

WESSEX CRYSTAL  
UNIT 4  
SILVER END INDUSTRIAL ESTATE  
SILVER END  
BRIEFLY HILL  
WEST MIDLANDS  
DY15 3JZ

16<sup>th</sup> April 2008

FAO: Mr Meadon

REPORT REF - HE 08 / 6151

### LA-PPC MONITORING OF THE SCRUBBER SYSTEM RELEASES

#### 1 INTRODUCTION

As per the provisions of the Wessex Crystal Limited LA-PPC permit, a study was undertaken by Mr T Growcott of Halcyon Environmental on April 11<sup>th</sup> 2008 to determine the releases of Hydrogen Fluoride (as HF) and Oxides of Nitrogen (NO<sub>x</sub>) sourced from the operation of the site's acid etch process tanks and their associated scrubber system.

This study was undertaken to determine data as detailed by Dudley Metropolitan Borough Council personnel as part of the site's LA-PPC emission monitoring protocol, and was undertaken over a typical period of working over approx. 2 hours.

Throughout this period the acid etch line was in use with a typical throughput of components.

Glassworks were immersed in the hydrofluoric acid solution as per normal process schedules. Fumes from the etch line were extracted via a purpose built extraction system, and then passed through a dedicated, purpose built scrubber plant. The scrubber plant was considered to be in very good condition, with no evidence of corrosion, leakages or potential failure points, producing a high linear velocity at the tank of up to 6 m/sec.

The scrubber was fitted with a dedicated mist eliminator and the main stack had inbuilt sampling portals.

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.
QGN001	Guidance on Assessing Uncertainty in Stack Emission Monitoring.

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).

The extraction, after the scrubber, discharged releases directly into the atmosphere via an elevated stack fitted with an acceleration cone. This section of the extraction system contained the two 25 mm. dia. portals from which all monitoring was undertaken.

## 1.2 SUMMARY

- (i) The sampling, monitoring and analytical procedures undertaken in this report has determined compliant HF and NO<sub>x</sub> releases from the scrubber system extraction.

The following analytical results were determined whilst normal production operations took place: -

Analyte	PG 4/1 Limit PG 3/6(04)	Determined Result	Date
Oxides of Nitrogen (mg/m <sup>3</sup> ) (expressed as 1-hour mean emission concentration) 2 hours at 15 second intervals = 480 readings	200	0.97	11/11/08
Fluorides (as HF) (mg/m <sup>3</sup> ) mean of 2 x 65 minute samples	5	0.041	11/11/08

- (ii) Flow and mean velocity determinations have established compliance for the scrubber systems.
- (iii) Emission discharge colour has been determined for the scrubber extraction system in accordance with LAPPC protocol and established as less than Ringelmann shade 0.5.
- (iv) Releases have been assessed and found to be free from droplets.



The efflux velocity has been determined to be compliant with PG 4/1 provisions to minimise any droplet entrainment in the emission discharge from the scrubber unit.

In terms of LAPPC compliance, the acid etch plant and its associated scrubber system were considered to be both BATNEEC and BPEO.

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

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

*WESSEX6151 LAPPC REP*



**SECTION 2**  
**SAMPLING AND MONITORING STRATEGY**





## 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.

Velocity data was determined using an Airflow Developments model PVM 100 Electronic Micromanometer used in conjunction with an Airflow Developments BS 1042 type 2.1 pitot system, with in line thermocouple. Calibrated Huger Sutronics temperature and pressure measurement devices were also used in these procedures.

### 2.2 SAMPLING EQUIPMENT

Sampling was undertaken using calibrated, purpose built, instrumentation using, in this instance, Casella and BMS high and low flow pumps as defined in the analytical methodology procedures detailed in this report.

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 BS 9096.

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 the Approved Code of Practice issued by the Source Testing Association, to within 100 %  $\pm$  10 % variance.

Airflows were monitored using A.G.L. type E6 electronic meters.

#### 2.2.1 NO<sub>x</sub> Determination as per PG4/1 (2002) Appendix 3

Air was extracted from the stacks isokinetically via a purpose built NO<sub>x</sub> stack sampling train, with the venturi nozzle located directly in the stack sampling points to minimise condensation losses.

#### 2.2.2 US EPA Method 26 Fluoride (expressed as HF) Determination

Fluoride was determined in accordance with Method 26a US CFR – Protection of the Environment, 40, Part 60 Appendix A – *Determination of hydrogen halide and halogen emissions from stationary sources – isokinetic method.*



The Fluoride determination was then carried out in a test laboratory within 24 hours, using an Ion Selective Electrode methodology and Ion Chromatography procedures.

Standard diluted solutions were prepared from Analar grade 0.1M Fluoride Standard solutions supplied from a proprietary manufacturer as calibration. The method has a claimed range and sensitivity of 0.02 - 2000 micrograms F/ml.

## 2.3 SAMPLING PROTOCOLS

### Calculation of Velocity of Flow:

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

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

Where:

Pv is Velocity Pressure in pascals.

$\rho$  is the density of dry air (free of CO<sub>2</sub>) at 1013mb, 273K in Kg/m<sup>3</sup>.

V is velocity in metres per second.

Dry air contains 78.1% Nitrogen (as N<sub>2</sub>), 20.9% Oxygen (as O<sub>2</sub>), 0.9% Argon (as Ar) and traces of CO<sub>2</sub> (0.03%), Ne, He, Kr, Xe, H<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, O<sub>3</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO, & I<sub>2</sub>.

Atomic Weight of Nitrogen is 14, Oxygen is 16, and Argon is 40.

Molecular Weight of Nitrogen (N<sub>2</sub>) is 28, Oxygen (O<sub>2</sub>) 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:

$$\begin{aligned} \text{Molar gas density} &= 0.781 \times 28 \text{ (for N}_2\text{)} + 0.209 \times 32 \text{ (for O}_2\text{)} + 0.009 \times 40 \text{ (for Ar)} \\ &= 28.916 \end{aligned}$$

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.

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<sup>3</sup>. The precise figure is 1.2928 Kg/m<sup>3</sup>.

If this figure is entered into the initial equation

$$Pv = \frac{1}{2} \rho V^2$$

It calculates out to

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

or

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

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 <sup>-1</sup> )
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. 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.

#### Location of Measuring Site:

The measuring site should be 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 airflow 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 9096 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 9096 allows 1 diameter. There will be places where even the rules of BS 9096 cannot be met, in which case, very considerable care is needed in obtaining readings.

#### 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.

Extractive Sampling points are chosen on the same basis, and BS 9096 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<sup>2</sup>, 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 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° 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  $\pi r^2$ . 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:

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

#### Calculation of Volume Flow:

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

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

Internal area of duct is calculated as:

$\pi r^2$  for a circular duct,  
or base x height for a square duct.

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

#### Conversion Factors ( $\text{mg/m}^3$ 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 stp  
1 millimole of HCl occupies 22.4 millilitres at stp 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 ( $\text{mg/m}^3$ ) or 22.4 millimetres per cubic metre (parts per million) ppm.

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





Specifically for HCl ppm x  $\frac{36.5}{22.4}$  = mg/m<sup>3</sup>

In general ppm x  $\frac{\text{molecular weight}}{22.4}$  = mg/m<sup>3</sup> 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<sup>3</sup> without the worry of changing volumes.

In the case of Nitric Oxide (NO) and Nitrogen Dioxide (NO<sub>2</sub>), NO exists at high temperature, as a breakdown product of NO<sub>2</sub>. When combined releases are released to atmosphere, the NO cools and re-oxidises to form NO<sub>2</sub>. Thus the PG notes required presentation of Nitrogen oxides (NO<sub>x</sub>) to be combined and expressed as NO<sub>2</sub>.

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

$$\text{ppm NO} + \text{ppm NO}_2 = \text{ppm NO}_x \text{ (as NO}_2\text{)}$$

The combined NO<sub>x</sub> concentration as NO<sub>2</sub> can then be calculated as above using the molecular weight of NO<sub>2</sub> as the basis for the calculation.

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

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

This allows for the fact that 1 mole of gas at 20°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<sup>-1</sup> mol<sup>-1</sup>





A more useful expression of the Gas Law is:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

This can be expressed to find an unknown as

$$V_1 = \frac{P_2 V_2 \times T_1}{T_2 P_1}$$

The correction equation can therefore be expressed as:

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

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 ( $K = ^\circ C + 273.15$ ) or Rankine ( $^{\circ}R = ^\circ F + 459.67$ )

All sampling and monitoring procedures were based on isokinetic sampling strategies, to assess process uniformity, with continuous on line assessment of flow rate and dynamic velocity measurements during process 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 BS 3405 protocols.

## 2.4 INITIAL STACK PROFILE STUDY

As per the provisions of BS 9096, 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 points. Both temperature and velocity profiles were measured. The study determined that the temperature variance across the two measured planes was less than 2 degrees C, and that velocity variances were within method tolerance specification.

There was no evidence of non-linear flow, spiralling or swirling flow, nor of pulsed airflow in the scrubber extraction system.

In this assessment the relative ratio of the cross sectional area of the stack and sampling head were determined.

The filter holder c.s.a. was noted as less than 10% of the stack duct 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 measurement.



## 2.5 CLIMACTIC CONDITIONS

The following climactic conditions were determined during the study period;-

Atmospheric Pressure (kPa)	100.8
Ambient Temperature (K)	278.9
Relative Humidity (%)	57.3
Visibility (m)	> 1000
Wind Direction	SE
Wind Speed (kph)	Light <15
Weather Conditions	Prolonged and heavy periods of rain, high winds, v. overcast and low cloud



**SECTION 3**

**ANALYTICAL METHODS SUMMARY**





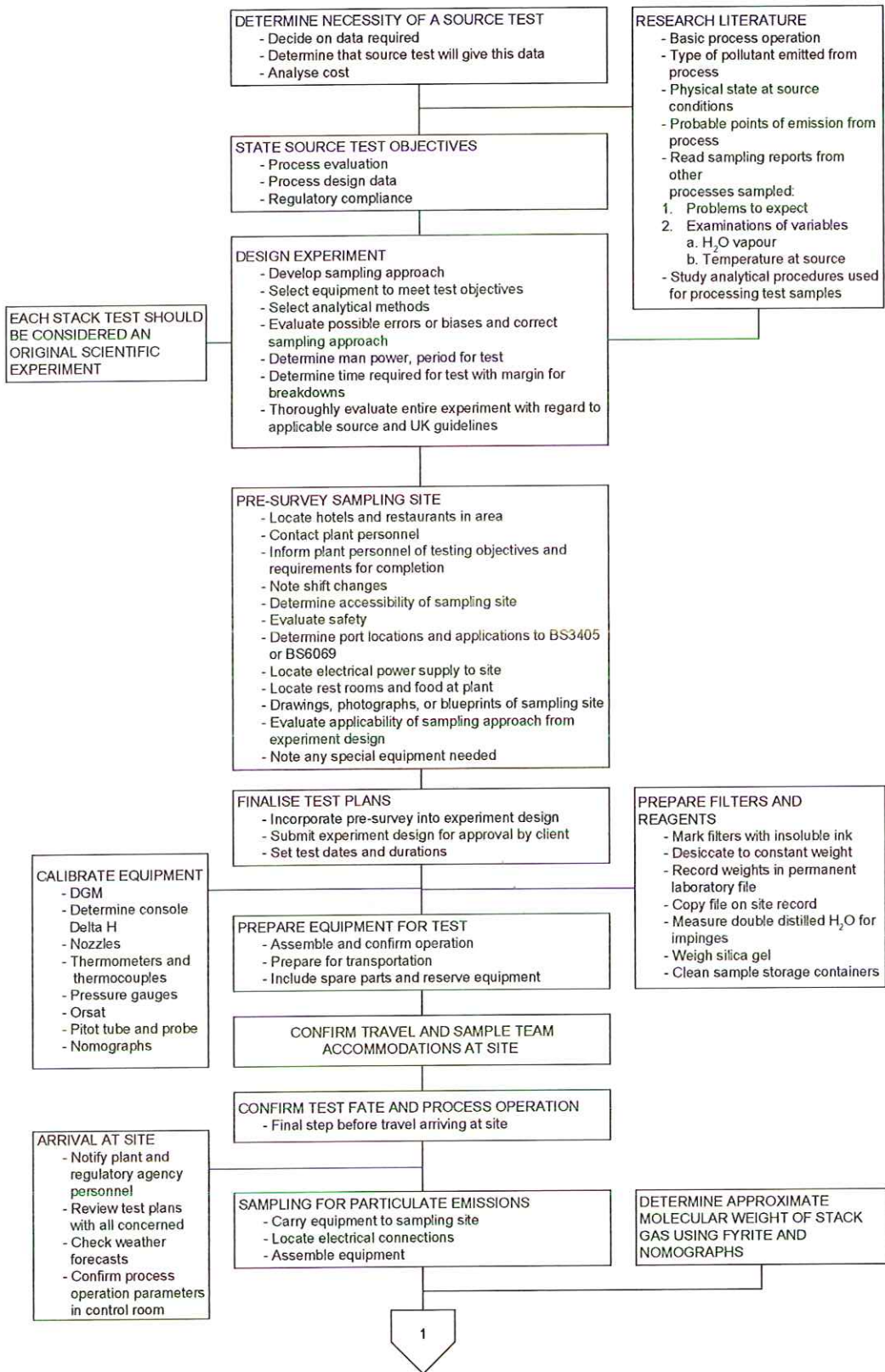
### 3 ANALYTICAL METHODS

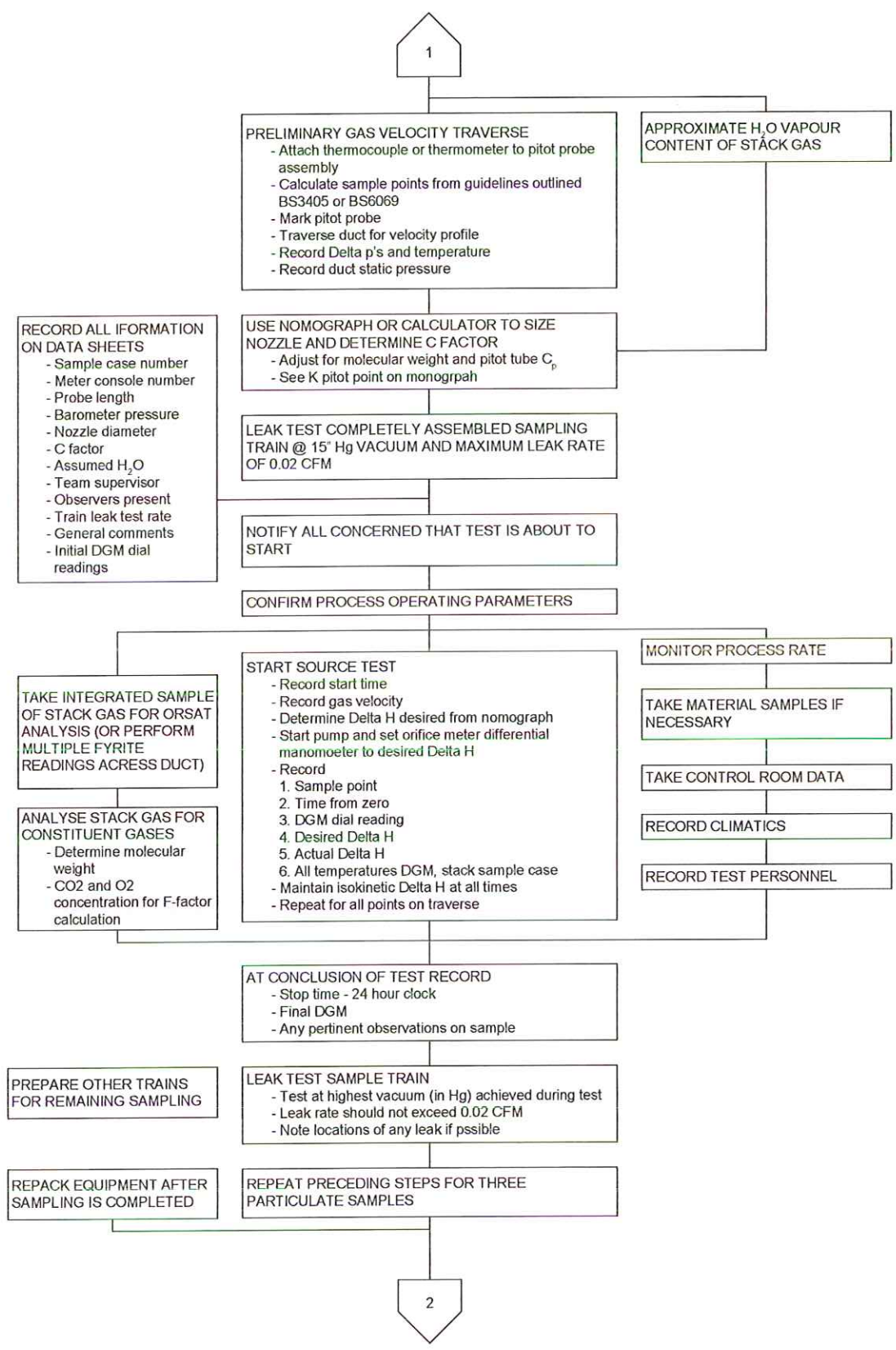
The following analytical methods were used to determine the data reported herein;-

	<b>ANALYTE</b>	<b>METHOD REFERENCE</b>
1	NO <sub>x</sub>	as defined in PG 4/1 (2002)
2	Fluorides (as HF)	US EPA Method 26a



## Planning and performing a stack test







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

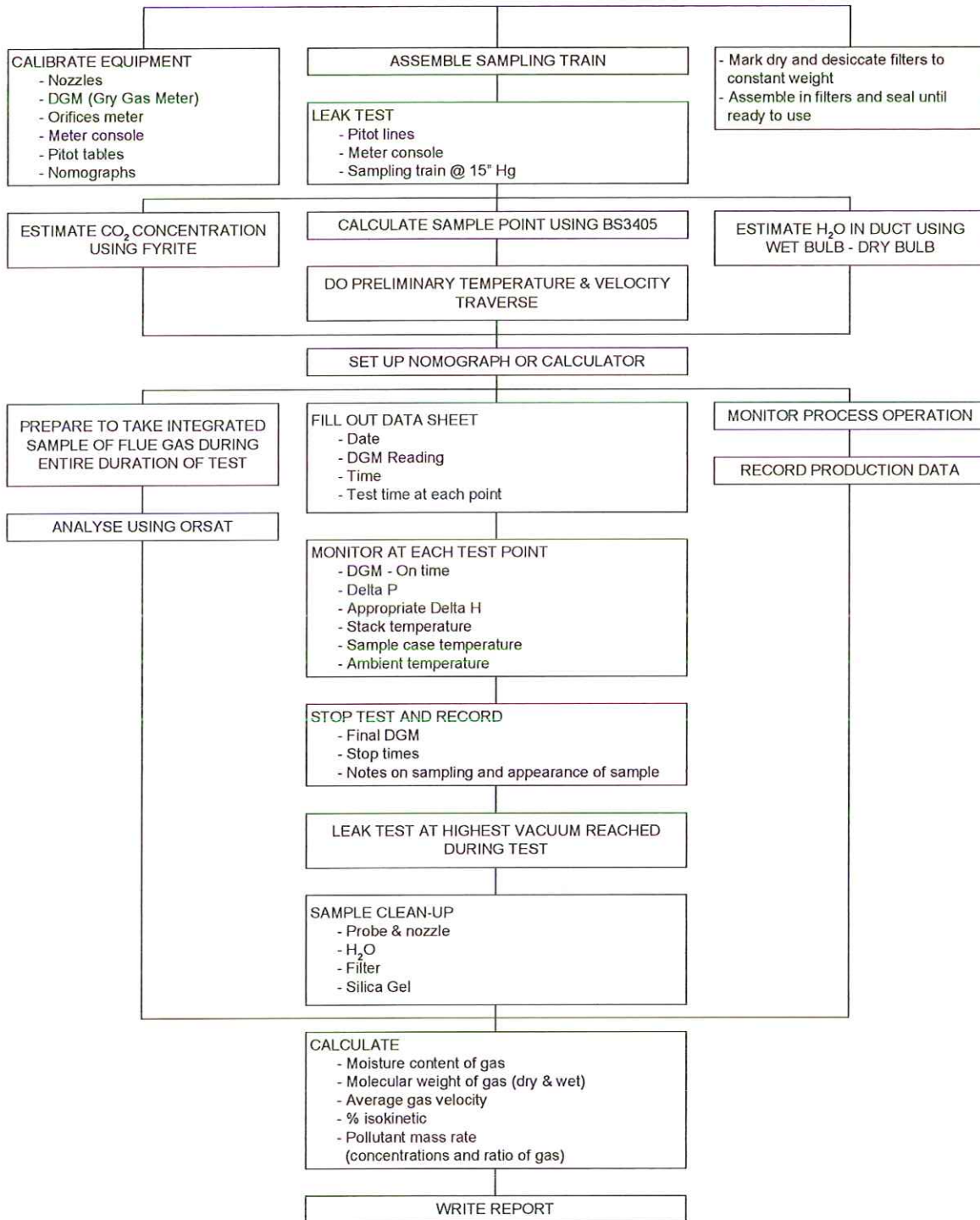
#### WRITE REPORT

- 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

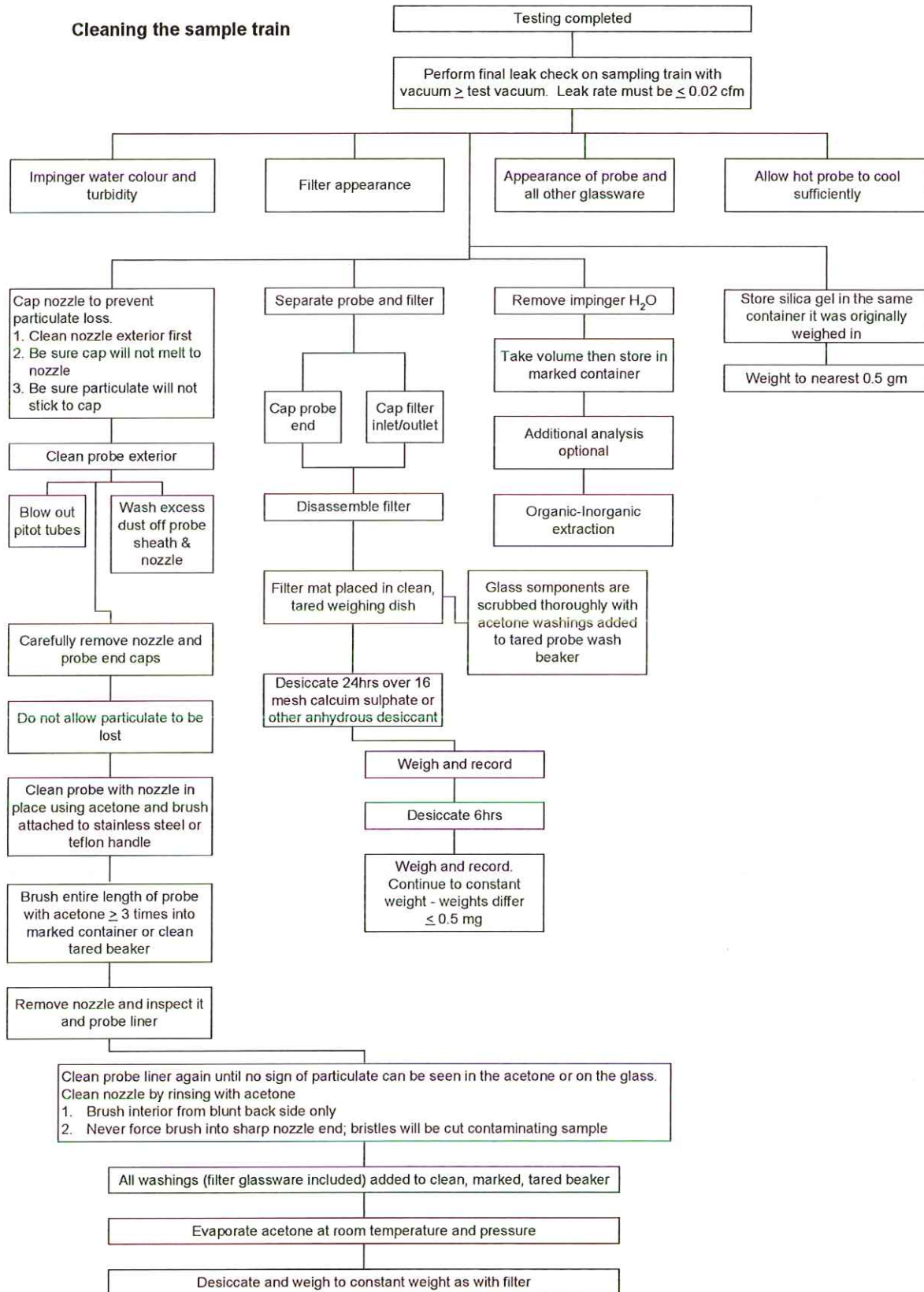
SEND REPORT WITHIN MAXIMUM TIME TO INTERESTED PARTIES



## Source Test Outline



## Cleaning the sample train





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

Type of Error	Source of Error	Quoted uncertainty	Estimate of component standard uncertainty (1SD)	Combined uncertainties (1SD)	Combined uncertainty (1SD)	Expanded uncertainty (95% confidence limits)
Precision-like Errors						
Random	Errors in setting to isokinetic conditions	≤+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%	±13.03%	±25.5%
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°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 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						
Random	Errors in setting to isokinetic conditions	≤+1%	≤+0.58%	±4.66%		
Systematic	Minimum sampling time of 3 minutes	+8%	+4.62%			
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 AND MASS FLOW RATE**





#### 4 MEAN EFFLUX VELOCITY RESULTS

The following velocities were determined for the scrubber extraction system; -

Table 4.1 Mean Efflux Velocity Results					
Stack Ref	Duration of Traverse Test	Tmax : Tmin	Vmax : V min	Mean Velocity (m/s).	Mass Flow Rate at T (m3/sec)
S001 0.34 m. dia. Plastic	08.40 – 0.9.45	See field sheet	See field sheet	9.67 at end 6.56 at port	0.5955 @ 278.9 K

These results are reported in accordance with BS 9096 sampling protocol, corrected to standard conditions as detailed in process specific PG 4/1 note provisions.



## 5 ANALYTICAL RESULTS

The following analytical results were determined whilst normal production operations took place: -

Analyte	PG 4/1 Limit	Determined Result
Oxides of Nitrogen (mg/m <sup>3</sup> ) (expressed as 1-hour mean emission concentration) 2 hours at 15 second intervals = 480 readings	200	0.97
Fluorides (as HF) (mg/m <sup>3</sup> ) mean of 2 x 65 minute samples	5	0.041

### Scrubber Stack – Fluoride (as HF) sampling data

Job Number:	HE 08 / 6151
Client:	Wessex Crystal
Date:	11 <sup>th</sup> November 2008
Release Point Stack Ref	S1
EPA Fluoride Sampling Train	-
Sample Number	6151/HF/001/2
Test Start (Ti)	08.35.00
Test Finish (Tf)	10.35.00
Stack Tester	T Growcott
Test Duration (mins)	120
Sampling Rate Interval (mins)	60
No. of Samples	2 x 60 mins
Mean Reading (mg/m <sup>3</sup> )	0.041

