Technical Note

CLIENT:	**Nyobolt Limited**
PROJECT:	**Pilot Facility**
SUBJECT:	**Low Impact Installation Criteria Assessment (REDACTED)**
JOB NO.:	**BM12404**
DATE:	**October 2024**
PREPARED BY:	**Dominiqua Drakeford-Allen (Associate Director)**

1.1.1 Nyobolt Limited have commissioned Wardell Armstrong to prepare this Technical Note, demonstrating how the Low Impact Installation (LII) Criteria is met for their Pilot Facility in Haverhill, Suffolk.

1.1.2 The full site address is Unit 1a and b, Homefield Road, Homefield Industrial Estate, Haverhill, CB9 8QP.

1.1.3 Nyobolt are seeking an environmental permit to authorise their operations which will produce product A. This material has the potential to significantly improve lithium-ion battery technology allowing the storage of large amounts of energy and helping to speed up the adoption of electric vehicle technologies. Nyobolt is at the cutting edge of research and development in this area.

1.1.4 The process is relatively simple in regard to stages; in that two metal oxides are milled, mixed, dried, baked, deagglomerated and blended. Appendix 1 provides a process overview.

1.1.5 There is one emission point to air, which is described in more detail in the table below.

1.1.6 The pilot facility will deal with relatively low volumes of materials; and incrementally increase production. In the first year it is anticipated that up to 20 tonnes of product A may be produced, increasing to 100 – 200 tonnes in the subsequent year and 900 tonnes in the year after that.

1.1.7 Table 1 below sets out the LII criteria and provides justification and detail for each element of the criteria. The principles that this assessment has been carried out against are those set out in Guidance Notes on Part B2 – General – New Bespoke Permit (EPB2 Version 17, September 2023).

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
A. Management Techniques	All of the criteria described below must be met without having to rely on significant management effort. In other words, the installation intrinsically must have only a low environmental impact, including under start up, shut down, or abnormal operating conditions.	The facility and associated processes are managed by Nyobolt, and under normal operating conditions have very low environmental risk. The process is relatively simple. It comprises of stages of precursors milled, mixed, dried, baked, deagglomerated and blended. The process does not need chemicals being added in at different stages in specific amounts, only water is added to aid in the cohesion of the two oxides. This is a pilot facility, and the volumes of material to be processed at any one time are relatively low. All of the following criteria described below rely on minimal management effort.	Yes
B. Wastewater	The installation must not release more than 50m³ per day of water from process activities conducted at the installation giving rise to effluent. No account need be taken of the volume of water exported from the installation as product. Characterise	There will be no release of water from process activities. Small amounts of aqueous non-hazardous slurry waste may occasionally arise during cleaning or sampling, which is incidental to the process.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
	and quantify any aqueous effluents released from the installation on a daily basis and provide justification that the installation releases no more than 50 m^3 per day of water from process activities.	No more than 50m^3 of waste water will be produced or released per day from the process activities undertaken at the facility. Nyobolt will endeavour re-using this to have zero waste. Nyobolt is already in discussion with Anglian Water with regards to the correct disposal of such waste, should this be the preferred route. If necessary, Nyobolt will collect such waste in IBCs and then filtered, precipitated or /flocculated to result in a solid product A waste and clean water. The procedure for flocculation is in development will be developed if required.	
C. Abatement Systems/releases to air	The installation must comply with the criteria in this guidance without having to rely on active abatement for releases to the environment outside of any buildings. Releases must not be dependent on continuing or correct operation of equipment, where failure of active pollution prevention systems could result in an unacceptable external release. For example, if the installation depends on active abatement in the form of scrubbers, filters or electrostatic precipitators to achieve the	Nyobolt have commissioned emissions testing on the furnace emission point, which emits outside of the building. From the emission testing (report provided as Appendix 2) and a H1 Assessment which has been carried out for emissions to air, it has been concluded that no active abatement is required for the point source emission to air.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
	releases to the environment set out in this guidance, it is unlikely that it can be treated as having only a low potential for impact. However, abatement systems installed solely for the protection of workers (where abatement is not to attenuate external environmental releases) need not be included in this assessment.	Internally, localised extraction is used by way of mobile extraction. This is a movable and mobile piece of equipment which can be used to 'hoover' fines during unloading of materials into tanks, or to clear up any spillages. The extraction system will have a HEPA filter, and fines will be collected into a drum. Nyobolt will seek to reintroduce fines back into the process where possible, to minimise losses. This system is in place to protect workers during operations. If this equipment wasn't used, there is extremely low risk of dust/particulate matter being airborne and leaving/escaping the building. The fines are heavy and are prone to settlement rather than becoming airborne.	
D. Emissions to groundwater	There must be no planned or fugitive emission from the permitted installation into the ground, or any soakaway. This does not preclude the discharge of clean rainwater run-off into soakaways.	There are no planned or fugitive emissions to groundwater. The facility and all associated operations will be carried out inside a building, which comprises impermeable flooring, impervious to leaks and spills.	Yes
E. Waste Production	The installation must not produce more than one tonne of waste or 10 kg of hazardous waste per day, averaged over a year, with not more than 20 tonnes of waste or 200 kg of hazardous waste being produced in any one day.	The substances used in the process are non-hazardous, and the only addition to the metal oxides is water.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
		Waste production from the process will be under the threshold of 1 tonne. There will no hazardous waste produced, and therefore will be within the criteria of less than 10kg of hazardous waste. Small amounts of aqueous non-hazardous slurry waste may occasionally arise during cleaning or sampling. Where possible, fines of material will be reused in the process to minimise losses. Nyobolt will endeavour re-using this to have zero waste.	
F. Energy Consumption	The installation must not consume energy at a rate greater than 3 MW or, if the installation uses a combined heat and power installation to supply any internal process heat, 10 MW. These limits apply to the sum of energy imported as electricity and produced on site through the combustion of fuels.	The furnace specification is provided as Appendix 3. The furnace is electric with the energy consumption rate approximately 0.4 MW, which is significantly lower than the energy consumption limit for Low Impact Installations.	Yes
G. Accident Prevention	You must have in place satisfactory containment measures to prevent fugitive emissions to surface water, sewer or land and ensure that these are adequately maintained at all times. This	There are no chemicals stored at the facility. The metal oxides used in the process are non-hazardous and non-reactive. The only addition to the metal oxides is water.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
	requirement applies to all substances present on site and in any quantity.	In the event of a spill or leak, this would comprise of either water, or water which contains metal oxide particles which would not be hazardous or reactive. The facility is within an enclosed unit, with impermeable flooring impervious to leaks and spills with a sealed drainage system. The equipment installed will be state of the art and installed by a qualified engineer. During operation, if an equipment failure is identified, operations will cease immediately to identify the fault. Any repairs will be carried out by a suitably qualified person. A defects log will be maintained to record and register any issues encountered, and detail of any remedial actions taken. The log will be held on site and electronic copies made.	

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
		Staff will undergo training suitable for their role and responsibilities. Refresher training will be delivered to staff in accordance with Nyobolt's training policy. Incoming raw materials and outgoing products will arrive and leave the site in secure containment.	
H. Noise	There must be only a low potential for causing offence due to noise. An installation will not be considered as a low impact installation if it may give rise to noise noticeable outside the installation boundary. This requires the exercise of judgement, taking account of any history of noise complaint arising from the installation and consideration of the likely offsite noise levels and proximity of sensitive receptors. Describe the main sources of noise from the installation, the nearest noise sensitive locations any relevant noise measurement surveys which have been undertaken; and the proposed techniques and measures for the control of noise. Provide justification that there is only a low potential for offence due to noise.	All operations will be carried out inside the building. For the health and safety of staff, a noise attenuation screen will be placed around the milling/mixing equipment. Given the site is located on a large industrial estate with no nearby sensitive receptors, e.g. residential, the risk of noise causing offence is considered very low and very unlikely to arise beyond the installation boundary.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
I. Emissions of polluting substances	Justify that there will be no likelihood of a release to the environment of any particular substance from the whole installation at a rate greater than that determined as insignificant as set out in our guidance note (see https://www.gov.uk/guidance/control-and-monitor-emissions-for-your-environmental-permit). Describe the nature, quantities and sources of foreseeable emissions from the installation.	Emissions testing has been undertaken for the emission point from the furnace to outside of the building. The emissions testing report is provided in Appendix 2. This emission testing demonstrated that the risk is so low, abatement is not required. The H1 Screening Tool has been completed, and the outcome confirms that no additional air quality modelling or further assessment is required.	Yes
J. Odour	There must be only a low potential for giving offence due to odour. An installation will not be considered as a low impact installation if it may give rise to an offensive smell noticeable outside the installation boundary. This requires the exercise of judgement, taking account of any history of odour complaint from the installation and whether this class of activity is known by experience to give rise to smells. A significant possibility or actual history of excursions or fugitive emissions, for example from stored materials, would suggest that the installation could not be treated as having a low impact. Provide details of	The metal oxides used in the process are inherently low odour materials. No organic chemicals are added during the production process, only water. The risk of odour from the operations is considered extremely low.	Yes

Table 1: Low Impact Installation – Supporting Evidence and Demonstration that Criteria is Met			
LII Principal	**Principal Description (EPB2 Version 17, September 2023)**	**Demonstration of Criteria being Met**	**Confirmation Criteria is Met (Yes/No)**
	potential sources of odour from the installation, for example from stored materials, and justify that there is only a low potential for offence due to odour.		
K. Compliance history	If any of the following enforcement actions have taken place at the same installation under the same management (and where appropriate, have not been overturned on appeal), then it will not normally be considered further as a low impact installation: prosecution* formal caution* suspension notice* enforcement notice relating to an actual or potential environment incident* * (All under EPR or the equivalent under previous environmental regimes)	Nyobolt Limited are a new operator and have no history of enforcement actions being taken against them. There is no history of enforcement action being taken at the facility.	Yes

APPENDICES

APPENDIX 1

Process Overview

APPENDIX 2

Emissions Testing

STACK EMISSIONS MONITORING REPORT

Units C & D
Bankside Trade Park
Cirencester
GL7 1YT
Tel: 01285 700 593

Your contact at SOCOTEC LTD
Mike Davies Business Manager - South Tel: 07976 297 465 Email: mike.davies@socotec.com

Operator & Address:
Nyobolt Limited 1b Homefield Road Haverhill Suffolk CB9 8QP

Permit Reference:
N/A - Investigative Test

Release Point:
Heat Treatment Exhaust

Sampling Date(s):
01 - 03 May 2024

SOCOTEC Job Number:	LSW 240525
Report Date:	05th June 2024
Version:	1
Report By:	Catherine Elsey
MCERTS Number:	MM 08 996
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mike Davies
MCERTS Number:	MM 02 087
Business Title:	MCERTS Level 2 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

CONTENTS

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Nyobolt Limited operates a lab furnace extraction process at Haverhill

SOCOTEC LTD were commissioned by Jenny Shackleton to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under trial operating conditions.

Plant

Heat Treatment Exhaust

Operator

Nyobolt Limited
1b Homefield Road
Haverhill
Suffolk
CB9 8QP

No Permit Applicable: Investigative

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.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Emission Limit Value (ELV)**	**Accreditation**
Tungsten Tungsten Emission Rate	mg/m³ g/hr	0.0496 0.2712	0.0030 0.0165	- -	None
Niobium Niobium Emission Rate	mg/m³ g/hr	0.00044 0.0024	0.000027 0.000148	- -	None
Moisture	%	1.94	0.06	-	MCERTS
Stack Gas Temperature	°C	37	-	-	MCERTS
Stack Gas Velocity	m/s	7.4	0.16	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	6600	330	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	5726	286	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	5615	280	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	5726	286	-	

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 without correction for water vapour

Note 1. At least one of the metals analysed fall outside of the labs UKAS accreditation. For an individual breakdown please refer to the individual metals summary table in appendix 2

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Heavy Metals Run 1	01 May 2024	12:55 - 01:14	2160 minutes
Preliminary Stack Traverse	30 April 2024	11:20	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Lab Furnace extraction
Continuous or batch	Batch
Product Details	Molten Metal
Part of batch to be monitored (if applicable)	Complete batch cycle.
Normal load, throughput or continuous rating	Normal operational cycle
Fuel used during monitoring	N/A
Abatement	None
Plume Appearance	None 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**
Heavy Metals	SRM - BS EN 14385	AE 108	1015	MCERTS	0 mg/m³	6.1%	N/A - No ELV
Moisture	SRM - BS EN 14790	AE 105	1015	MCERTS	0.003%	2.9%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	5 Pa	2.1%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	-	5.0%	N/A - No ELV

BS EN 14790 has been validated over a range of 4 - 40%. It is however the prefered method of the Environment Agency for concentrations below 4%

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 Analyis	Archive Period
Heavy Metals	Inductively coupled Plasma - Mass Spectrometry	M31	0605	None	RPS	24-03841-1 24 May 2024	8 Weeks

Please note, at least one of the metals analysed fall outside of the labs UKAS accreditation. For an individual breakdown please refer to the metals summary in appendix 2

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	Accreditation	Laboratory	Data Archive Location	Archive Period
Moisture	Gravimetric	AE 105	1015	MCERTS	SOCOTEC (Cirencester)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	27	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	7.1	m/s	-	-	-
Highest Gas Velocity	7.8	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	7.4	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.56	m
Width		m
Area	0.25	m^2
Port Depth	0	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	4" hole	
Number of lines used	1	
Number of points / line	1	
Duct orientation	Horizontal	
Filtration	Out Stack	

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Temporary
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)	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)

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

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

In this instance there were no deviations from the sampling and analytical methods employed.

APPENDICES

CONTENTS

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**
Heavy Metals	SRM - BS EN 14385	AE 108	1015	MCERTS	1
Moisture	SRM - BS 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	P3338	Horiba PG - 250 Analyser	-	Laboratory Balance	P3225
Box Thermocouples	P3338	FT-IR	-	Tape Measure	P582
Meter In Thermocouple	P3338	FT-IR Oven Box	-	Stopwatch	-
Meter Out Thermocouple	P3338	Bernath 3006 FID	-	Protractor	-
Control Box Timer	P3338	Signal 3030 FID	-	Barometer	P341
Oven Box	P3074	Servomex	-	Digital Micromanometer	P1940
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	P824
Probe Thermocouple	P3415	Thermo FID	-	Stack Thermocouple	P3242
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2109	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P3336	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	P1715	Heated Line Controller (1)	-	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)	-
Inclinometer (Swirl Device)	P2372			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 +/- %
-	-	-	-	-	-

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**
Mike Davies	MM 02 087	MCERTS Level 2	Sep-27	Mar-28	Jun-28	Jun-28	Aug-28	Sep-27
Catherine Elsey	MM 08 996	MCERTS Level 2	Dec-25	Dec-25	Dec-25	Feb-29	Mar-27	Nov-28
Warren Clark	MM 02 086	MCERTS Level 1	Sep-27	-	-	-	-	Sep-27
Athul Athul	MM 24 1828	MCERTS Trainee	Dec-28	-	-	-	-	Dec-28

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS SOLID & VAPOUR PHASES COMBINED

TOTAL HEAVY METALS COMBINED					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	ELV mg/m³	Emission Rate g/hr
Run 1	12:55 - 01:14 01 May 2024	0.05	0.0002	-	0.27
Field Blank	-	0.01	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

INDIVIDUAL METALS SUMMARY - SOLID & VAPOUR PHASES COMBINED

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr	Uncertainty %	UKAS Accredited
Tungsten	0.00011	0.04965	0.271	8%	×
Niobium	0.00011	0.00044	0.002	38%	×
Sum of Heavy Metals	0.00021	0.05009	0.274	6.1%	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - RUN 1 SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Tungsten	0.00003	856	0.02434	0.00008	890	0.02531
Niobium	0.00003	10.10	0.00029	0.00008	5.51	0.00016
Sum of Heavy Metals	0.00006	866	0.02462	0.00016	896	0.02547
Volume Sampled m^3		35.1748			35.1748	

Reference conditions are 273K, 101.3kPa without correction for water vapour

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - BLANK SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Tungsten	0.00003	137	0.00389	0.00008	337	0.00959
Niobium	0.00003	1.00	0.00003	0.00008	2.81	0.00008
Sum of Heavy Metals	0.00006	138	0.00392	0.00016	340	0.00967
Volume Sampled m^3		35.1748			35.1748	

Reference conditions are 273K, 101.3kPa without correction for water vapour

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1 — Heavy Metals

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	kPa	99.50
Stack static pressure, P_{static}	Pa	-5.00
$P_s = P_b + (P_{static})$	kPa	99.50
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	H_20 by Non Iso
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m	m^3	39.60
Gas meter correction factor, Y_d		0.97
Mean dry gas meter temperature, T_m		298.86
Mean pressure drop across orifice, DH	mmH_2O	29.77
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m + 273}$	m^3	34.49
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	35.1748
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		20.50
% oxygen reference condition		21
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0194
	%	1.94
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	0.02
O_2	%	20.50
Total	%	20.52
N_2 (100 -Total)	%	79.48
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.82
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.61
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	Pa	40.47
Mean stack gas temperature, T_s	K	315.17
Gas density (wet, ambient), p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.086
Stack Velocity, Vs $V_s = \frac{\sum_{i=1}^{n} V_i}{n}$	m/s	7.24
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.25
$Q_a = (60)(A_s)(V_s)$	m^3/min	107.0
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(Ts)}$	Dry	89.3
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(Ts)}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(Ts)}$	Wet	91
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	7.6
Nozzle area, A_n	mm^2	45.7
Total sampling time, q	min	2160.0
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	96.4
Acceptable isokinetic range 95% to 115%		Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS QA CHECKLIST

Leak Test Results	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable litre/min
Run 1	17.8	0.18	-	-381	0.36	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	96.4	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Temperature during storage / transit <25°C
Run 1	Quartz Fibre	90	126	Yes

Metals	Type of Absorbers - Metals	Absorption Solutions - Metals
Run 1	Glass	3.3% Nitric Acid, 1.5% Hydrogen Peroxide

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS ABSORBTION EFFICIENCY

Parameter		Total ug	3rd Absorber ug	Absorption Efficiency (%)	Required %	Pass / Fail
Tungsten	Run 1	1746	393	77	90	N/A No ELV
Niobium	Run 1	16	ND	100	90	N/A No ELV

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Non Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	12:28 - 16:28 30 April 2024	4.0123	4.0876	0.0753	1.9	0.00	2.9

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	240	4740	19.8	0.23	0.23	0.40	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.56	m
Stack Width, W		m
Stack Area, A	0.25	m^2
Average stack gas temperature	37	^oC
Stack static pressure	-0.005	kPa
Barometric Pressure	99.8	kPa

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	0.021048	0.000210	0.000413	0.020639	0.000206	0.000405
O_2	32	1.427679	20.500000	0.205000	0.292674	20.102103	0.201021	0.286994
N_2	28	1.249219	79.478952	0.794790	0.992866	77.936296	0.779363	0.973595
H_2O	18	0.803070	-	-	-	1.940962	0.019410	0.015587

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2860	kg/m^3
Wet Density (STP), P_{STW}	1.2766	kg/m^3
Dry Density (Actual), P_{Actual}	1.1156	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.108	kg/m^3

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of } H_2O) / (1 + (pi \text{ of } H_2O / 0.8036))$

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	30 April 2024
Time of Survey	11:20
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_2O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.05	27.7	2.8	37	7.1	1.7	-	<15
2	0.14	33.2	3.4	37	7.7	1.9	-	<15
3	0.42	33.8	3.5	37	7.8	1.9	-	<15
4	0.51	28.3	2.9	37	7.2	1.8	-	<15
Mean	-	30.8	3.1	37	7.4	1.8	-	-

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value Pa	End Value Pa	Difference %	Outcome	Start Value Pa	End Value Pa	Difference %	Outcome
Run 1	110	111	-0.9	Pass	108	109	-0.9	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH_2O (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	98	95	3.0	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	28	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	7.1	m/s	-	-
Highest Gas Velocity	7.8	m/s	-	-
Ratio of Gas Velocities	1.1	-	< 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, $V = K_{pt} \times (1\text{-}e) * \sqrt{(2 * DP_{pt} / P_{ActualW})}$		
Where: K_{pt} = Pitot tube calibration coefficient (1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**7.4**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	37	0	°C
Total Pressure	99.795	101.3	kPa
Oxygen	20.5	21	%
Moisture	1.94	1.94	%
Pitot tube calibration coefficient, K_{pt}	1.00		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	7.44	m/s
Stack Area (A)	0.25	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	6600.36	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	5726.22	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	5615.08	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	5726.22	m^3/hr

Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((21 - O_2a) / (21 - O_2s))

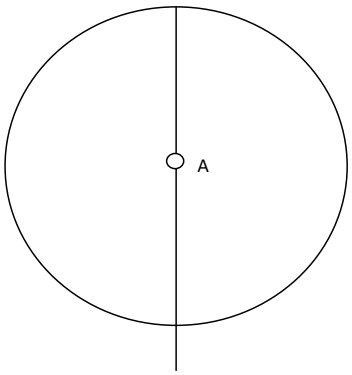
Nomenclature:
Ts = Absolute Temperature, Standard Conditions, 273 K
Ps = Absolute Pressure, Standard Conditions, 101.3 kPa
Ta = Absolute Temperature, Actual Conditions, K
Pa = Absolute Pressure, Actual Conditions, kPa
Ma = Water vapour, Actual Conditions, % Vol
Ms = Water vapour, Reference Conditions, % Vol
O_2a = Oxygen, Actual Conditions, % Vol
O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.56	m
Stack Width		m
Area	0.25	m^2

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



Sampling Line

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	8.9	0.05	< 15
2	25.0	0.14	< 15
3	75.0	0.42	< 15
4	91.1	0.51	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
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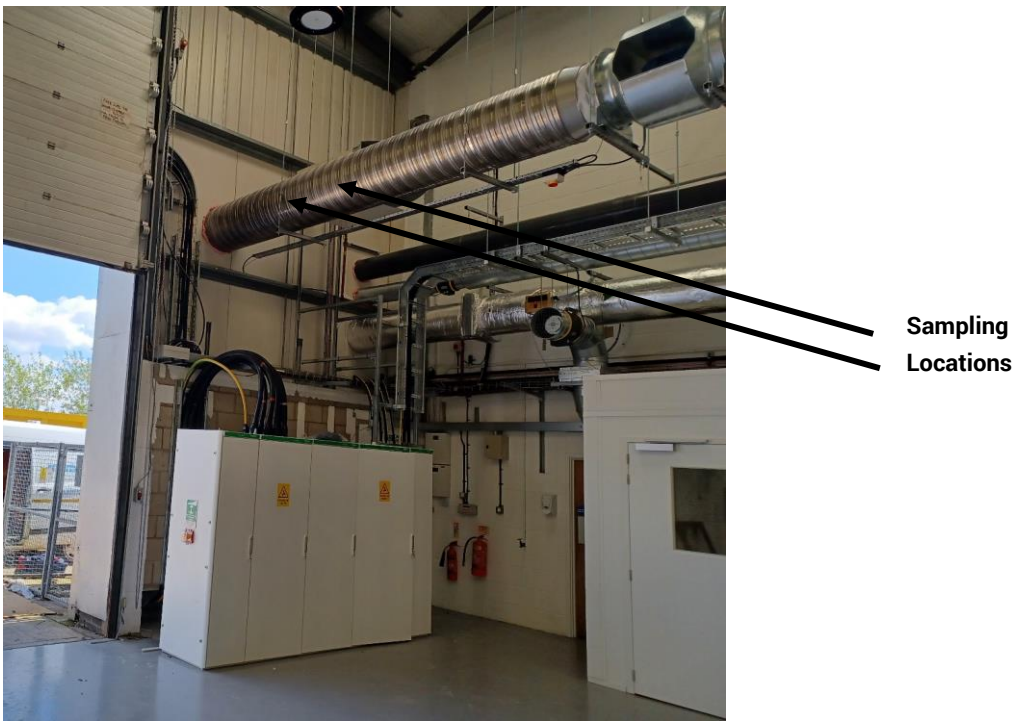
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

○ Isokinetic sampling point
● Isokinetic sampling points not used
◍ Non Isokinetic/Gases sampling point

SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - HEAVY METALS

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Concentration in impinger mg	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=10%**	**<5%**	**<=2%**
Run 1	0.070	2.0	0.50	1.0	0.10	0.05	-
as a %	0.20	0.73	0.50	1.0	-	3.00	1.01
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**

Run	Volume (STP) m³	O2 Correction -	Mass of Heavy Metals mg	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	34.5497	-	1762.0	0.0003	-	-
MU as mg/m^3	0.00068	-	0.0002	0.0003	0.00131	**0.0015**
MU as %	1.3530	-	0.4262	0.5854	2.62500	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.0030**	**mg/m³**	**6.08**	**% Result**	**-**	**% 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 m³	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	0.000395	2.0	0.50	1.0	N/A	-
as a %	0.0083	0.65	0.50	1.0	N/A	1.16
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m³	Mass Gained mg	O2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	4.1	75300	1.0	106.8	58	-
MU as % v/v	0.026	0.0027	-	0.013	0.0015	**0.029**
MU as %	1.29	0.13	-	0.67	0.077	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.059**	**% v/v**	**2.93**	**%**

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	7.4	m/s
Measured Volumetric Flow rate at Actual Conditions	6600	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination				
Uncertainty of pitot tube coefficient	-	0.010		
Uncertainty of mean local dynamic pressures	-	0.45		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurment device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	6.39	<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	0.00002		
Uncertainty of temperature measurement	K	1.58	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	509		
Uncertainty associated with the calculation of density	kg/m3	0.007		
Uncertainty associated with the measurement of local velocity	-	0.0001		
Uncertainty associated with the measurement of mean velocity	-	0.0001		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.08
Expanded uncertainty at a 95% Confidence Interval	0.16

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	1.1
Expanded uncertainty at a 95% Confidence Interval	2.1

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	168
Expanded uncertainty at a 95% Confidence Interval	330

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	2.5
Expanded uncertainty at a 95% Confidence Interval	5.0

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

APPENDIX 3

Furnace Specification