HE 07 / 5899

LA-PPC Compliance Monitoring Of The Spray Booth Releases

at

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for

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Study Period; - 25th. September 2007

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REPORT REF: - HE 07 / 5899

LA-PPC COMPLIANCE MONITORING OF THE SPRAY BOOTH RELEASES

1.1 INTRODUCTION

This study was undertaken to determine data as detailed by Huntingdon District Council Local Authority personnel as part of the Anglo ETI Limited site’s Local Authority – Pollution Prevention Control (LA-PPC) monitoring protocol.

This report relates to the determination of releases sourced from the extraction systems associated with the site’s 2 off spray booths. ETI S1 identifies the extraction duct associated with the spray booth No. 1.

ETI S2 identifies the extraction duct associated with the No. 2 spray finishing section. Both areas are extracted into 1 m. dia. circular ducts.

These spraying operations and the use of the site's extraction systems was noted as most akin to batch finishing rather than continuous operation.

The site has progressively adopted the increasing use of water based primer and primer surfacer coatings, high solids single and two pack systems and HVLP application technology, however top coats are still mainly solvent based systems encompassing compliant and non compliant systems.

The releases from these “coatings” operations are encompassed by the provisions of the Pollution Prevention and Control (England and Wales) Regulations 2000 and Process Guidance note PG 6/33 (2004) and are currently directed to the determination of VOC as C, free Isocyanate and total particulate matter.

Monitoring was undertaken over a continuous period per stack 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 report relates to studies undertaken by Mr T Growcott BSc (Hons) MRSC C Sci. C.Chem MIMF of Halcyon Environmental on September 25th. 2007 as per the specification brief.

Halcyon is a member of the Source Testing Association.

The author was formally trained in source testing via Clean Air Engineering (CAe) (1991), Casella (1992) and SGS (1991) and is a Sira registered Stack Tester (MM 03/314).

For this study; -

(i) BS EN 13284-1; *Stationary source releases – Determination of low range concentrations of dust – part 1: Manual Gravimetric method,* replaces the use of BS 3405 as the TPM determination method.

(ii) BS EN 12619: *Determination of the mass concentration of total organic carbon at low concentrations in flue gases – Continuous FID method* replaces the use of US EPA method 25 as the VOC determination method.

1.2 MONITORING RESULTS SUMMARY

The following analytical results were determined whilst normal production operations took place over specified sampling schedules; -

Stack ref	Location and shape	TPM mg/m^3	VOC as C mg/m^3	Isocyanate mg/m^3
1	ETI S1 Circular	2.80	18.9	<0.01
2	ETI S2 Circular	3.05	26.9	<0.01

1.3 EFFLUX VELOCITIES SUMMARY

The upgrading of the spray shop stack velocities, to comply with the specified minimum efflux velocity of 15 m/s has already been considered in ongoing site management upgrade initiatives.

Stacks have already had their chinaman's hats removed during upgrading, and been elevated to have a discharge point 3m. above roof ridge height.

For the 2008 study to have full compliance with Technical Guidance Note M1 and M3 provisions, each stack monitored in this exercise should have 2 off compliant portals installed rather than continue with the 20 mm. drilled sampling locations.

These should be located planar and 90° opposed.

The following mean efflux velocity results were determined; -

Stack ref.	**Location and shape**	**Discharge Temp degrees K**	**Tmax:Tmin**	**Vmax:Vmin**	**Corrected Mean Efflux Velocity m/sec**
1	ETI S1 Circular	291.9	1.010	1.447	15.08
2	ETI S2 Circular	293.8	1.008	1.892	15.14

Both stacks exceed the minimum specified mean efflux velocity of 15 m/sec defined in the process guidance note.

1.4 ODOUR PERCEPTION SUMMARY

Odour from the site's 2 off permitted stacks was assessed and determined to be perceived notably only at close proximity to the portals. The odour was probably sourced from the use of xylenes and toluol solvents used in the coatings formulation.

As the site progresses towards water based and water borne technologies both the amount of VOC releases and its odour will be significantly reduced.

1.5 FUTURE ACTIONS AND INITIATIVES

Future actions to achieve compliance are as follows; -

(i) Annual submission of the site's VOC solvent inventory

(ii) Continuance of use, wherever possible, of compliant and water borne coatings

(iii) Continuance of annual compliance monitoring

(iv) Compliance with the Solvent Releases Directive

A copy of this report (paper and electronic) should be sent to the Huntingdon District Council, Environment Services Dept. as per the site's LA-PPC authorisation.

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

GG ANGLO 5899 LAPPC REP

SECTION 2

SAMPLING AND MONITORING PROCEDURES

2 SAMPLING AND MONITORING STRATEGY

2.1 SAMPLING STRATEGY

The sampling strategy adopted was based upon remote sampling using the procedure detailed in BS 9096. The data was determined at sampling locations on each extraction system using the following instrumentation.

Mean efflux velocity data was determined using 2 off Airflow Developments model PVM100 electronic micro-manometers used in conjunction with 2 off Airflow Developments BS 1042 type 2.1A pitot systems, with in line thermocouples.

Calibrated Huger Sutronics temperature and pressure measurement devices were also used in these procedures.

All instrumentation used in this study carried calibration certification, traceable back to NPL standards

2.2 SAMPLING EQUIPMENT

Sampling was undertaken using calibrated, purpose built, instrumentation using, in this instance, Gilaire, BMS and Rothero & Mitchell high and low flow pumps used in conjunction with Aquaria sampling heads.

AGL gas monitoring instrumentation was used throughout the study.

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

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 Ka coefficients as detailed in Source Testing Association protocols to within 100 % I +/- 10 % variance.

2.2.1 TOTAL PARTICULATE MATTER DETERMINATION

(i) TPM by BS 9096: 1992 PROCEDURE

Periodic extractive sampling for Total Particulate Matter (TPM) was undertaken using 2 off Andersen sampling trains.

Sampling procedure was, within the limits of the sampling plane, in accordance with the main procedural requirements of BS 9096: 2002.

The sampling train was leak tested before commencement of the study

Samples are collected with the whole sampling assembly located inside the stack, thereby producing a dry sample. The sampling line includes a condensation trap, such that gas flow, gas volume, and gas temperature as measured at the pump all relate to dry gas.

The filters were submitted to a UKAS laboratory for post sampling reweighing.

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 each stack.

Specialist procedures were involved in the determination of VOC analytes using portable Signal Instruments 3030 PM FID instruments, and also absorption and trapping media followed by two stage thermal desorption Gas Chromatography and Mass Spectroscopy to identify organic compounds and thermally degraded products sourced from stoving operations.

A certified 80 ppm propane in synthetic air Air Products gas standard was supplied with the instrumentation.

This instrument sampled stack and duct air at its own predetermined rate, and air was passed through a Flame Ionisation detector within the unit. The electrical signal generated in a hydrogen-fuelled flame varies with VOC concentration. This variance is measured in the unit and read as methane equivalent by the instrument operator.

A correction coefficient is then applied from the equipment supplier's data tables.

2.2.3 ISOCYANATE DETERMINATIONS

Isocyanates were determined in accordance with US EPA method 207-1.

2.2.4 SAMPLING PROTOCOLS

The following stack sampling protocols were used to determine the data reported herein; -

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 principal 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:

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

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. But 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.

Measurements and Extractive Sampling:

Measurements are taken across the duct at points in the centre of a series of equal areas. In a square duct this is straightforward, but in a circular duct, it implies a series of points near to the edge of the stack, and very few measurements in the middle. BS 13284 /BS 9096 says that measurements may be taken at a series of 10 points evenly spaced across the duct.

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° 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:

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

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:

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

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

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

Thus:

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

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, or if more accuracy is required, using an Infra Red Gas 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:

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

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).

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

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

$$\textbf{Mole fraction of wet gas (Mw)} = 1 - \textbf{Mole fraction of dry gas (Md)}$$

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

$$\text{Molar stack gas density (Ds)} = \text{Md}\ \frac{(\%CO_2 \times 46}{100} + \frac{\%O_2 \times 32}{100} + \frac{\%N_2 + \%CO \times 28}{100}) + \text{Mw}\ \frac{(\%H_2O \times 18}{100})$$

In most cases the Molar stack gas density will work out as 29 ± 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 ($m^3\ min^{-1}$) = 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 width for a rectangular or square duct.

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

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 millimole 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 millilitres 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 $$\textbf{ppm} \times \frac{\textbf{molecular weight}}{\textbf{22.4}} = \textbf{mg/m}^3$$ **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 releases 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:

$$\textbf{ppm NO} + \textbf{ppm NO}_2 = \textbf{ppm NOx (as NO}_2\textbf{)}$$

The combined NOx 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:

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

This allows for the fact that 1 mole of gas at 20°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:

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

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)

2.2.5 INITIAL STACK PROFILE STUDY

As per the provisions of BS 9096 a stack/duct profile study was addressed prior to monitoring and sampling.

This study was undertaken at ten points in two trans-axial assessments at the sampling points. Both temperature and velocity profiles were measured. The study determined that the temperature variance across the two measured planes was less than Tmax:Tmin and Vmax:Vmin variances defined within method tolerance specification.

There was no evidence of non-linear flow, spiralling or swirling flow, or of pulsed airflow in either of the tested extraction systems.

In this assessment the relative ratio of the cross sectional area of the stack and Aquaria and Aztec sampling head were determined. The filter holder csa was noted as less than 10% of the stack csa, however, it was decided to maintain the filter body outside of the air streams to minimise sampling errors. The csa of the sample line was calculated on a 64 mm diameter.

2.2.6 MONITORING DIARY

All of the coatings used in the spray booths monitored during this study were based on conventional and catalysed air-drying/forced drying formulations.

The principle solvent and thinners associated with these paints were xylenes, toluol, n and iso butanol, aromatic and aliphatic hydrocarbons, aromatic naphthas, esters and glycols, methyl ethyl ketone and ethyl acetate.

All of the coatings which were applied in this study were considered to be typical of the ranges used in normal production schedules and operations. These were all purpose-formulated materials, produced to specific standards and performance specifications. All of the areas which were monitored were subject to in house QA and QC procedures and controls, with a notably high level of supervision and management.

2.2.7 CLIMACTIC CONDITIONS

The following climactic conditions were noted during the study; -

Parameter	25.09.2007
Ambient Temp K	289
Atmospheric Pressure kPas	104.7
Wind Direction-	SW
Visibility metres	> 1000
Relative Humidity %	42
Weather Conditions	Bright and sunny, no precipitation

SECTION 3

ANALYTICAL METHODS

3 ANALYTICAL METHODS

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

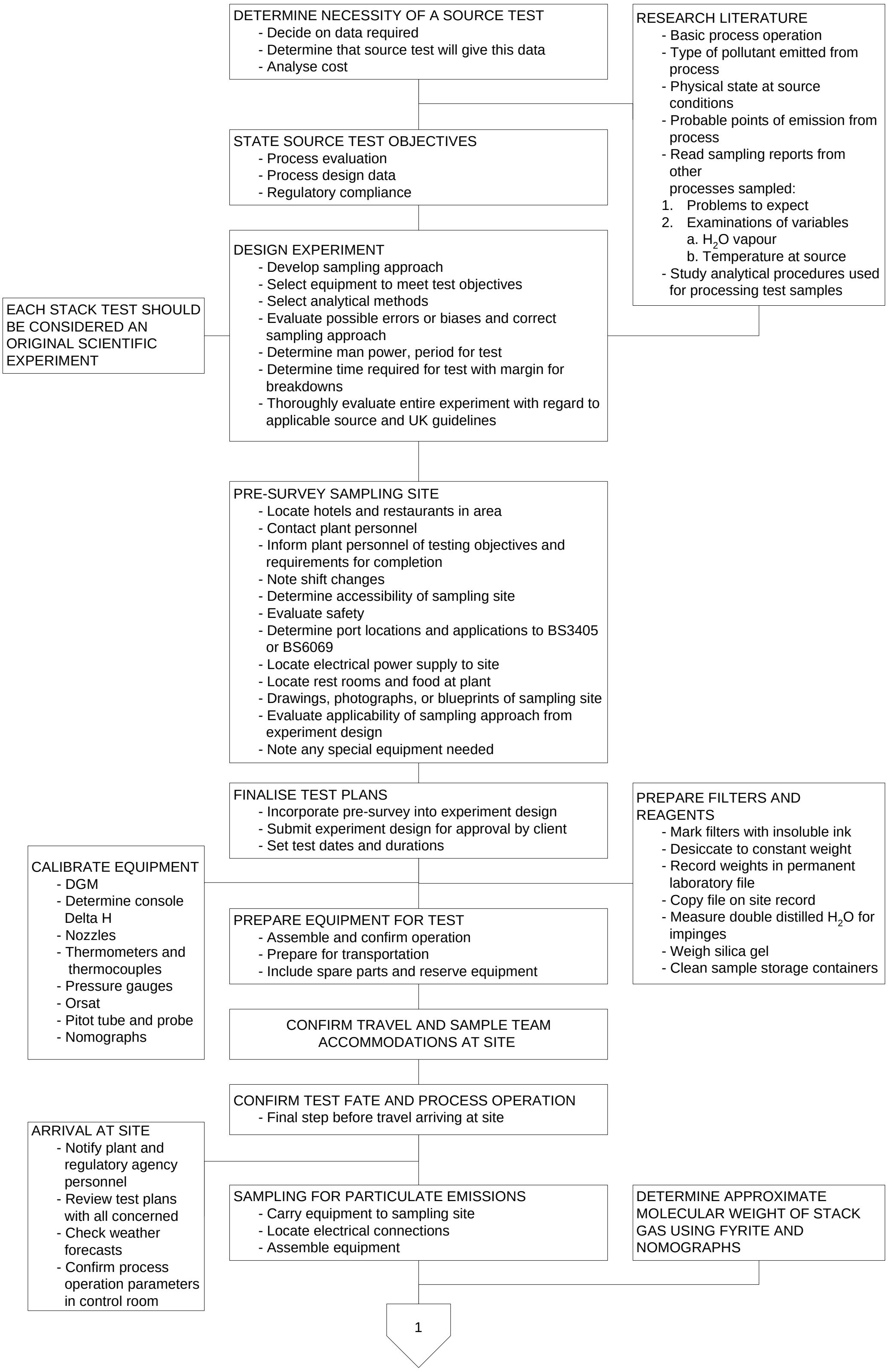
Substance	Standard or Method
Volatile Organic Compounds	BS EN 12619 Flame Ionisation Detector
Total Particulate Matter	BS 9096 Gravimetric

The data determined in this study may be utilised for further baseline comparisons against previous studies. all equipment which was hired in this study was sourced from an independent, UKAS accredited supply house.

Uncertainty Data – Monitoring Test Methods.

Substance	Standard or Method	Uncertainty value
Particulate	BS 9096	Uc =1.15 mg/m3 at a confidence of 95% or relative uncertainty of 23%
VOC (Total low range)	BS EN 12619	> 10 +/- 2 %

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 BS3405 or BS6069
- 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

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

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

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

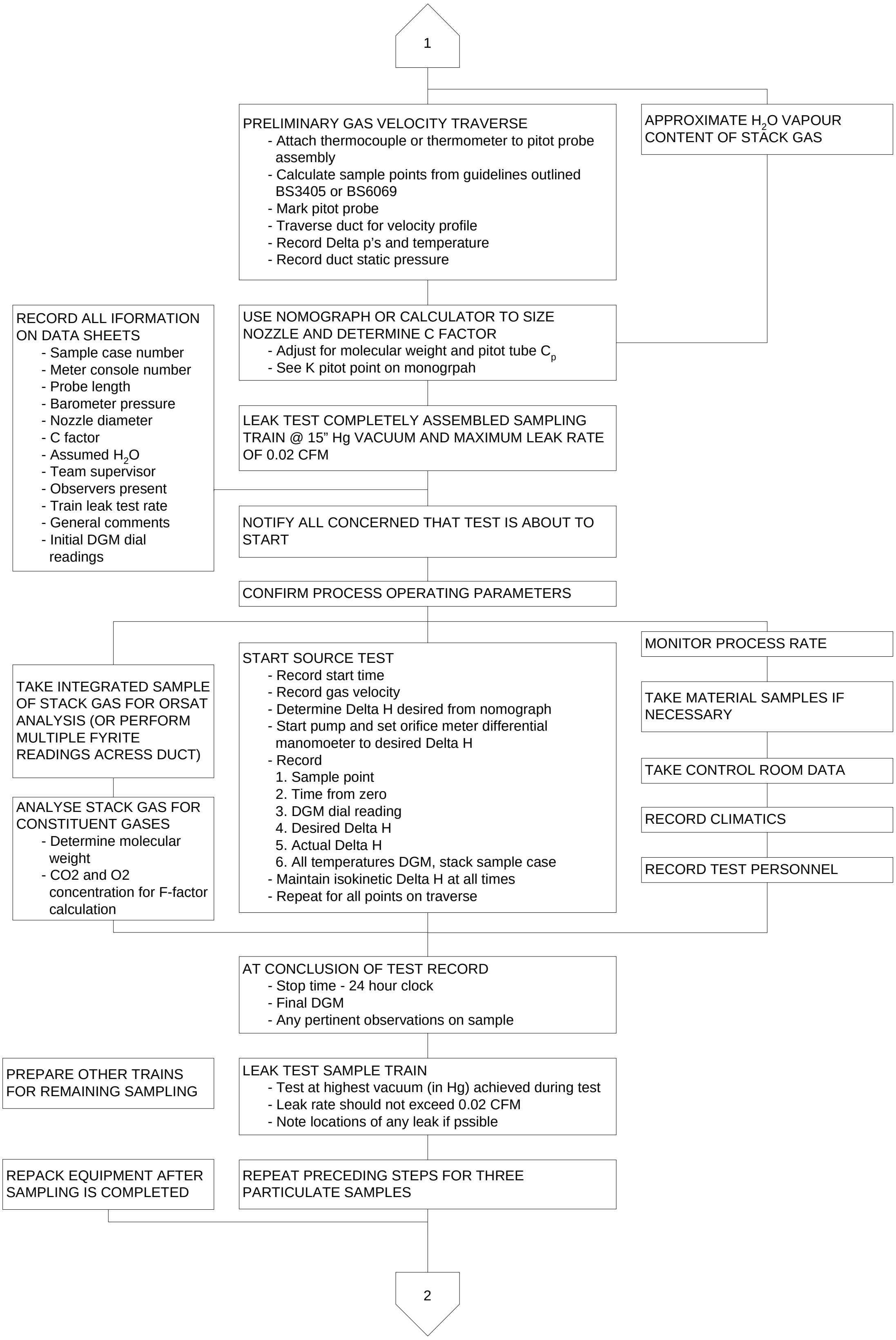
CONFIRM TRAVEL AND SAMPLE TEAM ACCOMMODATIONS AT SITE

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



PRELIMINARY GAS VELOCITY TRAVERSE
- Attach thermocouple or thermometer to pitot probe assembly
- Calculate sample points from guidelines outlined BS3405 or BS6069
- 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

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

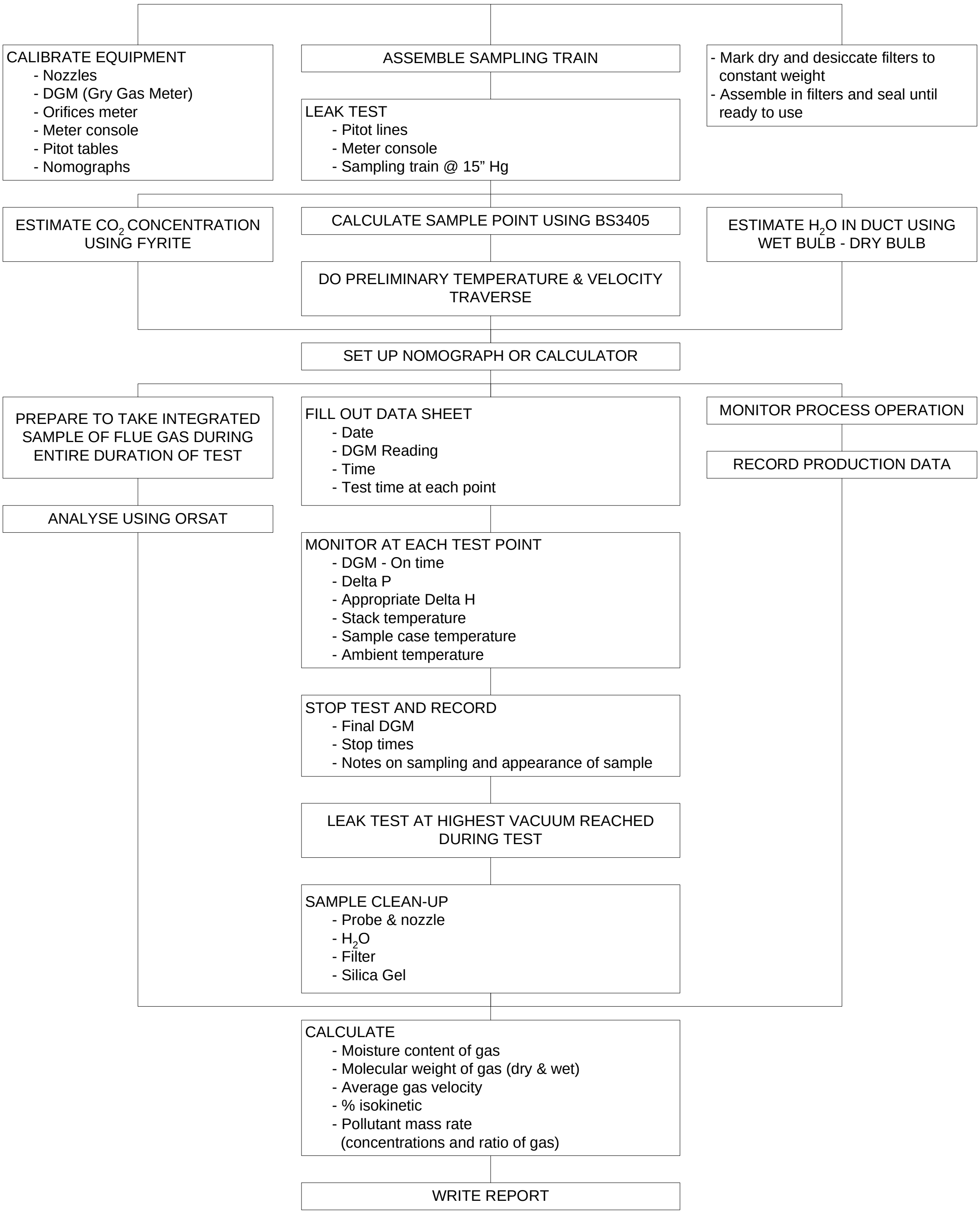
ANALYSE SAMPLES
- Follow BS3405, BS6069, HMIP A1, A2, M1, M2 guidelines
- Document procedures and any variations employed
- Prepare analytical Report Data

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



CALIBRATE EQUIPMENT
- Nozzles
- DGM (Gry Gas Meter)
- Orifices meter
- Meter console
- Pitot tables
- Nomographs

ASSEMBLE SAMPLING TRAIN

LEAK TEST
- Pitot lines
- Meter console
- Sampling train @ 15" Hg

- Mark dry and desiccate filters to constant weight
- Assemble in filters and seal until ready to use

ESTIMATE CO_2 CONCENTRATION USING FYRITE

CALCULATE SAMPLE POINT USING BS3405

DO PRELIMINARY TEMPERATURE & VELOCITY TRAVERSE

ESTIMATE H_2O IN DUCT USING WET BULB - DRY BULB

SET UP NOMOGRAPH OR CALCULATOR

PREPARE TO TAKE INTEGRATED SAMPLE OF FLUE GAS DURING ENTIRE DURATION OF TEST

ANALYSE USING ORSAT

FILL OUT DATA SHEET
- Date
- DGM Reading
- Time
- Test time at each point

MONITOR AT EACH TEST POINT
- DGM - On time
- Delta P
- Appropriate Delta H
- Stack temperature
- Sample case temperature
- Ambient temperature

STOP TEST AND RECORD
- Final DGM
- Stop times
- Notes on sampling and appearance of sample

LEAK TEST AT HIGHEST VACUUM REACHED DURING TEST

SAMPLE CLEAN-UP
- Probe & nozzle
- H_2O
- Filter
- Silica Gel

MONITOR PROCESS OPERATION

RECORD PRODUCTION DATA

CALCULATE
- Moisture content of gas
- Molecular weight of gas (dry & wet)
- Average gas velocity
- % isokinetic
- Pollutant mass rate (concentrations and ratio of gas)

WRITE REPORT

Cleaning the sample train

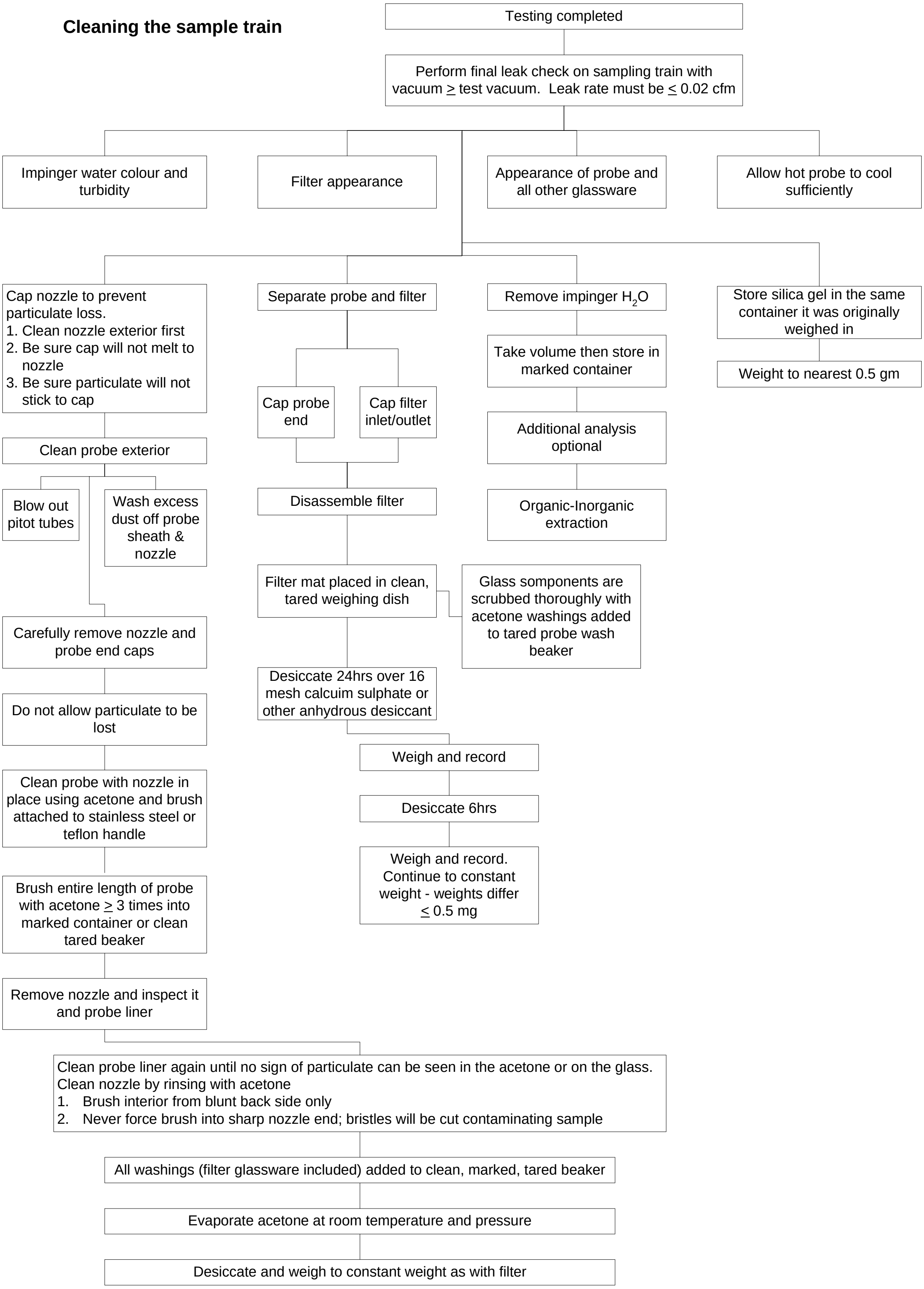


Table 1: Simple error analysis for particulate measurement, 4 Point Sampling (or 10 Point Sampling when Pitot Ratios >4:1≤9:1)

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					±13.03%	±25.5%
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 (see note below)	±13%	±6.63%	±7.22%		
	Minimum weight gain	assume ±2%	±1.5%			
	Pre=/Post-pitot reading within 10%	±2.5%	±1.44%			
	Temperature variations of 10% on 150^{o}C	±1/5%	±0.87%			
	Gas flow axis deviates up to 30^{o}	≤±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.

Table 2: Simple error analysis for measurement of mass flow particulates when not all the requirements of BS9096 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					±20.7%	±40.8%
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%		
	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.

SECTION 4

VISUAL AND OLFACTORY ASSESSMENTS

4 VISUAL AND OLFACTORY ASSESSMENTS

4.1 VISUAL ASSESSMENT

In accordance with the provisions of LA-PPC an assessment of process-associated releases was undertaken.

The assessment was carried out with reference to the methods and procedures detailed in BS 2742C.1969.

The process related releases were evaluated: the discharge colour for all of the 2 off extraction systems were determined as colourless and less than Ringlemann shade 0.5.

4.2 OLFACTORY ASSESSMENT

In accordance with the provisions of LA-PPC an assessment of stack releases was undertaken at the adjacent upwind and downwind perimeter fence lines.

Perceptive odour evaluations were non quantitative and dependant upon the assessors, however an evaluation by subjective procedures was carried out by specialist personnel familiar with odour assessment techniques.

The site’s releases were perceived as being of a low concentration odour, characteristic of "wet" and stoved paints and solvents, with a typically neutral, non-aggressive note determined only at the monitoring portals.

SECTION 5

MEAN EFFLUX VELOCITY MONITORING DATA

5 MEAN EFFLUX VELOCITY MONITORING RESULTS

The following parameters were determined for each defined extraction system; -

Stack ref.	Location and shape	Discharge Temp degrees K	Tmax:Tmin	Vmax:Vmin	Corrected Mean Efflux Velocity m/sec
1	ETI S1 Circular	291.9	1.010	1.447	15.08
2	ETI S2 Circular	293.8	1.008	1.892	15.14

These results are reported in accordance with sampling protocol, corrected to standard conditions as detailed in process specific PG 6/33 (2004) note provisions.

The field sheets are retained within Halcyon’s IT systems for future reference.

SECTION 6

ANALYTICAL RESULTS

6 ANALYTICAL RESULTS

The following analytical results were determined whilst normal production operations took place over specified sampling schedules;-

Stack ref	Location and shape	TPM mg/m^3	VOC as C mg/m^3	Isocyanate mg/m^3
1	ETI S1 Circular	2.80	18.9	<0.01
2	ETI S2 Circular	3.05	26.9	<0.01

* denotes emission discharges above the current PG 6/33 maximum limits.

These results are reported in accordance with the protocol defined by PG 6/33 (2004) guidance note and are expressed at standard reference conditions of 273.15K and 101.3 kPa, without correction for water vapour.

The following tables define monitoring schedules and results.

Stack ETI S1 – Volatile Organic Compounds (VOC as C)

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September 2007
Release Point Stack Ref	ETI S1
Instrument Type	FID
Calibration Gas	Methane
Sample Number	5899VOC/001/720
Test Start (Ti)	10.00
Test Finish (Tf)	13.00
Test Duration (mins)	180
% Carbon	75
Sampling Rate Interval (secs)	15
No. of Samples	720
Maximum Reading (mgC/m^3)	53
Minimum Reading (mgC/m^3)	1
Mean Reading (mgC/m^3)	18.9

Stack S2 – Volatile Organic Compounds (VOC as C)

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September 2007
Release Point Stack Ref	C43 S2
Instrument Type	FID
Calibration Gas	Methane
Sample Number	5899VOC/001/720
Test Start (Ti)	10.02
Test Finish (Tf)	13.02
Test Duration (mins)	180
% Carbon	75
Sampling Rate Interval (secs)	15
No. of Samples	720
Maximum Reading (mgC/m^3)	41
Minimum Reading (mgC/m^3)	2
Mean Reading (mgC/m^3)	26.9

Stack ETI S1 – Isocyanates (as NCO)

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September 2007
Release Point Stack Ref	ETI S1
US EPA 207-1 Sampling Train	-
Sample Number	5899/NCO/001/2
Test Start (Ti)	09.45
Test Finish (Tf)	10.45
Test Duration (mins)	63
Sampling Rate Interval (mins)	30
No. of Samples	2 x 30 mins
Mean Reading (mg/m^3)	< 0.01

ETI StackS2 – Isocyanates (as NCO)

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September 2007
Release Point Stack Ref	ETI S2
US EPA 207-1 Sampling Train	-
Sample Number	5899/NCO/001/2
Test Start (Ti)	09.40
Test Finish (Tf)	10.42
Test Duration (mins)	62
Sampling Rate Interval (mins)	30
No. of Samples	2 x 30 mins
Mean Reading (mg/m^3)	< 0.01

Stack ETI S1 – Total Particulate Matter

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September2007
Release Point Stack Ref	S1
Instrument Type	Anderson Portable
Sample Number	5899/TPM/001/2
Test Start (Ti)	09.55:00
Test Finish (Tf)	12.05:00
Test Duration (mins)	130
No. of Samples	2 x 60 mins
Maximum Reading (mg/m^3)	3.9
Minimum Reading (mg/m^3)	1.7
Mean Reading (mg/m^3)	2.80

Stack ETI S2 Total Particulate Matter

Job Number:	HE 07 / 5899
Client:	Anglo
Date:	25th. September 2007
Release Point Stack Ref	S2
Instrument Type	Anderson Portable
Sample Number	5899/TPM/001/2
Test Start (Ti)	09.45:00
Test Finish (Tf)	11.50:00
Test Duration (mins)	125
No. of Samples	2 x 60 mins
Maximum Reading (mg/m^3)	4.9
Minimum Reading (mg/m^3)	1.2
Mean Reading (mg/m^3)	3.05

APPENDIX 1

INSTRUMENTATION 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	08.11.2006	IC1145P
02	Airflow Developments	N / A	BS1042 2A	08.11.2006	IC1145P
03	Testo Analyser	00724899	325-1	10.09.2006	20615
04	Testo Flue GHS Pro BE	N / A	060095 2A	10.09.2006	20615
05	Rothero and Mitchell	7173	Airflow 3	Calibrated Internally Against Standard	HE 04 / 22612
06	Rothero and Mitchell	6886	Airflow 3	“	HE 04 / 22613
07	Rothero and Mitchell	4130	Airflow 3	“	HE 04 / 22614
08	Rothero and Mitchell	5217	Airflow 3	“	HE 04 / 22616
09	Rothero and Mitchell	9413	Airflow 3	“	HE 04 / 22617
10	Rothero and Mitchell	9228	Airflow 3	“	HE 04 / 22618
11	Rothero and Mitchell	1927	Airflow 3	“	HE 04 / 22615
12	Rothero and Mitchell	1567	Airflow 3	“	HE 04 / 22610
13	SKC	22721	22549 Rotameter 0.300mls/min	14.03.2005	10712
14	Knauer Modular HPLC System	162217		Daily Using Supelco Standards	
15	Digitron with pitot and thermo micro anemometer	451097801	PM 80	12.02.2006	ATP
16	Signal Instruments 3030	IHS		Hire certification	
17	Bubble Meter	22806	Optiflow 420	12.11.2006	HE 04 / 22714
18	Perkin Elmer 8600 GC	1092	S410 9C	12.11.2006	HE 04 / 22617