HE 16 / 1567

LA-PPC/EPR Compliance Monitoring

at

David Smith St Ives Ltd
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for

RanHeat Engineering Limited
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Study Period; - 17th February 2016

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23rd February 2016

FAO: Mr T Douglas

REPORT REF: - HE 16 / 1567

LA-PPC/EPR COMPLIANCE MONITORING OF THE WIESS UNIT AT DAVID SMITH, ST IVES, CAMBRIDGESHIRE

1.1 INTRODUCTION

This study was undertaken to determine data as detailed by David Smith St Ives Limited's Local Authority Pollution Prevention and Control (LA-PPC/EPR) permit provisions, as defined by Local Authority Environmental Services personnel, to assess the releases sourced from the operation of the site's Weiss wood burning boiler unit.

The report relates to monitoring studies undertaken on 17th February 2016 by Mr T Growcott, BSc (Hons) MRSC C Sci C Chem, of Halcyon Environmental in respect of the determination of Process Guidance Note PG 1/12 (2013) defined analytes.

In this study the wood burning unit system was fully operational, burning the wood feed stocks sourced from site manufacturing activities. Monitoring was undertaken continuously over a 3-hour period.

The author was formally trained in source testing via Clean Air Engineering (CAe) (1991), Casella (1992) and SGS (1991) and is STA registered (MM 03/314). Monitoring was undertaken over a continuous period to determine the results quoted and in accordance with the following Source Testing Association (STA) codes of practice; -

Document	Title
M 1054	STA Minimum Standards of Testing and Reporting
M 1055	STA Code of Practice
MIG001	Measurement of Specific Organic Compounds in Source Releases
QGN001	Guidance on Assessing Uncertainty in Stack Emission Monitoring

The plant's monitoring portals were located on the exit side of the discharge fan in the main transfer duct leading to the stack. The portals were accepted as being located satisfactorily in the exhaust stack by Local Authority personnel.

1.2 SUMMARY

The sampling, monitoring and analytical procedures undertaken in this report have determined analyte data site sourced emissions relating to the Weiss unit as per PG 1/12 provisions.

The following results were determined; -

Analyte	Test 1	Test 2	Mean	PG 1/12 (2013) Max Limit
1. Carbon Monoxide CO (mg/m^3)	480 samples (120 minutes at 15 second intervals)		247	250
2. TPM (mg/m^3)	98.44 1 x 30 mins sample	91.62 1 x 30 mins sample	95.08	200
3. VOC as C (mg/m^3)	480 samples (120 minutes at 15 second intervals)		5.441	20
4. Oxygen (%)	480 samples (120minutes at 15 second intervals)		12.21	-
5. Water Vapour (%)	1 x 60 mins sample		2.419	-
6. Oxides of Sulphur SOx (mg/m^3)	480 samples (120 minutes at 15 second intervals)		1.39	-
7. Oxides of Nitrogen NOx (mg/m^3)	480 samples (120 minutes at 15 second intervals)		103	400
8. Formaldehyde (mg/m^3)	0.71 (1 x 30 min sample)	0.62 (1 x 30 min sample)	0.665	5
9 Chlorides (as HCl) (mg/m^3)	(2 x 30 min sample)	-	1.28	100
10 Hydrogen Cyanide	(2 x 30 min sample)	-	<0.2	5

Sampling, monitoring and analytical procedures have determined process sourced direct releases from the Weiss unit's stack with respect to the concentration limits detailed under LA-PPC/EPR process documentation, and SO_x, NO_x and Oxygen concentrations.

1. Emission discharge colour has been determined in accordance with LA-PPC/EPR protocol and established as less than Ringlemann Shade 0.5 throughout the study period.

2. Emission discharges have been assessed and found to be free from droplets as defined within PG 1/12 note provisions.

3. Flow and mean velocity determinations have established data for the wood burner’s stack, which have indicated compliance above specified minimum efflux velocity requirements.

   The Weiss unit’s stack mean efflux velocity was determined to be 12.88m/sec its discharge temperature.

A copy of this report should be sent to Local Authority within 8 weeks of receipt.

Tim Growcott B Sc (Hons) MRSC C Chem C Sci MIMF
Senior Partner

RANH 1567 LAPPC REP

SECTION 2

SAMPLING AND MONITORING STRATEGIES

2 SAMPLING AND MONITORING STRATEGIES

2.1 SAMPLING STRATEGY

The main sampling and monitoring studies were completed following initial determination of the wood burner unit's stack thermal and flow profiles as detailed in BS 13284-1.

The data reported herein was compiled in accordance with the methodologies and procedures detailed in STA approved specifications, in addition to specific GC-MS methodologies and the use of approved Draeger tube methods and procedures.

The data reported herein was determined at the two stack portal locations, using the following instrumentation.

Velocity data was determined using a standard Airflow Developments model PVM 100 electronic micro-manometer, (HE 03-012) used in conjunction with a BS 1042 type 2.1 pitot system (HE 03-045), with in line thermocouple.

Calibrated flow, humidity, temperature and pressure measurement devices were also used in these procedures, using Huger-Sutronics and AGL instrumentation.

This procedure was based on BS 6911-1.

2.2 SAMPLING EQUIPMENT

Sampling was undertaken using BMS high and low flow pumps as defined in the analytical methodology procedures detailed in the next section of this report.

Samples were obtained using conventional Andersen probes located in the stack. These were connected to insulated transfer lines, of less than 0.5 m. length, to minimise condensation losses.

The port sealing system was tested prior to each run, and a leak rate of less than 0.02 % was recorded.

2.2.1 BS 13284-1 TOTAL PARTICULATE MATTER DETERMINATION

The procedure employed was that detailed in BS 13284-1.

Air was extracted from the main stack isokinetically over 2 x 30 minute sampling periods and via a purpose built stack-sampling train located directly at the duct portals to minimise condensation losses. The filters were retained for gravimetric measurement in post sampling analysis.

2.2.2 BS 12619 VOC DETERMINATION

Both direct reading and post sampling laboratory-based procedures were used to produce the data reported herein. Direct measurements were determined via a sampling train located adjacent to the main stack portals.

Direct reading measurements were made as detailed in BS 12619 using a Signal Instruments 3030PM instrument with FID calibrated for 20 ppm propane in air - ex Air Products.

Indirect measurements were made using composite Activated Charcoal and Tenax adsorption tubes, used in conjunction with low flow pumps.

The tubes were then analysed in laboratory based procedures using Gas Chromatography + Mass Spectroscopy by Halcyon personnel. This analysis detailed the VOC emissions as Carbon residues.

2.2.3 GAS COMPONENT DETERMINATIONS

The gaseous components of the emission stream were also determined.

Analyses were undertaken for NO_x, SO_x, CO, CO_2 and Oxygen using a Eurotron series 3000 Professional Combustion Gas Analyser. This instrument had its own probe system and operated by direct measurement of the stack emissions. These measurements were made via a number of on site analyses within the instrument using comparative assessments against pre conditioned calibrated internal standards. The instrument had its own gas conditioning system and pre calibrated internal measurement standards. This instrument was using for direct reading of the transfer duct emissions.

Water (moisture) content was determined in accordance with using Halcyon test equipment.

2.2.4 CHLORIDES (as HCl) DETERMINATION, ALDEHYDES AND HYDROGEN CYANIDE

Total Chloride was determined in accordance with the latest standard method of determination, BS EN 1911-3. This methodology was supplied from the Source Testing Association as the most accurate procedure for the determination of HCl. The method provides procedures for isokinetic sampling, the suggest methodology when particulate matter is anticipated in the emission stream.

The procedure was adhered to in strict accordance with defined methodology other than in the use of a full heated sampling line due to space limitations. The sampling head was determined to be at temperatures in excess of 150 degrees C at the sampling tip, and in excess of 150 degrees C at the filter body. Simultaneous temperature measurements determined that the emission stream temp was in excess of 60degrees C at the bubbler bottle and not less than 60 degrees C at both sampling pumps.

Chloride analyses were undertaken using the ion exchange chromatography procedure detailed in BS EN 1911-3. This procedure was considered to give identical results to the alternative mercuric thiocyanate methodology, and not have the significant interferences of the silver nitrate potentiometric methodology.

The ion exchange method is the only one of the three options, which also gives indicative distinction of the presence of volatile chlorides, which may be present in the sampling solutions.

Chloride determination was calculated using BS EN 1911 section 4.5 equations.

Aldehydes and Hydrogen Cyanide were determined using BS 13649.

2.2.5 SAMPLING PROTOCOLS

All sampling and monitoring procedures were based on basic isokinetic sampling strategies, to assess process uniformity, with continuous on line assessment of flow rate and dynamic velocity measurements during unit operation.

All flow rate and velocity measurement instrumentation was calibrated prior to, during and after each sampling run.

All sampling planes and points of determination were corrected in accordance with isokinetic correction Ka coefficients as detailed in Source Testing Association protocols.

Monitoring was based on the Approved 1999 Code of Practice produced by the Source Testing Association.

Calculation of Velocity of Flow:

The basic formula for calculating velocity of flow from velocity pressure is:

$$\text{Velocity Pressure (Pv)} = \tfrac{1}{2}\, \rho\, V^2$$

Where:

Pv is Velocity Pressure in pascals.

ρ is the density of dry air (free of CO_2) at 1013mb, 273K in Kg/m^3.
V is velocity in metres per second.

Dry air contains 78.1% Nitrogen (as N_2), 20.9% Oxygen (as O_2), 0.9% Argon (as Ar) and traces of CO_2 (0.03%), Ne, He, Kr, Xe, H_2, CH_4, N_2O, O_3, SO_2, NO_2, NH_3, CO, & I_2.

Atomic Weight of Nitrogen is 14, Oxygen is 16, and Argon is 40. Molecular Weight if Nitrogen (N_2) is 28, Oxygen (O_2) is 32 and Argon (Ar) is 40.

Molar Density of a complex gas mixture, such as air, can be calculated using the proportions of gas present, and the molecular weights of the component gases. Thus using the 3 principle components of dry air:

Molar gas density = 0.781 x 28 (for N_2) + 0.209 x 32 (for O_2) + 0.009 x 40 (for Ar)
= 28.916

When the figures are made more accurate, and all the other trace gases added into the equation, **Molar Gas Density of Air** works out to be **28.9644**. This is normally approximated to 29.

The following calculations can be utilised (in most cases), where molar gas density is in the range of 28-30, (see note on determination of flue gas density).

In some combustion stacks the density can be found to be outside this range, in which case the calculations need to be modified by substituting the actual value into the basic equation, and following the calculation through.

One mole of gas occupies 22.4136 litres at 273 K, 1013mb. (Normally approximated to 22.4). One mole of air occupies the same volume and weighs 28.9644 g. Thus the **Density of Dry Air** at 273 K, 1013 mb works out at 1.292 Kg/m^3. The precise figure is 1.2928 Kg/m^3.

If this figure is entered into the initial equation

$$Pv = \tfrac{1}{2}\, \rho\, V^2$$

It calculates out to; -

Velocity (metres per second) = $1.244 \sqrt{Pv}$ (at 273 K, 1013 mb)

or

Velocity (metres per second) = $1.280 \sqrt{Pv}$ (at ambient: 289 K, 1013mb)

This equation can be applied at or near standard conditions. Where conditions vary significantly from standard, corrections can be made according to the following formula:

$$V = 1.280 \sqrt{\frac{1013 \times T \times 101300}{Pa \times 289 \times (101300+Ps)} \times Pv}$$

This equation corrects for atmospheric pressure (Pa), expressed in millibars, Temperature expressed in Kelvin (T), and static pressure in the stack (Ps) in pascals. It multiplies out to give:

$$V = 762.7 \sqrt{\frac{T \times Pv}{Pa\ (101300+Ps)}} \times Pv$$

Where:

V	=	Velocity of Flow on metres per second (ms^{-1})	
T	=	Temperature in Kelvin (Kelvin = ^{o} Celsius + 273)	(K)
Pv	=	Velocity Pressure in pascals	(Pa)
Ps	=	Static Pressure in pascals	(Pa)
Pa	=	Atmospheric Pressure in millibars (1 millibars = 100 pascals)	(mb)

To apply this equation, Pv should be entered as the root mean square of all velocity pressure readings. Where the majority of the readings do not vary by more than 25% from the mean figure, the mean provides a satisfactory answer. The equation gives velocity of flow at temperature T, static pressure Ps, and atmospheric pressure Pa.

Measurement of Air Flow in Stacks:

Correct isokinetic sampling is dependent on accurate assessment of air velocity in the duct or flue. Because of the potentially hot, acid conditions found in flues, the instrument of choice for measuring flow is one that measures differential pressure, and does not insert an instrument with electronic or moving parts into the duct. There are several other types of instrument available for measuring airflow, but these should not, as a general rule, be used in flue stacks.

Pressure in Ducts:

There are 4 factors that affect the perceived pressure in a duct:

1. Movement of air produces a measurable Velocity Pressure (also known as Dynamic Pressure).
2. Static Pressure, is exerted in all directions, by the compression, expansion, or heating process that is moving the air.
3. Atmospheric (Barometric) Pressure
4. Temperature.

Micro manometer & Pitot Tube:

The pitot tube is the differential pressure probe, it is designed to create minimal turbulence in the flow. The British Standard design has an ellipsoidal nose, which is inserted to face the flow. The tube is very directional and needs to be accurately aligned into the flow, to produce the best result. Unfortunately the pressure bearing on the nose of the instrument is Velocity Pressure, but with the addition of static pressure.

To eliminate this problem, the pitot tube is made with a separate tapping to measure static pressure alone. The BS tube is made double, with tappings at right angles to the flow, whereas the American S type pitot consists of two separate tubes 180^{o} opposed. The two types of pitot tube have different response factors (sometimes called the K factor), and this may require the use of a correction factor in calculating flow. The response factor for the BS type is 1.0 and for the S type is 0.85.

The original instrument for measuring air pressure is the U tube manometer. By attaching the two tappings of the pitot tube, one to each side of the manometer, Static pressure is applied to both sides, and its effect is eliminated, allowing a direct reading of Velocity pressure. The inclined manometer is an improvement on the U tube, because it allows for more accurate readings of pressure. However it does require careful leveling before use, and an electronic micro manometer is more user friendly.

With either type of instrument it is important that it is connected up with the Velocity pressure tapping bearing on the positive side of the instrument.

Calculating & Presentation of Results (Measurements & Corrections):

Particulate sampling is always assessed gravimetrically (by weight). Filter material of all types is pre weighed, exposed in the sampling line and re-weighed.

This procedure may require drying of the filter medium before re-weighing, if the sampling was conducted at a temperature below the dew point. In all circumstances, filters require careful handling to avoid loss particulate, and also loss of original fibrous material. Weight of particulate collected is thus derived from the difference of the two weights and is normally expressed in milligrams (g^{-3}) or micrograms (g^{-6}). The balance should be calibrated against a traceable standard before and after each batch of filters is weighed / re-weighed.

Volume of gas collected is normally determined either by multiplying sampling flow rate (litres/minute) by time elapsed (minutes) to get a final volume in litres, or by utilising a direct reading from a gas meter.

In both cases, volume calculated is at ambient temperature and pressure and requires correcting to standard conditions. The gas meter or flow meter should be regularly re-calibrated against a traceable standard, and this may impose an extra calibration factor on the results to obtain correct ambient volume.

If the sampling line, does not include a silica gel trap, but only a condensate trap, (as in the BCURA or CEGB Mk111A) the air passing to the meters can be assumed to be water saturated at ambient conditions, and this too required compensation.

Schedule A & B processes require presentation of results in milligrams per cubic metre, and / or parts per million, as standardised to the following conditions:

Temperature	273K (0^{o} Celsius)
Barometric Pressure	101.3KPa, (1013mb)
Humidity	Dry
Oxygen	3%, 6%, 8%, 11%, 15%, 18% depending on combustion process

The various calculations and conversions are explained in the subsequent paragraphs.

Determination of Isokinetic Sampling Rate:

To obtain correct samples of particulates, turbulence caused by sampling must be minimised. This is achieved by making the velocity of flow into the sampling probe equal to the velocity flow moving along the duct or stack.

This sampling technique is called isokinetic sampling, and its use enables the collection of representative samples, by eliminating the distortion of sample reliability caused by variation in proportion of light particulates collected.

Velocity of flow is determined by the use of pitot tube and micro manometer. This is normally calculated at the stack temperature. The gas volume measuring equipment is normally functioning at about ambient temperature (Gas moving along the sampling line rapidly cools to ambient).

To calculate isokinetic flow rate, first the gas velocity must be calculated as at ambient. This is done using the standard gas equation (See Calculation of Results).

$$\frac{\text{Pressure x Volume}}{\text{Temperature}} = \text{Constant}$$

Thus for a stack of uniform width volume is proportional to velocity, hence:

$$\text{Velocity}_{\text{ambient}} = \frac{\text{pressure}_{\text{stack}} \text{ x Velocity}_{\text{stack}} \text{ x Temperature}_{\text{ambient}}}{\text{Temperature}_{\text{stack}} \text{ x Pressure}_{\text{ambient}}}$$

As atmospheric pressure remains equal this item cancels out of the equation.
Sampling rate (litres per minute) is a function of stack velocity (metres per second) and probe tip area (square centimetres), derived from pr^2. The rationale is as below:

$$\text{Metres per second (m/s) x } \frac{100}{60} = \text{centimetres per minute (cm/min)}$$

$$\text{Centimetres per minute (cm/min) x Square centimetres (cm}^2\text{) = Cubic Centimetres per minute (cm}^3\text{/min)}$$

$$\frac{\text{Cubic Centimetres per minute (cm}^3\text{/min)}}{1000} = \text{Litres per minute (l/min)}$$

Thus:

$$\textbf{Sampling Rate (l/min)} = \frac{\textbf{Ambient Stack Flow (m/s) x Tip area (cm}^2\textbf{)}}{\textbf{600}}$$

Determination of Flue Gas Density:

Stack gas density is determined by measuring the concentration of Carbon Dioxide, Carbon monoxide and Oxygen in the stack. This can be done using a combustion analyser.

The residual dry atmospheric gas is assumed for the purpose of this calculation to be Nitrogen. Nitrogen concentration is calculated as follows:

$$\% N_2 = 100 - (\% CO_2 + \% O_2 + \% CO)$$

The proportion if each gas in the dry mixture can then be utilised to calculate the dry molar gas density as shown previously:

$$\textbf{Molar Dry Gas Density (Dd)} = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%\ O_2 \times \frac{32}{100}\right) + \left(\%CO + \%N_2 \times \frac{28}{100}\right)$$

Flue gases however also contain water. The water is condensed out of the sampling line, (to protect the sampling pump), and is weighted.

The volume of gas occupied by the collected condensate water can be calculated from the volume occupied by 1 mole of standard gas (ie. 22.4 litres at 273K, 1013mb).

$$\textbf{Gas Phase Volume of Water (litres) = Weight of Water (grams)} \times \frac{22.4}{28}$$

Dry gas volume of the sample is measured by the gas meter in the sampling line. Total gas volume (wet) collected is therefore the sum of the calculated water volume above and the dry gas volume measured.

Total (Wet) Gas Volume = Dry Gas Volume + Gas phase Water Volume

Using the above relationship, the proportion of dry gas in the total volume collected, (Mole Faction of Dry Gas), can be calculated as follows:

$$\textbf{Mole Fraction of dry gas (Md)} = \frac{\textbf{Dry gas volume}}{\textbf{Total gas volume}}$$

Mole fraction of wet gas can be calculated similarly, or as

Mole fraction of wet gas (Mw) = 1 - Mole fraction of dry gas (Md)

Density of stack gas can then be calculated from the density of dry stack gas calculated above, and the Mole Fractions calculated.

Thus:

Molar Density
of dry gas (Dd) x Mole fraction of dry gas (Md) + 18 (1 - Md)
= Molar Stack gas density (Ds)

This latter equation is identical in methodology to the earlier equation for deriving molar gas density of dry gas, but now includes an extra derived function for water

$$\text{Molar stack gas density (Ds)} = \text{Md}\left(\frac{\%CO2 \times 46}{100} + \frac{\%O2 \times 32}{100} + \frac{\%N2 + \%CO \times 28}{100}\right) + \text{Mw}\left(\frac{\%H2O \times 18}{100}\right)$$

In most cases the Molar stack gas density will work out as 29 $\pm$ 1. In this case, the normal equation for stack flow will prove to be satisfactory.

Calculation of Volume Flow:

Volume flow is calculated from flow velocity and internal area of the stack or duct as follows:

Volume flow (m^3 /min) = Velocity (ms^{-1}) x Internal Area of Duct (m^2) x 60

Internal area of duct is calculated as:

pr[2] for a circular duct,
or base x height for a square duct.

To convert m^3min^{-1} to cubic feet per minute (cfm) multiply by 35.315

Oxygen Correction:

The principal behind the oxygen correction is that a complete combustion process would consume all the oxygen, releasing only Carbon Dioxide and Water. Thus the more efficient the combustion process, the less Oxygen is released.

Many processes however function less efficiently than they should, and many others are designed to operate with a large excess of air, or additions of cool air to facilitate the erection of less heat resistant stacks.

The oxygen correction is designed to recalculate the concentration of pollutant gases found, assuming that the process if functioning at a reasonable efficiency for its type.

Thus Gas & Oil fired combustion plant are corrected to 3% O_2, Coal fired combustion plant at 6% O_2, Clinical Waste Incinerators at 11% O_2, and Gas Turbines at 15% O_2. Other processes may be standardised to other Oxygen concentrations.

Oxygen makes up about 20.9% of normal air; this is used in the correction factor, which is as follows:

$$\textbf{Corrected Pollutant Concentration (mg/m}^3\textbf{)} = \frac{(20.9 - \text{Standard } O_2\%)}{(20.9 - \text{Measured } O_2\%)} \times \text{Measured Conc}^n$$

This means that where a combustion process is running more efficiently than required, the correction factor will effectively decrease the final corrected concentration of pollutant. Conversely, where the process is inefficient, the Oxygen correction can dramatically increase the final result.

The correction is only used in combustion processes, and is applied identically to all pollutant gases and particles.

Conversion Factors (mg/m^3 and ppm):

Final results of particulate concentrations in air are always presented as a weight by volume measure (e.g. milligrams per cubic metre).

Gases can be presented as a weight by volume, or as a volume measure (parts per million). Unfortunately, there is no standard methodology within the Process Guidance notes and both types of measure are used, often in the same note. It is thus, important to be able to change between the two methods of calculating gas concentration.

Hydrogen chloride will be used to illustrate the two methods as follows:

Hydrogen chloride has molecular weight of 36.5. 1 mole of HCl occupies 22.4 litres at s.t.p. 1 milli -mole of HCl occupies 22.4 millilitres at s.t.p. 1 millimole weighs 36.5 milligrams.

If 1 millimole of HCl is dispersed in 1 cubic metre of air then this is a concentration of 36.5 milligrams per cubic metre (mg/m^3) or 22.4 millimetres per cubic metre (parts per million) ppm.

So for HCl 36.5 mg/m^3 = 22.4 ppm

Specifically for HCl $\text{ppm} \times \frac{36.5}{22.4} = \text{mg/m}^3$

In general $\text{ppm} \times \frac{\text{molecular weight}}{22.4} = \text{mg/m}^3$ **at standard conditions (273 K, 1013mb)**

The concept of parts per million is particularly useful, because gas volumes expand and contract with temperature and pressure. Because all gases occupy the same volume, ppm does not change with temperature.Thus a gas concentration recorded in ppm at high temperature, is still the same at low temperature, and at standard conditions, allowing a direct conversion to mg/m^3 without the worry of changing volumes.In the case of Nitric Oxide (NO) and Nitrogen Dioxide (NO_2), NO exists at high temperature, as a breakdown product of NO_2. When combined emissions are released to atmosphere, the NO cools and re-oxidises to form NO_2. Thus the PG notes required presentation of Nitrogen oxides (NOx) to be combined and expressed as NO_2.

Because both gases occupy the same volume the ppm concentrations can be directly added such that:

ppm NO + ppm NO_2 = ppm NOx (as NO_2)

The combined NO_x concentration as NO_2 can then be calculated as above using the molecular weight of NO_2 as the basis for the calculation.

Occasionally (for example in Occupational Hygiene applications), the conversion equation is presented as:

$$\text{mg/m}^3 = \text{ppm} \times \frac{\text{molecular weight}}{24}$$

This allows for the fact that 1 mole of gas at 20^{o}C, 1013 mb, occupies 24 litres, and is correct for use at ambient conditions. It is not correct to use this equation at standard conditions.

Temperature and Pressure:

Assuming that stack gases obey the standard Gas Laws, then:

$$\frac{\text{Atmospheric Pressure (mb)} \times \text{Volume (m}^3\text{)}}{\text{Temperature (K)}} = \text{Molar Gas Content}$$

or

$$\frac{PV}{T} = K$$

The Molar Gas Constant equals 8.3143 J K^{-1} mol^{-1}

A more useful expression of the Gas Law is:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This can be expressed to find an unknown as; -

$$V1 = \frac{P_2V_2}{T_2} \times \frac{T_1}{P_1}$$

The correction equation can therefore be expressed as:

$$\text{Standardised Volume} = \frac{\text{Recorded Pressure}}{\text{Std Pressure (1013)}} \times \frac{\text{Std Temperature (273)}}{\text{Recorded Temperature}} \times \text{Recorded Volume}$$

For this correction to work, any unit of pressure can be utilised (inches of water, millimetres of mercury, millibars, kilopascals etc.) provided that the standard atmosphere is expressed in similar units. Temperature must however be worked in Absolute Units e.g. Kelvin (K = ^{o}C + 273.15) or Rankine (^{o}R = ^{o}F + 459.67)

2.2.6 INITIAL STACK PROFILE STUDY

As per the provisions BS 6911-1, a stack profile study was addressed prior to monitoring and sampling. This study was undertaken at 17points in two transaxial assessments at the sampling portal locations. Both temperature and velocity profiles were measured. The study determined that the temperature variance across the two measured planes was less than 10 C, and that velocity variances were within method tolerance specification. (Pre-test measurements determined that the sampling head was less than 10 % of the total stack cross sectional area.

2.2.7 CLIMACTIC CONDITIONS

The following climactic conditions were noted during the study; -

Ambient Temperature - K	279
Atmospheric Pressure - kPas	100.5
Relative Humidity - %	31
Wind Speed - kph	< 10
Wind Direction	NW
Visibility metres	> 1000
Weather	Bright and clear

2.2.8 QA - QC PROCEDURES

Halcyon operates QA - QC procedures following the guidelines of Halcyon QA.QC Doc 1. Halcyon is a member of the Source Testing Association.

2.2.9 UNCERTAINTY MEASUREMENTS

Halcyon operates the measurement of uncertainty in accordance with; -

"Guidance on Assessing Uncertainty in Stack Emission Monitoring" Dr.J.Pullen STA Quality Task Group

SECTION 3

ANALYTICAL PROCEDURES

3 ANALYTICAL PROCEDURES AND METHODS

The following analytical methods were used to determine the data reported herein; -

	Analyte	Method Reference
1	CO / CO_2	IS0 15058 / ISO 12039
2	Total Particulate Matter	BS 13284-1
3	VOC	BS 12619
4	VOC as Carbon	BS 12619
5	Water Content	BS 14790
6	Oxygen	ISO 12039
7	Free Formaldehyde	Halcyon Test Method HALC.EPA.HCHO 01 Impingers + automated dynamic titrimetry / BS 13649
8	Chlorides	BS 1911-3
9	Hydrogen Cyanide	MDHS 56 / 2 for analysis / BS 13649
10	NOx	EN 14792

**Eurotron Combustion Gas Analyser instrument

Planning and performing a stack test

DETERMINE NECESSITY OF A SOURCE TEST
- Decide on data required
- Determine that source test will give this data
- Analyse cost

RESEARCH LITERATURE
- Basic process operation
- Type of pollutant emitted from process
- Physical state at source conditions
- Probable points of emission from process
- Read sampling reports from other processes sampled:
  1. Problems to expect
  2. Examinations of variables
     a. H_2O vapour
     b. Temperature at source
- Study analytical procedures used for processing test samples

STATE SOURCE TEST OBJECTIVES
- Process evaluation
- Process design data
- Regulatory compliance

EACH STACK TEST SHOULD BE CONSIDERED AN ORIGINAL SCIENTIFIC EXPERIMENT

DESIGN EXPERIMENT
- Develop sampling approach
- Select equipment to meet test objectives
- Select analytical methods
- Evaluate possible errors or biases and correct sampling approach
- Determine man power, period for test
- Determine time required for test with margin for breakdowns
- Thoroughly evaluate entire experiment with regard to applicable source and UK guidelines

PRE-SURVEY SAMPLING SITE
- Locate hotels and restaurants in area
- Contact plant personnel
- Inform plant personnel of testing objectives and requirements for completion
- Note shift changes
- Determine accessibility of sampling site
- Evaluate safety
- Determine port locations and applications to BS 13284-1 or ISO 9096:2003
- Locate electrical power supply to site
- Locate rest rooms and food at plant
- Drawings, photographs, or blueprints of sampling site
- Evaluate applicability of sampling approach from experiment design
- Note any special equipment needed

FINALISE TEST PLANS
- Incorporate pre-survey into experiment design
- Submit experiment design for approval by client
- Set test dates and durations

CALIBRATE EQUIPMENT
- DGM
- Determine console Delta H
- Nozzles
- Thermometers and thermocouples
- Pressure gauges
- Orsat
- Pitot tube and probe
- Nomographs

PREPARE FILTERS AND REAGENTS
- Mark filters with insoluble ink
- Desiccate to constant weight
- Record weights in permanent laboratory file
- Copy file on site record
- Measure double distilled H_2O for impinges
- Weigh silica gel
- Clean sample storage containers

PREPARE EQUIPMENT FOR TEST
- Assemble and confirm operation
- Prepare for transportation
- Include spare parts and reserve equipment

CONFIRM TRAVEL AND SAMPLE TEAM ACCOMMODATIONS AT SITE

CONFIRM TEST FATE AND PROCESS OPERATION
- Final step before travel arriving at site

ARRIVAL AT SITE
- Notify plant and regulatory agency personnel
- Review test plans with all concerned
- Check weather forecasts
- Confirm process operation parameters in control room

SAMPLING FOR PARTICULATE EMISSIONS
- Carry equipment to sampling site
- Locate electrical connections
- Assemble equipment

DETERMINE APPROXIMATE MOLECULAR WEIGHT OF STACK GAS USING FYRITE AND NOMOGRAPHS

1

1

PRELIMINARY GAS VELOCITY TRAVERSE
- Attach thermocouple or thermometer to pitot probe assembly
- Calculate sample points from guidelines outlined BS 13284-1 or IO 9096:2003
- Mark pitot probe
- Traverse duct for velocity profile
- Record Delta p's and temperature
- Record duct static pressure

APPROXIMATE H_2O VAPOUR CONTENT OF STACK GAS

USE NOMOGRAPH OR CALCULATOR TO SIZE NOZZLE AND DETERMINE C FACTOR
- Adjust for molecular weight and pitot tube C_p
- See K pitot point on monogrpah

RECORD ALL IFORMATION ON DATA SHEETS
- Sample case number
- Meter console number
- Probe length
- Barometer pressure
- Nozzle diameter
- C factor
- Assumed H_2O
- Team supervisor
- Observers present
- Train leak test rate
- General comments
- Initial DGM dial readings

LEAK TEST COMPLETELY ASSEMBLED SAMPLING TRAIN @ 15" Hg VACUUM AND MAXIMUM LEAK RATE OF 0.02 CFM

NOTIFY ALL CONCERNED THAT TEST IS ABOUT TO START

CONFIRM PROCESS OPERATING PARAMETERS

TAKE INTEGRATED SAMPLE OF STACK GAS FOR ORSAT ANALYSIS (OR PERFORM MULTIPLE FYRITE READINGS ACRESS DUCT)

ANALYSE STACK GAS FOR CONSTITUENT GASES
- Determine molecular weight
- CO2 and O2 concentration for F-factor calculation

START SOURCE TEST
- Record start time
- Record gas velocity
- Determine Delta H desired from nomograph
- Start pump and set orifice meter differential manomoeter to desired Delta H
- Record
  1. Sample point
  2. Time from zero
  3. DGM dial reading
  4. Desired Delta H
  5. Actual Delta H
  6. All temperatures DGM, stack sample case
- Maintain isokinetic Delta H at all times
- Repeat for all points on traverse

MONITOR PROCESS RATE

TAKE MATERIAL SAMPLES IF NECESSARY

TAKE CONTROL ROOM DATA

RECORD CLIMATICS

RECORD TEST PERSONNEL

AT CONCLUSION OF TEST RECORD
- Stop time - 24 hour clock
- Final DGM
- Any pertinent observations on sample

PREPARE OTHER TRAINS FOR REMAINING SAMPLING

LEAK TEST SAMPLE TRAIN
- Test at highest vacuum (in Hg) achieved during test
- Leak rate should not exceed 0.02 CFM
- Note locations of any leak if pssible

REPACK EQUIPMENT AFTER SAMPLING IS COMPLETED

REPEAT PRECEDING STEPS FOR THREE PARTICULATE SAMPLES

2

2

SAMPLE CLEAN-UP AND RECOVERY
- Clean samples in laboratory or other clean area removed from site and protected from the outdoors
- Note sample conditions
- Store samples in quality assurance containers
- Mark and label all samples
- Pack carefully for shipping if analysis is not done on site

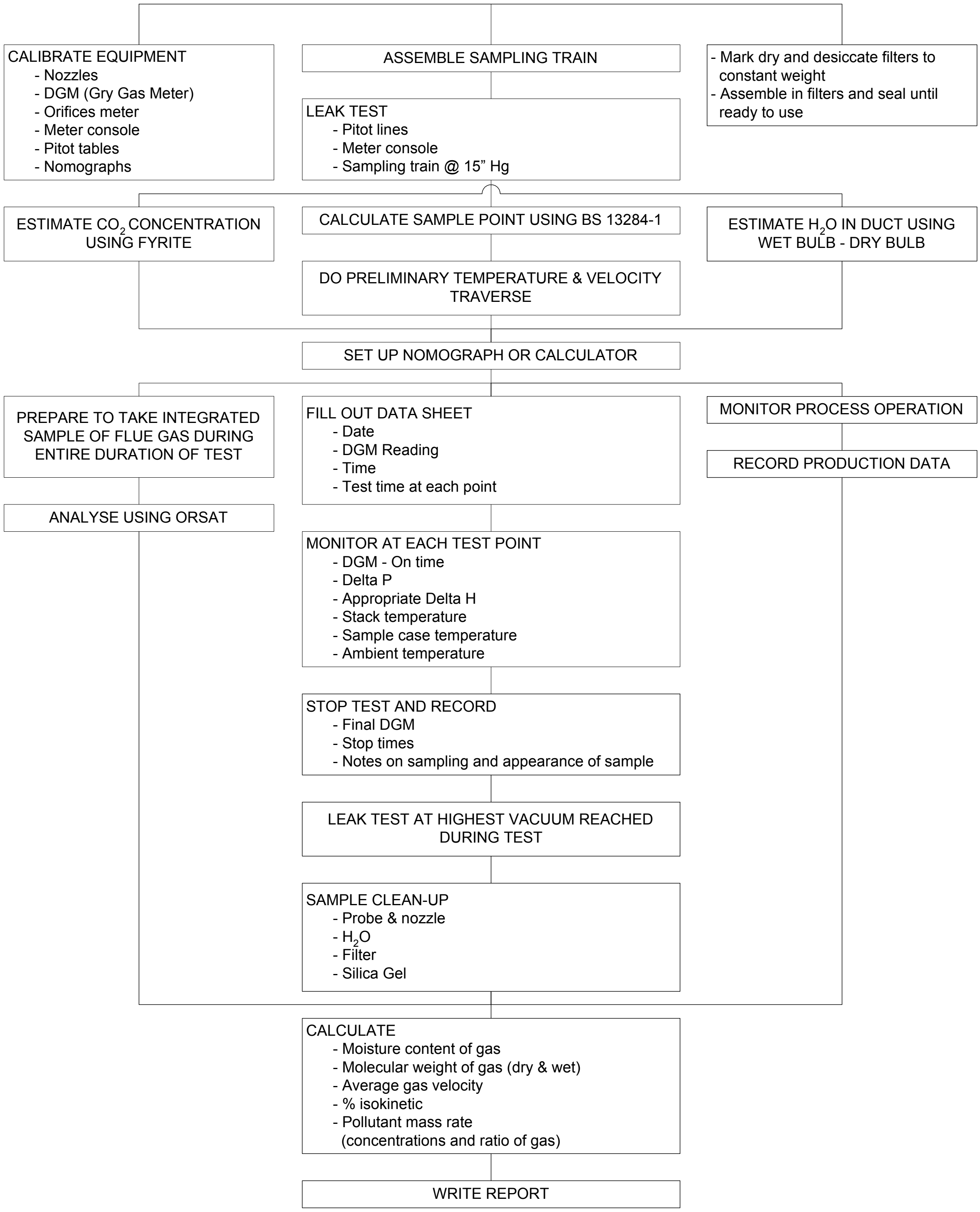
ANALYSE SAMPLES
- Follow BS 13284-1, ISO 9096:2003, EA, A1, A2, M1, M2 guidelines
- Document procedures and any variations employed
- Prepare analytical Report Data

CALCULATE
- Moisture content of stack gas
- Molecular weight of gas
- Volume sampled at standard conditions
- Concentration / standard volume
- Control device efficiency
- Volumetric flow rate of stack gas
- Calculate pollutant mass rate

WRITE REPORT
- Prepare as possible legal document
- Summarise results
- Illustrate calculations
- Give calculated results
- Include all raw data (process & test)
- Attach descriptions of testing and analytical methods
- Signature of analytical and test personnel

SEND REPORT WITHIN MAXIMUM TIME TO INTERESTED PARTIES

Source Test Outline



Cleaning the sample train

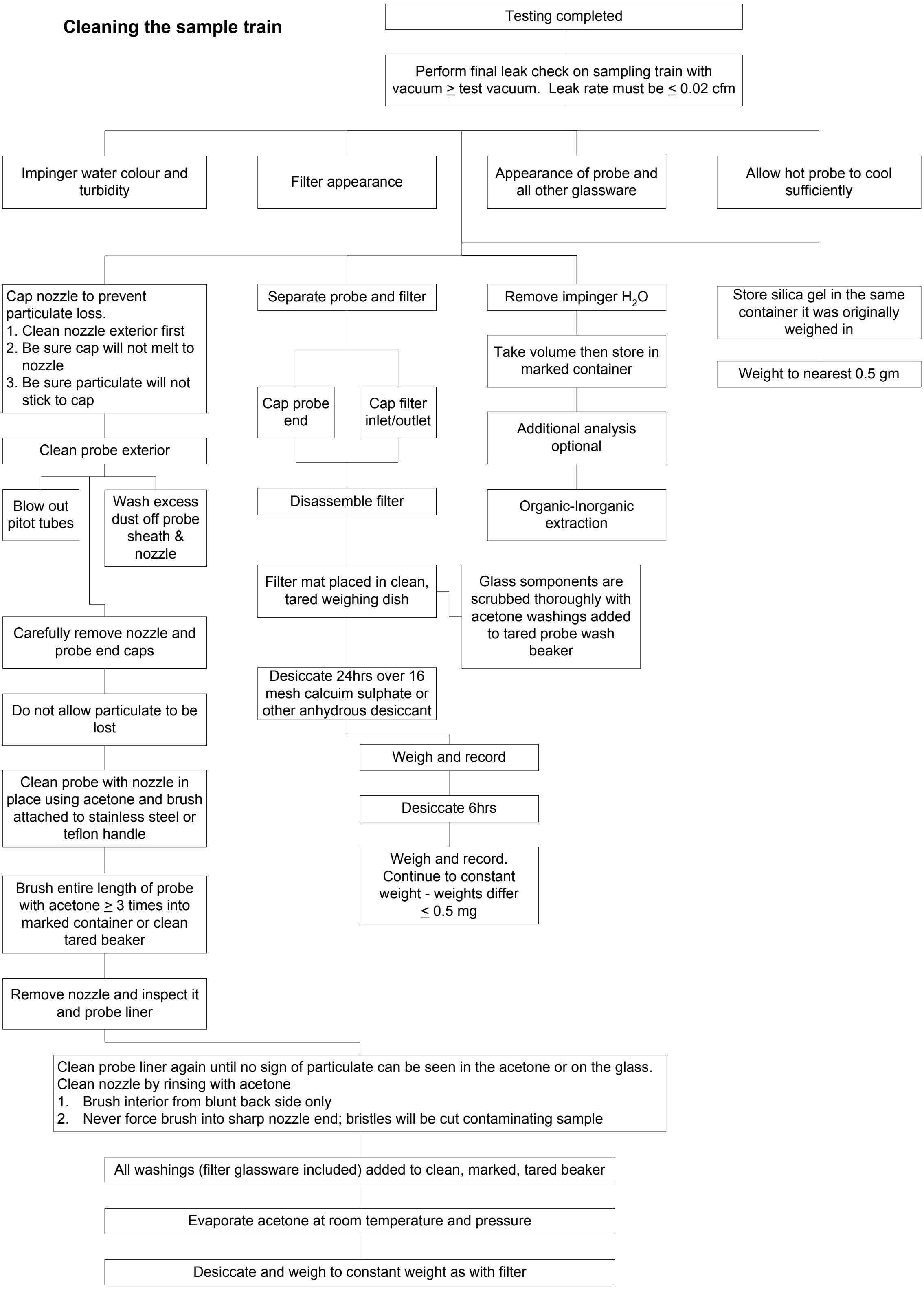


Table 1: Simple error analysis for particulate measurement, 4 Point Sampling (or 10 Point Sampling when Pitot Ratios >4:1≤9:1)

Type of Error	Source of Error	Quoted uncertainty	Estimate of component standard uncertainty (1SD)	Combined uncertainties (1SD)	Combined uncertainty (1SD)	Expanded uncertainty (95% confidence limits)
Precision-like Errors						
Random	Errors in setting to isokinetic conditions Minimum sampling time of 3 minutes	≤±1% ±8%	≤±0.58% ±4.62%	±4.66%		
Systematic						
Accuracy-like Errors						
Random	Measure flue dimensions to ±10mm/m	±2%	±1.15%	±1.15%		
Systematic	Number of sampling points (see note below) Minimum weight gain Pre=/Post-pitot reading within 10% Temperature variations of 10% on 150°C Gas flow axis deviates up to 30°	±13% assume ±2% ±2.5% ±1/5% ≤±3.5% velocity	±6.63% ±1.5% ±1.44% ±0.87% ≤±2.02% velocity	±7.22%	±13.03%	±25.5%

Note: Type A component uncertainty, quoted at 95% confidence limits. All other component uncertainties assumed to be Type B.

Table 2: Simple error analysis for measurement of mass flow particulates when not all the requirements of BS 13284-1 are met.

Deviation from standard: Only nearest 2 points of 4 on each of sampling lines can be reached (circular duct); pre/post sampling velocities differed by 20%; Highest to lowest pitot reading 15:1.

Type of Error	Source of Error	Quoted uncertainty	Estimate of component standard uncertainty (1SD)	Combined uncertainties (1SD)	Combined uncertainty (1SD)	Expanded uncertainty (95% confidence limits)
Precision-like Errors						
Random	Errors in setting to isokinetic conditions	≤±1%	≤±0.58%	±4.66%		
	Minimum sampling time of 3 minutes	±8%	±4.62%			
Systematic						
Accuracy-like Errors						
Random	Measure flue dimensions to ±10mm/m	±2%	±1.15%	±1.15%		
Systematic	Number of sampling points, and highest:lowest pitot readings 15:1 (see note below)	±(13+12)%=25%	±12.78%	±14.88%	±20.7%	±40.8%
	Bias due to non-symmetrical points	±7.5%	±4.33%			
	Minimum weight gain	assume ±2%	±1.5%			
	Pre/Post-pitot readings differ by 20%	±10%	±5.77%			
	Temperature variation of 10% on 150°C	±1.5%	±0.87%			
	Gas flow axis deviates up to 30°	≤±3.5% velocity	≤±2.02% velocity			

Note: Type A component uncertainty, quoted at 95% confidence limits. All other component uncertainties assumed to be Type B.

UNCERTAINTY CALCULATIONS 2015; EUROTRON 3000 SERIES COMBUSTION GAS ANALYSER						
CARBON DIOXIDE		**OXYGEN**				
0	12	0	20.9	Xr		
0.03	12	0	20.9			
0.03	12	0	20.9			
0.03	12	0	20.9			
0.02	12.01	0	20.91			
0.03	12	0	20.9			
0.03	12.01	0	20.9			
0.03	12	0	20.9			
0.03	12.01	-0.01	20.9			
0.03	12	0	20.9			
0.03	12.01	0	20.9			
0.03	12	0	20.91			
0.03	12.00	0.00	20.90	Mean	x	
0.00	0.00	0.00	0.00	SD	S	
0.04	0.00	0.00	0.00	D = x - Xr		
0.35	**0.10**		**0.07**	**Uncertainty**	**Ud = sqrt (3 x d)**	
	12		20.9	Xr	Span Gases	
	1.30		1.30		Relative Uncertainty %	BOC
	20.00		25.00		Instrument Range	
	0.26		**0.33**		% / ppm Uncertainty	
	0.40		**0.50**		Linearity	Eurotron
	0.20		**0.25**		Zero Drift	Eurotron
	0.20		**0.25**		Span Drift	Eurotron
	0		0		Interferents % & ppm	Halcyon
	0.022		0.0275		Linearity % & ppm	Halcyon
	0.06		0.075		Zero SD	Halcyon
	0.03		0.0375		Span SD	Halcyon
	0.0012		0.00209		Atmospheric Pressure	Halcyon
	0.02		0.025		Voltage	½ of EN
	0.018		0.0375		Ambient Temperature	½ of EN
	0		0		Losses & Leakages	Halcyon
	0.1		0.1		Zero Drift % & ppm	Halcyon
	0.02		0.02		Span Drift % & ppm	Halcyon
Carbon Dioxide		**Oxygen**				
Sum Sqs	0.0161094		0.0202231			
SqRt	0.126923		0.142208	Combined Uncertainty of Range		
	0.248769		0.2787277	Expanded Uncertainty		
	0.9951		**1.1149**	**% Uncertainty**		

UNCERTAINTY CALCULATIONS 2015 VOC as C using SIGNAL3030 FID						
783.1		82.3		8.25		Certified Values of propane conc in ppm
Signal Instruments PM 3030 FID mA readings						
17.17	1.77	17.43	1.52	15.48	2.69	
17.16	1.79	17.43	1.52	15.55	2.69	
17.18	1.79	17.46	1.52	15.62	2.61	
17.14	1.77	17.51	1.52	15.58	2.63	
17.16	1.76	17.47	1.54	15.54	2.63	
17.14	1.77	17.43	1.52	15.54	2.63	
17.19	1.77	17.45	1.5	15.56	2.65	
17.14	1.78	17.41	1.5	15.66	2.67	
17.12	1.77	17.47	1.52	15.52	2.67	
17.14	1.78	17.43	1.5	15.6	2.65	
17.15	1.75	17.37	1.52	15.5		
17.15	1.77	17.44	1.52	15.56	2.65	Mean
0.02	0.01	0.03	0.01	0.05	0.03	SD
2.23	2.23	2.23	2.23	2.23	2.26	Students t p357 Stats Book
0.04	0.03	0.08	0.03	0.11	0.06	Repeatabilily SD x t
0.00	0.00	0.00	0.00	0.00	0.00	Bias = mean – true
0.04	0.03	0.08	0.03	0.11	0.06	Uncertainty bias = repeatability
0.26	**1.43**	**0.45**	**1.69**	**0.72**	**2.22**	**Instrument Percentage Uncertainty**
1.00	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**Gas Percentage Uncertainty**
1.03	**1.74**	**1.09**	**1.96**	**1.23**	**2.43**	**Overall Calculated % Uncertainty**
±2%	**±2%**	**±2%**	**±2%**	**±2%**	**±3%**	**Working Figures % of Reading**

UNCERTAINTY FOR PARTICULATE SAMPLING TO EN 13284 -1: 2002 PRINCIPAL UNCERTAINTIES FOR PARTICULATE SAMPLE OF 10mg					
Balance (PBS) at 100mg	= 0.022mg	95%		0.0220	0.0005
Volume Measurement (Schlumberger)(Labcal) 400L	= 0.5% of vol	2 litres	4	4.000	16.0000
	+ resolution	0.2 litres	0.025	0.1200	0.0144
DGM	= 2.3%			4.6000	21.1600
Change in DGM temperature	= 10/293			0.0341	0.0012
Change in atmospheric pressure	= 2/1013			0.0020	0.0000
No change in humidity (dry gas)					
No change in oxygen (LEV System)					
				Sum Sqs	37.1761
				Sq rt	6.0972
				Expanded Result	**6.1%**

UNCERTAINTY FOR HCl SAMPLING TO EN 13649: 2002 UNCERTAINTY FOR A SERIES F DUPLICATE MEASUREMENTS OF HCl			
Sd 0.141 mean 6.88 = ± 2.06%			
Double to allow for less good data (& / absolute accuracy & standards)			
Double to 95%	± 8.24	**Expanded Result = ±**	**8.20%**
Continuous process = no change in humidity			
V little change in temperature			
Low flow pumps with counters, so not identical flows, but results divided by volume (Halcyon bubble flow meter cal)			
Laboratories do not provide uncertainty estimates on analytical results			

SECTION 4

MEAN EFFLUX VELOCITY DATA

4 FLOW DYNAMICS RESULTS

The following results were determined using the calculations and correction coefficients detailed in BS 13284-1.

The following results were determined at the portal locations; -

TABLE 4.1 MEAN EFFLUX VELOCITY RESULTS.		
Sampling Location	**Mean Efflux Velocity m/sec @ T**	**Discharge Temp K**
Portal	12.87	402.44

Mean efflux velocity is specifically determined as the initial criteria to all subsequent sampling work, this being fully dependent upon the reported value being obtained correctly. Errors included in this initial measurement may be significant if not correctly identified and eliminated from the test procedure. The errors associated within any typical test are reported in the standard Halcyon Test Report.

Sampling locations are generally defined in Technical Guidance Notes M1 and M2, as are the access portal descriptions.

When undertaking mean efflux velocity, the standard working tool in the pitot tube; descriptions of various pitots are defined in TGN M1. All pitot tubes must be in good working order, with current calibration and with use of the correct sampling nozzles for static and dynamic pressure determinations. Results are normally displayed on a suitable electronic micro-manometer. Many of these devices are equipped with basic calculation software such that once the stack dimensions have been entered and the procedure completed, the velocity, mass flow at T and at reference conditions can all be completed from pre-programmed calculation matrices. Data determined in the field can be directly transposed into standard document formats to simplify the calculation tasks.

The supporting kit equipment that is used will determine ambient and stack temperature, ambient barometric pressure, relative humidity and oxygen levels; again this information can be entered into pre-programmed calculator matrices to establish data at T and reference conditions as required by permit provisions.

The standard methods of determination are defined in the relevant ISO or BS protocol, typically ISO 9096: 2003 of BS 13284 – 1: 2002. The test statement should be included whether the testing is supporting isokinetic sampling or not.

Essentially the pitot is used to traverse the stack during testing, normally across at least 2 sampling planes. From the initial study the tester confirms that Vmax:Vmin, Tmax:Tmin, drift angle, gas homogeneity and droplet tests are completed and met. The typical working area of the stack is usually > 5 hydraulic diameters above a bend or joint, in a straight section of the stack. The probe is inserted at the correct location and allowed to monitor for approx. 2 – 3 minutes before the reading is determined.

Normally up to 16 or 17 test locations are measured within a circular stack and 4 or 8 locations in a square or rectangular stack. All locations are reported in the standard Halcyon Test Report as are any determined Uncertainty values.

Velocity measurements are obtained and then stored in the electronics and a mean value calculated. The meeting of the sampling provisions is normally deemed more relevant than the geometry of the sampling port; if the sampling plane criteria are met then a non-standard port is usually considered as secondary. As such for part A2 and B processes the use of the BS 3405 portal is still considered as acceptable.

The formula for the determination on MEV is defined within the standard Halcyon format.

Of critical importance is the safety of and Stack Tester; this being implicit within the standard sampling procedure. The stack tester's safe working is defined within STA guidance and often a compromise must be considered in full compliance with TGN M1 and the significance of the Working at Height Regulations.

TGN M1 defines the configuration of the approved stack sampling platform, and this is applied strictly to A1 permitted sites, however A2 and B permitted sites often do not have such platforms in place. It is then necessary for the tester to complete a suitable risk assessment and minimise any risks.

The current STA view is that sampling must only take place from safe locations; the use of ladders is strictly prohibited and the use of cherry pickers only considered appropriate once a safe working evaluation and full risk assessment have been completed. The STA regards the formal and documented training for Working at height as an implicit provision on any stack testers' portfolio.

Halcyon personnel normally utilise the STA Guidance documentation, Disclosure of Hazards document and Risk Assessment format as a condition of their site activities.

The duct airflow stream temperature was measured continuously using a Casella W1720 thermo - anemometer probe in the stack portals.

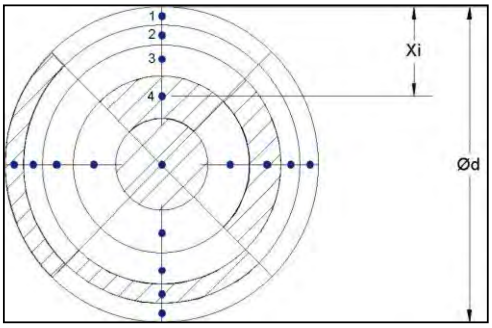
The implicit BS 6911-1 error factor of +/- 12 % was considered as satisfactory, as was the + 6.2% isokinetic correction factor applied to the calculation.

Pitot Measurements

BS 13284-1		BS 13284-1	
BS 6911	Y	*Please tick the relevant box*	

Client:	*David Smith St Ives Limited*	**Date:**	*17th February 2016*	
Address:	*Marley Road*	**Operator:**	*T Growcott*	
	St Ives	**Job Number:**	*HE 16 / 1567*	
	Huntingdon	**Location:**	*Wood Burner*	
	Cambs PE 27 3EX	**Instruments:**	*!M Pitot + BS 1042 Pitot*	
Details of Duct:	*Insulated Steel*		**Atmos. P (pa)**	**Atmos. Temp K**
Duct Shape:	*Circular*	**Initial:**	100.1	278
Dimension / Dia.:	0.3	**Final:**	100.9	280
Area:	0.07068	**Mean:**	*100.5*	*279*
	Axis 1:	**Axis 2:**	**Gas Homogeneity Check:**	Pass

Traverse Point	Temp K	Temp K^2	Velocity kPa	V^2
1	129.4	16744.36	89	7921
2	129.5	16770.25	90	8100
3	129.5	16770.25	97	9409
4	129.6	16796.16	106	11236
5	129.4	16744.36	115	13225
6	129.5	16770.25	117	13689
7	129.5	16770.25	118	13924
8	129.6	16796.16	120	14400
9	129.2	16692.64	103	10609
10	129.4	16744.36	105	11025
11	129.5	16770.25	107	11449
12	129.5	16770.25	112	12544
13	129.5	16770.25	100	10000
14	129.4	16744.36	103	10609
15	129.4	16744.36	107	11449
16	129.5	16770.25	109	11881
17	129.1	16666.81	116	13456
Total	*2200.5*	*284835.57*	*1814*	*194926*
Average	*129.441176*	*16755.03353*	*106.7058824*	*11466.23529*
RMS		129.4412358		107.0805085



O2 reference	11%
Humidity %	31
Ambient K	279
Negative Pressure	Pass
Drift Angle	<15°
Dry Gas Correction	Y
Pitot Correction	Y
T Correction	Y
Vmax : Vmin	Pass
Tmax : Tmin	Pass
V_{rms}	107.0805085
Pitot Calibration	*1.002*
Static Pressure Pv (Pascals)	-1.9
Mean Stack Temperature K	402.4412358
Moisture Content %	2.892

SECTION 5

ANALYTICAL RESULTS

5 ANALYTICAL SEQUENCE AND RESULTS

The monitoring strategy was undertaken over 1/2 day.

An ongoing continuous assessment of emission clarity, colour and odour at the point of discharge were also undertaken. At no time during this study was there any indication of colouration by dense or black smoke.

Periodic monitoring of O_2, water vapour, CO, SOx, NOx and VOC were undertaken.

TPM measurement was undertaken on 2 x 30 minute sampling schedules with the filters located outside of the stack. A blank was performed for each test scenario.

5.1 ANALYTICAL RESULTS

Analytical mean result data is detailed below: -

Analyte	Test 1	Test 2	Mean	PG 1/12 (2013) Max Limit
1. Carbon Monoxide CO (mg/m^3)	480 samples (120 minutes at 15 second intervals)		247	250
2. TPM (mg/m^3)	98.44 1 x 30 mins sample	91.62 1 x 30 mins sample	95.08	200
3. VOC as C (mg/m^3)	480 samples (120 minutes at 15 second intervals)		5.441	20
4. Oxygen (%)	480 samples (120minutes at 15 second intervals)		12.21	-
5. Water Vapour (%)	1 x 60 mins sample		2.419	-
6. Oxides of Sulphur SOx (mg/m^3)	480 samples (120 minutes at 15 second intervals)		1.39	-
7. Oxides of Nitrogen NOx (mg/m^3)	480 samples (120 minutes at 15 second intervals)		103	400
8. Formaldehyde (mg/m^3)	0.71 (1 x 30 min sample)	0.62 (1 x 30 min sample)	0.665	5
9 Chlorides (as HCl) (mg/m^3)	(2 x 30 min sample)	-	1.28	100
10 Hydrogen Cyanide	(2 x 30 min sample)	-	<0.2	5

Stack S1 – Volatile Organic Compounds (VOC as C)

Job Number:	HE 16 / 1567
Client:	David Smith St Ives
Date:	17th February 2016
Release Point Stack Ref	S1
Instrument Type	FID
Calibration Gas	Methane
Sample Number	1567/VOC/001 - 480
Test Start (Ti)	08.15.00
Test Finish (Tf)	10.15.00
Test Duration (mins)	120
% Carbon	75
Sampling Rate Interval (secs)	15
No. of Samples	480
Maximum Reading (mgC/m^3)	11
Minimum Reading (mgC/m^3)	0
Mean Reading (mgC/m^3)	5.441

Stack S1 – Total Particulate Matter

Job Number:	HE 16 / 1567
Client:	David Smith St Ives
Date:	17th February 2016
Release Point Stack Ref	S1
Tester	T Growcott
Test Method	BS 13284-1
STA Reference	MM 03 / 314
-ve Pressure Test	Pass
Droplet Test	Pass
Vmax:Vmin Test	Pass
Tmax:Tmin Test	Pass
Pressure Differential Test	Pass
Drift Angle	<15°
Gas Homogeneity Test	20 point CO Pass
Instrument Type	Anderson Portable
Sample Number	1567/TPM/001/2
Test Start (Ti)	08.20.00
Test Finish (Tf)	09.27.00
Test Duration (mins)	67
Heater Box Inlet C	18
Heater Box Outlet C	19
MID 1 Correction	Duplicate Samples
Sampling Head	TPM 002
Sampling Points	4
No. of Samples	2 x 30 mins
Maximum Reading (mg/m^3)	98.44
Minimum Reading (mg/m^3)	91.62
Mean Reading (mg/m^3)	95.08

Stack S1 – Water Vapour

Job Number:	HE 16 / 1567
Client:	David Smith St Ives
Date:	17th February 2016
Release Point Stack Ref	S1
Instrument Type	US EPA method 4 test box
Sample Number	1567/Water/001/2
Test Start (Ti)	09.30.00
Test Finish (Tf)	10.37.00
Test Duration (mins)	67
No. of Samples	1 x 60 mins
Mean Reading (%)	2.419

Stack S1 – Formaldehyde

Job Number:	HE 16 / 1567
Client:	David Smith St Ives
Date:	17th February 2016
Release Point Stack Ref	S1
Instrument Type	Halcyon Test Box
Sample Number	1567HCHO/001/2
Test Start (Ti)	08.20.00
Test Finish (Tf)	09.23.00
Test Duration (mins)	63
No. of Samples	2 x 30 mins
Maximum Reading (mg/m^3)	0.71
Minimum Reading (mg/m^3)	0.62
Mean Reading (mg/m^3)	0.665

Stack S1 – Chlorides (as HCl)

Job Number:	HE 16 / 1567
Client:	David Smith St Ives
Date:	17th February 2016
Release Point Stack Ref	S1
BS 1911-3 Sampling Train	Test Box 2
Sample Number	1567/HCl/001/2
Test Start (Ti)	10.05.00
Test Finish (Tf)	11.08.00
Test Duration (mins)	68
Sampling Rate Interval (mins)	30
No. of Samples	2 x 30
Mean Reading (mg/m^3)	1.27

Stack S1 – Gaseous Components

Job Number:	HE 16 / 1567	HE 16 / 1567	HE 16 / 1567
Client:	David Smith St Ives	David Smith St Ives	David Smith St Ives
Date:	17th February 2016	17th February 2016	17th February 2016
Release Point Stack Ref	S1	S1	S1
Instrument Type	Eurotron Combustion Gas Analyser		
Calibration Gas	Self Calibrating Cells		
Sample Number	1567/CO/001 - 480	1567/NOx/001 - 480	1567/SOx/001 - 480
Test Start (Ti)	08.00.00	08.00.00	08.00.00
Test Finish (Tf)	10.00.00	10.00.00	10.00.00
Test Duration (mins)	120	120	120
Sampling Rate Interval (secs)	15	15	15
No. of Samples	480	480	480
Maximum Reading (mg/m^3)	782	129	7
Minimum Reading (mg/m^3)	103	98	1
Mean Reading (mg/m^3)	247	103	1.39

These results are reported in accordance with the protocol defined by LA-PPC/EPR and are expressed at standard reference conditions of 273K and 101.3 k Pa, with correction for 11 % oxygen content. The main VOC components determined in post sampling analyses were hydrocarbons and pyrolysis fragments as anticipated from wood feeds stocks. The TPM components determined in the duct air stream emission were composed mainly of carbonised soots.

SECTION 6

VISUAL ASSESSMENT

6 VISUAL ASSESSMENT

6.1 VISUAL ASSESSMENT

In accordance with the provisions of LA-PPC/EPR an assessment of discharge emissions was undertaken throughout the monitoring period.

The assessment was carried out with reference to the methods and procedures detailed in BS 2742C.

The process related emissions were evaluated; the emission discharge colour for the stack was determined as < RInglemann shade 0.5 throughout the study period.

APPENDIX 1

INSTRUMENT CALIBRATION LOG

HALCYON ENVIRONMENTAL CALIBRATION RECORD LOG

	Doc. Ref:	CL001

No.	Equipment	Serial Number	Model	Date of Calibration	Certificate Number
01	Airflow Developments	114575	PVM 100	As per supplied certificate	IC1146P
02	Airflow Developments	-	BS 1042 Pitot Tube	As per supplied certificate	IC1147P
03	Eurotron Gas Analyser	00724899	3000 Professional	As per supplied certificate	JMW
04	Eurotron	00724899	Probe	As per supplied certificate	20615
05	PCE	150613856	PFM 2 Micro-manometer	As per supplied certificate	HE 15 / 1445
06	PCE	150613856	PFM BS 1042 Pitot Tube	As per supplied certificate	HE 15 / 1445
07	PCE	150613857	PFM 2 Micro-manometer	As per supplied certificate	HE 15 / 1446
08	PCE	150613857	PFM BS 1042 Pitot Tube	As per supplied certificate	HE 15 / 1446
09	Casella	-	High Flow Pump 1	As per supplied certificate	HE 15 / 1447
10	Casella	-	High Flow Pump 2	As per supplied certificate	HE 15 / 1448
11	Casella	-	High Flow Pump 3	As per supplied certificate	HE 15 / 1449
12	Casella	-	High Flow Pump 4	As per supplied certificate	HE 15 / 1450
13	SKC	22721	22549 Rotameter 0.300mls/min	As per supplied certificate	HE 15 / 1451
14	Airflow Developments	-	1m BS 1042 Pitot Tube	As per supplied certificate	HE 15 / 1452
15	Digitron with pitot and thermo micro anemometer	451097801	PM 80	As per supplied certificate	HE 15 / 1453
16	Testo	-	325 - 1	As per supplied certificate	HE 15 / 1454
17	Testo	-	325 - 1	As per supplied certificate	HE 15 / 1455
18	Bubble Meter	22806	Optiflow 420	Monthly	HE 15 / 1456

Issue Status:	*14*											**Compiled:**
Date of Issue	*12/2015*											*T Growcott*
Approved:												*Halcyon Environmental*

CERTIFICATE OF CALIBRATION

ISSUED BY:	JMW Limited	DATE OF ISSUE:	08/01/2016
		CERTIFICATE SERIAL NUMBER:	5120492
		PAGE:	1 OF 1 PAGES

JMW Limited
The Calibration Lab
Warwick House
Perry Road
Harlow, CM18 7NF

Tel: 01279 307100
Fax: 01279 307101
www.jmwlimited.co.uk

Customer/Acc. No:	Halcyon Environmental H9981		Location:	WV6 7YD
Instrument:	Eurotron Unigas 3000+		Calibration Interval:	12 months
Instrument S/No:	159580		Calibration Date:	08/01/2016
Instrument ID No:	N/A		Calibrated by (Op. No):	04
JMW Proc. No:	2558		Approved by (Op. No):	29

Traceability:	The instrument referred to in this certificate was re-calibrated by applying known concentrations of test gas mixtures and recording the indicated values (gas ranges) and by applying nominal values at a number of points and recording the indicated values (temperature ranges). The test gas mixtures and equipment used, for which the company maintains traceability to international standards by means of certificates issued by the supplier, are listed below (ambient air at the internationally recognised value of 20.9%v/v).
Allowances:	The allowance is based on the manufacturers published specification where available or recognised industry standards.
Limitations of Use:	The following results do not carry any implications as to the long term stability of the instrument.
Environmental Conditions:	The ambient temperature and humidity throughout the calibration period were uncontrolled and unmonitored but were, typically 20°C ±5°C and 50% RH ±20% RH.

CALIBRATION REFERENCE STANDARDS

Reference	Description	Uncertainty	JMW Ref	Description	Uncertainty
N/A	Ambient air @ 20.9%v/v oxygen	Absolute	043	100ppm (nom) nitric oxide	±2%
036	Oxygen @ 0.000005%v/v	±2%	041	Temperature indicator/simulator	±0.25°C
014	500ppm (nom) carbon monoxide	±2%	023	Digital pressure calibrator	±2 mbar
085	40ppm (nom) sulphur dioxide	±2%			

ACCESSORIES

	Present	Sound		Present	Sound		Present	Sound
Filter assy:	Y	Y	Battery charger:	N	N/A	Sampling line/probe:	Y	N
Printer:	Y	Y						

PRE-CALIBRATION FUNCTIONAL CHECKS

Instrument is -	Complete:	Y	Free from damage:	Y	Operational:	Y
	Pump is operational:	Y	Battery charges/discharges:	Y		

RESULTS

Range	Applied value	Allowance	As received: Indicated reading	P/F	After adjustment: Indicated reading
Oxygen:	0% v/v	±0.5%v/v	0.1%v/v	P	
0-25% v/v	Ambient air @ 20.9% v/v	20.8-21.0%v/v	20.9%v/v	P	
Carbon monoxide:	0ppm	±10ppm	0ppm	P	0ppm
0-20000ppm	CO/air @ 500ppm	475-525ppm	492ppm	P	500ppm
Nitric oxide:	0ppm	±5ppm	0ppm	P	0ppm
0-4000ppm	NO/air @ 100ppm	95-105ppm	95ppm	P	100ppm
Sulphur dioxide:	0ppm	±5ppm	0ppm	P	0ppm
0-4000ppm	SO_2/N_2 @ 40ppm	35-45ppm	36ppm	P	40ppm
Temperature:	0°C	±0.3°C	0°C	P	
0-1000°C	250°C	249.0-251.0°C	250°C	P	
	500°C	498.0-502.0°C	500°C	P	
	750°C	747.5-752.5°C	750°C	P	
Pressure:	50.0mbar	49.5-50.5mbar	50.00	P	
0.100 hPa/mbar	75.0mbar	74.2-75.8mbar	75.10	P	
	100.0mbar	99.0-101.0mbar	100.10	P	

The uncertainties are for a confidence probability of not less than 95%

(2558-005/A)

APPENDIX 2

STATEMENT OF COMPETENCY

Halcyon Environmental
27 Brunel Grove
The Woodlands
Perton
Wolverhampton
WV6 7YD

Mobile: 07779 008725

E-Mail: tim@halcyon-environmental.co.uk

Qualifications:

B Sc (Hons) Applied Chemistry
Member of the Royal Society of Chemistry MRSC
Chartered Chemist C.Chem
Chartered Scientist C.Sci
Member of the Institute of Metal Finishing (MIMF)
Member of the Source Testing Association (STA)
STA registration MM 03/314
Member of the American Chemical Society (MACS)

Current Position

Halcyon Environmental: Senior Partner

Responsible for the operation of a specialist environmental consultancy including sales and marketing, presentations, technical procedures, litigation protocol, analytical strategies and Environmental Management Systems Protocols.

Halcyon Environmental is a consultancy specifically committed to advise and support Industrial and Private Sector clients in achieving and effectively maintaining compliance with existing and new environmental legislation and is a member of the Metal Finishing Association and Surface Engineering Association.

Courses Attended

2011	Bruker; Introduction of Infra Red Spectroscopy	
2009	Lanyard Training and Working at Height – Kingfisher Access Course	
2008	STA M Certs Level 1 Training Course	
2008	STA M Certs TE3 Revision Training; Gases and Vapours by Extractive Manual Measurement	
2008	IEMA presentations	
	Introduction to the REACH Regulations	Rolls Royce Sinfin
	Introduction to the EUPD	Environment Agency
	Introduction to EPP	Environment Agency
2001/2/3/4/7/8	PCME; Total Particulate Monitoring – Isokinetic, Triboelectric, Tribostatic, Scintillation, Optical and CEM methods and systems	

2007	PCME; On Line, Real Time Monitoring and Calibration
2007	Environmental Compliance (ECL): An Introduction to BS 14181
2007	Environmental Compliance (ECL): Gas Monitoring Systems
2007	CBiss - Instrumental Continuous Gas Monitoring Applications
2006	PCME; Particulate Monitoring Techniques and Calibration Methods
2006	Turbidity Monitoring Techniques; Partech Instruments
2006	PCME; Dust Reporter 2 Software and Filter Management
2006	PCME; Improving OMA Score/ Interpreting Guidance Notes
2006	PCME; PMT in the Metal Industries – Case Studies
2006	MCERT for Effluent Monitoring; Partech Instruments
2005	PCME; – Continuous Particulate Monitoring Systems (CEMS)
2002	PCME; Optical and Probe based Technologies for Emission Monitoring
2002	PCME; CEMS Analyser Systems
2002	PCME / C Biss; Cross Duct, Heated Extractive and Drying Extractive Techniques and the requirements of CEMS Systems, MCERTS and OMA
2001	Disa An Introduction to Abatement Systems
2001	PCME Particulate Monitoring Solutions FMC
2001	PCME; Particle Velocity and Mass Monitoring Techniques FMC
2001	PCME; Ambient Monitoring Techniques FMC
2001	PCME; MCERTS and TUV Accreditation Schemes FMC
2000	PCME; Practical Demonstrations for TSP PM-10 and Pm 2.5 monitoring
2000	PCME; Monitoring of Suspended Solids in Gas Streams
2000	PCME; System Configuration and Reporting
2000	Servomex; The Continuous Monitoring of Gaseous Emissions
2000	PCME; Particulate Monitoring and the Workplace
1997	Air Pollution Standing Conference – NEC
1997	Monitoring as a Management Tool; SEC/ MFA Workshop
1997	FMEA to Design – Out Problems MFA / Ad – Qual Workshop
1997	Practical Application of Personal Protective Equipment – MFA / Racal Workshop

1997	Solid Wastes – A Finisher's Perspective; MFA
1997	Oven Temperature Control using Radio Telemetry; Grant Instruments
1997	Introduction to Air Sampling; SKC Ltd
1997	Profitability and the Monitoring and Control of Energy and Water; Marquis Associates
1996	European Perspectives on Environmental Best Practice; ERM
1996	Regulatory Developments in the UK WM Hazardous Waste Unit
1996	Thermal Sand Reclamation – Economic Drivers Towards Installation, Landfill Tax and its Consequences; Thermofire
1996	Metal Screen Filters as a Candidate for Best Practice; Air Filters
1996	Ceramic Filters and Secondary Metal Processing; Withers Metals
1996	Environmental Technology Best Practice Programme; ETSU
1996	Accounting for Environmental Performance; MRC
1996	Principle and Practice of Waste Management; Wedge Holdings
1996	The Waste Minimisation Agenda; UOW Workshop
1995	Air Pollution Standing Conference; NEC
1994	Eurosafe - Personal Protective Equipment; Assessing Needs and Choice
1994	GEC A Practical Approach to Health and Safety Management
1994	MOHS – Health Surveillance
1994	Government Policy Towards Business and the Environment – MFA Conference
1994	Engineering Industry and Environmental Pressure – MFA Conference /EEF
1994	Is BS 7750 Relevant to Metal Finishing; MFA Workshop
1994	EPA and the Metal Finishing Sector; MFA Workshop
1994	Environmental Management; Practical Implementation and Action; Business Link
1993	Environmental Education - WALCAT Workshop
1991	Clean Air Engineering: Environmental Source Monitoring
1991	Clean Air Engineering: Isokinetic Emission Monitoring
1991	SGS - Sports Ground Services – Introduction to Barrier Testing
1991	SGS - Hillsborough Barrier Enquiry – Measurement and Reporting
1991	SGS "Green Dove - EMS Sales Strategy"

1990	SGS "Principles of International Trade"
1990	SGS "Sales and Marketing - Value Added Strategies"
1990	SGS Yarsley "TQM Principles and Practices"
1990	SGS “Principles of Environmental Auditing ”module 1”
1990	SGS “BS 5750 Auditing Protocols”
1990	SGS “Introduction to the Green Dove Strategy”
1990	SGS "BS 5750 Management Systems; Planned strategy"
1990	SGS Principles of Environmental Auditing “module 2”
1990	SGS CoSHH LEV Regulation 9.2 Inspection and Testing
1990	SGS -Statutory Inspection and Testing of LEVs (In house course)
1990	SGS - Principles of Cargo Full Out Turn Guarantee (FOG)
1990	SGS - Analysis of Fragrances and Perfumes
1990	SGS - Perfumes; Olfactory Odour Analysis
1989	SGS/Polymer Laboratories - Method derivation for the analysis of perfume samples
1989	SGS/Dyson - Method derivation for the analysis of perfume samples
1989	SGS - Method derivation for the olfactory analysis of perfume and fragrance samples
1989	SGS - Method derivation for the reporting of olfactory assessment of perfume and fragrance samples
1990	SGS - Analysis of Precious and Semi - Precious Metals (London Metals Exchange)
1990	SGS - Analysis of Gold and its alloys (London Metals Exchange)
1990	SGS - Analysis of Heavy Metals (Toy Testing Division)
1990	SGS - Analysis of Heavy Metals (Soil Testing)
1990	SGS - Analysis of Water Samples (Soil and Groundwater Testing)
1990	SGS - Litigation and International Liability - Perfume Fraud Investigations
1990	SGS - Analysis of Fuels (Aviation and Automotive)
1990	SGS - Vehicle Repair Centres; EPA Support and Monitoring
1990	SGS - Analysis of Cements and Concrete Testing
1990	SGS - Principles of Calibration and Metrology
1989	BASF - Source Testing

1989	BASF International Analytical Conference
1989	BASF - Principles of LIMS
1989	BASF - Selective Ion Electrode Analytical Methods
1989	BASF - HPLC Analytical Methods
1989	BASF - Gas Chromatography Analytical Methods; Column Selection
1989	BASF - Gas Chromatography Analytical Methods; Calibration
1989	BASF - Gas Chromatography Analytical Methods; Detector Selection
1989	BASF - Gas Chromatography Analytical Methods; Principles of Integration
1989	BASF - Infra Red Spectroscopy Analytical Methods
1989	BASF - Measurement of Molecular Weight Distribution by HPLC
1989	BASF/Polymer Laboratories – Method derivation for the analysis of acrylic resins; column selection and analytical methodology
1989	BASF/polymer laboratories – Knauer Instrumentation familiarisation
1989	BASF/Casella Environmental Monitoring Methods; Selection of Absorption Media
1989	BASF/Casella Environmental Monitoring Methods; Pumped and Passive sampling
1989	BASF/Casella – Field sampling of Acrylate Monomers
1989	BASF/Casella – Method derivation for the analysis of airborne Acrylate Monomers and Pre-polymers
1989	BASF/Casella – Method derivation for the analysis of airborne solvents
1989	BASF/Casella – Method derivation for the analysis of airborne Isocyanate Monomers and Pre-polymers
1989	BASF/Casella – Method derivation for the analysis of airborne Urethane Monomers and Pre-polymers
1989	BASF - Method derivation for the analysis of Polysiloxane Pre-polymers
1989	BASF - Method derivation for the analysis of Rolls Royce Paint and subsequent solvent adjustments
1989	BASF - Method derivation for the analysis of Vauxhall Motors Paint and subsequent solvent adjustments
1989	BASF - Method derivation for the analysis of Ford Motor Company Paint and subsequent solvent adjustments
1989	BASF - Method derivation for the analysis of Can Coating solvent / odour emissions
1989	BASF - Method derivation for the analysis of electrophoretic oven emissions

1989	BASF - Method derivation for the analysis of DETA/TETA electrophoretic solvent analysis and subsequent solvent adjustments
1989	BASF/Casella - Method derivation for the analysis of BL paints – site based
1989	BASF/Casella - Reporting of Environmental Emissions
1989	BASF/Perkin Elmer – GC/FID/ECD systems familarisation
1988	Qualified First Aider CPR Procedures
1986	Management and Motivation
1980	BASF/ Paint Research Association: Paint Formulation
1980	Wilkins and Mitchell/PPJ – Paint Management and Process Optimisation
1980	Wilkins and Mitchell/ICI VDU Management and Process Optimisation
1980	Wilkins and Mitchell/Tecalamit – Paint Management and Process Optimisation
1979	Wolverhampton Polytechnic: Advanced Analytical Procedures

Recent Awards, Presentations And Publications

2012	Alwin Metals ISO 14001 and 9001 – 2008 support
2010	Sealine International ISO 14001 support
2009	Coram Showers ISO 14001 support
2009	Kaby Engineers Ltd ISO 14001 support
2008	Road Show Speaker – West Bromwich Albion; REACH and its Implications
2007	Williams Alloys and Residues – support to ISO 14001
2006 – 2009	Monthly contributor to Corporate Times
2006	SEA meeting; House of Lords
2006	PCME Road Show Speaker – Ricoh Stadium
2005	Tonge & Taylor ISO 14001
2003	Calcast Limited ISO 14001
2003	C E Marshall (Wolverhampton) Ltd ISO 14001
2003	PCME Road Show Speaker; Celtic SFC
2002	Speaker – Cortec Seminar, University of Coventry – An Introduction to IPPC
2002	PCME Road Show Speaker; Manchester United FC
2002	Kings Triplex Holdings – ISO 14001

2001/4	PCME Road Show – Monitoring of Particulates – Workplace and Environment
2001	Lanstar ISO 14001
2001	Lanstar ; Introduction to the Principles of Gas Chromatography
2001	Yale Security Products UK Ltd – ISO 14001
2001	Oldbury Aluminium Alloys Ltd. – ISO 14001
1998	World Metals Congress - Budapest. First 10 ISO 14001 foundries - Consultancy support to Transtec Group.
1998	Transtec Group - ISO 14001 - Birmingham, Droitwich, Llanidloes.
1998	Johnson Controls - ISO 14001 - Silloth and Wednesbury.
1998	MPL- Key Group - 1st Plastic Moulder to ISO14001 - Tamworth.
1998	MFA - Waste management and minimisation seminar.
1998	ISO 14001 -The Environmental Standard - BLB.
1997	JRI Technologies - 1st. Foam producer to ISO 14001.
1995	BS 7750 - A practical guide to compliance. Various industrial sites.
1995	"Environmental by Design" - fundamentals of design strategy seminars
1995	"Design for Disassembly" - fundamentals of product recycling and reuse.
1995	"Product Finite Life Analysis - Environmental Aspects" - GEC Group.
1995	Wolverhampton Centre of Engineering Excellence: "Safe usage, storage, handling and disposal of industrial liquids" seminars.
1995	Wolverhampton Centre of Engineering Excellence: EPA "Directors in the Dock" seminars.
1994	Wolverhampton Centre of Engineering Excellence: EPA Awareness workshop training.
1994	BLB: Practical Environmental Management.
1994	Birmingham Chamber of Commerce: EHS Management.
1994	Speaker - MPS "Environmental Awareness" Seminars.
1994	Inst. Elec. Engineers: EPA Evening presentation.
1994	Inst. Met. Finishing: Instrumentation and Capability.
1992	Metal Finishing Association: EPA Awareness Seminars.
1994	Transactions on the Inst. Met. Finishing: EHS legislation, effects on the M F Industry - Annual Technical Conference article.

1992 Ceramic Industries International: "Not Entailing Excessive Cost" EPA article.

Career Resume

Tim Growcott is the Senior Partner in Halcyon Environmental, a UK based consultancy, which specialises in Environmental Consulting Services. The consultancy works with around 500 company customers, from engineering to chemical specialists, foam and plastic users, MOD and RAF site's and specialist operators.

Trained formally as an Industrial Chemist, he has worked with companies including Mander Brothers in paints, BL Heavy Vehicles Division at Guy Motors in heavy vehicle manufacturing and Wilkins & Mitchell in domestic appliance manufacturing.

Latterly he worked with the Inmont Corporation and BASF in automotive and printing industry coatings development, and SGS in specialist environmental roles, undertaking diverse environmental issues including sales, marketing, site investigation work, litigation and liability, the development of environmental systems including EN ISO 14001.

Halcyon has undertaken specific and broad spectrum environmental issues with regard to environmental compliance, forward business environmental planning, and cradle to grave strategies that include environmental significance in product design and manufacturing, product finite life analysis, design for disassembly and renewable and recyclable resources.

Halcyon was recognised by the World Metal Congress, held in Budapest in achieving EN ISO 14001 with one of its customers as one of the world's first 10 foundries to achieve the standard.

Halcyon personnel have supported the recent transfer of business from the mainland UK to Bulgaria and are developing business in Portugal.