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Office of Climate, Licensing & Resource Use
PO Box 3000
Johnstown Castle Estate
County Wexford

04 Oct 2017

IPC Reg. No: PO465-02
Re: Letter of 29 June 2016 Request for Information according to Reg. 10(2)(b)(ii) of EPA(IPC) (Licensing) Regulations 2013 - Follow up Monitoring Report

Dear Mr. Clabby,

Further to the submission of additional information as requested by the Agency under Reg 10 , I am enclosing a follow up monitoring report on Air emissions from the proposed A2-05 emission point , the subject of the licence application. This monitoring report is the analysis of samples taken from the upgraded process equipment 'Walther Trowal' ROTAMAT System, as described in our response to item No. 4 of the Reg. 10 response.

We declare that the content of the electronic files on the accompanying CD-ROM is a true copy of the original form.

Please find enclosed the following documents for review:

- Reg 10 Request follow Monitoring Report Hardcopy: 1 signed original, I copy
- 2 electronic copies of all files on CD-ROM

Please do not hesitate to contact us with any queries you may have,

Yours sincerely,

Anna Garvey
Environmental Manager
G. Bruss GmbH DICHTUNGSTECHNIK
Finisklin Road,
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CONFIDENTIAL REPORT

AIR EMISSIONS SURVEY
August 2017

AT
G BRUSS GMBH
Finisklin Road,
Sligo

Licence Reg. P0465-01
TMS Environment Ref. 24420

Commencement Date: 03 August 2017 **Completion Date: 15 September 2017**

Reporting	**Site Personnel**	**Analysts**
Enda Flood	Enda Flood	
James Carroll		

Approved by:

Imelda Shanahan

Dr Imelda Shanahan
Technical Manager

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1. Reports shall not be reproduced except in full, without prior approval of TMS Environment Ltd
2. This report relates only to the items tested
3. Complaints should be addressed in writing to the Quality Manager

EXECUTIVE SUMMARY

This Air Emissions report presents results of emissions monitoring from emission point A2-05 at G Bruss GmbH, Finisklin Road, Sligo, County Sligo. Monitoring has been conducted to satisfy the customer's requirements in respect of the following parameters:

Emission Point	Monitoring Parameters
A2-05	• T.A. Luft Classes I, II & III • TOC as C • Propan-2-ol • Di-butyl Tin • Velocity and Temperature

Measurements were completed on 03 August 2017. Details of the monitoring methods employed, Standard Reference Methods used and Guidance Notes consulted are presented in Section 4.0 of this report together with information on the equipment used and the monitoring personnel.

Monitoring for VOCs was carried out at an emission point located at a position pre-abatement while simultaneously at an emission point post-abatement system. The results for VOC monitoring at both points are to be used to assess the effectiveness of the abatement system.

Monitoring for TOC as C was also conducted at points pre- and post-abatement, however monitoring did not occur simultaneously. TOC concentration rises rapidly at commencement of a batch but remain relatively constant throughout the batch.

1.0 Scope

This Air Emissions report presents results of emissions monitoring from emission point A2-05 at G Bruss GmbH, Finisklin Road, Sligo, County Sligo. Monitoring has been conducted to satisfy the customer's requirements in respect of the following parameters:

Table 1-1 Scope of Monitoring Survey

Reporting period		***August 2017***	
EMISSION Point	***PARAMETER***	***SAMPLING METHOD AND MEDIUM & ANALYSIS METHODOLOGY***	***STANDARD REFERENCE METHOD***
A2-1(a)	Speciated VOC's	Non-isokinetic / Absorbent tube absorption / Analysis by solvent desorption followed by GC-MS or GC-FID	CEN/TS 13649:2014
	TEMPERATURE PRESSURE VELOCITY, FLOW	Pitot tube coupled with pressure measurement device or anemometer, and temperature measurement device	EN/ISO 16911-1:2013

2.0 Survey protocol

2.1 Protocol

TMS Environment Ltd personnel conducted the monitoring survey on 03 August 2017. Emissions to atmosphere from the Emission Point, A2-05 were monitored during the visit.

The survey was completed in order to meet the requirements of the company's IPPC Licence (Reg. No. P0465-02)

Relevant Process conditions during the survey are summarized below.

Table 2-1: Operational information during testing

Emission monitoring point	Date and time	Details
A2-05	03 August 2017 13:50 to 15:30	Normal operation, Batch process, process lasts for periods of 7 - 9 mins, 2 batches monitored over 30 minute period.

A Site Specific Protocol was prepared in accordance with EPA Air Guidance Note AG1 and CEN/TS 15675:2007 after a site review has been conducted with site personnel. A site risk assessment was completed prior to commencement of any monitoring to confirm that the monitoring could be carried out in a safe manner. All necessary PPE was worn at all times on site.

3.0 Monitoring Results

The results of the air emission monitoring reported in this document are presented in tables below. The methods used are defined by Standard Operating Procedures (SOP), each SOP has a unique number, details regarding each SOP are given in Part 2 of this report. Specific parameters monitored in each TA Luft Class are detailed in the Appendices.

3.1 Results for Emission Point A2-05, Pre Abatement Monitoring, 03 August 2017, 14:37 to 15:10

Parameter	Emission limit value	Emission results	Uncertainty	Units	Mass Emission kg/hr	Compliance
Di-Butyl Tin Laurate	N/S	<1.4	±0.28	mg/m³	<0.001	N/A
VOC Screen (including Xylene)	N/S	666.5	±70	mg/m³	0.41	N/A
VOC Total	N/S	1493	±308	mg/m³	0.931	N/A
Isopropyl Alcohol	N/S	19.2	±3.97	mg/m³	0.012	N/A
Volume Flow	N/S	624	±36	m³/hr	-	N/A

3.2 Results for Emission Point A2-05, Pre Abatement TOC Monitoring, 03 August 2017, 14:41 to 15:11

Parameter	Emission limit value	Emission results	Uncertainty	Units	Mass Emission kg/hr	Compliance
TOC as C	N/S	2306.9	±452	mg/m³	1.49	N/A

3.3 Results for Emission Point A2-05, Post Abatement Monitoring, 03 August 2017, 14:37 to 15:10

Parameter	Emission limit value	Emission results	Uncertainty	Units	Mass Emission kg/hr	Compliance
Di-Butyl Tin Laurate	N/S	<1.37	±0.28	mg/m³	<0.001	N/A
VOC Screen (including Xylene)	N/S	<0.68	±0.14	mg/m³	<0.001	N/A
VOC Screen (excluding targets)	N/S	<0.68	±0.14	mg/m³	<0.001	N/A
Isopropyl Alcohol	N/S	3.6	±0.75	mg/m³	0.002	N/A
Volume Flow	N/S	646	±37	m³/hr	-	N/A

3.4 Results for Emission Point A2-05, Post Abatement TOC Monitoring, 03 August 2017, 13:50 to 14:20

Parameter	Emission limit value	Emission results	Uncertainty	Units	Mass Emission kg/hr	Compliance
TOC as C	N/S	393.2	±77.0	mg/m^3	0.255	N/A

3.5 Reference Conditions for emission point A2-05

Reference Conditions for concentrations and volume flow as expressed as:

Temperature, K	Pressure, kPa	Oxygen %	Moisture %
273	101.3	N/A	Dry

3.6 Discussion of Results

Based on a review of MSDS's supplied by the Client a VOC screen was run on the tubes used during monitoring of both pre and post abatement monitoring locations. This VOC screen specifically looked for concentrations of Di-butyl Tin Laurate, Xylene in TA Luft Class II and Isopropyl Alcohol (IPA) in TA Luft Class III as well as Aliphatic Hydrocarbons.

Analysis of the TOC as C data shows a rapid increase in the concentration at the beginning of a spray batch and then a relatively constant level until the end of the process. After completion of the batch, the TOC levels drop back to near ambient levels.

The concentration of organics in the emissions after abatement is significantly lower than the pre-abatement levels. Abatement efficiencies were calculated at 99.9% (VOC) and 81% (IPA) based on the survey results. The % abatement efficiency based on the TOC readings (83%) should be considered in the context that the pre- and post-abatement TOC measurements were not recorded simultaneously.

4.0 Supporting Information

4.1 Monitoring team information

Name	Function	Qualification
Enda Flood	Environmental Scientist	• PgC Green Tech (2010) UCD Dublin • BAgSc (2008) UCD Dublin

4.2 *Substance(s) monitored, SOP's and Standard Methods*

Substance Monitored	SOP	Standard Method	Analysis by	ISO 17025 Accreditation Status	Analysis Date
Speciated VOCs	QP-SITE-2016	EN 13649	SAL	B	16 Aug - 06 Sept 2017
VOCs	QP-SITE-2016	EN 13649	SAL	D	16 Aug - 06 Sept 2017
TOC as C	QP-SITE-2025	EN 12619	TMS	A	03 Aug 2017
Velocity & Temp	QP-SITE-2006	EN 13284-1:2002/ EN/ISO 16911-1:2013	TMS	A	03 Aug 2017

Note 1: ISO 17025 Accreditation Status: **A** – TMS accredited for Monitoring and Analysis, **B** - TMS accredited for Monitoring, sub contract lab accredited for analysis; **D** TMS not accredited for monitoring as non-accredited analysis is carried out by sub-contract lab

4.3 *Equipment used and Quality checks*

Equipment	Equipment ID	Quality Check
Deluxe SKC Sampling pump	M-S-E-20-7 M-S-E-20-4 M-S-E-20-3 M-S-E-20-6	On-site per and post calibration check

4.4 *Reporting results*

4.4.1 *Expression of test results*

All test results are expressed to one decimal place lower than the Emission Limit Value (ELV), while uncertainty of measurement results are expressed to two decimal places lower than the ELV, e.g. where an ELV of 50mg/m^3 applies, the reported result shall be reported to the first decimal place e.g. 6.6mg/m^3 with the uncertainty of measurement reported to two decimal places, e.g. ±0.12mg/m^3.

4.4.2 *Reporting results less than the detection limit*

If a single result is reported as being less than the limit of detection, the measurement result is expressed using a less than "<" sign, e.g. <0.005 mg/Nm^3. Where a number of parameter results, found to be less than the limit of detection, are expressed as an overall parameter, these results are calculated as per Section 3.3, Method 3 (Half the Limit of Detection) of the EPA *BREF Guidance on the General Principles of Monitoring*. This percentage method provides an estimation of the value of the measurement. It is reported without the less than "<" sign, e.g. 0.05 mg/Nm^3.

4.4.3 *Uncertainty calculation*

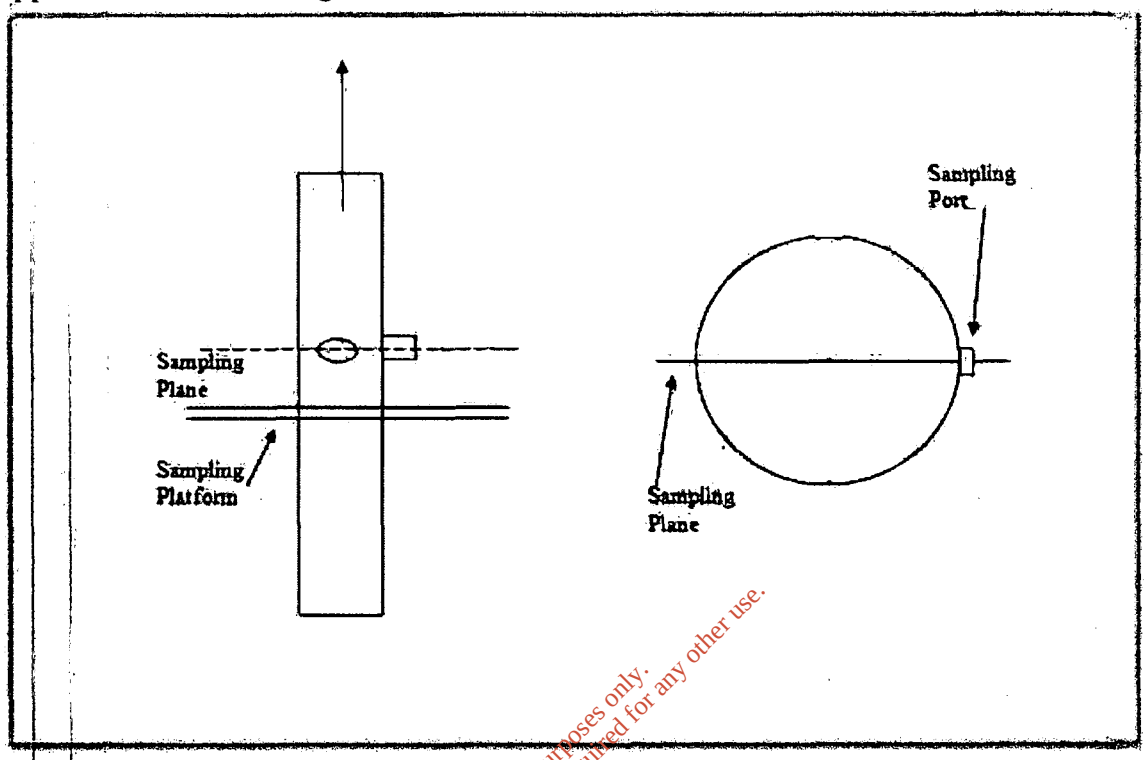
An estimation of the uncertainty of measurement is attached to all measurements. Measurement uncertainties are based on calibration data and laboratory repeatability experiments. All uncertainties are given at a 95% confidence, based on applying a coverage factor of k=2 to the combined uncertainties for each measurement. The uncertainty of measurement associated with emissions monitoring are provided in the Table below.

Table 4-1: Uncertainty of Measurement

Parameter	Source of uncertainty	Estimated uncertainty %	Combined uncertainty %	Expanded uncertainty % (95% confidence level)
TOC	Oxygen Analyser	6	9.80	20%
	Temperature Analyser	0.5		
	FID	5		
VOC	Velocity	2	10.32	21%
	CSA	1		
	Stack Pressure	2		
	Stack Temperature	2		
	Analysis	5		
Volume Flow	Velocity	2	2.9	5.81%
	Stack Temperature	0.5		
	Stack Pressure	0.5		
	O_2	1		
	CSA	2		

Appendix 1: Emission Point A2-05 Pre- and Post Abatement Points

Appendix1:1 – Stack Diagram



Stack Diameter	0.36
Stack Cross Sectional Area	0.10
Number of Ports	1
Number of sampling planes	1
Number of Sampling points per line	1
Power supply available	110 supply
Shelter at platform	Yes

Appendix 1:2 - Stack Measurements Pre Abatement VOC Run

Reference method		EN 13649	
Sampling date		03 August 2017	
Sampling time		14:37 to 15:10	
Sampling technique			
Flue gas sampling system		SKC pumps with Tygon tubing low flow tube holder	
Oxygen measurement technique		N/A	
Material			
Sampling material		Charcoal tubes	
Sampling conditions			
Average sampling flow rate [l/min]		0.5 per tube	
Total sampling time [min]		33	
Sampled volume of the dry gas at STP [m^3]		0.015	
Average flue gas temp temperature [°C]		29.7	
Reference conditions		**Actual conditions**	
Moisture [%]	Dry	Moisture [%]	Dry
Temperature [K]	273	Temperature [K]	303
Pressure [kPa]	101.3	Pressure [kPa]	99.10
Oxygen [%]	N/A	Oxygen [%]	N/A
Deviation from isokinetic conditions [%]		N/A	
Deviation from reference method		There was no deviation from reference method.	

Appendix 1:3 - Stack Measurements Pre Abatement TOC Run

Reference method	EN 12619
Sampling date	03 August 2017
Sampling time	14:41 to 15:11
Sampling technique	
TOC	Flame ionisation detection
Material	
Sampling probe material	SS, PTFE
Fuel	Hydrogen
Span calibration gas	Propane 90.0 ppm
Zero calibration gas	Ambient air after passing charcoal filter
Span gas drift [% of the range]	<2
Zero gas drift [% of the range]	<2
Sampling conditions	
Duct diameter [m]	0.36
Number of sampling ports	1
Number of sampling lines	Single point sampling
Heated line temperature [°C]	180
Number of sampling points per line	1
Average flue gas velocity [m/s]	1.93
Average flue gas temp temperature [°C]	29.0

Sampling conditions

Conditions	Reference	Sampling plane
Moisture	Dry	2.92
Temperature [K]	273	303
Pressure [kPa]	101.3	99.60
Oxygen [%]	N/A	N/A

Deviation from reference method

There was no deviation from reference method

Appendix 1:4 - Stack Measurements Post Abatement VOC Run

Reference method		EN 13649	
Sampling date		03 August 2017	
Sampling time		14:37 to 15:10	
Sampling technique			
Flue gas sampling system		SKC pumps with Tygon tubing low flow tube holder	
Oxygen measurement technique		N/A	
Material			
Sampling material		Charcoal tubes	
Sampling conditions			
Average sampling flow rate [l/min]		0.5 per tube	
Total sampling time [min]		33	
Sampled volume of the dry gas at STP [m^3]		0.015	
Average flue gas temp temperature [°C]		21	
Reference conditions		**Actual conditions**	
Moisture [%]	Dry	Moisture [%]	Dry
Temperature [K]	273	Temperature [K]	294
Pressure [kPa]	101.3	Pressure [kPa]	99.90
Oxygen [%]	N/A	Oxygen [%]	N/A
Deviation from isokinetic conditions [%]		N/A	
Deviation from reference method		There was no deviation from reference method.	

Appendix 1:5 - Stack Measurements Post Abatement TOC Run

Reference method	EN 12619
Sampling date	03 August 2017
Sampling time	13:50-14:20
Sampling technique	
TOC	Flame ionisation detection
Material	
Sampling probe material	SS, PTFE
Fuel	Hydrogen
Span calibration gas	Propane 90.0 ppm
Zero calibration gas	Ambient air after passing charcoal filter
Span gas drift [% of the range]	<2
Zero gas drift [% of the range]	<2
Sampling conditions	
Duct diameter [m]	0.36
Number of sampling ports	1
Number of sampling lines	Single point sampling
Heated line temperature [°C]	180
Number of sampling points per line	1
Average flue gas velocity [m/s]	1.93
Average flue gas temp temperature [°C]	20.0

Sampling conditions

Conditions	Reference	Sampling plane
Moisture	Dry	2.92
Temperature [K]	273	293
Pressure [kPa]	101.3	99.60
Oxygen [%]	N/A	N/A

Deviation from reference method

There was no deviation from reference method

Appendix 1:6 – Equipment Calibration

Instrument	Equipment ID	Calibration Parameter	Reading before Calibration	Reading post Calibration	Reading post sampling
SKC Pump	M-S-E-20-7	Volume Flow	500 ml/min	500 ml/min	500 ml/min
SKC Pump	M-S-E-20-4	Volume Flow	500 ml/min	500 ml/min	500 ml/min
SKC Pump	M-S-E-20-3	Volume Flow	500 ml/min	500 ml/min	500 ml/min
SKC Pump	M-S-E-20-6	Volume Flow	500 ml/min	500 ml/min	500 ml/min

Appendix 1:7 Parameter results

Parameter	unit	24420-2 (Blank)	24420-5	24420-8	24420-3 (Blank)	24420-6	24420-9
Isopropyl Alcohol	µg	*<5*	*280*	*53*	-	-	-
Di-butyl Tin	µg	*NA*	*NA*	*NA*	*<20*	*<20*	*<20*

Appendix 1:8 Parameter results

Parameter	unit	24420-1 (Blank)	24420-4 Pre-Abatement	24420-7 Post Abatement
VOC's Screen excluding targets	µg	<10	12,000	8
VOCs including targets	µg	< 10	9730	< 10
Octane, 2-methyl	µg	ND	880	ND
Heptane 3-ethyl-2-methyl	µg	ND	1000	ND
Ethyl benzene	µg	ND	1600	ND
Nonane	µg	ND	1200	ND
M - / p- xylene	µg	ND	1300	ND
1-ethyl-4-methyl cyclohexane	µg	ND	810	ND
o-xylene	µg	ND	1300	ND
Propylcyclohexane	µg	ND	400	ND
Cyclohexane, 1-ethy-2,3 dimethyl	µg	ND	680	ND
Branched benzene (C10)	µg	ND	530	ND

No significant peaks detected in VOC screen, screen included analysis for Xylene and Aliphatic hydrocarbons.

Appendix II
Calibration Certificates

M-S-E-1-1 27 Apr 17 EF

Certificate of Calibration

Date of issue: 20-Apr-17

Certificate Number **N 022121**

0687

Chell Instruments Ltd
Folgate House
Folgate Road
North Walsham
NR28 OAJ
England

Telephone 01692 502003 direct line
Fax 01692 500088
e-mail pcm@chell.co.uk
web site www.chell.co.uk

Chell *Gas Pressure Vacuum & Flow*

Page 1 of 8 pages

Approved Signatory

Name [ ] P.C.A. Marks [ ] J. Shanahan
[H] P.J. Kerrison

Signature

CUSTOMER DETAILS

Name: TMS Environment - Ireland

Address: 53 Broomhill Drive
Tallaght, Dublin 24
Ireland

Purchase order No.: PO D-17-8891

Chell Job No.: 25238

UNIT UNDER TEST DETAILS

Manufacturer: Tecora TCR

Model & description: Isostack G4.1.8mc Sampler

Serial / I.D. No.: 11420244P (M-S-E-1-1)

Ranges calibrated: DGM Qmax 3.6m3/Hr (60 l/min), Electical simulation K type thermocouple om & pitot DP transducers 0 to 2500 Pa, om & pitot absolute pressure, 12 to 60 l/min mass flow orifice meter. DGM single point temperature check.

CALIBRATION DETAILS

Laboratory conditions: 20 °C ±1°C 30%RH ± 20%RH

Standards & equipment used: STD0043, STD0011A, STD0042, STD0047A, STD0051B, STD0050, STD0016

Calibration completed: 20-Apr-17

Engineers note: The instrument was received with no obvious signs of major damage or contamination.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements. The uncertainty is true at the time observations were recorded and is not indicative of the instruments' ability to retain the calibrated value(s) with time.

UKAS is one of the signatories to the Multilateral Agreement of the European co-operative for Accreditation (EA) for the mutual recognition of calibration certificates issued by accredited laboratories.

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. 0687

Certificate Number N 022121

Method:

The UUT was calibrated using a PPC3 Pressure Calibrator/Controller in gauge mode of operation. For differential pitot channel calibration the test pressures were applied to the + test port on the front of the instrument. Calibration of the OM (orifice meter) differential pressure was performed by applying test pressures to the test hoses at the internal orific meter tappings, observing the direction of flow.

Reference (low) ports of the differential sensors were maintained at ambient pressure and were pressure cycled and leak checked. Readings were taken from the Sensor list of the 'Check test' sub menu.

The SI unit of pressure (Pa) is realised using a conversion factor of: 1

Results: **Differential pressure, as found**

Pitot differential

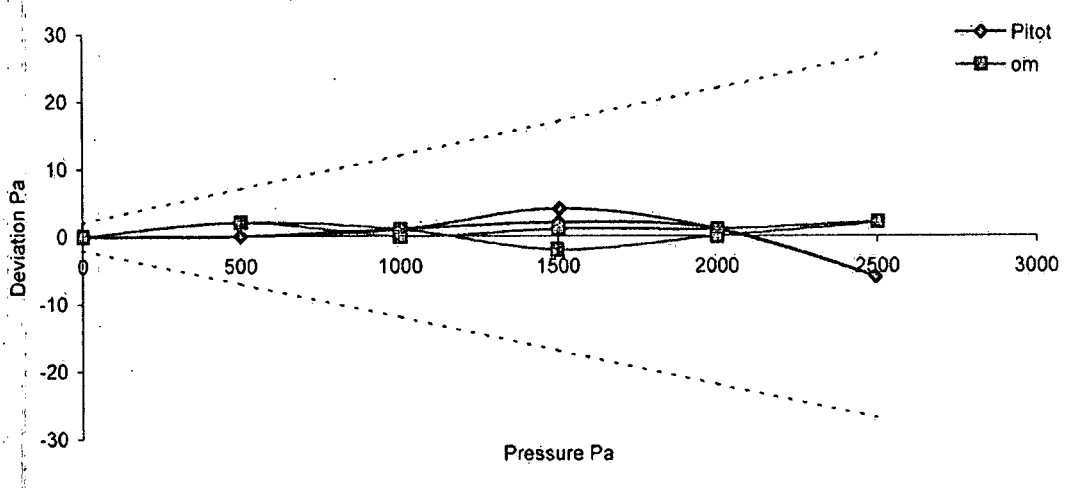
Standard pressure Pa	UUT indication Pa	Deviation Pa	Measurement uncertainty Pa
0.0	0	0	1.5
500.0	500	0	1.5
1000.0	1001	1	1.5
1500.0	1502	2	1.5
2000.0	2001	1	1.5
2500.0	2494	-6	1.5
2000.0	2001	1	1.5
1500.0	1504	4	1.5
1000.0	1001	1	1.5
500.0	500	0	1.5
0.0	0	0	1.5

Orifice (om) flow meter differential

Standard pressure Pa	UUT indication Pa	Deviation Pa	Measurement uncertainty Pa
0.0	0	0	1.8
500.0	502	2	1.8
1000.0	1001	1	1.8
1500.0	1498	-2	1.8
2000.0	2000	0	1.8
2500.0	2502	2	1.8
2000.0	2001	1	1.8
1500.0	1501	1	1.8
1000.0	1000	0	1.8
500.0	502	2	1.8
0.0	0	0	1.8

Uncertainty of applied pressure: 0.0031 % + 0.76 Pa

UUT repeatability ±: 0.65 Pa



Calibrated By:

Template number: (Method 5 template)

MS-E-1-1 27 APR 17 EF

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. 0687

Certificate Number N 022121

Method:

The thermocouple of each channel was connected to a precision electrical thermocouple simulator using K type thermocouple wire and connectors.
The following sequence of simulated temperatures were applied and the resulting indications recorded.

The UUT had previously been powered-up for a minimum of 30 minutes prior to calibration.

Results: **Electrical thermocouple simulation**

Standard temperature °C	Fumes channel °C	Aux 1 channel °C	Aux 2 channel °C	Probe channel °C	Box channel °C
0.0	0.5	0.4	-0.1	0.1	-0.1
240.0	239.8	239.8	239.2	239.6	239.5
480.0	480.1	480.1	479.5	480.0	479.9
720.0	721.0	720.8	720.3	720.8	720.7
960.0	961.1	961.0	960.4	960.9	960.7
1200.0	1200.6	1200.5	1199.9	1200.4	1200.1
0.0	0.5	0.4	-0.1	0.1	0.0

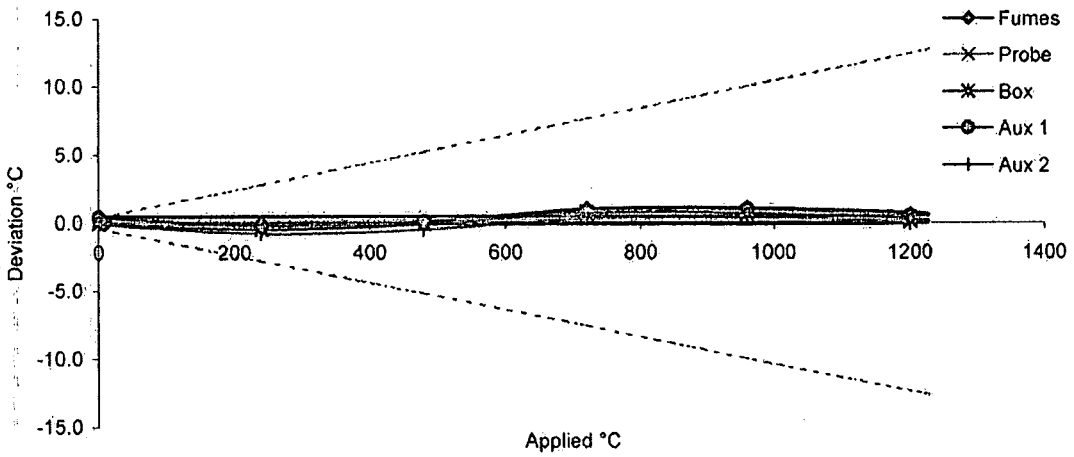
Uncertainty of measurement: 0.30 °C

Results: **DGM ambient temperature probe check.**

A calibrated temperature probe was placed in good thermal contact with the UUT 'meter' probe and allowed to stabilise at ambient temperatrue before recording the following data.

Standard measured temperature: 21.89 °C
UUT meter temperature: 22.10 °C

Ambient temperature comparison uncertainty: 0.30 °C



Calibrated By:

Template number: (Method 5 template)

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. **0687**

Certificate Number **N** 022121

Method:

The UUT was calibrated using a PPC3 Pressure Calibrator/Controller in absolute mode of operation. The test gas used was dry filtered air.

Test pressures were applied directly to the the internal absolute pressure sensors in isolation of the differential sensors in order to avoid overpressure damage. The sensors were pressure cycled and leak checked prior to calibration. Readings were taken whilst system was in run mode.

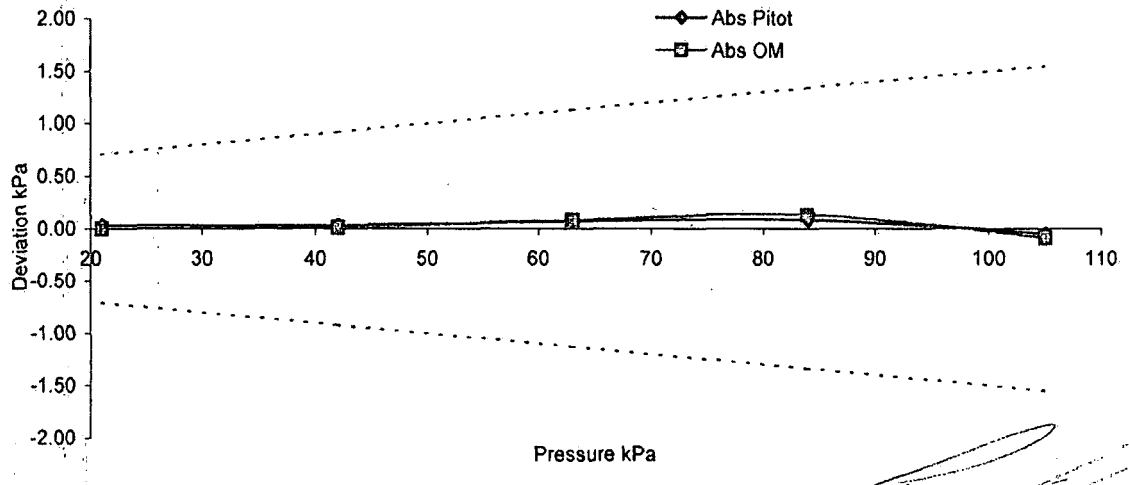
Results: **As found** *(no adjustment required)* UUT full scale: 105 kPa

Absolute Pressure

Pressure unit conversion factor (kPa) : 1

Standard applied pressure kPa	Abs Pitot (duct p) kPa	Abs pitot deviation kPa	Abs OM (P line) kPa	Abs OM deviation kPa	Measurement uncertainty kPa
21.000	21.03	0.03	21.00	0.00	0.013
42.000	42.03	0.03	42.02	0.02	0.013
63.000	63.07	0.07	63.08	0.08	0.014
84.000	84.08	0.08	84.13	0.13	0.015
105.000	104.95	-0.05	104.91	-0.09	0.016
84.000	84.08	0.08	84.13	0.13	0.015
63.000	63.07	0.07	63.08	0.08	0.014
42.000	42.03	0.03	42.01	0.01	0.013
21.000	21.03	0.03	21.00	0.00	0.013

Uncertainty of applied pressure:	0.0029	% +	0.0039	kPa
UUT resolution:	0.01	kPa		
UUT repeatability:	0.001	kPa		



Calibrated By:

Template number: (Method 5 template)

MSE-1-1 27 APR 17 CF

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. **0687**

Certificate Number N 022121

Method:

The instrument orifice meter was calibrated using a series of precision sonic nozzles located upstream of the UUT gas inlet port. UUT measurements were recorded from page 1 of flux test in 'Flowrate' mode of operation. The absolute pressure was measured at the downstream tapping of the orifice meter and the temperature was measured at the outlet of the internal dry gas meter and used to calculate the true volumetric flow rate of dry air at the DGM.

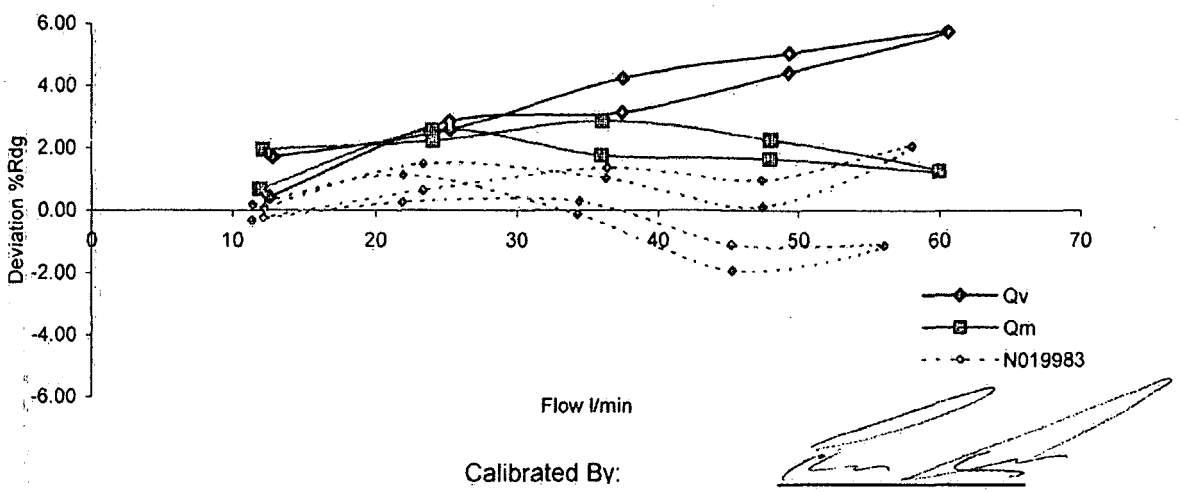
'Normalised' mass flow units are referenced to a standard temperature and pressure shown below (0°C & 101.325kPa).

Reference conditions (STP)

Standard temperature:	**273**	K
Standard reference pressure:	**101.3**	kPa

Results: **As found flow rate (orifice meter)**

% of UUT full scale	Standard flow (Qm) Nl/min	Equivalent flow (Qv) l/min	UUT (act f) lt/min	Deviation from std %	UUT (std f) Nl/min	Deviation from std %	Measurement Uncertainty %
0	0.000	0.000	0.00	n/a	0.00	n/a	n/a
20	11.889	12.567	12.62	0.42	11.97	0.68	6.8
40	23.976	25.203	25.92	2.85	24.59	2.56	5.2
60	36.014	37.456	38.63	3.14	36.65	1.77	4.6
80	47.987	49.234	51.41	4.42	48.78	1.65	5.2
100	59.991	60.565	64.04	5.74	60.76	1.28	3.3
80	48.055	49.314	51.80	5.04	49.14	2.26	5.2
60	36.039	37.481	39.07	4.24	37.07	2.86	4.6
40	24.024	25.237	25.89	2.59	24.56	2.23	5.2
20	12.113	12.801	13.02	1.71	12.35	1.96	6.8
0	0.000	0.000	0.00	n/a	0.00	n/a	n/a



Calibrated By:

Template number: (Method 5 template)

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. **0687**

Certificate Number N 022121

Method:

The instrument orifice meter was calibrated using a series of precision sonic nozzles located upstream of the UUT gas inlet port. UUT measurements were recorded from page 1 of flux test in 'Flowrate' mode of operation. The absolute pressure was measured at the downstream tapping of the orifice meter and the temperature was measured at the outlet of the internal dry gas meter and used to calculate the true volumetric flow rate of dry air at the DGM.

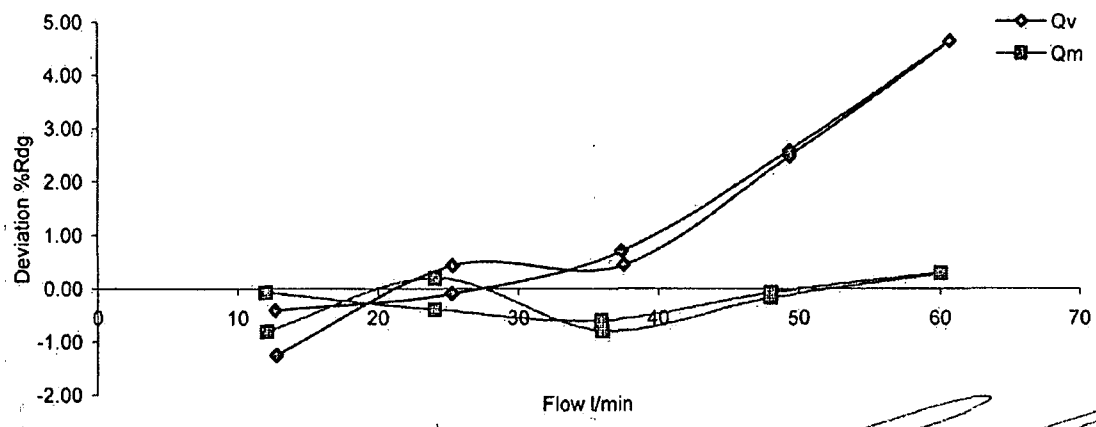
'Normalised' mass flow units are referenced to a standard temperature and pressure shown below (0°C & 101.325kPa).

Reference conditions (STP)

Standard temperature:	**273**	K
Standard reference pressure:	**101.3**	kPa

Results: **As left flow rate (orifice meter)**

% of UUT full scale	Standard flow (Qm) Nl/min	Equivalent flow (Qv) l/min	UUT (act f) lt/min	Deviation from std %	UUT (std f) Nlt/min	Deviation from std %	Measurement Uncertainty %
0	0.000	0.000	0.00	n/a	0.00	n/a	n/a
20	12.067	12.770	12.61	-1.25	11.97	-0.80	3.6
40	24.023	25.261	25.37	0.43	24.07	0.20	2.8
60	36.035	37.521	37.69	0.45	35.75	-0.79	3.6
80	48.001	49.296	50.52	2.48	47.92	-0.17	2.8
100	60.015	60.643	63.46	4.64	60.19	0.29	3.3
80	48.022	49.311	50.59	2.59	47.99	-0.07	2.4
60	35.937	37.396	37.66	0.70	35.72	-0.60	2.6
40	24.015	25.243	25.22	-0.09	23.92	-0.40	1.8
20	11.988	12.682	12.63	-0.41	11.98	-0.07	1.5
0	0.000	0.000	0.00	n/a	0.00	n/a	n/a



Calibrated By:

Template number: (Method 5 template)

MSE-121 27 APR17 EF

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. **0687**

Certificate Number **N 022121**

Method Statement:

Test flows were set up using a gas regulator upstream of the DGM internal inlet port via a set of precision sonic nozzles upstream of the DGM.
The standard flow rate was recorded at the start and end of each measurement.

UUT measurements were recorded from page 2 of flux test in 'Flowrate' mode of operation.

The gas temperature and barometric pressure were measured at the outlet port of the meter under test, to enable the calculation of the true volumetric flow rate. All volumetric flow units assume the test gas (dry filtered air) obeys the ideal gas law. Back-pressure and viscosity effects were not corrected for.

The meter totalizer timing method is traceable to the UK off-air frequency standard.
The meter was mounted vertically with the test ports facing upwards.

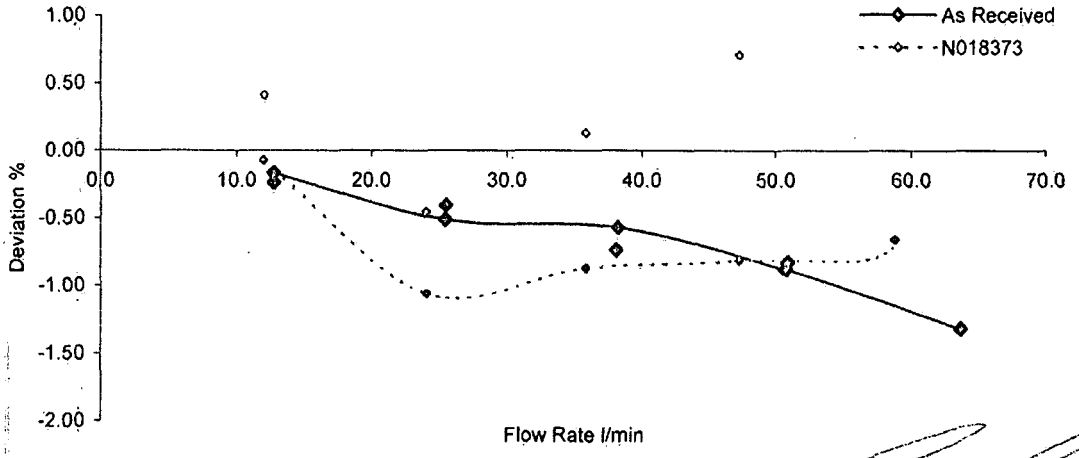
The quoted measurement uncertainty includes contributions from the UUT such as resolution, repeatability as well as applied flow rate and pressure, temperature and time measurements taken during the calibration.

The UUT units of volume are: litres
The UUT resolution is: 0.001 litres

Results: **As Received**

Standard flow rate l/min	Total volume passed litres	UUT Counter sample litres	Deviation from standard % Rdg
12.750	51.5104	51.424	-0.17
25.473	102.0432	101.518	-0.51
38.207	154.3192	153.435	-0.57
50.785	203.7996	202.003	-0.88
63.668	255.4364	252.067	-1.32
50.909	224.7125	222.855	-0.83
38.100	153.2752	152.141	-0.74
25.499	106.0510	105.619	-0.41
12.775	51.0998	50.978	-0.24

Uncertainty of measurement: 0.63 %



Calibrated By:

Template number: (Method 5 template)

Certificate of Calibration

UKAS Accredited Calibration Laboratory No. **0687**

Certificate Number **N** 022121

Method Statement:

Test flows were set up using a gas regulator upstream of the DGM internal inlet port via a set of precision sonic nozzles upstream of the DGM.
The standard flow rate was recorded at the start and end of each measurement.

UUT measurements were recorded from page 2 of flux test in 'Flowrate' mode of operation.

The gas temperature and barometric pressure were measured at the outlet port of the meter under test, to enable the calculation of the true volumetric flow rate. All volumetric flow units assume the test gas (dry filtered air) obeys the ideal gas law. Back-pressure and viscosity effects were not corrected for.

The meter totalizer timing method is traceable to the UK off-air frequency standard.
The meter was mounted vertically with the test ports facing upwards.

The quoted measurement uncertainty includes contributions from the UUT such as resolution, repeatability as well as applied flow rate and pressure, temperature and time measurements taken during the calibration.

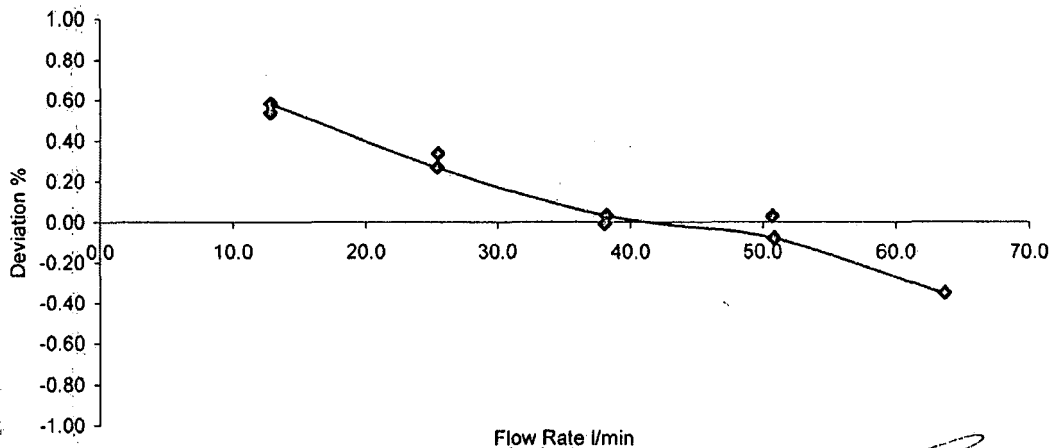
DGM corection factor adusted within 'calibration' sub-menu prior to recording the following results.

The UUT units of volume are: litres
The UUT resolution is: 0.001 litre

Results: **After adjustment**

Standard flow rate l/min	Total volume passed litre	UUT Counter sample litre	Deviation from standard % Rdg
12.773	51.2085	51.506	0.58
25.399	102.1798	102.454	0.27
38.217	153.6319	153.678	0.03
50.854	203.1616	202.998	-0.08
63.591	262.3768	261.459	-0.35
50.721	272.7252	272.803	0.03
38.065	153.1753	153.161	-0.01
25.459	104.1519	104.503	0.34
12.763	51.7555	52.033	0.54

Uncertainty of measurement: 0.63 %



Calibrated By:

Template number: (Method 5 template)