

STACK EMISSIONS MONITORING REPORT



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Operator & Address:

Radnor Hills Mineral Water Co Ltd
Heartsease Farm
Knighton
Powys
LD7 1LU

Permit Reference:


EPR Permit: EPR/AB3697CN

Release Point:

Boiler 6

Sampling Date(s):

29th October 2024

| | |
|-------------------------|---|
| SOCOTEC Job Number: | LSW 241048 |
| Report Date: | 14th November 2024 |
| Version: | 1 |
| Report By: | Amy Tanner |
| MCERTS Number: | MM 21 1644 |
| MCERTS Level: | MCERTS Level 2 - Team Leader |
| Technical Endorsements: | 1, 2 & 4 |
| Report Approved By: | Jose Navarro |
| MCERTS Number: | MM 19 1542 |
| Business Title: | MCERTS Level 2 - Project Manager |
| Technical Endorsements: | 1, 2, 3 & 4 |
| Signature: |  |



1015



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Radnor Hills Mineral Water Co Ltd operates a steam/heat raising boiler process at Knighton which is subject to EPR Permit EPR/AB3697CN, under the Environmental Permitting Regulations 2016.

SOCOTEC LTD were commissioned by Benjamin Price 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 EPR Permit, EPR/AB3697CN.

Plant

Boiler 6

Operator

Radnor Hills Mineral Water Co Ltd
Heartsease Farm
Knighton
Powys
LD7 1LU

EPR Permit: EPR/AB3697CN

Stack Emissions Monitoring Test House

SOCOTEC - Cirencester Laboratory
Units C & D
Bankside Trade Park
Cirencester
GL7 1YT
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 |
| Sulphur Dioxide | mg/m ³ | 5.6 | 0.98 | 35 | MCERTS |
| Oxides of Nitrogen (as NO ₂) | mg/m ³ | 116 | 4.0 | 200 | MCERTS |
| Carbon Monoxide | mg/m ³ | 21 | 1.7 | - | MCERTS |
| Oxygen | % v/v | 14.6 | 0.305 | - | MCERTS |
| Moisture | % | 7.21 | 0.36 | - | MCERTS |
| Stack Gas Temperature | °C | 164 | - | - | MCERTS |

ND = None Detected,

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

The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

EXECUTIVE SUMMARY

| MONITORING TIMES | | | |
|-----------------------|------------------|----------------|-------------------|
| Parameter | Sampling Date(s) | Sampling Times | Sampling Duration |
| Sulphur Dioxide Run 1 | 29 October 2024 | 10:10 - 11:10 | 60 minutes |
| Combustion Gases | 29 October 2024 | 10:10 - 11:10 | 60 minutes |

EXECUTIVE SUMMARY

| PROCESS DETAILS | |
|---|-----------------------------|
| Parameter | Process Details |
| Description of process | Steam/heat raising boiler |
| Continuous or batch | Continuous |
| Product Details | Steam and Heat |
| Part of batch to be monitored (if applicable) | Any representative period |
| Normal load, throughput or continuous rating | Rated Thermal Input 4.11 MW |
| Fuel used during monitoring | LPG |
| Abatement | None |
| Plume Appearance | Steam plume visible |

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 Environment Agency technical Guidance 'Monitoring stack emissions: techniques and standards for periodic monitoring'.

| MONITORING METHODS | | | | | | | |
|-----------------------|---|-----------------------------------|--------------------|-------------------------|--------------------------------|----------------------------------|-------------------------------|
| Species | Method Standard Reference Method / Alternative Method | SOCOTEC Technical Procedure | UKAS Lab Number | Method Accreditation | Limit of Detection (LOD) | Calculated MU +/- % Result | Calculated MU +/- % ELV |
| Sulphur Dioxide | SRM - BS EN 14791 | AE 112 | 1015 | MCERTS | 0.258 mg/m ³ | 17.3% | 2.79% |
| Oxides of Nitrogen | SRM - BS EN 14792:2017 | AE 102 | 1015 | MCERTS | 1.44 mg/m ³ | 3.5% | 2.02% |
| Carbon Monoxide | SRM - BS EN 15058:2017 | AE 102 | 1015 | MCERTS | 0.39 mg/m ³ | 8.2% | N/A - No ELV |
| Oxygen | AM - BS EN 14789:2017 | AE 102 | 1015 | MCERTS | 0.01% | 2.1% | N/A - No ELV |
| Moisture | SRM - BS EN 14790 | AE 105 | 1015 | MCERTS | 0.1% | 5.0% | N/A - No ELV |

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 No. Date of Analysis | Archive Period |
| Sulphur Dioxide | Ion Chromatography | ASC/SOP/110 | 1252 | MCERTS | SOCOTEC (Bretby) | ASC/64862 | 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 (Cirencester) | SOCOTEC (Cirencester) | 5 years |
| Carbon Monoxide | Non Dispersive Infra Red | AE 102 | 1015 | MCERTS | SOCOTEC (Cirencester) | SOCOTEC (Cirencester) | 5 years |
| Oxygen | Zirconia Cell | AE 102 | 1015 | MCERTS | SOCOTEC (Cirencester) | SOCOTEC (Cirencester) | 5 years |
| Moisture | Gravimetric | AE 105 | 1015 | MCERTS | SOCOTEC (Cirencester) | - | - |

EXECUTIVE SUMMARY

| DUCT CHARACTERISTICS | | |
|----------------------|----------|----------------|
| | Value | Units |
| Shape | Circular | - |
| Depth | 0.60 | m |
| Width | - | m |
| Area | 0.28 | m ² |
| Port Depth | 0 | mm |

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

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

| M1 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) | N/A |
| Platform has vertical base boards (approximately 0.25 m high) | N/A |
| Platform has removable chains / self closing gates at the top of ladders | N/A |
| Handrail / obstructions do not hamper insertion of sampling equipment | N/A |
| Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m | N/A |

Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Velocity Survey

Unable to perform a velocity survey due to sample port location and size. Therefore no mass emissions were reported

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

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 Standard Reference Method / Alternative Method | SOCOTEC Technical Procedure | UKAS Lab Number | MCERTS Accredited Method | Number of Samples |
| Sulphur Dioxide | SRM - BS EN 14791 | AE 112 | 1015 | MCERTS | 1 |
| Oxides of Nitrogen | SRM - BS EN 14792:2017 | AE 102 | 1015 | MCERTS | 1 |
| Carbon Monoxide | SRM - BS EN 15058:2017 | AE 102 | 1015 | MCERTS | 1 |
| Oxygen | AM - BS EN 14789:2017 | AE 102 | 1015 | MCERTS | 1 |
| Moisture | SRM - BS EN 14790 | AE 105 | 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 | P2947 | Horiba PG-250 Analyser | P1339 | Laboratory Balance | P3225 |
| Box Thermocouples | - | FT-IR | - | Tape Measure | - |
| Meter In Thermocouple | - | FT-IR Oven Box | - | Stopwatch | P2733 |
| Meter Out Thermocouple | - | Bernath 3006 FID | - | Protractor | - |
| Control Box Timer | - | Signal 3030 FID | - | Barometer | - |
| Oven Box | - | Servomex | - | Digital Micromanometer | P1909 |
| Probe | - | JCT Heated Head Filter | - | Digital Temperature Meter | P1639 |
| Probe Thermocouple | - | Thermo FID | - | Stack Thermocouple | - |
| Probe | - | Stackmaster | - | Mass Flow Controller | - |
| Probe Thermocouple | - | FTIR Heater Box for Heated Line | - | MFC Display module | - |
| S-Pitot | - | Anemometer | - | 1m Heated Line (1) | - |
| L-Pitot | P2511 | Ecophysics NOx Analyser | - | 1m Heated Line (2) | - |
| Site Balance | P3321 | Chiller (JCT/MAK 10) | P2542 | 1m Heated Line (3) | - |
| Last Impinger Arm | - | Heated Line Controller (1) | P9645 | 5m Heated Line (1) | - |
| Dioxins Cond. Thermocouple | - | Heated Line Controller (2) | - | 10m Heated Line (1) | - |
| Callipers | - | Site temperature Logger | - | 10m Heated Line (2) | - |
| Small DGM | - | | | 15m Heated Line (1) | - |
| Heater Controller | - | | | 20m Heated Line (1) | P2546 |
| Inclinometer (Swirl Device) | P3079 | | | 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 +/- % |
| Oxygen | CJ16 | BOC | - | 9.99 | 2.0 |
| Nitric Oxide | CB42 | BOC | 203.9 | - | 2.0 |
| Carbon Monoxide | CB42 | BOC | 101.7 | - | 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 |
| Jose Navarro | MM 19 1542 | MCERTS Level 2 | Dec-25 | Oct-30 | Apr-29 | Dec-25 | Mar-26 | May-29 |
| Amy Tanner | MM 21 1644 | MCERTS Level 2 | Sep-26 | May-28 | Apr-29 | - | Jul-28 | Sep-26 |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| SULPHUR DIOXIDE SUMMARY | | | | | |
|-------------------------|----------------------------------|------------------------------------|--------------------------|--------------------------|-----------------------|
| Test | Sampling Times | Concentration mg/m ³ | LOD mg/m ³ | ELV mg/m ³ | Emission Rate g/hr |
| Run 1 | 10:10 - 11:10 29 October 2024 | 5.6 | 0.258 | 35 | - |
| Field Blank | - | 0.588 | - | - | - |

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

SULPHUR DIOXIDE QUALITY ASSURANCE CHECKLIST

| | Barometric Pressure Kpa | Average Oxygen Value for Referencing % | Total Sample Volume @ ref Conditions m ³ | Mean Sampling Rate l/min | Pre Sampling Leak Rate l/min | Post Sampling Leak Rate l/min | Acceptable Leak Rate l/min | Leak Tests Acceptable? |
|-------|-----------------------------------|--|--|------------------------------------|--|---|--------------------------------------|---------------------------|
| Run 1 | 102.8 | 14.6 | 0.090 | 4.2 | 0.01 | 0.01 | 0.08 | Yes |

| | Filter Material | Filter Size mm | Max. Filtration Temp. °C | Temperature during storage / transit <25°C | Type of Absorbers | Absorption Solutions |
|-------|-----------------|-------------------|--------------------------------|--|----------------------|------------------------|
| Run 1 | Sinter | 15 micron | 180 | N/A | PTFE | 0.3% Hydrogen Peroxide |

SULPHUR DIOXIDE ABSORPTION EFFICIENCY

| Parameter | Total ug | IMP C ug | Absorption Efficiency % | Acceptable Absorption Efficiency % | Absorption Efficiency Acceptable ? |
|-----------|-------------|-------------|----------------------------|---------------------------------------|---------------------------------------|
| Run 1 | 506.5 | ND | 100 | 95 | Yes |

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

| Test | Sampling Time and Date | Concentration mg/m ³ | LOD mg/m ³ | ELV mg/m ³ | Emission Rate g/hr |
|--------------------|----------------------------------|------------------------------------|--------------------------|--------------------------|-----------------------|
| Oxides of Nitrogen | 10:10 - 11:10 29 October 2024 | 116 | 1.44 | 200 | N/A |
| Carbon Monoxide | 10:10 - 11:10 29 October 2024 | 21.0 | 0.39 | - | N/A |

| Test | Sampling Time and Date | Concentration % | LOD % |
|--------|----------------------------------|--------------------|----------|
| Oxygen | 10:10 - 11:10 29 October 2024 | 14.58 | 0.01 |

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

PRE-SAMPLING CALIBRATION DATA

| | |
|------------|-----------------|
| Date | 29 October 2024 |
| Start Time | 09:41 |
| End Time | 09:49 |

| | |
|--------------------------|-------|
| Chiller Temperature (°C) | 2.2 |
| Requirement | < 4°C |
| Compliant | Yes |

| Gas | Range (ppm / %) | Zero Reading at analyser | Span Reading at analyser | Zero Check at analyser | Zero Check down line | Span Check down line | Response Time (Secs) | Leak Rate % |
|-----------------|--------------------|-----------------------------|-----------------------------|---------------------------|-------------------------|-------------------------|-------------------------|----------------|
| Nitric Oxide | 250 | 0.00 | 196.5 | 0.20 | 0.10 | 196.6 | 35 | -0.05 |
| Carbon Monoxide | 100 | 0.10 | 158.4 | 0.10 | 0.10 | 158.5 | 36 | -0.06 |
| Oxygen | 25 | 0.03 | 10.02 | 0.03 | 0.02 | 10.01 | 38 | 0.10 |

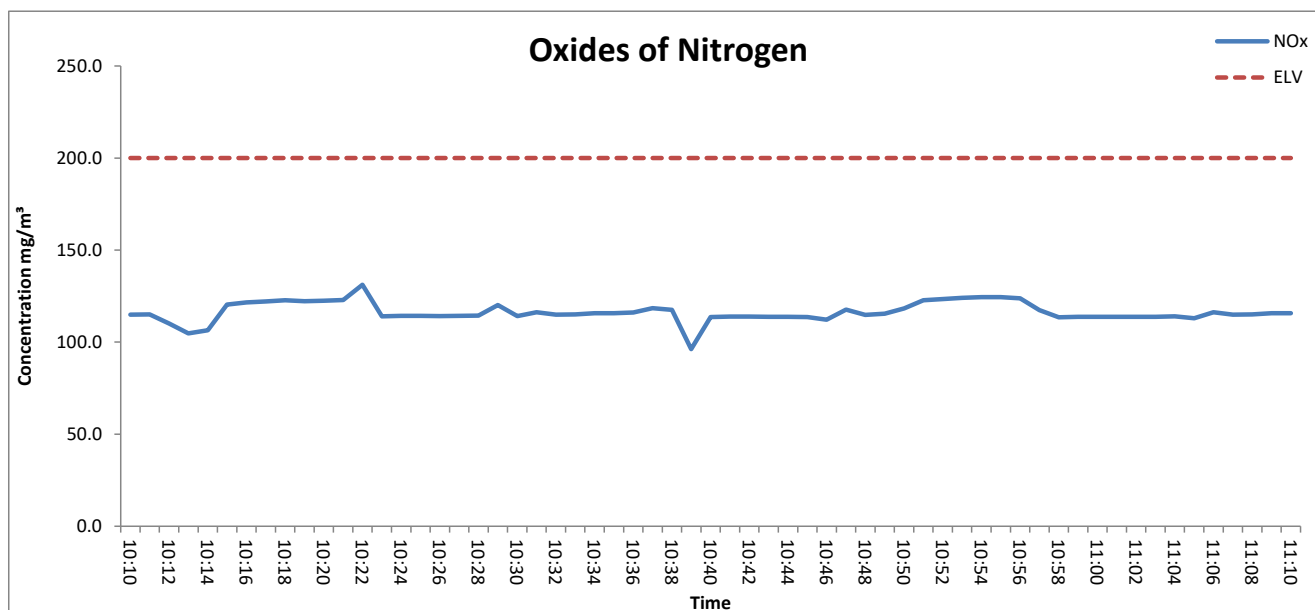
POST-SAMPLING CALIBRATION DATA

| | |
|------------|-----------------|
| Date | 29 October 2024 |
| Start Time | 11:15 |
| End Time | 11:26 |

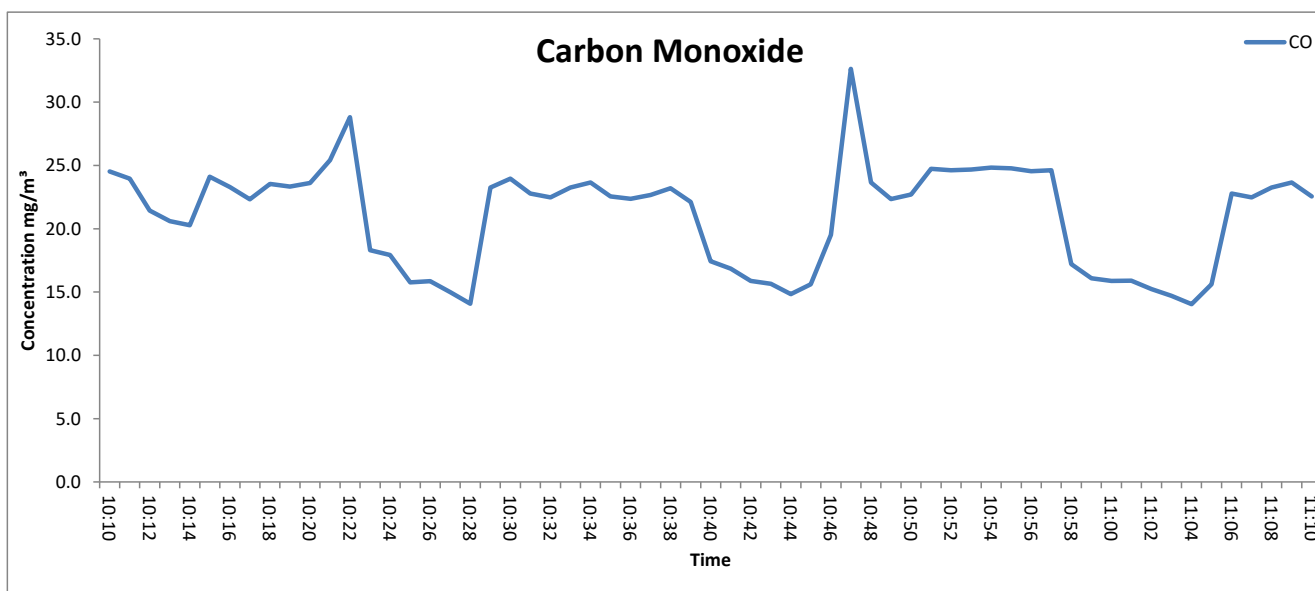
| | |
|--------------------------|-------|
| Chiller Temperature (°C) | 2.4 |
| Requirement | < 4°C |
| Compliant | Yes |

| Gas | Zero Check at Analyser | Span Check at Analyser | Zero Drift (%) | Span Drift (%) | Corrected for Zero Drift | Corrected for Span Drift | Corrected Values ppm / % |
|-----------------|---------------------------|---------------------------|-------------------|-------------------|-----------------------------|-----------------------------|-----------------------------|
| Nitric Oxide | 0.10 | 196.4 | -0.05 | 0.00 | x | x | N/A - not corrected |
| Carbon Monoxide | 0.20 | 158.5 | 0.06 | 0.00 | x | x | N/A - not corrected |
| Oxygen | 0.01 | 10.00 | -0.20 | 0.00 | x | x | N/A - not corrected |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts
OXIDES OF NITROGEN (as NO₂) EMISSIONS CHART

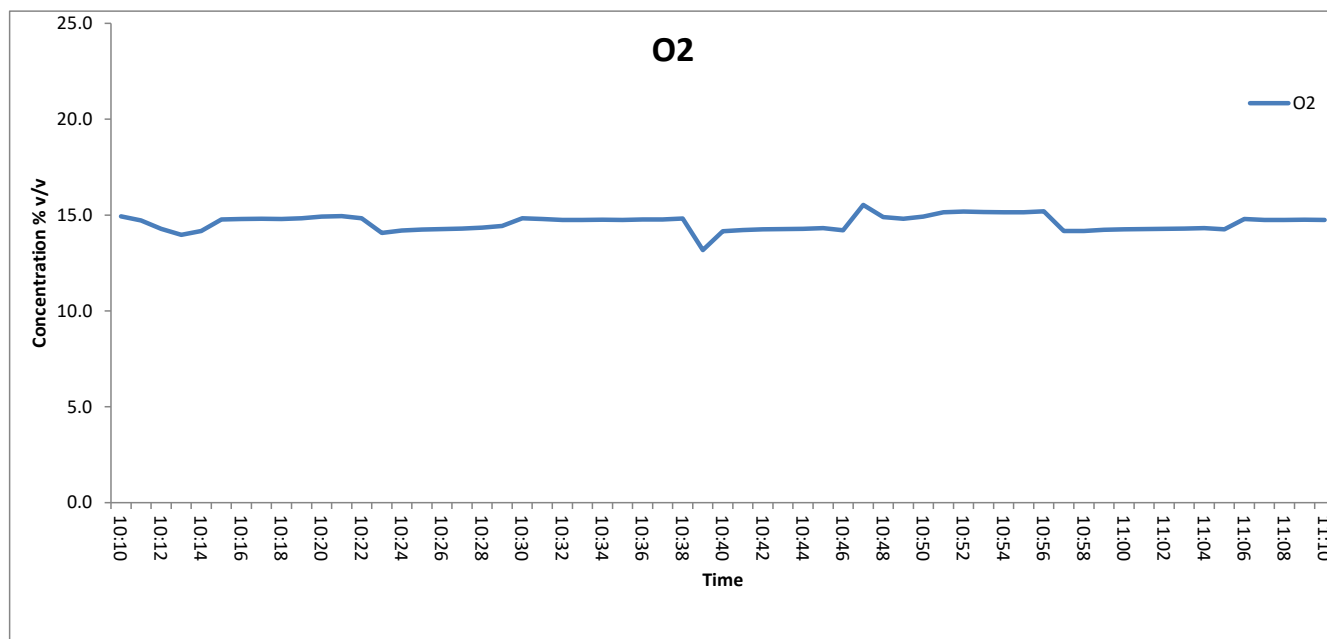


CARBON MONOXIDE EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OXYGEN EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

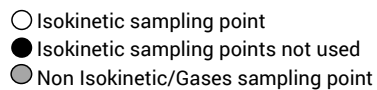
MOISTURE CALCULATIONS

| Moisture Determination - Non Isokinetic | | | | | | | |
|---|----------------------------------|--------------|------------|------------|---------------|------|-------------|
| Test Number | Sampling Time and Date | Start Weight | End Weight | Total gain | Concentration | LOD | Uncertainty |
| | | kg | kg | kg | % | % | % |
| Run 1 | 10:10 - 11:10 29 October 2024 | 3.0843 | 3.0921 | 0.0078 | 7.2 | 0.10 | 5.0 |

| Moisture Quality Assurance | | | | | | | |
|----------------------------|---------------------------|---------------------------|------------------------|--------------------------|------------------------|-------------------------------|------------------------|
| Test Number | Sampling Duration mins | Total Volume Sampled l | Sampling Rate l/min | Start Leak Rate l/min | End Leak Rate l/min | Acceptable Leak Rate l/min | Leak Tests Acceptable? |
| Run 1 | 60 | 125 | 2.1 | 0.01 | 0.04 | 0.04 | Yes |

STACK DIAGRAM

| Non-Isokinetic/Gases Sampling | | | |
|-------------------------------|-----------------------|---------------------|-------|
| Sampling Point | Distance (% of Depth) | Distance into Stack | Units |
| A | 50 | 0.30 | m |

[illegible]

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC SULPHUR DIOXIDE

| Run | Sampled Volume m ³ | Sampled Gas Temp K | Sampled Gas Pressure kPa | Sampled Gas Humidity % by volume | Oxygen Content % by volume | Limit of Detection % by mass | Leak % |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|---------------------------------|----------------|
| MU required | <=2% | <2.5 k | <=1% | <=1% | <=10% | ≤ 5% of ELV | <=2% |
| Run 1 | 0.0001 | 2.000 | 0.500 | 1.000 | 0.100 | 0.064 | - |
| as a % | 0.094 | 0.697 | 0.486 | 1.000 | 0.686 | 1.112 | 0.238 |
| compliant? | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

| Run | Volume (STP) m ³ | Mass of Sulphur Dioxide mg | O2 Correction - | Leak mg/m ³ | Lab Uncertainty mg | Combined uncertainty |
|-------------------------|--------------------------------|-------------------------------|--------------------|---------------------------|-----------------------|----------------------|
| Run 1 | 0.0867 | 0.9280 | 2.8054 | 0.0078 | - | - |
| MU as mg/m ³ | 0.0742 | 0.3893 | 0.0879 | 0.0078 | 0.2707 | 0.488 |
| MU as % | 1.3159 | 6.9036 | 1.5586 | 0.1375 | 4.8 | - |

| | | | | | | |
|---|--------------|-------------------------|--------------|-----------------|-------------|--------------|
| R1 - Uncertainty expressed at a 95% confidence level (where k = 2) | 0.976 | mg/m³ | 17.31 | % Result | 2.79 | % ELV |
|---|--------------|-------------------------|--------------|-----------------|-------------|--------------|

(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 - MOISTURE

| Run | Sampled Volume m ³ | Sampled Gas Temp K | Sampled Gas Pressure kPa | Sampled Gas Humidity % by volume | Oxygen Content % by volume | Leak % |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|-------------|
| MU required | ≤ 2% | ≤ 2% | ≤ 1% | ≤ 1% | ≤ 10% | ≤ 2% |
| Run 1 | 0.0000417 | 2.0 | 0.50 | 1.0 | 0.1 | - |
| as a % | 0.03 | 0.46 | 0.49 | 1.0 | 0.69 | 0.48 |
| compliant? | Yes | Yes | Yes | Yes | Yes | Yes |

| Run | Volume (STP) m ³ | Mass Gained mg | O2 Correction - | Leak mg/m ³ | Uncollected Mass mg | Combined uncertainty |
|-------------|--------------------------------|-------------------|--------------------|---------------------------|------------------------|----------------------|
| Run 1 | 0.08 | 7800 | 2.8 | 172.9 | 58 | - |
| MU as % v/v | 0.09 | 0.10 | 0.07 | 0.02 | 0.06 | 0.17 |
| MU as % | 1.2 | 1.3 | 1.56 | 0.3 | 0.7 | - |

| | | | | |
|---|-------------|--------------|-------------|----------|
| R1 - Uncertainty expressed at a 95% confidence level (where k = 2) | 0.34 | % v/v | 4.96 | % |
|---|-------------|--------------|-------------|----------|

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

| | | |
|--------------------------------|-------|-------------------|
| Limit value | 200 | mg/m ³ |
| Concentration @ Ref conditions | 116.2 | mg/m ³ |
| Cal gas conc | 418 | mg/m ³ |
| Analyser Full Scale | 513 | mg/m ³ |

| | Value | Units | specification | MU Met? |
|--|-------|-------------------------------|--------------------|---------|
| Response time | 35 | seconds | 180 | Yes |
| Logger sampling interval | 60 | seconds | - | - |
| Measurement period | 60 | minutes | - | - |
| Number of readings in measurement | 60 | - | - | - |
| Repeatability at zero | 0.11 | % full scale | <1 % range | Yes |
| Repeatability at span level | 0.1 | % full scale | <2 % range | Yes |
| Deviation from linearity | -0.40 | % of value | <2 % range | Yes |
| Zero drift | -0.05 | % full scale | <5% range / 24hr | Yes |
| Span drift | 0.00 | % full scale | <5% range / 24hr | Yes |
| volume or pressure flow dependence | 0.25 | % of full scale/3 kPa | <2 % / 3 kPa | Yes |
| atmospheric pressure dependence | 0.25 | % of full scale/2 kPa | <3% / 2 kPa | Yes |
| ambient temperature dependence zero / span | 0.25 | % full scale/10K | <3% range / 10 K | Yes |
| Combined interference | 0.01 | % range | <4% of Range | Yes |
| dependence on voltage | 0.02 | % full scale/10V | < 0.1%vol /10 volt | Yes |
| Influence of Vibration | N/A | % of upper limit of Cal range | <2% | - |
| losses in the line (leak) | 0.02 | % of value | < 2% of value | Yes |

| Performance characteristic | Uncertainty | Value of uncertainty quantity |
|-----------------------------------|-------------|-------------------------------|
| repeatability | $U_r = S_r$ | 0.0037 |
| lack of fit | U_{lof} | -0.2309 |
| short term zero drift | $U_{d,z}$ | -0.0294 |
| short term span drift | $U_{d,s}$ | 0.0000 |
| influence of Ambient Temp at Zero | $U_{t,z}$ | 0.0191 |
| influence of Ambient Temp at Span | $U_{t,s}$ | 0.0344 |
| influence of sample gas pressure | U_p | 0.0000 |
| influence of sample gas flow | U_{fit} | 0.1732 |
| influence of supply voltage | U_v | 0.0445 |
| Combined Interference | U_i | 0.0042 |
| Uncertainty of Cal gas | U_{adj} | 2.0390 |

| | | |
|--|--------|-------------------|
| Measurement uncertainty (Concentration Measured) | 116.23 | mg/m ³ |
| Combined uncertainty | 2.06 | mg/m ³ |
| Expanded at a 95% confidence interval | 4.04 | mg/m ³ |

| | | |
|--|------|-------|
| Expanded uncertainty expressed with a level of confidence of 95% | 2.02 | % ELV |
|--|------|-------|

| | | |
|--|-----|-------------------|
| Expanded uncertainty expressed with a level of confidence of 95% | 4.0 | mg/m ³ |
|--|-----|-------------------|

| | | |
|--|-----|---------|
| Expanded uncertainty expressed with a level of confidence of 95% | 3.5 | % value |
|--|-----|---------|

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

| | | |
|--------------------------------|-------|-------------------|
| Limit value | - | mg/m ³ |
| Concentration @ Ref conditions | 21.0 | mg/m ³ |
| Cal gas conc | 127.1 | mg/m ³ |
| Analyser Full Scale | 125 | mg/m ³ |

| Performance characteristics | Value | Units | specification | MU Met? |
|--|-------|-------------------------------|--------------------|---------|
| Response time | 36 | 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 | <5% range / 24hr | Yes |
| Span drift | 0.00 | % full scale | <5% range / 24hr | Yes |
| volume or pressure flow dependence | 0.1 | % of full scale/3 kPa | <2 % / 3 kPa | Yes |
| atmospheric pressure dependence | 0.22 | % of full scale/2 kPa | <3% / 2 kPa | Yes |
| ambient temperature dependence zero / span | 0.5 | % full scale/10K | <3% range / 10 K | Yes |
| Combined interference | 0.03 | % of Range | <4% of Range | Yes |
| dependence on voltage | -0.03 | % 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 | $U_{d,s}$ | 0.04 |
| influence of Ambient Temp zero | $U_{t,z}$ | 0.01 |
| influence of Ambient Temp span | $U_{t,s}$ | 0.01 |
| influence of sample gas pressure | U_p | 0.00 |
| influence of sample gas flow | U_{fit} | 0.07 |
| influence of supply voltage | U_v | -0.02 |
| Combined Interference | U_i | 0.60 |
| Uncertainty of Cal gas | U_{adj} | 0.51 |

| | | |
|--|-----|-------------------|
| Measurement uncertainty (Concentration Measured) | 7.4 | mg/m ³ |
| Combined uncertainty | 0.9 | mg/m ³ |
| Expanded uncertainty | 1.7 | mg/m ³ |

| | | |
|--|-----|-------------------|
| Expanded uncertainty expressed with a level of confidence of 95% | - | % ELV |
| Expanded uncertainty expressed with a level of confidence of 95% | 1.7 | mg/m ³ |
| Expanded uncertainty expressed with a level of confidence of 95% | 8.2 | % value |

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

| | | |
|------------------------|-------|------|
| Reference | 3 | %vol |
| Reported Concentration | 14.58 | %vol |
| Calibration gas | 9.99 | %vol |
| Analyser Full Scale | 25 | %vol |

| | Value | Units | specification | MU Met? |
|------------------------------------|-------|-----------------------|--------------------|---------|
| Response time | 38 | seconds | 180 | Yes |
| Logger sampling interval | 60 | seconds | - | - |
| Measurement period | 60 | minutes | - | - |
| Number of readings in measurement | 60 | - | - | - |
| Repeatability at zero | 0.25 | % full scale | <1 % range | Yes |
| Repeatability at span level | 0.15 | % full scale | <2 % range | Yes |
| Deviation from linearity | 0.13 | % of value | <2 % range | Yes |
| Zero drift | -0.20 | % full scale | <5% range / 24hr | Yes |
| Span drift | 0.00 | % full scale | <5% range / 24hr | Yes |
| volume or pressure flow dependence | 0.03 | % of full scale/3 kPa | <2 % / 3 kPa | Yes |
| atmospheric pressure dependence | 0.05 | % of full scale/2 kPa | <3% / 2 kPa | Yes |
| ambient temperature dependence | -0.08 | % full scale/10K | <3% range / 10 K | Yes |
| Combined interference | 0.14 | % range | <4% of Range | Yes |
| dependence on voltage | 0.00 | % full scale/10V | < 0.1%vol /10 volt | Yes |
| losses in the line (leak) | 0.14 | % of value | < 2% of value | Yes |
| Uncertainty of calibration gas | 0.1 | % of value | < 2% of value | Yes |

| Performance characteristic | Uncertainty | Value of uncertainty quantity |
|-----------------------------------|-------------|-------------------------------|
| repeatability | $U_r = S_r$ | 0.0083 |
| lack of fit | U_{lof} | 0.0751 |
| short term zero drift | $U_{d,z}$ | -0.1156 |
| short term span drift | $U_{d,s}$ | 0.0000 |
| influence of Ambient Temp at Zero | $U_{t,z}$ | -0.0001 |
| influence of Ambient Temp at Span | $U_{t,s}$ | 0.0003 |
| influence of sample gas pressure | U_p | 0.0000 |
| influence of sample gas flow | U_{fit} | 0.0173 |
| influence of supply voltage | U_v | 0.0001 |
| Combined Interference | U_i | 0.0485 |
| Uncertainty of Cal gas | U_{adj} | 0.0500 |

| | | |
|--|-------|-------|
| Measurement uncertainty (Concentration Measured) | 14.58 | % vol |
| Combined uncertainty | 0.16 | % vol |
| Expanded uncertainty | 0.30 | % vol |

| | | |
|--|------|-------|
| Expanded uncertainty expressed with a level of confidence of 95% | 0.30 | % vol |
|--|------|-------|

| | | |
|--|------|---------|
| Expanded uncertainty expressed with a level of confidence of 95% | 2.09 | % value |
|--|------|---------|

Maximum permissible uncertainty is 6% of value or 0.3% by volume.

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

https://www.surveymonkey.co.uk/r/CAE_customer_feedback_weblink