| O <sub>2</sub>                            | 32              | 1.427679                          | 20.300000         | 0.203000                 | 0.289819                            | 17.893555         | 0.178936                 | 0.255463                            |
| N <sub>2</sub>                            | 28              | 1.249219                          | 79.043333         | 0.790433                 | 0.987425                            | 69.673214         | 0.696732                 | 0.870371                            |
| H <sub>2</sub> O                          | 18              | 0.803070                          | -                 | -                        | -                                   | 11.854408         | 0.118544                 | 0.095199                            |

Where:  $p = M / 22.41$      $pi = r \times p$

| Calculation of Stack Gas Densities          |        |                   |
|---|--------|-------------------|
| Determinand                                 | Result | Units             |
| Dry Density (STP), $P_{STD}$                | 1.2901 | kg/m <sup>3</sup> |
| Wet Density (STP), $P_{STW}$                | 1.2324 | kg/m <sup>3</sup> |
| Dry Density (Actual), $P_{Actual}$          | 1.0598 | kg/m <sup>3</sup> |
| Average Wet Density (Actual), $P_{ActualW}$ | 1.012  | kg/m <sup>3</sup> |

Where:

$P_{STD}$  = sum of component concentrations, kg/m<sup>3</sup> (not including water vapour)  
 $P_{STW} = (P_{STD} + pi \text{ of H}_2\text{O}) / (1 + (pi \text{ of H}_2\text{O} / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$   
 $P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**PRELIMINARY STACK SURVEY**

**TRAVERSE 1**

|                              |               |
|------------------------------|---------------|
| Date of Survey               | 03 May 2022   |
| Time of Survey               | 13:20 - 13:30 |
| Velocity Measurement Device: | S-Type Pitot  |

| Sampling Line A |                        |                                  |  |         |              |   |                      |                  |
|-----------------|------------------------|----------------------------------|--|---------|--------------|---|----------------------|------------------|
| Traverse Point  | Distance into duct (m) | DP pt Pa (average of 3 readings) | DP pt mmH <sub>2</sub> O (average of 3 readings) | Temp °C | Velocity m/s | Volumetric Flow Rate (actual) m <sup>3</sup> /s | O <sub>2</sub> % Vol | Angle of Swirl ° |
| 1               | 0.07                   | 213.6                            | 21.8   | 57      | 17.3         | 72.0  | 20.9                 | <15              |
| 2               | 0.21                   | 241.7                            | 24.7   | 57      | 18.4         | 76.6  | -                    | <15              |
| 3               | 0.38                   | 199.6                            | 20.4   | 57      | 16.8         | 69.6  | -                    | <15              |
| 4               | 0.61                   | 152.6                            | 15.6   | 57      | 14.6         | 60.9  | -                    | <15              |
| 5               | 1.15                   | 124.1                            | 12.7   | 57      | 13.2         | 54.9  | -                    | <15              |
| 6               | 1.69                   | 113.4                            | 11.6   | 57      | 12.6         | 52.5  | -                    | <15              |
| 7               | 1.92                   | 135.6                            | 13.8   | 57      | 13.8         | 57.4  | -                    | <15              |
| 8               | 2.09                   | 122.5                            | 12.5   | 57      | 13.1         | 54.5  | -                    | <15              |
| 9               | 2.23                   | 73.8                             | 7.5  | 57      | 10.2         | 42.3  | -                    | <15              |
| -               | -                      | -                                | -  | -       | -            | -   | -                    | -                |
| Mean            | -                      | 153.0                            | 15.6   | 57      | 14.5         | 60.1  | 20.9                 | -                |

| Sampling Line B |                        |                                  |  |         |              |   |                      |                  |
|-----------------|------------------------|----------------------------------|--|---------|--------------|---|----------------------|------------------|
| Traverse Point  | Distance into duct (m) | DP pt Pa (average of 3 readings) | DP pt mmH <sub>2</sub> O (average of 3 readings) | Temp °C | Velocity m/s | Volumetric Flow Rate (actual) m <sup>3</sup> /s | O <sub>2</sub> % Vol | Angle of Swirl ° |
| 1               | 0.07                   | 280.3                            | 28.6   | 58      | 19.9         | 82.5  | 20.9                 | <15              |
| 2               | 0.21                   | 207.4                            | 21.2   | 58      | 17.1         | 71.0  | -                    | <15              |
| 3               | 0.38                   | 185.2                            | 18.9   | 58      | 16.1         | 67.1  | -                    | <15              |
| 4               | 0.61                   | 152.2                            | 15.5   | 58      | 14.6         | 60.8  | -                    | <15              |
| 5               | 1.15                   | 170.5                            | 17.4   | 58      | 15.5         | 64.4  | -                    | <15              |
| 6               | 1.69                   | 131.0                            | 13.4   | 58      | 13.6         | 56.4  | -                    | <15              |
| 7               | 1.92                   | 96.7                             | 9.9  | 58      | 11.7         | 48.5  | -                    | <15              |
| 8               | 2.09                   | 109.4                            | 11.2   | 58      | 12.4         | 51.6  | -                    | <15              |
| 9               | 2.23                   | 83.6                             | 8.5  | 58      | 10.8         | 45.1  | -                    | <15              |
| -               | -                      | -                                | -  | -       | -            | -   | -                    | -                |
| Mean            | -                      | 157.4                            | 16.1   | 58      | 14.6         | 60.8  | 20.9                 | -                |

**PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST**

| PITOT LEAK CHECK |                                |                              |              |         |                                |                              |              |         |
|------------------|--------------------------------|------------------------------|--------------|---------|--------------------------------|------------------------------|--------------|---------|
| Run              | Pre Traverse Leak Rate         |                              |              |         | Post Traverse Leak Rate        |                              |              |         |
|                  | Start Value mmH <sub>2</sub> O | End Value mmH <sub>2</sub> O | Difference % | Outcome | Start Value mmH <sub>2</sub> O | End Value mmH <sub>2</sub> O | Difference % | Outcome |
| Run 1            | 145                            | 144                          | 0.7          | Pass    | 149                            | 148                          | 0.7          | Pass    |

To complete a compliant pitot leak check a pressure of over 80 mmH<sub>2</sub>O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

| S-Type Pitot Stagnation Check |                 |                |                 |                               |
|-------------------------------|-----------------|----------------|-----------------|-------------------------------|
| Run                           | Stagnation (Pa) | Reference (Pa) | Difference (Pa) | Outcome (Permitted +/- 10 Pa) |
| Run 1                         | -164            | -160           | -4.0            | Pass                          |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**PRELIMINARY STACK SURVEY (CONTINUED)**

| Sampling Plane Validation Criteria             |        |       |             |           |
|--|--------|-------|-------------|-----------|
| EA Technical Guidance Note (Monitoring) M1     | Result | Units | Requirement | Compliant |
| Lowest Average Differential Pressure           | 74     | Pa    | >= 5 Pa     | Yes       |
| Lowest Gas Velocity                            | 10.2   | m/s   | -           | -         |
| Highest Gas Velocity                           | 19.9   | m/s   | -           | -         |
| Ratio of Gas Velocities                        | 1.9    | -     | < 3 : 1     | Yes       |
| Maximum angle of flow with regard to duct axis | <15    | °     | < 15°       | Yes       |
| No local negative flow                         | Yes    | -     | -           | Yes       |

| Calculation of Stack Gas Velocity, V   |      |     |
|--|------|-----|
| Velocity at Traverse Point, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / P_{ActualW}}$ |      |     |
| <b>Where:</b>  |      |     |
| $K_{pt}$ = Pitot tube calibration coefficient  |      |     |
| (1-e) = Compressibility correction factor, assumed at a constant 0.998                             |      |     |
| Average Stack Gas Velocity, $V_a$  | 14.5 | m/s |

| Calculation of Stack Gas Volumetric Flowrate, Q |         |           |       |
|---|---------|-----------|-------|
| Duct gas flow conditions                        | Actual  | Reference | Units |
| Temperature                                     | 58      | 0         | °C    |
| Total Pressure                                  | 100.738 | 101.3     | kPa   |
| Oxygen  | 20.3    | 21        | %     |
| Moisture  | 11.85   | 0.00      | %     |
| Pitot tube calibration coefficient, $K_{pt}$    | 0.84    |           |       |

| Gas Volumetric Flowrate                           |          |                    |
|---|----------|--------------------|
|   | Result   | Units              |
| Average Stack Gas Velocity ( $V_a$ )              | 14.55    | m/s                |
| Stack Area (A)                                    | 4.16     | m <sup>2</sup>     |
| Gas Volumetric Flowrate (Actual), $Q_{Actual}$    | 217614.3 | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (STP, Wet), $Q_{STP}$     | 178756.7 | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$ | 157566.2 | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (REF), $Q_{Ref}$          | 157566.2 | m <sup>3</sup> /hr |

**Where:**

$$Q_{Actual} = V_a \times A \times 3600$$

$$Q_{STP} = Q (Actual) \times (T_s / T_a) \times (P_a / P_s) \times 3600$$

$$Q_{STP,Dry} = Q (STP) / (100 - (100 / Ma)) \times 3600$$

$$Q_{Ref} = Q (STP) \times ((100 - Ma) / (100 - Ms)) \times ((21 - O_{2a}) / (21 - O_{2s}))$$

**Nomenclature:**

$T_s$  = Absolute Temperature, Standard Conditions, 273 K

$P_s$  = Absolute Pressure, Standard Conditions, 101.3 kPa

$T_a$  = Absolute Temperature, Actual Conditions, K

$P_a$  = Absolute Pressure, Actual Conditions, kPa

$Ma$  = Water vapour, Actual Conditions, % Vol

$Ms$  = Water vapour, Reference Conditions, % Vol

$O_{2a}$  = Oxygen, Actual Conditions, % Vol

$O_{2s}$  = Oxygen, Reference Conditions, % Vol





APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER**

| Run                | Sampled Volume<br>m <sup>3</sup> | Sampled Gas Temp<br>K | Sampled Gas Pressure<br>kPa | Sampled Gas Humidity<br>% by volume | Oxygen Content<br>% by volume | Limit of Detection<br>% by mass | Leak<br>%  | Uncollected Mass<br>mg |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|---------------------------------|------------|------------------------|
| <b>MU required</b> | ≤ 2%                             | ≤ 2%                  | ≤ 1%                        | ≤ 1%                                | ≤ 10%                         | ≤ 5% of ELV                     | ≤ 2%       | ≤ 10% of ELV           |
| Run 1              | 0.001                            | 2.0                   | 0.50                        | 1.0                                 | N/A                           | 0.1800                          | -          | -                      |
| as a %             | 0.20                             | 0.62                  | 0.49                        | 1.0                                 | N/A                           | 1.61902                         | -96.24     | 0.001                  |
| <b>compliant?</b>  | <b>Yes</b>                       | <b>Yes</b>            | <b>Yes</b>                  | <b>Yes</b>                          | <b>N/A</b>                    | <b>Yes</b>                      | <b>Yes</b> | <b>Yes</b>             |

| Run                     | Volume (STP)<br>m <sup>3</sup> | Mass of particulate<br>mg | O <sub>2</sub> Correction<br>- | Leak<br>mg/m <sup>3</sup> | Uncollected Mass<br>mg | Combined uncertainty |
|-------------------------|--------------------------------|---------------------------|--------------------------------|---------------------------|------------------------|----------------------|
| Run 1                   | 0.47                           | 1.2000                    | 1.0                            | -1.1995                   | 0.0001                 | -                    |
| MU as mg/m <sup>3</sup> | 0.03                           | 0.3238                    | -                              | -1.1995                   | 0.0002                 | <b>1.24</b>          |
| MU as %                 | 1.30                           | 15.0000                   | -                              | -55.566                   | 0.0087                 | -                    |

|   |             |                         |               |                 |              |              |
|---|-------------|-------------------------|---------------|-----------------|--------------|--------------|
| <b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b> | <b>2.49</b> | <b>mg/m<sup>3</sup></b> | <b>115.14</b> | <b>% Result</b> | <b>12.43</b> | <b>% ELV</b> |
|---|-------------|-------------------------|---------------|-----------------|--------------|--------------|

(k is a coverage factor which gives a 95% confidence in the quoted figures)

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - ISOCYANATES**

| Run                | Sampled Volume m <sup>3</sup> | Sampled Gas Temp K | Sampled Gas Pressure kPa | Sampled Gas Humidity % by volume | Oxygen Content % by volume | Leak %     | Uncollected Mass mg |
|--------------------|-------------------------------|--------------------|--------------------------|----------------------------------|----------------------------|------------|---------------------|
| <b>MU required</b> | ≤ 2%                          | ≤ 2%               | ≤ 1%                     | ≤ 1%                             | ≤ 10%                      | ≤ 2%       | ≤ 10% of ELV        |
| Run 1              | 0.001                         | 2                  | 0.5                      | 1                                | N/A                        | -          | -                   |
| as a %             | 0.20                          | 0.68               | 0.49                     | 1.00                             | N/A                        | 1.00       | 0.00                |
| <b>compliant?</b>  | <b>Yes</b>                    | <b>Yes</b>         | <b>Yes</b>               | <b>Yes</b>                       | <b>N/A</b>                 | <b>Yes</b> | <b>Yes</b>          |

| Run                     | Volume (STP) m <sup>3</sup> | Mass of Isocyanates mg | O2 Correction - | Leak mg/m <sup>3</sup> | Uncollected Mass mg | Combined uncertainty |
|-------------------------|-----------------------------|------------------------|-----------------|------------------------|---------------------|----------------------|
| Run 1                   | 0.50                        | 0.0007                 | 1.00            | 0.000                  | 0.0000              | -                    |
| MU as mg/m <sup>3</sup> | 0.00                        | 0.0004                 | -               | 0.000                  | 0.0000              | <b>1.44</b>          |
| MU as %                 | 1.32                        | 0.0028                 | -               | 0.579                  | 0.00                | -                    |

|   |              |                         |              |                 |             |              |
|---|--------------|-------------------------|--------------|-----------------|-------------|--------------|
| <b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b> | <b>0.001</b> | <b>mg/m<sup>3</sup></b> | <b>56.69</b> | <b>% Result</b> | <b>1.24</b> | <b>% ELV</b> |
|---|--------------|-------------------------|--------------|-----------------|-------------|--------------|

(k is a coverage factor which gives a 95% confidence in the quoted figures)  
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC INPUT**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE**

|                                |       |                   |
|--------------------------------|-------|-------------------|
| Limit value                    | 600   | mg/m <sup>3</sup> |
| Concentration @ Ref conditions | 26.9  | mg/m <sup>3</sup> |
| Cal gas conc                   | 208.8 | mg/m <sup>3</sup> |
| Analyser Full Scale            | 250   | mg/m <sup>3</sup> |

| Performance characteristics                | Value | Units                         | specification      | MU Met? |
|--|-------|-------------------------------|--------------------|---------|
| Response time                              | 29    | seconds                       | 180                | Yes     |
| Logger sampling interval                   | 60    | seconds                       | -                  | -       |
| Measurement period                         | 60    | minutes                       | -                  | -       |
| Number of readings in measurement          | 60    | -                             | -                  | -       |
| Repeatability at zero                      | 0.1   | % full scale                  | <1 % range         | Yes     |
| Repeatability at span level                | 0.2   | % full scale                  | <2 % range         | Yes     |
| Deviation from linearity                   | 0.61  | % of value                    | <2 % range         | Yes     |
| Zero drift                                 | -0.06 | % full scale                  | <2% range / 24hr   | Yes     |
| Span drift                                 | -0.84 | % full scale                  | <2% range/24hr     | Yes     |
| volume or pressure flow dependence         | 0.2   | % of full scale/3 kPa         | <2 % / 3 kPa       | Yes     |
| atmospheric pressure dependence            | 0.44  | % of full scale/2 kPa         | <3% / 2 kPa        | Yes     |
| ambient temperature dependence zero / span | -0.8  | % full scale/10K              | <3% range / 10 K   | Yes     |
| Combined interference                      | -0.01 | % of Range                    | <4% of Range       | Yes     |
| dependence on voltage                      | -0.06 | % full scale/10V              | < 0.1%vol /10 volt | Yes     |
| Influence of Vibration                     | N/A   | % of upper limit of Cal range | <2%                | N/A     |
| losses in the line (leak)                  | 0.00  | % of value                    | < 2% of value      | Yes     |
| Uncertainty of calibration gas             | 1.00  | % of value                    | < 2% of value      | Yes     |

N/A - Horiba's are not effected by Vibration

| Performance characteristic       | Uncertainty | Value of uncertainty quantity |
|----------------------------------|-------------|-------------------------------|
| repeatability                    | $U_r = S_r$ | 0.003                         |
| lack of fit                      | $U_{lof}$   | 0.12                          |
| short term zero drift            | $U_{d,z}$   | 0.35                          |
| short term span drift            | $U_{d,s}$   | -0.03                         |
| influence of Ambient Temp zero   | $U_{t,z}$   | 0.03                          |
| influence of Ambient Temp span   | $U_{t,s}$   | 0.14                          |
| influence of sample gas pressure | $U_p$       | 0.03                          |
| influence of sample gas flow     | $U_{fit}$   | 0.14                          |
| influence of supply voltage      | $U_v$       | -0.09                         |
| Combined Interference            | $U_i$       | -0.29                         |
| Uncertainty of Cal gas           | $U_{adj}$   | 0.84                          |

|  |      |                   |
|--|------|-------------------|
| Measurement uncertainty (Concentration Measured) | 26.9 | mg/m <sup>3</sup> |
| Combined uncertainty                             | 1.0  | mg/m <sup>3</sup> |
| Expanded uncertainty                             | 1.9  | mg/m <sup>3</sup> |

|  |     |                   |
|--|-----|-------------------|
| Expanded uncertainty expressed with a level of confidence of 95% | 0.3 | % ELV             |
| Expanded uncertainty expressed with a level of confidence of 95% | 1.9 | mg/m <sup>3</sup> |
| Expanded uncertainty expressed with a level of confidence of 95% | 7.2 | % value           |

Developed for the STA by R Robinson, NPL

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE**

|  |        |                    |
|--|--------|--------------------|
| Measured Velocity at Actual Conditions             | 14.5   | m/s                |
| Measured Volumetric Flow rate at Actual Conditions | 217614 | m <sup>3</sup> /hr |

| Performance Characteristics & Source of Value                 | Units      | Values  | Requirement                                | Compliant |
|---|------------|---------|--|-----------|
| Uncertainty of Local Gas Velocity Determination               | -          | 0.010   |  |           |
| Uncertainty of pitot tube coefficient                         | -          | 1.28    |  |           |
| Uncertainty of mean local dynamic pressures                   | -          | 1.28    |  |           |
| Factor loading, function of the number of measurements.       | 3 readings | 0.591   | minimum 3                                  | Yes       |
| Range of measurement device                                   | pa         | 1000    |  |           |
| Resolution  | pa         | 1.00    |  |           |
| Calibration uncertainty                                       | pa         | 24.32   | <1% of Value or 20 Pa whichever is greater | Yes       |
| Drift   | % range    | 0.10    |  |           |
| Linearity   | % range    | 0.06    | <2% of value                               | Yes       |
| Uncertainty of gas density determination                      |            |         |  |           |
| Uncertainty of molar mass determination                       | kg/mol     | 0.00027 |  |           |
| Uncertainty of temperature measurement                        | K          | 1.69    | <1% of value                               | Yes       |
| Uncertainty of absolute pressure in the duct                  | pa         | 514     |  |           |
| Uncertainty associated with the estimate of density           | -          | 0.008   |  |           |
| Uncertainty associated with the measurement of local velocity | -          | 0.0001  |  |           |
| Uncertainty associated with the measurement of mean velocity  | -          | 0.0002  |  |           |

| Measurement Uncertainty - Velocity                | m/s  |
|---|------|
| Combined uncertainty                              | 0.18 |
| Expanded uncertainty at a 95% Confidence Interval | 0.35 |

Note - The expanded uncertainty uses a coverage factor of  $k = 2$ .

| Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval | %   |
|---|-----|
| Expressed as a % of the Measured Velocity                                 | 1.2 |
| Expanded uncertainty at a 95% Confidence Interval                         | 2.4 |

| Measurement Uncertainty Volumetric Flow Rate      | m <sup>3</sup> /hr |
|---|--------------------|
| Combined uncertainty                              | 5705               |
| Expanded uncertainty at a 95% Confidence Interval | 11181              |

Note - The expanded uncertainty uses a coverage factor of  $k = 2$ .

| Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval | %   |
|---|-----|
| Expressed as a % of the Measured Volumetric Flow Rate                                 | 2.6 |
| Expanded uncertainty at a 95% Confidence Interval                                     | 5.1 |

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

## END OF REPORT

*Thank you for choosing SOCOTEC for your environmental monitoring needs. We hope our services have met your requirements and that you are fully satisfied with your experience of working with us, we really do value your custom and would welcome your feedback. We would appreciate it if you could take a moment to complete a short online questionnaire so that we can improve our operations and address any areas that have not met with your expectations, by clicking on the following*

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