RanHeat ENGINEERING LTD

WOOD COMBUSTION EQUIPMENT - INDUSTRIAL HEATING SYSTEMS - BIOMASS BURNING PLANTS

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Mr Jeremy Warren.
David Smith St. Ives Ltd.
Marley Road
St. Ives
Cambridgeshire
PE27 3EX

4 February 2009

Dear Jeremy,

Further to the tests carried out on the 28th January please find enclosed two copies of the test results on your boiler.

As you can see the boiler was just over the limit for CO, but was OK on all other aspects. The problem with the CO was that we were not able to run the boiler continuously for the duration of the test, it kept switching off at working temperature.

We also found a break in the flue pipe along the horizontal flue run that needs to be repaired, this resulted in the tests being taken from a different location but this would not have made a difference to the results. (but it needs repairing anyway)

In previous years we have been able to run the boiler long enough by switching to the higher temperature when we began the test, unfortunately the boiler had been set to the higher temperature before we arrived at 7.50 am and was actually at working temperature when we arrived.

The dissipater is not able to keep the boiler under load even in cold weather. The boiler got to working temperature 5 times during the 90 minute test, as a result of this the average for the CO is 6% over the limit. Had the boiler been able to run continuously for the duration of the test the result would have been below the limit.

One set of results should be forwarded to you EHO as soon as possible.

I enclose our invoice for your kind attention.

Yours sincerely,

Chris Franklin
Enc.

HALCYON ENVIRONMENTAL

Environmental Consulting Services

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HE 09 / 6549

LA-PPC/EPR Compliance Monitoring

at

David Smith St Ives Ltd
Marley Road
St Ives
Huntingdon
Cambs
PE27 3EX

for

RanHeat Engineering Limited
62 St James Mill Road
Northampton
NN5 5JP

Study Period; - 28th. January 2009

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62 ST JAMES MILL ROAD
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31st. January 2009

FAO: Mr C Franklin - Director

REPORT REF: - HE 09 / 6549

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 January 28th 2009 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 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 2-hour period during which time RanHeat personnel were on site.

The author was formally trained in source testing via Clean Air Engineering (CAe) (1991), Casella (1992) and SGS (1991) and is Sira 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

V.A.T. Reg. No: 559 7297 78

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.

Direct emissions were monitored in the stack as per BS 13284 protocol compliant 100 mm dia BSP capped portals.

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 Max Limit
1. Carbon Monoxide CO (mg/m^3)	360 samples (90 minutes at 15 second intervals)		265	250
2. TPM (mg/m^3)	178.6 1 x 60 mins sample	158.9 1 x 60 mins sample	168.75	200
3. VOC as C (mg/m^3)	480 samples (120 minutes at 15 second intervals)		10.98	20
4. Oxygen (%)	360 samples (90 minutes at 15 second intervals)		10.89	-
5. Water Vapour (%)	8.92 1 x 60 mins sample	7.17 1 x 60 mins sample	8.02	-
6. Oxides of Sulphur SOx (mg/m^3)	360 samples (90 minutes at 15 second intervals)		3.67	-
7. Oxides of Nitrogen NOx (mg/m^3)	360 samples (90 minutes at 15 second intervals)		56	-
8. Formaldehyde (mg/m^3)	1.02 (1 x 30 min sample)	0.67 (1 x 30 min sample)	0.845	-

The results of this study have determined that releases sourced from operation of the plant were not compliant with the provisions of the site's LA-PPC/EPR documentation.

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 2 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 17.195 m/s 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

RANH6549 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 9096 and BS13284.

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 US EPA Method 2, "The Determination of Stack Gas Velocity and Volumetric Flow Rates (Type S Pitot Tubes)", and EPA Method 3B "Gas Analysis for the Determination of Emission Rate Correction Factor or Excess Air".

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 convention Aquaria 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 TOTAL PARTICULATE MATTER DETERMINATION

The procedure employed was that detailed in BS13284.

Air was extracted from the main stack isokinetically over 2 x 60 minute sampling periods and via a purpose built stack-sampling train located directly in 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.

Further procedures were involved in the determination of free Formaldehyde using direct reading Draeger tubes.

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 Eutron 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 EPA Method 4 using Halcyon test equipment (HE 03-141).

2.2.4 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:

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

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).

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

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:

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

Centimetres per minute (cm/min) x Square centimetres (cm^2) = Cubic Centimetres per minute (cm^3/min)

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

Thus:

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

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).

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

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:

Mole Fraction of dry gas (Md) = Dry gas volume / 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

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

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:

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

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:

Corrected Pollutant Concentration (mg/m^3) = $\frac{(20.9 - \text{Standard } O_2\%)}{(20.9 - \text{Measured } O_2\%)}$ x 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 ppm x $\frac{36.5}{22.4}$ = mg/m^3

In general ppm x $\frac{\text{molecular weight}}{22.4}$ = 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:

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

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:

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

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:

Standardised Volume = $\frac{\text{Recorded Pressure}}{\text{Std Pressure (1013)}} \times \frac{\text{Std Temperature (273)}}{\text{Recorded Temperature}} \times$ 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 = °C + 273.15) or Rankine (°R = °F + 459.67)

2.2.5 INITIAL STACK PROFILE STUDY

As per the provisions of BS 9096 and BS 13284, a stack profile study was addressed prior to monitoring and sampling. This study was undertaken at ten points 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 as detailed in BS 13284).

2.2.6 CLIMACTIC CONDITIONS

The following climactic conditions were noted during the study; -

Ambient Temperature - K	278.9
Atmospheric Pressure - kPas	100.2
Relative Humidity - %	34
Wind Speed - kph	< 10
Wind Direction	SW
Visibility metres	> 1000
Weather	Dense low cloud, gusting winds, prolonged periods of heavy rain

2.2.7 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.

2.2.8 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

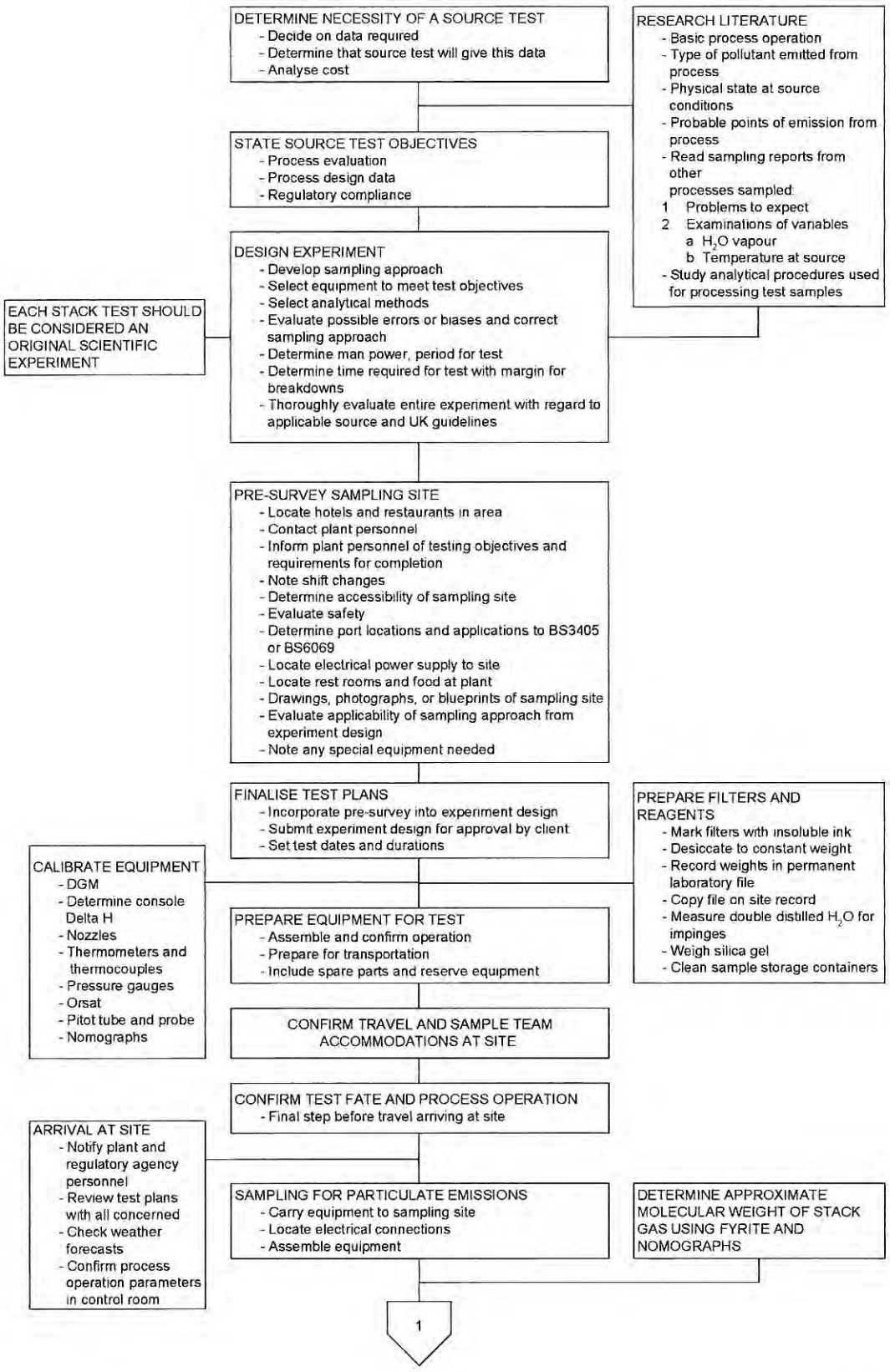
3 ANALYTICAL PROCEDURES AND METHODS

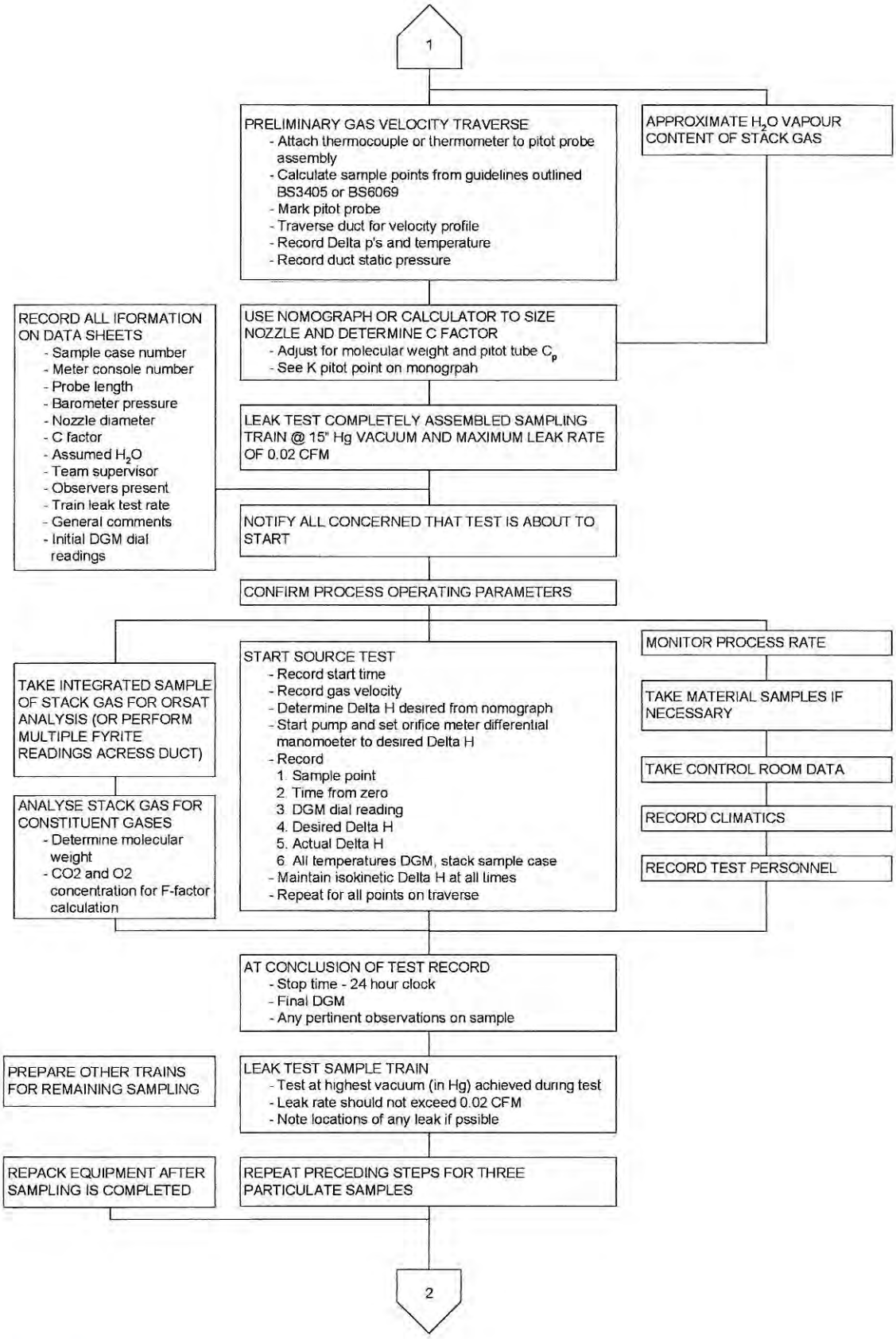
The following analytical methods were used to determine the data reported herein; -

	Analyte	Method Reference
1	CO / CO_2	**Direct reading EPA Methods 3/3B
2	Total Particulate Matter	BS 13284
3	VOC	BS 12619
4	VOC as Carbon	BS 12619
5	Water Content	EPA Method 4
6	Oxygen	**Direct reading
7	Free Formaldehyde	Halcyon Test Method HALC.EPA.HCHO 01 Impingers + automated dynamic titrimetry

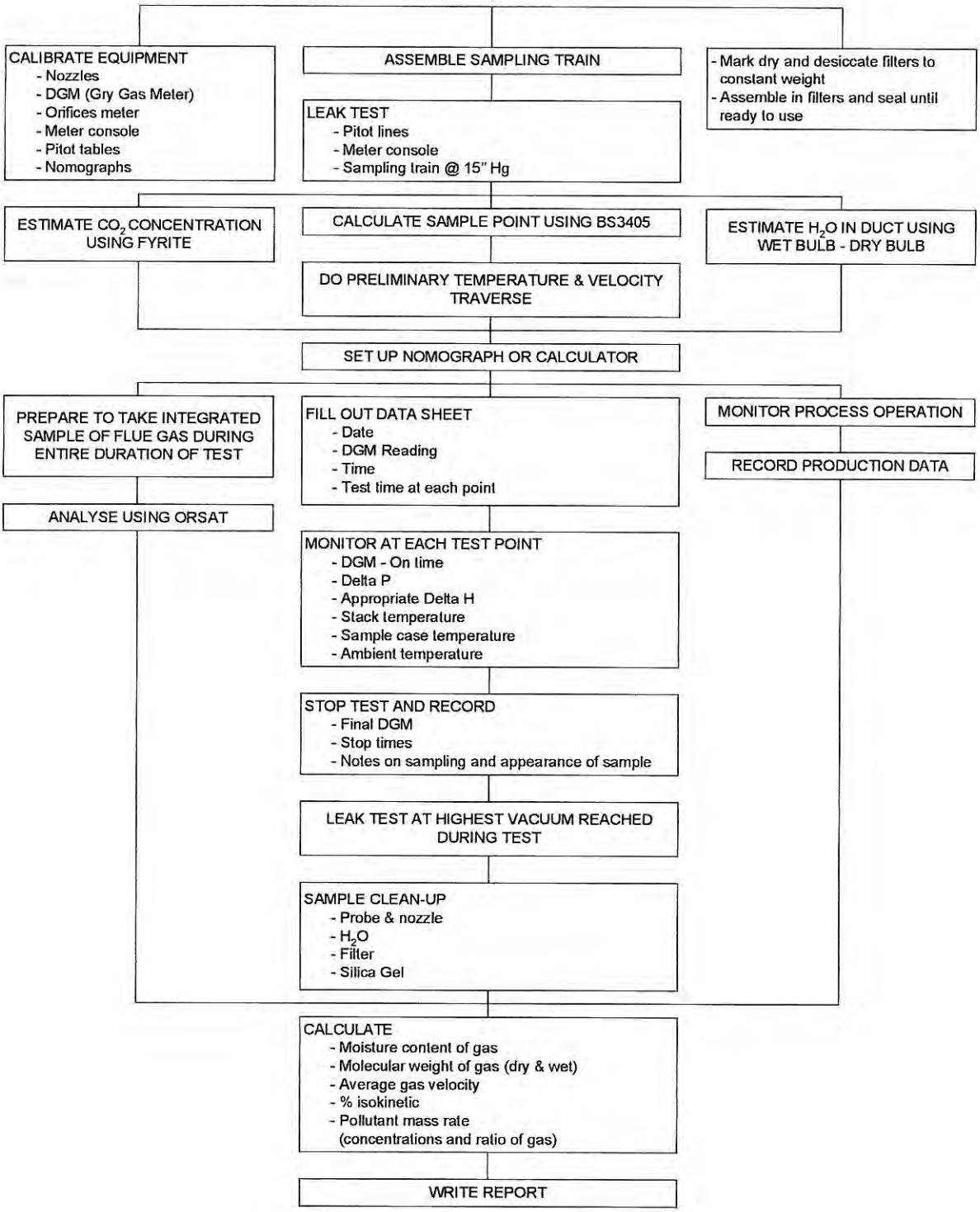
****Testo Combustion Gas Analyser instrument**

Planning and performing a stack test




1
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
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
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
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

Source Test Outline



Cleaning the sample train

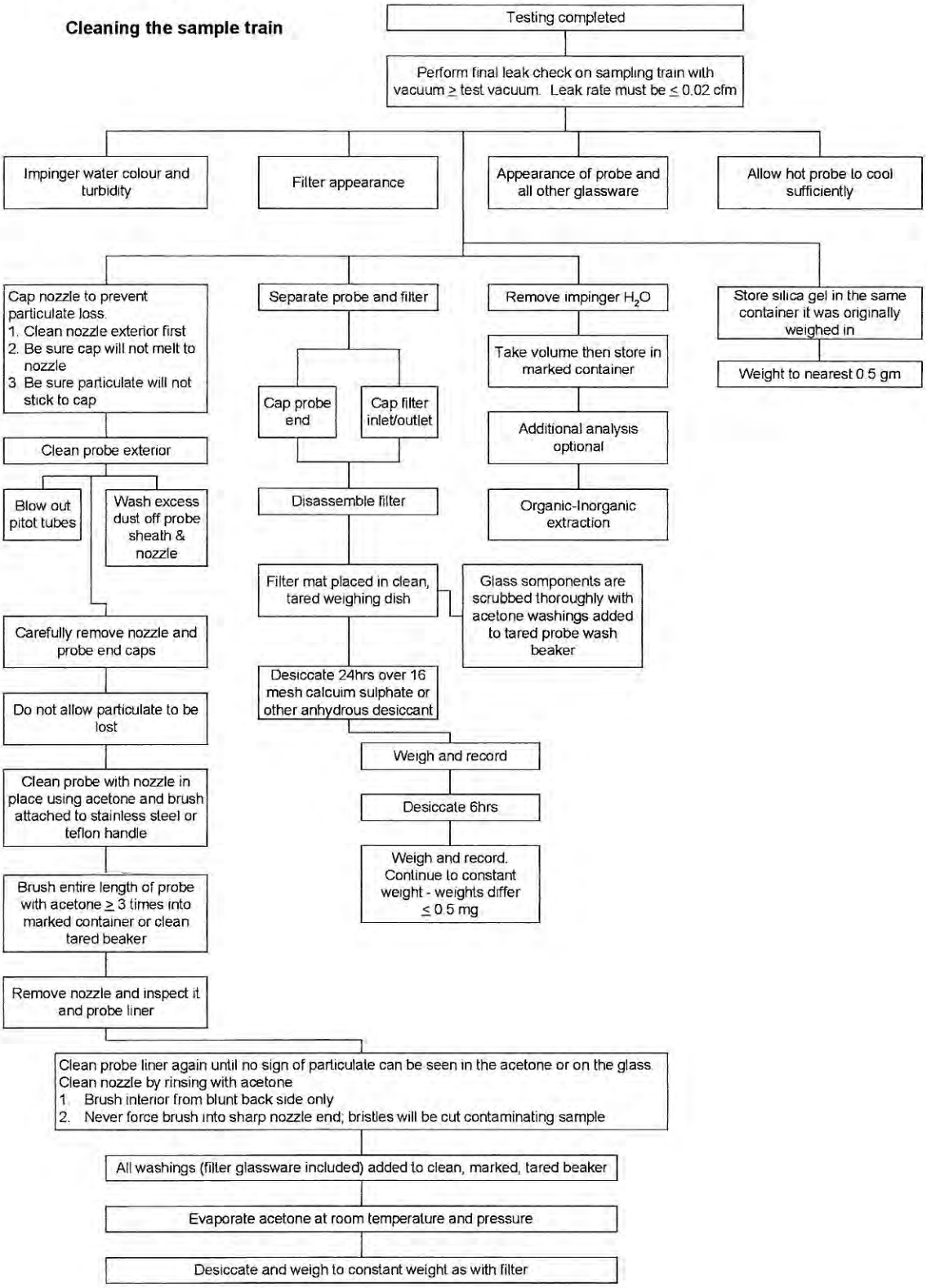


Table 1: Simple error analysis for particulate measurement, 4 Point Sampling (or 10 Point Sampling when Pitot Ratios >4:1≤9:1)

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					±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%			
	Minimum weight gain	assume ±2%	±1.5%			
	Pre=/Post-pitot reading within 10%	±2.5%	±1.44%	±7.22%		
	Temperature variations 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.

Table 2: Simple error analysis for measurement of mass flow particulates when not all the requirements of BS 9096 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%		±20.7%	±40.8%
	Bias due to non-symmetrical points	±7.5%	±4.33%			
	Minimum weight gain	assume ±2%	±1.5%	±14.88%		
	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

MEAN EFFLUX VELOCITY DATA

4 FLOW DYNAMICS RESULTS

The following results were determined using the calculations and correction coefficients detailed in BS 9096.

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**
Traverse 1	17.22	428.9
Traverse 2	17.17	422.53

Mean Efflux velocity = 17.195 m/sec @ 425.715 K

10 point trans-axial temp traverse ratio Tmax:Tmin = 1.0157:1

10 point trans-axial velocity traverse ratio Vmax:Vmin = 1.834:1

The duct airflow stream temperature was measured continuously using a Casella W1720 thermo - anemometer probe (HE 03-034) in the stack portals.

The implicit BS 9096 error factor of +/- 12 % was considered as satisfactory, as was the + 3% isokinetic correction factor applied to the calculation.

SECTION 5

ANALYTICAL RESULTS

5 ANALYTICAL SEQUENCE AND RESULTS

The monitoring strategy was undertaken over one 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 black smoke.

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

TPM measurement was undertaken on 2 x 60 - minute sampling schedules with the filters located outside of the stack.

5.1 ANALYTICAL RESULTS

Analytical mean result data is detailed below: -

Analyte	Test 1	Test 2	Mean	PG 1/12 Max Limit
1. Carbon Monoxide CO (mg/m^3)	360 samples (90 minutes at 15 second intervals)		265	250
2. TPM (mg/m^3)	178.6 1 x 60 mins sample	158.9 1 x 60 mins sample	168.75	200
3. VOC as C (mg/m^3)	480 samples (120 minutes at 15 second intervals)		10.98	20
4. Oxygen (%)	360 samples (90 minutes at 15 second intervals)		10.89	-
5. Water Vapour (%)	8.92 1 x 60 mins sample	7.17 1 x 60 mins sample	8.02	-
6. Oxides of Sulphur SOx (mg/m^3)	360 samples (90 minutes at 15 second intervals)		3.67	-
7. Oxides of Nitrogen NOx (mg/m^3)	360 samples (90 minutes at 15 second intervals)		56	-
8. Formaldehyde (mg/m^3)	1.02 (1 x 30 min sample)	0.67 (1 x 30 min sample)	0.845	-

Stack S1 – Volatile Organic Compounds (VOC as C)

Job Number:	HE 09 / 6549
Client:	David Smith St Ives
Date:	28th.Jan 2009
Release Point Stack Ref	S1
Instrument Type	FID
Calibration Gas	Methane
Sample Number	6549/VOC/001 - 480
Test Start (Ti)	08.30:00
Test Finish (Tf)	10.30:00
Test Duration (mins)	120
% Carbon	75
Sampling Rate Interval (secs)	15
No. of Samples	480
Maximum Reading (mgC/m^3)	16
Minimum Reading (mgC/m^3)	0
Mean Reading (mgC/m^3)	10.89

Stack S1 – Total Particulate Matter

Job Number:	HE 09 / 6549
Client:	David Smith St Ives
Date:	28th.Jan 2009
Release Point Stack Ref	S1
Instrument Type	Anderson Portable
Sample Number	6549/TPM/001/2
Test Start (Ti)	08.45:00
Test Finish (Tf)	10.48.00
Test Duration (mins)	123
No. of Samples	2 x 60 mins
Maximum Reading (mg/m^3)	178.6
Minimum Reading (mg/m^3)	158.9
Mean Reading (mg/m^3)	168.75

Stack S1 – Water Vapour

Job Number:	HE 09 / 6549
Client:	David Smith St Ives
Date:	28th.Jan 2009
Release Point Stack Ref	S1
Instrument Type	US EPA method 4 test box
Sample Number	6549/Water/001/2
Test Start (Ti)	08.50:00
Test Finish (Tf)	10.50:00
Test Duration (mins)	120
No. of Samples	2 x 60 mins
Maximum Reading (%)	8.92
Minimum Reading (%)	7.12
Mean Reading (%)	8.02

Stack S1 – Formaldehyde

Job Number:	HE 09 / 6549
Client:	David Smith St Ives
Date:	28th.Jan 2009
Release Point Stack Ref	S1
Instrument Type	Halcyon Test Box
Sample Number	6549HCHO/001/2
Test Start (Ti)	09.00:00
Test Finish (Tf)	10.04:00
Test Duration (mins)	64
No. of Samples	2 x30 mins
Maximum Reading (mg/m^3)	1.02
Minimum Reading (mg/m^3)	0.67
Mean Reading (mg/m^3)	0.845

Stack S1 – Gaseous Components

Job Number:	HE 09 / 6549	HE 09 / 6549	HE 09 / 6549
Client:	David Smith St Ives	David Smith St Ives	David Smith St Ives
Date:	28th.Jan 2009	28th.Jan 2009	28th.Jan 2009
Release Point Stack Ref	S1	S1	S1
Instrument Type	Eutron Combustion Gas Analyser		
Calibration Gas	Self Calibrating Cells		
Sample Number	6549/CO/001 - 360	6549/NOx/001 - 360	6549/SOx/001 - 360
Test Start (Ti)	09.00:00	09.00:00	09.00:00
Test Finish (Tf)	10.30:00	10.30:00	10.30:00
Test Duration (mins)	90	90	90
Sampling Rate Interval (secs)	15	15	15
No. of Samples	360	360	360
Maximum Reading (mg/m^3)	458	78	8
Minimum Reading (mg/m^3)	0	1	
Mean Reading (mg/m^3)	265	56	3.67

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 AND OLFACTORY ASSESSMENTS

6 VISUAL AND OLFACTORY ASSESSMENTS

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:1969.

The process related emissions were evaluated; the emission discharge colour for the stack was determined as < RInglemann shade 2 throughout the study period.

6.2 OLFACTORY ASSESSMENT

In accordance with the provisions of LA-PPC/EPR an assessment of Weiss unit's releases was undertaken at the point of discharge.

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 unit's emissions were assessed as a low impact perceived odour, characterised by a typical neutral notes at close proximity.

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	12.11.2008	IC1145P
02	Airflow Developments	N / A	BS1042 2A	12.11.2008	IC1145P
03	Testo Analyser	00724899	325-1	16.10.2008	20615
04	Testo Flue GHS Pro BE	N / A	060095 2A	16.10.2008	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	02.12.2008	10712
14	Knauer Modular HPLC System	162217		Daily Using Supelco Standards	
15	Digitron with pitot and thermo micro anemometer	451097801	PM 80	14.11.2008	ATP
16	Signal Instruments 3030	IHS		Hire certification	
17	Bubble Meter	22806	Optiflow 420	14.11.2008	HE 04 / 22714
18	Perkin Elmer 8600 GC	1092	S410 9C	daily	HE 04 / 22617

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Approved:												Halcyon Environmental

HALCYON ENVIRONMENTAL CALIBRATION RECORD LOG

Issue Status:	Draft	01	02	03	04	05	06					Compiled:
Date of Issue	12/2003	06/2004	05/2005	10/2005	09/2006	12.2006	11.2007					T Growcott
Approved:												Halcyon Environmental