

Stack Emissions Monitoring Report

commissioned by Airtech ECS Ltd

Operator Name

Federal-Mogul Coventry Ltd | Tenneco

Operator Address

Holbrook Lane
Holbrooks, Coventry
CV6 4BG
PPC Permit PPC/197

Release Point

Main Stack

Monitoring Organisation Name & Address

Atesta Ltd
Unit 2, Asher Court, Lyncastle Way
Appleton, Warrington
WA4 4ST

Monitoring Report Written By

Brian Jacob | Senior Team Leader
MCERTS Level 2 | MM 06 693 | TE1 TE2 TE3 TE4 | expires on 17/08/2025

Monitoring Report Approved By

Matt Pendlebury | Technical Support Manager
MCERTS Level 2 | MM 04 535 | TE1 TE2 TE3 TE4 | expires on 31/03/2026



Job Reference: JOB-1341

Report Date | Version Number

13/12/2024 | Version 1

Dates of the Monitoring Campaign

02/12/2024

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Report Contents and Monitoring Objectives

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Monitoring Objective

The monitoring objective was to conduct stack emissions monitoring to demonstrate compliance against a set of emission limit values (ELVs) as specified in the Site's Environmental Permit.

Special Requirements

There were no special requirements for this monitoring campaign.

Opinions and Interpretations

Any opinions or interpretations contained within this test report are outside the scope of Atesta's MCERTS / ISO 17025 accreditation.

Part 1: Executive Summary - Monitoring Results Summary

Monitoring Results - Summary

test parameter	EXPRESSED AS A CONCENTRATION				EXPRESSED AS A MASS EMISSION				reference conditions	accreditation status
	result	uncertainty in result +/-	limit (ELV)	units	result	uncertainty in result +/-	limit (ELV)	units		
Total Particulate Matter	0.67	0.36	20	mg/m³	2.5	1.3		g/hr	STP, wet	MCERTS
Sulphur Dioxide	0.061	0.0049		mg/m³	0.22	0.021		g/hr	STP, wet	MCERTS
Chromium, Cobalt & Nickel	0.013	0.0022	5	mg/m³	0.048	0.0085		g/hr	STP, wet	MCERTS
Chromium	0.0070	0.0012		mg/m³	0.026	0.0046		g/hr	STP, wet	MCERTS
Cobalt	0.0015	0.00020		mg/m³	0.0055	0.00077		g/hr	STP, wet	MCERTS
Nickel	0.0045	0.00065		mg/m³	0.017	0.0025		g/hr	STP, wet	MCERTS
Stack Gas Water Vapour	0.98	0.038		% v/v					actual	MCERTS
Stack Gas Temperature	24.2			°C					actual	MCERTS
Stack Gas Velocity	18.2	0.30		m/s					actual	MCERTS
Stack Gas Flow Rate (ACTUAL)	4040	195		m³/hr					actual	MCERTS
Stack Gas Flow Rate (REF)	3709	179		m³/hr					STP, wet	MCERTS

The stack gas water vapour, temperature, velocity and flow rates in the above table are calculated as an average of all of the results recorded during this monitoring campaign

The uncertainty in the result is reported at a 95% Confidence Interval in the same units as the monitoring result. In practice, this means that 95 times out of 100, the true result will lie within the stated range.

Part 1: Executive Summary - Monitoring Results Further Details

Monitoring Results - Further Details

		EXPRESSED AS A CONCENTRATION				EXPRESSED AS A MASS EMISSION				sampling date times	run time (mins)	H ₂ O (% v/v)	reference conditions
test parameter	run	result	uncertainty in result +/-	limit (ELV)	units	result	uncertainty in result +/-	limit (ELV)	units				
Total Particulate Matter	R1	0.67	0.36	20	mg/m³	2.5	1.3		g/hr	02/12/2024 11:00 - 12:00	60	0.96	STP, wet
Sulphur Dioxide	R1	0.061	0.0049		mg/m³	0.22	0.021		g/hr	02/12/2024 11:00 - 12:00	60	0.96	STP, wet
Chromium, Cobalt & Nickel	R1	0.013	0.0022	5	mg/m³	0.048	0.0085		g/hr	02/12/2024 12:09 - 13:09	60	1.0	STP, wet
Chromium	R1	0.0070	0.0012		mg/m³	0.026	0.0046		g/hr	02/12/2024 12:09 - 13:09	60	1.0	STP, wet
Cobalt	R1	0.0015	0.00020		mg/m³	0.0055	0.00077		g/hr	02/12/2024 12:09 - 13:09	60	1.0	STP, wet
Nickel	R1	0.0045	0.00065		mg/m³	0.017	0.0025		g/hr	02/12/2024 12:09 - 13:09	60	1.0	STP, wet
Velocity & Flow Rate Traverse	R1	17.8	0.30		m/s	3953	191		m³/hr	02/12/2024 10:37 - 10:42			actual
Stack Gas Water Vapour		0.98	0.038		% v/v								actual
Stack Gas Temperature		24.2			°C								actual
Stack Gas Velocity		18.2	0.30		m/s								actual
Stack Gas Flow Rate (ACTUAL)		4040	195		m³/hr								actual
Stack Gas Flow Rate (REF)		3709	179		m³/hr								STP, wet

The stack gas water vapour, temperature, velocity and flow rates in the above table are calculated as an average of all of the results recorded during this monitoring campaign

The uncertainty in the result is reported at a 95% Confidence Interval in the same units as the monitoring result. In practice, this means that 95 times out of 100, the true result will lie within the stated range.

Part 1: Executive Summary - Monitoring and Analytical Methods

Monitoring and Analytical Methods

where analysis required	MONITORING					ANALYSIS					
test parameter	laboratory	accreditation number	technical procedure	reference method	monitoring status	laboratory	accreditation number	analytical procedure	analytical technique	analysis status	accreditation status
Total Particulate Matter	ATA	10706	TP-01	EN 13284-1	MCERTS	ATA	10706	AP-01	Gravimetric	MCERTS	MCERTS
Sulphur Dioxide	ATA	10706	TP-10	EN 14791	MCERTS	RPS	0605	C27	IC	MCERTS	MCERTS
Chromium, Cobalt & Nickel	ATA	10706	TP-05a	EN 14385	MCERTS	RPS	0605	M31	ICP-MS	MCERTS	MCERTS
Chromium	ATA	10706	TP-05a	EN 14385	MCERTS	RPS	0605	M31	ICP-MS	MCERTS	MCERTS
Cobalt	ATA	10706	TP-05a	EN 14385	MCERTS	RPS	0605	M31	ICP-MS	MCERTS	MCERTS
Nickel	ATA	10706	TP-05a	EN 14385	MCERTS	RPS	0605	M31	ICP-MS	MCERTS	MCERTS
Water Vapour	ATA	10706	TP-03	EN 14790	MCERTS	ATA	10706	TP-03	Gravimetric	MCERTS	MCERTS

where analysis not required	MONITORING										
test parameter	laboratory	accreditation number	technical procedure	reference method	monitoring status	measurement technique & equipment					accreditation status
Velocity & Flow Rate Traverse	ATA	10706	TP-04a	EN 16911-1 TR 17078	MCERTS	Pitot Tube, Thermocouple & Thermomanometer					MCERTS

Summary of Monitoring Deviations (from Appendix 2)

test parameter	run	details of monitoring deviation
All	1	There were no deviations associated with the monitoring employed.

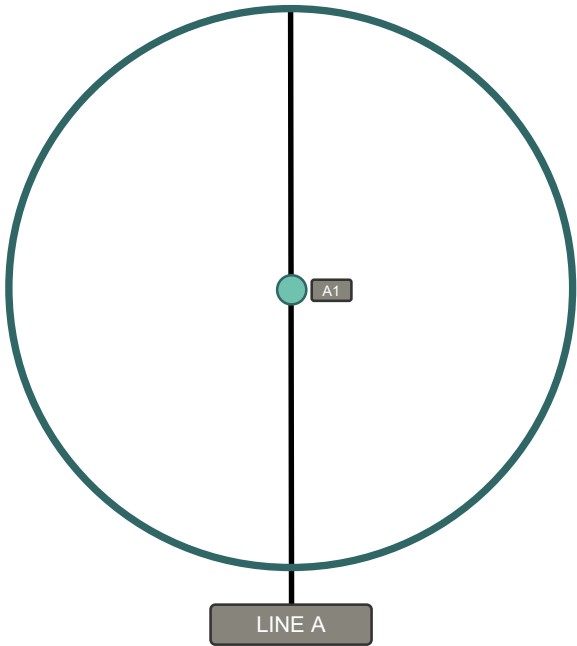
Part 1: Executive Summary - Monitoring Location

Monitoring Location Photos



Identification of Sampling Points on a Duct Diagram

refer to Appendix 2 - Raw Data to see how the points on this diagram relate to the points used for each test



Part 1: Executive Summary - Duct and Sampling Platform Information

Duct Characteristics | Sampling Ports

parameter	units	value	parameter	value	summary of all sample ports available
shape	-	Circular	primary sample port size	4" BSP	4" BSP
dimensions	-	Diameter = 0.28 m	primary sample port depth cm	9	
area	m²	0.06	primary sample ports number of sampling lines available	2	
orientation	-	Vertical			

Sampling Location General Information

general information	details
type location access	Permanent Outside with shelter available in nearby building Ladder

CEMS | Abatement Systems

parameter	details
abatement system/s	AAF Fabripulse M6-168 bag filtration unit
CEMS installed on the stack	N/A

Sampling Plane Validation Criteria Summary (EN 15259) from Stack Traverse/s

criteria in EN 15259	units	value	allowed	compliant
lowest differential pressure	Pa	270.0	> 5 Pa	Yes
lowest traverse velocity	m/s	17.8	-	-
highest traverse velocity	m/s	17.8	-	-
mean traverse velocity	m/s	17.8	-	-
ratio traverse velocities	: 1	1.00	< 3 : 1	Yes
angle of swirl compliance	°	< 15	< 15°	Yes
no local negative flow	-	Yes	-	Yes

Part 1: Executive Summary - Sampling Location and Operating Information

Process Details

process detail	details
plume appearance on day of monitoring	No visible plume
type of process	Melting of ferrous alloys using electrical induction furnaces
batch or continuous process	Batch
fuel type	N/A
feedstock	Metal ingots
typical load / throughput of plant	2 electrical induction furnaces of capacity 50 kg and 300 kg
details of any unusual process occurrences	None

Part 2: Supporting Information - Appendix 1: Monitoring Personnel, Analysis Laboratories and Test Equipment Used

Monitoring Personnel

name	position	MCERTS level number expiry	MCERTS technical endorsements
Brian Jacob	Senior Team Leader	MCERTS Level 2 MM 06 693 17/08/2025	TE1 TE2 TE3 TE4
Ben Kudilil	Technician	MCERTS Level 1 MM 23 1781 26/05/2028	-

Analysis Laboratories

laboratory	ISO 17025 accreditation number	laboratory short name	laboratory phone number
Atesta North West	10706	ATA	0800 970 8945
RPS Laboratories Salford	0605	RPS	0161 872 2443

Test Equipment Used

equipment type	A-EQ ID
Source sampling console	50
Low flow sampling MFCs	
ThermoFID / iFID mobile	
Horiba PG-350E multigas analyser	
Gasmet DX4000 FTIR	
Gasmet PSS	
Protea AtmosFIR	
Protea PIB Pump	
Gasmet syringe calibrator	
M&C PSS5-C conditioning unit	
Digital thermomanometer	222
Top pan balance kit	242

equipment type	A-EQ ID
Pitot	123
Calipers	240
Barometer	241
Timer	399
Tape measure	223
Heated head filter	
Heated tee	
10m heated line	
1.5m heated line	
Odour barrel	
Vacuum chamber	
Dilution probe	

equipment type	A-EQ ID
10m umbilical	203
30m umbilical	
Heated probe	288
Filter oven	284
Ambient thermocouple	165
Stack thermocouple	342
Exit thermocouple	
Condenser thermocouple	
Tubes kit thermocouple	
2-way heater controller	
Air sampling pump	
5-figure analytical balance	1

Part 2: Supporting Information - Appendix 2: Total Particulate Matter | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Total Particulate Matter	mg/m³	0.67 ± 0.36	g/hr	2.5 ± 1.3

Analytical Laboratory Information

parameter	details
name of analytical lab	ATA
lab analytical procedure	AP-01
lab analytical technique	Gravimetric Analysis Accreditation: MCERTS
date analysis completed	06/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	11:00 - 12:00 60 minutes tested by: BJ BK
standard technical procedure	EN 13284-1 TP-01
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
filter IDs	Sample: F-6224 Blank: F-6223

parameter	details
pre-use filter conditioning temperature	250°C
filter size, material & location	47mm QF Out Stack heated to 120°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.091	2.00	Pass
leak test	%	0.80	2.00	Pass	0.67	2.00	Pass
filter intact	-	Yes	-	Pass	-	-	-
filter no signs of water marks	-	Yes	-	Pass	-	-	-
maximum run filter temperature	°C	120	< 230	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	-	3.9	20.0	Pass	-	-	-
isokinetic variation	%	99.6	95 - 115	Pass	-	-	-

Breakdown of Results reference conditions are: STP, wet

parameter	sample volume [m³]	LOD [mg]	mass on filter [mg]	mass in rinse [mg]	mass total [mg]	LOD result [mg/m³]	result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
sample run F-6224	1.1002	0.10	-0.54	1.28	0.74	0.091	0.67	0.67	2.5
blank F-6223	1.1002	0.10	-0.55	0.22	-0.33	0.091	-0.3	0.091	

Part 2: Supporting Information - Appendix 2: Total Particulate Matter | Run 1

Raw Data | Calculations

data	units	value
P _{bar}	mmHg	758.3
P _g	Pa	220.0
ΔH _@	mmH ₂ O	44.3
P _m	mmHg	761.6
P _s	mmHg	760.0
V _m (DGM)	m ³	1.1730
Y _d	-	1.0049
C _{stp}	-	0.3592

data	units	value
T _m	°C	22.8
ΔH _{av}	Pa	368.6
ΔP _{av}	Pa	286.2
m _{wts}	g	8.6
M _w	g/mol	18.0
V _{mol}	m ³ /mol	0.0222
T _s	°C	24.8
R _{wv} (H ₂ O)	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.35
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f _{WA}	0.995

metered volume calculations	units	value
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{mTa} = (V _{mTstw})(T _s + 273) / (P _s) / (C _{stp})	m ³	1.2004
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp}) / ((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.0897
vol dry, V _{mSSstd} [from side stream sampling (if applicable)]	m ³	N/A
vol dry, V _{mTstd} [total volume metered]	m ³	1.0897
vol wet, V _{mTstw} = (V _{mTstd})(100 / (100 - R _{wv}))	m ³	1.1002
vol dry O ₂ , V _{mTstdO₂} = (V _{mTstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mTstwO₂} = (V _{mTstw}) / (O _{2facw})	m ³	N/A

isokinetic calculations	units	value
isokinetic rate, %I _r = ((K ₄)(T _s)(V _{mTstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	99.6

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, ρ = ((Ms / 1000)(Ps)(0.133322)(1000)) / ((R)(Ts + 273))	kg/m ³	1.160
velocity of stack gas, v _s = (f _{WA})(C _p) / ((2(ΔP _{av}) / (ρ)))	m/s	18.5
stack gas flow actual stack conditions, Q _a = (60)(60)(A _s)(v _s)	m ³ /hr	4096.1
stack gas flow dry, Q _{std} = (Q _a)(P _s)(C _{stp}) / (1 - (R _{wv} / 100)) / (T _s + 273)	m ³ /hr	3718.2
stack gas flow wet, Q _{stw} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)	m ³ /hr	3754.4
stack gas flow dry O ₂ , Q _{stdO₂} = (Q _a)(P _s)(C _{stp}) / (1 - (R _{wv} / 100)) / ((T _s + 273)(O _{2facd}))	m ³ /hr	N/A
stack gas flow wet O ₂ , Q _{stwO₂} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)(O _{2facw})	m ³ /hr	N/A

Part 2: Supporting Information - Appendix 2: Total Particulate Matter | Run 1

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m³	MU factor O ₂ correction
DGM meter volume, V _m	m³	1.1730	0.0059	0.50	≤5%	-	-	-	N/A
DGM temperature, T _m	K	295.8	2.0	0.68	≤2%	-	-	-	
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤2%	-	-	-	overall MU for O ₂ correction
DGM humidity, H _m	% v/v	0	1.0	1.00	≤2%	-	-	-	N/A
DGM volume STP, V _{mstd}	m³	-	-	-	-	1.0897	0.62	0.0095	
leak, L	% ¹ mg/m³ ²	0.61 ¹	-	0.61	≤2%	0.0024 ²	1.00	0.0024	method deviation factor
mass of particulate, m	mg	0.74	0.20	0.91	-	0.74	0.91	0.18	1.00
uncollected mass, m _{uc}	mg	0	-	0	≤10% total mass	0	1.00	0	
combined MU								0.18	
expanded MU 95% CI (k = 1.96) including method deviations MU								0.36	
expanded MU 95% CI (k = 1.96) as percentage of measured value								53%	
expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission								53.3%	result
expanded MU 95% CI (k = 1.96) as percentage of ELV [allowable 20%]								1.8%	Pass

method and sampling deviations									
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.									

Part 2: Supporting Information - Appendix 2: Sulphur Dioxide | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Sulphur Dioxide	mg/m³	0.061 ± 0.0049	g/hr	0.22 ± 0.021

Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	C27
lab analytical technique	IC Analysis Accreditation: MCERTS
date analysis completed	10/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	11:00 - 12:00 60 minutes tested by: BJ BK
standard technical procedure	EN 14791 TP-10
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
impinger material capture media	Borosilicate Glass 0.3% H ₂ O ₂

parameter	details
filter size, material & location	47mm QF Out Stack heated to 120°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1 (total)
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance ² The concentration in the last absorber was less than 5 times the analytical LOD.

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.027	N/A	N/A
leak test	%	0.80	2.00	Pass	0.67	2.00	Pass
absorption efficiency	%	69.0	N/A ²	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	3.9	20.0	Pass	-	-	-
isokinetic variation	%	99.6	95 - 115	Pass	-	-	-

Breakdown of Results reference conditions are: STP, wet

parameter	sample volume [m³]	LOD [mg]	impingers [front back] [mg/l]	impinger volume [front back] [ml]	mass total [mg]	LOD result [mg/m³]	result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
sample run	1.1002	0.021	0.17 0.14	271 148	0.067	0.019	0.061	0.061	0.22
blank	1.1002	0.015	0.1	301	0.03	0.014	0.027	0.027	

Part 2: Supporting Information - Appendix 2: Sulphur Dioxide | Run 1

Raw Data | Calculations

data	units	value
P _{bar}	mmHg	758.3
P _g	Pa	220.0
ΔH _@	mmH ₂ O	44.3
P _m	mmHg	761.6
P _s	mmHg	760.0
V _m (metered)	m ³	1.1730
Y _d	-	1.0049
C _{stp}	-	0.3592

data	units	value
T _m	°C	22.8
ΔH _{av}	Pa	368.6
ΔP _{av}	Pa	286.2
m _{wtS}	g	8.6
M _w	g/mol	18.0
V _{mol}	m ³ /mol	0.0222
T _s	°C	24.8
R _{wv} (H ₂ O)	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.35
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f _{WA}	0.995

isokinetic metered volume calculations	units	value
isokinetic rate, %I _r = ((K ₄)(T _s)(V _{mstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	99.6
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{ma} = (V _{mstw})(T _s + 273) / (P _s) / (C _{stp})	m ³	1.2004
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp}) / ((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.0897
vol wet, V _{mstw} = (V _{mstd})(100 / (100 - R _{wv}))	m ³	1.1002
vol dry O ₂ , V _{mstdO₂} = (V _{mstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mstwO₂} = (V _{mstw}) / (O _{2facw})	m ³	N/A

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, ρ = ((M _s / 1000)(P _s)(0.133322)(1000)) / ((R)(T _s + 273))	kg/m ³	1.160
velocity of stack gas, v _s = (f _{WA})(C _p)√((2(ΔP _{av}) / (ρ)))	m/s	18.5
stack gas flow actual stack conditions, Q _a = (60)(60)(A _s)(v _s)	m ³ /hr	4096.1
stack gas flow dry, Q _{std} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / (T _s + 273))	m ³ /hr	3718.2
stack gas flow wet, Q _{stw} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)	m ³ /hr	3754.4
stack gas flow dry O ₂ , Q _{stdO₂} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / ((T _s + 273)(O _{2facd})))	m ³ /hr	N/A
stack gas flow wet O ₂ , Q _{stwO₂} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)(O _{2facw})	m ³ /hr	N/A

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m ³
DGM meter volume, V _m	m ³	1.1730	0.0059	0.50	≤2%	-	-	-
DGM temperature, T _m	K	295.8	2.0	0.68	≤1%	-	-	-
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤1%	-	-	-
DGM humidity, H _m	% v/v	0	1.0	1.00	≤1%	-	-	-
DGM volume STP, V _{mstd}	m ³	-	-	-	-	1.0897	0.06	0.00086
leak, L	% ¹ mg/m ³ ²	0.61 ¹	-	0.61	≤2%	0.00021 ²	1.00	0.00021
laboratory result, L _r	% ¹ mg/m ³ ²	3.9 ¹	-	3.9	-	0.0023 ²	1.00	0.0023
combined MU								0.0025
expanded MU 95% CI (k = 1.96) including method deviations MU								0.0049
expanded MU 95% CI (k = 1.96) as percentage of measured value								8.1%
expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission								9.4%

MU factor O ₂ correction
N/A

overall MU for O ₂ correction
N/A

method deviation factor
1.00

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

Part 2: Supporting Information - Appendix 2: Chromium, Cobalt & Nickel | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Chromium, Cobalt & Nickel	mg/m³	0.013 ± 0.0022	g/hr	0.048 ± 0.0085

Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	M31
lab analytical technique	ICP-MS Analysis Accreditation: MCERTS
date analysis completed	12/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	12:09 - 13:09 60 minutes tested by: BJ BK
standard technical procedure	EN 14385 TP-05a
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
impinger material capture media	Borosilicate Glass Filter HNO ₃ H ₂ O ₂

parameter	details
filter size, material & location	47mm QF Out Stack heated to 160°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance (General)

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.003	0.5	Pass
leak test	%	0.67	2.00	Pass	0.87	2.00	Pass
maximum impingers temperature	°C	13.0	30.0	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	3.8	20.0	Pass	-	-	-
isokinetic variation	%	102.4	95 - 115	Pass	-	-	-

Part 2: Supporting Information - Appendix 2: Chromium, Cobalt & Nickel | Run 1

Breakdown of Results

reference conditions are: STP, wet

sample run									
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [front back] [mg]	mass total [mg]	LOD result [mg/m³]	sample result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
Chromium, Cobalt & Nickel	1.1165	0.002	0.012	0.0022 0.00086	0.015	0.0018	0.013	0.013	0.048

blank									
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [mg]		mass total [mg]	LOD result [mg/m³]	blank result [mg/m³]	result reported [mg/m³]
Chromium, Cobalt & Nickel	1.1165	0.0019	0.0031	0.00027		0.0034	0.0017	0.003	0.003

Quality Assurance (Extended)

absorption efficiency				
parameter	absorption efficiency %	allowable %	QA result	further details
Chromium, Cobalt & Nickel	94.1	90	Pass	-

detection limit			
parameter	detection limit µg/m³	allowable µg/m³	QA result
Chromium, Cobalt & Nickel	1.79	5	Pass

Part 2: Supporting Information - Appendix 2: Chromium, Cobalt & Nickel | Run 1

Raw Data | Calculations

data	units	value
P _{bar}	mmHg	758.3
P _g	Pa	220.0
ΔH _@	mmH ₂ O	44.3
P _m	mmHg	761.6
P _s	mmHg	760.0
V _m (metered)	m ³	1.1970
Y _d	-	1.0049
C _{stp}	-	0.3592

data	units	value
T _m	°C	24.5
ΔH _{av}	Pa	361.5
ΔP _{av}	Pa	280.8
m _{wt}	g	9.1
M _w	g/mol	18.0
V _{mol}	m ³ /mol	0.0222
T _s	°C	26.8
R _{wv} (H ₂ O)	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.34
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f _{WA}	0.995

isokinetic metered volume calculations	units	value
isokinetic rate, %I _r = ((K ₄)(T _s)(V _{mstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	102.4
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{ma} = (V _{mstw})(T _s + 273) / (P _s) / (C _{stp})	m ³	1.2260
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp}) / ((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.1053
vol wet, V _{mstw} = (V _{mstd})(100 / (100 - R _{wv}))	m ³	1.1165
vol dry O ₂ , V _{mstdO₂} = (V _{mstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mstwO₂} = (V _{mstw}) / (O _{2facw})	m ³	N/A

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, ρ = ((Ms / 1000)(Ps)(0.133322)(1000)) / ((R)(Ts + 273))	kg/m ³	1.152
velocity of stack gas, v _s = (f _{WA})(C _p)√((2(ΔP _{av}) / (ρ)))	m/s	18.4
stack gas flow actual stack conditions, Q _a = (60)(60)(A _s)(v _s)	m ³ /hr	4070.5
stack gas flow dry, Q _{std} = (Q _a)(P _s)(C _{stp}) / (1 - (R _{wv} / 100)) / (T _s + 273)	m ³ /hr	3669.8
stack gas flow wet, Q _{stw} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)	m ³ /hr	3707.0
stack gas flow dry O ₂ , Q _{stdO₂} = (Q _a)(P _s)(C _{stp}) / (1 - (R _{wv} / 100)) / ((T _s + 273)(O _{2facd}))	m ³ /hr	N/A
stack gas flow wet O ₂ , Q _{stwO₂} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)(O _{2facw})	m ³ /hr	N/A

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m ³
DGM meter volume, V _m	m ³	1.1970	0.0060	0.50	≤2%	-	-	-
DGM temperature, T _m	K	297.5	2.0	0.67	≤1%	-	-	-
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤1%	-	-	-
DGM humidity, H _m	% v/v	0	1.0	1.00	≤1%	-	-	-
DGM volume STP, V _{mstd}	m ³	-	-	-	-	1.1053	0.01	0.00018
leak, L	% ¹ mg/m ³ ²	0.5 ¹	-	0.50	≤2%	0.000037 ²	1.00	0.000037
laboratory result, L _r	% ¹ mg/m ³ ²	8.6 ¹	-	8.6	-	0.0011 ²	1.00	0.0011
combined MU								0.0011
expanded MU 95% CI (k = 1.96) including method deviations MU								0.0022
expanded MU 95% CI (k = 1.96) as percentage of measured value								17%
expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission								17.7%
expanded MU 95% CI (k = 1.96) as percentage of ELV [allowable 20%]								0.044%

MU factor O ₂ correction
N/A

overall MU for O ₂ correction
N/A

method deviation factor
1.00

result

Pass

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

Part 2: Supporting Information - Appendix 2: Chromium | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Chromium	mg/m³	0.007 ± 0.0012	g/hr	0.026 ± 0.0046

Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	M31
lab analytical technique	ICP-MS Analysis Accreditation: MCERTS
date analysis completed	12/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	12:09 - 13:09 60 minutes tested by: BJ BK
standard technical procedure	EN 14385 TP-05a
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
impinger material capture media	Borosilicate Glass Filter HNO ₃ H ₂ O ₂

parameter	details
filter size, material & location	47mm QF Out Stack heated to 160°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance (General)

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.0012	N/A	N/A
leak test	%	0.67	2.00	Pass	0.87	2.00	Pass
maximum impingers temperature	°C	13.0	30.0	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	3.8	20.0	Pass	-	-	-
isokinetic variation	%	102.4	95 - 115	Pass	-	-	-

Part 2: Supporting Information - Appendix 2: Chromium | Run 1

Breakdown of Results

reference conditions are: STP, wet

sample run									
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [front back] [mg]	mass total [mg]	LOD result [mg/m³]	sample result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
Chromium	1.1165	0.00069	0.0057	0.0016 0.00052	0.0078	0.00061	0.007	0.007	0.026

blank								
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [mg]	mass total [mg]	LOD result [mg/m³]	blank result [mg/m³]	result reported [mg/m³]
Chromium	1.1165	0.00066	0.0012	0.00012	0.0013	0.00059	0.0012	0.0012

Quality Assurance (Extended)

absorption efficiency				
parameter	absorption efficiency %	allowable %	QA result	further details
Chromium	93.3	90	Pass	-

detection limit			
parameter	detection limit µg/m³	allowable µg/m³	QA result
Chromium	0.61	5	Pass

Part 2: Supporting Information - Appendix 2: Chromium | Run 1

Raw Data | Calculations

data	units	value
P _{bar}	mmHg	758.3
P _g	Pa	220.0
ΔH _@	mmH ₂ O	44.3
P _m	mmHg	761.6
P _s	mmHg	760.0
V _m (metered)	m ³	1.1970
Y _d	-	1.0049
C _{stp}	-	0.3592

data	units	value
T _m	°C	24.5
ΔH _{av}	Pa	361.5
ΔP _{av}	Pa	280.8
m _{wt}	g	9.1
M _w	g/mol	18.0
V _{mol}	m ³ /mol	0.0222
T _s	°C	26.8
R _{wv} (H ₂ O)	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.34
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f _{WA}	0.995

isokinetic metered volume calculations	units	value
isokinetic rate, %I _r = ((K ₄)(T _s)(V _{mstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	102.4
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{ma} = (V _{mstw})(T _s + 273) / (P _s) / (C _{stp})	m ³	1.2260
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp}) / ((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.1053
vol wet, V _{mstw} = (V _{mstd})(100 / (100 - R _{wv}))	m ³	1.1165
vol dry O ₂ , V _{mstdO₂} = (V _{mstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mstwO₂} = (V _{mstw}) / (O _{2facw})	m ³	N/A

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, ρ = ((M _s / 1000)(P _s)(0.133322)(1000)) / ((R)(T _s + 273))	kg/m ³	1.152
velocity of stack gas, v _s = (f _{WA})(C _p)√((2(ΔP _{av}) / (ρ)))	m/s	18.4
stack gas flow actual stack conditions, Q _a = (60)(60)(A _s)(v _s)	m ³ /hr	4070.5
stack gas flow dry, Q _{std} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / (T _s + 273))	m ³ /hr	3669.8
stack gas flow wet, Q _{stw} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)	m ³ /hr	3707.0
stack gas flow dry O ₂ , Q _{stdO₂} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / ((T _s + 273)(O _{2facd})))	m ³ /hr	N/A
stack gas flow wet O ₂ , Q _{stwO₂} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)(O _{2facw})	m ³ /hr	N/A

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m ³
DGM meter volume, V _m	m ³	1.1970	0.0060	0.50	≤2%	-	-	-
DGM temperature, T _m	K	297.5	2.0	0.67	≤1%	-	-	-
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤1%	-	-	-
DGM humidity, H _m	% v/v	0	1.0	1.00	≤1%	-	-	-
DGM volume STP, V _{mstd}	m ³	-	-	-	-	1.1053	0.01	0.000099
leak, L	% ¹ mg/m ³ ²	0.5 ¹	-	0.50	≤2%	0.00002 ²	1.00	0.00002
laboratory result, L _r	% ¹ mg/m ³ ²	8.6 ¹	-	8.6	-	0.0006 ²	1.00	0.0006
combined MU								0.00061
expanded MU 95% CI (k = 1.96) including method deviations MU								0.0012
expanded MU 95% CI (k = 1.96) as percentage of measured value								17%
expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission								17.7%

MU factor O ₂ correction
N/A

overall MU for O ₂ correction
N/A

method deviation factor
1.00

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

Part 2: Supporting Information - Appendix 2: Cobalt | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Cobalt	mg/m³	0.0015 ± 0.0002	g/hr	0.0055 ± 0.00077

Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	M31
lab analytical technique	ICP-MS Analysis Accreditation: MCERTS
date analysis completed	12/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	12:09 - 13:09 60 minutes tested by: BJ BK
standard technical procedure	EN 14385 TP-05a
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
impinger material capture media	Borosilicate Glass Filter HNO ₃ H ₂ O ₂

parameter	details
filter size, material & location	47mm QF Out Stack heated to 160°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance (General)

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.0005	N/A	N/A
leak test	%	0.67	2.00	Pass	0.87	2.00	Pass
maximum impingers temperature	°C	13.0	30.0	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	3.8	20.0	Pass	-	-	-
isokinetic variation	%	102.4	95 - 115	Pass	-	-	-

Part 2: Supporting Information - Appendix 2: Cobalt | Run 1

Breakdown of Results

reference conditions are: STP, wet

sample run									
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [front back] [mg]	mass total [mg]	LOD result [mg/m³]	sample result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
Cobalt	1.1165	0.00059	0.0014	0.00017 0.000089	0.0017	0.00053	0.0015	0.0015	0.0055

blank								
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [mg]	mass total [mg]	LOD result [mg/m³]	blank result [mg/m³]	result reported [mg/m³]
Cobalt	1.1165	0.00056	< 0.0005	< 0.000061	< 0.00056	0.0005	< 0.0005	< 0.0005

Quality Assurance (Extended)

absorption efficiency				
parameter	absorption efficiency %	allowable %	QA result	further details
Cobalt	94.6	90	Pass	-

detection limit			
parameter	detection limit µg/m³	allowable µg/m³	QA result
Cobalt	0.53	5	Pass

Part 2: Supporting Information - Appendix 2: Cobalt | Run 1

Raw Data | Calculations

data	units	value
P _{bar}	mmHg	758.3
P _g	Pa	220.0
ΔH _@	mmH ₂ O	44.3
P _m	mmHg	761.6
P _s	mmHg	760.0
V _m (metered)	m ³	1.1970
Y _d	-	1.0049
C _{stp}	-	0.3592

data	units	value
T _m	°C	24.5
ΔH _{av}	Pa	361.5
ΔP _{av}	Pa	280.8
m _{wt}	g	9.1
M _w	g/mol	18.0
V _{mol}	m ³ /mol	0.0222
T _s	°C	26.8
R _{wv} (H ₂ O)	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.34
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f _{WA}	0.995

isokinetic metered volume calculations	units	value
isokinetic rate, %I _r = ((K ₄)(T _s)(V _{mstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	102.4
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{ma} = (V _{mstw})(T _s + 273) / (P _s) / (C _{stp})	m ³	1.2260
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp}) / ((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.1053
vol wet, V _{mstw} = (V _{mstd})(100 / (100 - R _{wv}))	m ³	1.1165
vol dry O ₂ , V _{mstdO₂} = (V _{mstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mstwO₂} = (V _{mstw}) / (O _{2facw})	m ³	N/A

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, ρ = ((M _s / 1000)(P _s)(0.133322)(1000)) / ((R)(T _s + 273))	kg/m ³	1.152
velocity of stack gas, v _s = (f _{WA})(C _p)√((2(ΔP _{av}) / (ρ)))	m/s	18.4
stack gas flow actual stack conditions, Q _a = (60)(60)(A _s)(v _s)	m ³ /hr	4070.5
stack gas flow dry, Q _{std} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / (T _s + 273))	m ³ /hr	3669.8
stack gas flow wet, Q _{stw} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)	m ³ /hr	3707.0
stack gas flow dry O ₂ , Q _{stdO₂} = (Q _a)(P _s)(C _{stp}) / ((1 - (R _{wv} / 100)) / ((T _s + 273)(O _{2facd})))	m ³ /hr	N/A
stack gas flow wet O ₂ , Q _{stwO₂} = (Q _a)(P _s)(C _{stp}) / (T _s + 273)(O _{2facw})	m ³ /hr	N/A

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m ³
DGM meter volume, V _m	m ³	1.1970	0.0060	0.50	≤2%	-	-	-
DGM temperature, T _m	K	297.5	2.0	0.67	≤1%	-	-	-
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤1%	-	-	-
DGM humidity, H _m	% v/v	0	1.0	1.00	≤1%	-	-	-
DGM volume STP, V _{mstd}	m ³	-	-	-	-	1.1053	0.00	0.000021
leak, L	% ¹ mg/m ³ ²	0.5 ¹	-	0.50	≤2%	0.0000043 ²	1.00	0.0000043
laboratory result, L _r	% ¹ mg/m ³ ²	6.6 ¹	-	6.6	-	0.000097 ²	1.00	0.000097
combined MU								0.0001
expanded MU 95% CI (k = 1.96) including method deviations MU								0.0002
expanded MU 95% CI (k = 1.96) as percentage of measured value								13.1%
expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission								14%

MU factor O ₂ correction
N/A

overall MU for O ₂ correction
N/A

method deviation factor
1.00

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

Part 2: Supporting Information - Appendix 2: Nickel | Run 1

Results reference conditions are: STP, wet

parameter	units	result ± MU (95% CI)	units	result ± MU (95% CI)
Nickel	mg/m³	0.0045 ± 0.00065	g/hr	0.017 ± 0.0025

Analytical Laboratory Information

parameter	details
name of analytical lab	RPS
lab analytical procedure	M31
lab analytical technique	ICP-MS Analysis Accreditation: MCERTS
date analysis completed	12/12/2024

General Information

parameter	details
sampling date	02/12/2024
sampling times testing team	12:09 - 13:09 60 minutes tested by: BJ BK
standard technical procedure	EN 14385 TP-05a
volume metering device	XD-502 Digital Source Sampling Console
nozzle & probe material	Titanium
filter housing material	Borosilicate Glass
impinger material capture media	Borosilicate Glass Filter HNO ₃ H ₂ O ₂

parameter	details
filter size, material & location	47mm QF Out Stack heated to 160°C
number sampling lines available	2
number sampling lines used	1
number sampling points ideal per line	1
number sampling points used per line	1
sampling point IDs	A1

Quality Assurance (General)

QA parameter	units	sample run			blank (taken on 02/12/2024)		
		value	allowable	result	value	allowable	result
maximum allowable blank	mg/m³	-	-	-	0.0013	N/A	N/A
leak test	%	0.67	2.00	Pass	0.87	2.00	Pass
maximum impingers temperature	°C	13.0	30.0	Pass	-	-	-
silica trap <50% faded	-	Yes	-	Pass	-	-	-
are water droplets present	-	No	-	-	-	-	-
water vapour MU	%	3.8	20.0	Pass	-	-	-
isokinetic variation	%	102.4	95 - 115	Pass	-	-	-

Part 2: Supporting Information - Appendix 2: Nickel | Run 1

Breakdown of Results

reference conditions are: STP, wet

sample run									
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [front back] [mg]	mass total [mg]	LOD result [mg/m³]	sample result [mg/m³]	result reported [mg/m³]	mass emission [g/hr]
Nickel	1.1165	0.00073	0.0044	0.00039 0.00025	0.005	0.00065	0.0045	0.0045	0.017

blank								
parameter	sample volume [m³]	LOD [mg]	filter / rinse [mg]	impingers [mg]	mass total [mg]	LOD result [mg/m³]	blank result [mg/m³]	result reported [mg/m³]
Nickel	1.1165	0.00069	0.0014	0.000092	0.0015	0.00062	0.0013	0.0013

Quality Assurance (Extended)

absorption efficiency				
parameter	absorption efficiency %	allowable %	QA result	further details
Nickel	95.0	90	Pass	-

detection limit			
parameter	detection limit µg/m³	allowable µg/m³	QA result
Nickel	0.65	5	Pass

Part 2: Supporting Information - Appendix 2: Nickel | Run 1

Raw Data | Calculations

data	units	value
P_{bar}	mmHg	758.3
P_{g}	Pa	220.0
$\Delta H_{\text{@}}$	mmH ₂ O	44.3
P_{m}	mmHg	761.6
P_{s}	mmHg	760.0
V_{m} (metered)	m ³	1.1970
Y_{d}	-	1.0049
C_{stp}	-	0.3592

data	units	value
T_m	°C	24.5
ΔH_{av}	Pa	361.5
ΔP_{av}	Pa	280.8
m_{wts}	g	9.1
M_w	g/mol	18.0
V_{mol}	m ³ /mol	0.0222
T_s	°C	26.8
$R_{wv} (H_2O)$	% v/v	1.0

data	units	value
%CO _{2d}	% v/v (est)	0.06
%O _{2d}	% v/v (est)	10.90
%O _{2w}	% v/v (est)	N/A
%N _{2d}	% v/v	89.04
%O _{2ref}	% v/v	N/A
O _{2facd}	-	N/A
O _{2facw}	-	N/A
C _p (pitot)	-	0.84

data	units	value
M _d	g/mol	28.45
M _s	g/mol	28.34
R	J/mol	8.314
K ₄	-	4.64E+06
A _s	m ²	0.06
D _n	mm	4.80
A _n	mm ²	18.10
θ (sample time)	mins	60

where (est) refers to an estimated value

data	value
f_{WA}	0.995

isokinetic metered volume calculations	units	value
isokinetic rate, %I _f = ((K ₄)(T _s)(V _{mstd})) / ((P _s)(v _s)(A _n)(θ)(1 - (R _{wv} / 100)))	%	102.4
allow favourable O ₂ correction	-	N/A
vol actual stack conditions, V _{ma} = (V _{mstw})(T _s + 273) / (P _s) / (C _{slp})	m ³	1.2260
vol dry, V _{mstd} = (V _m)(Y _d)(C _{stp})/((P _{bar} + (ΔH _{av} / 9.80665 / 13.6)) / (T _m + 273))	m ³	1.1053
vol wet, V _{mstw} = (V _{mstd})(100 / (100 - R _{wv}))	m ³	1.1165
vol dry O ₂ , V _{mstdO₂} = (V _{mstd}) / (O _{2facd})	m ³	N/A
vol wet O ₂ , V _{mstwO₂} = (V _{mstw}) / (O _{2facw})	m ³	N/A

stack gas density velocity volume flow rate calculations	units	value
density of stack gas, $\rho = ((M_s / 1000)(P_s)(0.133322)(1000)) / ((R)(T_s + 273))$	kg/m ³	1.152
velocity of stack gas, $v_s = (f_{WA})(C_p)\sqrt{((2\Delta P_{av}) / (\rho))}$	m/s	18.4
stack gas flow actual stack conditions, $Q_a = (60)(60)(A_s)(v_s)$	m ³ /hr	4070.5
stack gas flow dry, $Q_{std} = (Q_a)(P_s)(C_{stp})(1 - (R_{wv} / 100)) / (T_s + 273)$	m ³ /hr	3669.8
stack gas flow wet, $Q_{stw} = (Q_a)(P_s)(C_{stp}) / (T_s + 273)$	m ³ /hr	3707.0
stack gas flow wet O ₂ , $Q_{stdO_2} = (Q_a)(P_s)(C_{stp})(1 - (R_{wv} / 100)) / ((T_s + 273)(O_{2facd}))$	m ³ /hr	N/A
stack gas flow wet O ₂ , $Q_{sthO_2} = (Q_a)(P_s)(C_{std}) / (T_s + 273)(O_{2facw})$	m ³ /hr	N/A

Measurement Uncertainty (MU) Calculations

parameter	units	value	standard MU	MU as %age	required standard	value	sens coeff.	MU mg/m³
DGM meter volume, V _m	m³	1.1970	0.0060	0.50	≤2%	-	-	-
DGM temperature, T _m	K	297.5	2.0	0.67	≤1%	-	-	-
DGM pressure, P _m	kPa	101.5	0.50	0.49	≤1%	-	-	-
DGM humidity, H _m	% v/v	0	1.0	1.00	≤1%	-	-	-
DGM volume STP, V _{mstd}	m³	-	-	-	-	1.1053	0.00	0.000064
leak, L	% ¹ mg/m³ ²	0.5 ¹	-	0.50	≤2%	0.000013 ²	1.00	0.000013
laboratory result, L _r	% ¹ mg/m³ ²	7.2 ¹	-	7.2	-	0.00033 ²	1.00	0.00033
			combined MU					0.00033
			expanded MU 95% CI (k = 1.96) including method deviations MU					0.00065
			expanded MU 95% CI (k = 1.96) as percentage of measured value					14.4%
			expanded MU 95% CI (k = 1.96) as percentage of measured value for mass emission					15.2%

MU factor O₂ correction
N/A

overall MU for O ₂ correction
N/A

method deviation factor
1.00

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.

Part 2: Supporting Information - Appendix 2: Velocity & Flow Rate Traverse | Run 1

Supporting Information

parameter	units	value
barometric pressure	kPa	101.1
average wet density	kg/m³	1.175
average stack static pressure	Pa	220.0
pitot tube coefficient, C _p	-	0.836

ND = Not Detected

NM = Not Measured

Line A

static pressure = 220 Pa

Pt	Depth m	ΔP Pa	Temp °C	Vel m/s	Swirl °
1	0.14	270.0	21.0	17.8	< 15

General Information

parameter	details
traverse date	02/12/2024
traverse times performed by	10:37 - 10:42 performed by: BJ BK
standard technical procedure	EN 16911-1 TR 17078 TP-04a
device used	S-type Pitot with KIMO MP 210 (500Pa module)

Limit of Detection (LOD) is 1 m/s for this device combination

Quality Assurance

parameter	details
result of pitot stagnation test	Pass
result of pitot leak check (pre)	Pass
result of pitot leak check (post)	Pass
water droplets present	No

Part 2: Supporting Information - Appendix 2: Velocity & Flow Rate Traverse | Run 1

Measurement Uncertainty (MU) Calculations

ND = Not Detected		
parameter	units	value
standard uncertainty on the coefficient of the pitot tube	-	0.0015
standard uncertainty associated with the mean local dynamic pressures	Pa	4.3
standard uncertainty associated with the molar mass of the gas	-	0.000014
standard uncertainty associated with the temperature	K	1.5
standard uncertainty associated with the absolute pressure in the duct	Pa	176
standard uncertainty associated with the density of the gas effluent	kg/m³	0.0064
standard uncertainty associated with the local velocities	m/s	0.15
standard uncertainty associated with the mean velocity	m/s	0.15

ND = Not Detected		
parameter	units	value
standard uncertainty associated with the mean velocity (95% CI)	m/s	0.3
standard uncertainty associated with the mean velocity (95% CI), relative	%	1.7
standard uncertainty associated with the volume flow rate @ actual (95% CI)	m³/hr	191
standard uncertainty associated with the volume flow rate @ actual (95% CI), relative	%	4.8
standard uncertainty associated with the volume flow rate @ ref 1 (95% CI)	m³/hr	177
standard uncertainty associated with the volume flow rate @ ref 1 (95% CI), relative	%	4.8

method and sampling deviations
Sampling was performed in full compliance with the Standard, technical procedure and regulatory requirements.