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HE 02/3390

LAAPC Compliance Monitoring

at

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

for

RanHeat Engineering Limited.
Unit 28,
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Brackmills,
Northampton,
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Study Period ;- 8th. February 2002.

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SECTION. CONTENTS.

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12.02.2002.

F.a.o. Mr.C.Franklin - Director.

REPORT REF:- HE 02/ 3390.

LAAPC Compliance Monitoring of the WIESS Unit at David Smith St.Ives, St.Ives, Cambridgeshire.

1.1. INTRODUCTION.

This study was undertaken to determine data as detailed by David Smith St. Ives Ltd.'s Local Authority Air Pollution Control (LAAPC) part B authorisation 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 February 8th. 2002 by Mr.T .Growcott of Halcyon Environmental in respect of the determination of PG 1/12 process guidance note 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 and Local Authority personnel were on site.

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, although their position was not strictly compliant with the provisions of BS 3405:1983.

Direct emissions were monitored in the stack as per BS 3405 protocol (4 and 8 point locations across two sampling planes) and via the 2 BS 3405 compliant 100 mm. dia. BSP capped portals.

1.2. SUMMARY.

1) 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 results of this study have determined that releases sourced from operation of the plant were compliant with the provisions of the site's E.P.A. documentation.

Site sourced V.O.C. was measured at 14.4 mg/m3, (cf. 20mg/m3 max. as per PG 1/12).

T.P.M. was measured at 119.7 mg/m3, (cf. 200mg/m3 max. as per PG 1/12).

2) 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 E.P.A. process documentation, and SOx, CO_2 , NOx and Oxygen concentrations.

Free Formaldehyde was also measured and found to be < 1 mg/m3.

Mean CO was measured at 231 mg/m3, (cf 250 mg/m3 max.as per PG 1/12).

All other gaseous emissions were measured as within the site's authorisation provisions and below the maximum consents.

3) Perimeter visual and olfactory subjective and quantitative procedures have established minimal perceived odour proximal at the point of discharge, and at ground level, from process related compounds.

4) Emission discharge colour has been determined in accordance with E.P.A. protocol and established as less than Ringlemann Shade 1 throughout the study period.

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

6) 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 19.3 m/s at discharge temperature.

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

Tim Growcott
Senior Partner.

RANH3380.REP

SOURCE TESTING STA ASSOCIATION MEMBER

Halcyon Environmental

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 3405.

The data reported herein was compiled in accordance with the methodologies and procedures detailed in BS 3405, and US EPA method 1, 2, 3, 4 and 25 specifications, in addition to specific GC-MS methodologies and the use of approved Draeger tube methods and procedures.

The sampling and monitoring strategy utilised for this study was based upon remote sampling using the statistical linear log procedure detailed in BS 3405:1983.

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

Velocity data was determined using a standard Flow Dynamics model EDM 2500 Electronic Micromanometer (HE 02-023) used in conjunction with a BS 1042 type 2A pitot system (HE 02-027), 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 U.S. E.P.A. Method 2, "The Determination of Stack Gas Velocity and Volumetric Flow Rates (Type S Pitot Tubes)", and E.P.A. 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. TOTAL PARTICULATE MATTER DETERMINATION.

The procedure employed was that detailed in BS3405:1983.

Total Particulate Matter was determined using preweighed 47 mm. dia. ceramic filters obtained from a specialist environmental test house.

Air was extracted from the main stack isokinetically over a series of 30 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. V.O.C. 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 E.P.A. Method 25 using a Signal Instruments 3030PM instrument with F.I.D. calibrated for 80 ppm and 800 ppm propane in air - ex Air Products.

Indirect measurements were made using composit 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 V.O.C. 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 NOx, SOx, CO , CO_2 and Oxygen using a Quintox model 9008 Combustion Gas Analyser (EIH 987).

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 02-141).

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:

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

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 $= 0.781 \times 28$ (for N_2) $+ 0.209 \times 32$ (for O_2) $+ 0.009 \times 40$ (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 = ° 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.

Location of Measuring Site:

The measuring site was located in a region of linear flow. Smooth flow in a duct has a meniscus like profile, with maximum flow in the middle of the stack, which is unaffected by the surface roughness of the exterior walls, and a reduced flow at the edges. Where the flow is turbulent, such as after a fan, a corner, a junction, or a damper, flow measurement is rendered impossible. Similarly before these obstacles air flow is broken up.

The measuring site (both for flow measurement and extractive sampling) should thus be located 5 - 6 diameters downstream of the last point creating turbulence, in a straight run of ductwork. BS 3405 allows 1 diameter for a bend, 2 for a junction and 3 for a fan or damper. It should also be at least two diameters upstream of the next point creating turbulence. BS 3405 allows 1 diameter. There will be places where even the rules of BS 3405 cannot be met, in which case, very considerable care is needed in obtaining readings.

Measurements and Extractive Sampling:

Measurements were 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. These points are calculated by the Log linear rule for circular ducts, and the Log Tchebycheff rule for rectangular ducts. BS 3405 says that measurements may be taken at a series of 10 points evenly spaced across the duct.

Extractive Sampling points are chosen on the same basis, and BS 3405 says that samples should be collected at 2 points across each of two traverses, in small stacks. Where the stack has an internal area greater than $2.5m^2$, 4 sampling points should be used on each traverse.

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 which 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 air flow, but these should not, as a general rule, be used in flue stacks.

Pressure in Ducts:

There are 4 factors which effect 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 which 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 levelling 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 required dying 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° Celsius)
Barometric Pressure	101.3KPa, (1013mb)
Humidity	Dry
Oxygen	3%, 6%, 8%, 11%, 15%, 18% depending of 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:

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

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

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

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:

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

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) = $\dfrac{\textbf{Dry gas volume}}{\textbf{Total gas volume}}$

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 methogology to the earlier equation for deriving molar gas density of dry gas, but now includes an extra derived function for water

$$\text{Molar stack gas density (Ds)} = \text{Md}\ \frac{(\%CO_2 \times 48}{100} + \frac{\%O_2 \times 32}{100} + \frac{\%N_2 + \%CO \times 28)}{100} + \text{Mw}\ \frac{(\%H_2O \times 18)}{100}$$

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 sec) = 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 $m^3 min^{-1}$ 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/m³ 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/m³) or 22.4 millimetres per cubic metre (parts per million) ppm.

So for HCl 36.5 mg/m³ = 22.4 ppm

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

In general $\quad \text{ppm} \times \frac{\text{molecular weight}}{22.4} = \text{mg/m}^3$ **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/m³ 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:

$$\textbf{ppm NO + ppm } NO_2 \textbf{ = ppm NOx (as } NO_2\textbf{)}$$

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:

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

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.

Particulates:

The sampling of stack particulates was undertaken using an Italian (Aquaria) sampling line following the main procedural requirements of BS 3405 EPA Method 17.

Procedure is as follows:

1. Determine correct location of measuring and sampling points.

2. Measurement of stack flow using BS 1042 ellipsoidal nosed pitot tube, with electronic micro manometer and thermometer.

3. Calculation of flow rates, isokinetic sampling rates, sampling locations etc.

4. Sampling over four 15 -30 minute periods, to obtain optimum samples at the point specified by BS 3405.

Samples are collected onto pre-weighed 47mm glass fibre filters, 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. Exposed filter samples are re-weighed, to obtain weight of particulate collected.

If required the filter material and particulate sample can be digested, prior to analysis of metals by Atomic absorption spectrophotometry (AA), or Inductively coupled plasma atomic emission spectrophotometry (ICP-AES).

This introductory protocol is amplified, by a further series of protocols, including diagrams, copies of record sheets, and an explanation of the calculations involved in presenting results of extractive sampling methods.

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 = °C + 273.15) or Rankine (°R = °F + 459.67)

2.2.5. INITIAL STACK PROFILE STUDY.

As per the provisions of BS 3405, 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.

(Pretest measurements determined that the sampling head was less than 10 % of the total stack cross sectional area as detailed in BS 3405:1983).

2.2.6. CLIMACTIC CONDITIONS.

The following climactic conditions were noted during the study;-

AMBIENT TEMP C	9
ATMOSPHERIC PRESSURE mBas	1,005
RELATIVE HUMIDITY %	58.7
WIND SPEED k.p.h.	GUSTING TO 32
WIND DIRECTION	W
VISIBILITY metres	> 1000
WEATHER	OVERCAST WITH CONTINUOUS LOW CLOUD, PERIODS OF HEAVY RAIN.

2.2.7. Q.A.-Q.C. PROCEDURES.

Halcyon operates Q.A.- Q.C. procedures following the guidelines of ;-

EPA 600/9-76-005	**1976**	**Quality Assurance Handbook for Air Pollution Measurement Systems, Vol.1.**
EPA 600/4-77-027b	**1979**	**As above Vol.3.**

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 1998/99

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 + E.P.A. METHODS 3/3B
2) TOTAL PARTICULATE MATTER.	BS3405
3) V.O.C.	EPA METHOD 25
4) V.O.C. as Carbon.	*EPA METHOD 25 + MS/GC
5) NOx	**Direct reading
6) SOx	**Direct reading
7) Water Content.	EPA METHOD 4
8) Oxygen.	**Direct reading
9) Free Formaldehyde	Draeger tube + Activated charcoal back up tube.

* Specific analytical procedures for certain speciated V.O.C. analytes was based on E.P.A method 25 + Mass spec / GC methodologies.

**Quintox direct reading Combustion Gas Analyser instrument.

SECTION 4.

MEAN VELOCITY DATA.

4. FLOW DYNAMICS RESULTS.

The following results were determined using the calculations and correction coefficients detailed in BS3405:1983

The following results were determined at the portal locations ;-

TABLE 4.1 MEAN EFFLUX VELOCITY RESULTS.

SAMPLING LOCATION.	MEAN VELOCITY (m/s)	DISCHARGE TEMP(C)
TEST 1	19.4	143
TEST 2	19.2	139

10 point transaxial temp traverse ratio Tmax:Tmin = 1.1176

10 point transaxial velocity traverse ratio Vmax:Vmin = 1.672:1

The duct air flow stream temperature was measured continuously using a Casella W1720 thermo - anemometer probe *(HE 02-034) in the stack portals.*

The implicit BS 3405 error factor of +/- 25.5 % was considered as satisfactory, as was the +8 % isokinetic correction factor applied to the calculation.

SECTION 5.

ANALYTICAL RESULTS.

5. ANALYTICAL SEQUENCE AND RESULTS.

The monitoring strategy was undertaken over one standard working half 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 V.O.C. were undertaken.

T.P.M. measurement was undertaken on 30 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. CO (mg/m3)	223	239	231	250
2. T.P.M. (mg/m3)	106.7	132.8	119.7	200
3. VOC as C (mg/m3)	16.9	11.9	14.4	20
4. OXYGEN (%)	12.6	10.7	11.65	-
5. WATER VAPOUR (%)	3.8	4.9	4.35	-
6. SOx (mg/m3)	1.2	0.14	0.67	-
7. NOx (mg/m3)	34.9	41.2	38.05	-
8. FORMALDEHYDE (mg/m3)	< 1	< 1	< 1	-

*** N.B.

These results are reported in accordance with the protocol defined by E.P.A. and are expressed at standard reference conditions of 273K and 101.3 k Pa, with correction for 11 % oxygen content.

The main V.O.C. components determined in post sampling analyses were hydrocarbons and pyrolysis fragments as anticipated from wood feeds stocks. The T.P.M. components determined in the duct air stream emission were composed mainly of carbonised soots.

Table 1: Simple error analysis for particulates measurement, 4 Point Sampling (or 8 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%	±1.15%			
	Pre-/Post-pitot reading within 10%.	±2.5%	±1.44%			
	Temperature variations of 10% on 150°C.	±1.5%	±0.87%			
	Gas flow axis deviates up to 30°.	≤±3½% 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 of particulates when not all the requirements of BS3405 are met.

Deviation from Standard: Only nearest 2 points of 4 on each of 2 sampling lines can be reached (circular duct); pre/post sampling velocities differed by 20%; Highest to lowest pitot readings 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 (Note below).	±(13+12)%=25%	±12.78%	±14.88%		
	Bias due to non-symmetrical points	±7.5%	±4.33%			
	Minimum weight gain	assume ±2%	±1.15%			
	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°	≤±3½% velocity	≤±2.02% velocity			

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

sta-sea2.lwp

SECTION 6.

VISUAL AND OLFACTORY ASSESSMENTS.

6. VISUAL AND OLFACTORY ASSESSMENTS.

6.1. VISUAL ASSESSMENT.

In accordance with the provisions of E.P.A., 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 2742:1969.

The process related emissions were evaluated; the emission discharge colour for the stack was determined as in excess of Ringlemann shade 1.

6.2. OLFACTORY ASSESSMENT.

In accordance with the provisions of E.P.A. 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.

6.3. NOISE ASSESSMENT.

With reference to noise, the operation of the plant facilities detailed within this report was not perceived to be exceptional nor excessive as to be considered a nuisance with regard to noise and its effect on site operators and the local Community.

SOURCE TESTING STA ASSOCIATION MEMBER

Halcyon Environmental

Received 10/5/01

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Wood fired boiler flue emission readings taken 01.03.2001

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----------------------------
        testo 300
----------------------------
        - Testo -


01.03.21          10:33h


Fuel: COAL

175.5 °C    FlueGas.Temp
 10.4 %     O2 -content
  278 ppm   CO -content
  9.3 %     CO2 content
0.003       Ratio
 85.2 %     EffGross
 88.8 %     EffNet
 97.2 %     Excess air
  548 ppm   CO undil.
----- hPa   FlueDraught
 30.5 °C    Amb.Air.Temp

----------------------------
SmokeNo.       : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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----------------------------
        testo 300
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        - Testo -


01.03.21          10:34h


Fuel: COAL

174.9 °C    FlueGas.Temp
  9.8 %     O2 -content
  243 ppm   CO -content
  9.8 %     CO2 content
0.002       Ratio
 85.8 %     EffGross
 89.4 %     EffNet
 86.9 %     Excess air
  454 ppm   CO undil.
----- hPa   FlueDraught
 30.5 °C    Amb.Air.Temp

----------------------------
SmokeNo.       : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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        testo 300
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        - Testo -


01.03.21          11:04h


Fuel: COAL

178.5 °C    FlueGas.Temp
  8.2 %     O2 -content
  234 ppm   CO -content
 11.2 %     CO2 content
0.002       Ratio
 85.2 %     EffGross
 88.9 %     EffNet
 63.8 %     Excess air
  383 ppm   CO undil.
----- hPa   FlueDraught
  7.3 °C    Amb.Air.Temp

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SmokeNo..      : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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----------------------------
        testo 300
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        testo 300
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        - Testo -


01.03.21          12:31h


Fuel: COAL

184.2 °C    FlueGas.Temp
  8.2 %     O2 -content
  233 ppm   CO -content
 11.3 %     CO2 content
0.002       Ratio
 85.0 %     EffGross
 88.7 %     EffNet
 63.5 %     Excess air
  381 ppm   CO undil.
----- hPa   FlueDraught
  8.7 °C    Amb.Air.Temp

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SmokeNo.       : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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        testo 300
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        testo 300
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        testo 300
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        - Testo -


01.03.21          13:36h


Fuel: COAL

180.2 °C    FlueGas.Temp
  8.7 %     O2 -content
  232 ppm   CO -content
 10.8 %     CO2 content
0.002       Ratio
 86.2 %     EffGross
 89.9 %     EffNet
 76.2 %     Excess air
  395 ppm   CO undil.
----- hPa   FlueDraught
 29.1 °C    Amb.Air.Temp

----------------------------
SmokeNo.       : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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        testo 300
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        testo 300
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        testo 300
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        - Testo -


01.03.21          13:40h


Fuel: COAL

188.4 °C    FlueGas.Temp
  7.1 %     O2 -content
  235 ppm   CO -content
 12.1 %     CO2 content
0.002       Ratio
 86.4 %     EffGross
 90.2 %     EffNet
 51.6 %     Excess air
  356 ppm   CO undil.
----- hPa   FlueDraught
 25.0 °C    Amb.Air.Temp

----------------------------
SmokeNo.       : - - - - - -

Average        :  -----
OilDerivative:    -----

HeatCarrierTmp.:  --- °C
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        testo 300
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```