



Ricardo
Energy & Environment

Air Quality Monitoring in Scotland: Site Operators' Manual

Report for the Scottish Government

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- Appendix B – Safety Data Sheets for Gases
- Appendix C – Glossary of Abbreviations and Conversion Factors
- Appendix D– Calibration Sheet
- Appendix E– Equipment Support Unit Procedures

Part A – General Background Information

Part A comprises sections 1-10 of this manual. These contain general information which is relevant to all Site Operators. This includes background information on air quality monitoring in Scotland, the roles and responsibilities of the various contractors, principles of operation of the monitoring equipment, and the general principles of calibration.

However, the details of the procedures Site Operators need to carry out at each routine site visit vary, depending on the types of analyser at each site. These site-specific (or equipment-specific) instructions are provided in Part B.

1 Introduction

The Scottish Government undertakes automatic monitoring of ambient concentrations of a wide range of air pollutants, as part of joint national programmes run in conjunction with Defra, the Welsh Government and the Department of the Environment in Northern Ireland. In addition a large number of Local Authorities in Scotland measure air quality as part of requirements of the Local Air Quality Review and Assessment process.

Monitoring data from all the automatic air quality monitoring carried out in Scotland are made available via the “Air Quality in Scotland” website at www.scottishairquality.co.uk.

This website has been created to provide a ‘one stop shop’ resource for information covering all aspects of air pollution in Scotland. The site is funded by the Scottish Government. It was designed from the outset to be:

- Accurate and reliable
- Comprehensive
- User-friendly
- Easily navigable
- As interactive as possible
- Able to meet the needs of the general public as well as technical, local government and regulatory user communities.

Since 2006, all automatic monitoring data within the Scottish Air Quality Database (SAQD) on the website have been subject to harmonised QA/QC procedures. These procedures are the same as those applied to national network air quality monitoring stations within the UK Automatic Urban and Rural Network (AURN). This ensures that all data in the database are quality assured and are traceable to UK national calibration standards for the various pollutants.

This is the Site Operators’ Manual for automatic air quality monitoring in Scotland. It has been prepared by Ricardo-AEA for the Local Site Operators responsible for day to day operation of the air quality monitoring sites that make up Scotland’s automatic air quality monitoring network. Its purpose is to provide the Local Site Operators (LSOs) with the information they need in order to operate the sites correctly, and to the same standards as the AURN.

1.1 What is Covered by This Manual

In order for a full quality system to be applied to the Scottish air quality monitoring network, it is important that all operations are harmonised and documented, and that all participants understand their responsibilities. This manual addresses on-site procedures, in order to ensure uniform operation and maintenance of monitoring stations by different site operators and equipment support units.

Specific issues addressed in this site operations manual include:

- Overall requirements for site performance
- Site selection criteria
- Station infrastructure
- Instrumentation

- Routine and non-routine site operational procedures
- Routine and non-routine Equipment Support Unit procedures
- Site housekeeping
- On-site calibration procedures.

Part A of this manual provides general background information on the objectives, structure and management of the network. Part B covers routine and non-routine site operations to be carried out by the Site Operator as well as a description of the procedures to be carried out by the Equipment Support Unit.

Please note that this manual is only **part** of the full quality system for the Scottish Air Quality Network. It is not meant to constitute a full quality system for the network (which requires full documentation and standardisation of the performance of the entire measurement chain). **It does not include:**

- Evaluation and selection of equipment and infrastructure
- Data handling systems
- Data scaling, checking and review
- Long-term data ratification
- Data dissemination techniques
- Data bulletins and reports
- Primary gas calibration procedures
- Site auditing
- Network intercalibrations
- Traceability chains for the network.

1.2 Updating and Version Control

From time to time, quality assurance and quality control (QA/QC) methodologies may need to be updated in response to changing circumstances or needs. Therefore, this manual is a working document, intended to be updated when equipment or procedures change. It has been written in a modular format, so individual sections can be replaced when needed.

This manual is provided in electronic format, and the latest version is available on the “Air Quality in Scotland” website forum at <http://www.scottishairquality.co.uk/index.php> (Printed copies are not provided). If you are a Site Operator, it is **your responsibility** to ensure that you download and use the most up to date version.

2 About Scottish Air Quality Monitoring

2.1 Objectives of Scottish Air Quality Monitoring

The main objectives of Scotland’s air quality monitoring are as follows:

- Providing information that can be used in local air quality review and assessments as required by the UK Air Quality Strategy.

-
- Providing information about air quality to the public.
 - Helping understand long-term trends in air pollution concentrations.
 - Measuring the effectiveness of policies intended to control air pollution.
 - Monitoring compliance with statutory air quality limit values set by Scottish legislation.
 - Some sites are also part of the national air quality monitoring network – the Automatic Urban and Rural Network (AURN). These Fulfilling the UK's legal obligation as a Member State of the European Union, to carry out air quality monitoring. (Note: not all sites in Scotland are used for compliance monitoring with respect to European air quality directives – only those which are part of the national monitoring network, the AURN).

The data may also be used for a variety of other purposes, such as in scientific research to help understand the factors that affect air quality.

2.2 Locations of Monitoring Stations

The home page of “Air Quality in Scotland” at <http://www.scottishairquality.co.uk/index.php> contains an interactive map of Scotland's automatic air quality monitoring stations. Figure 2-1 shows part of this map as an example. The colours and numbers shown on the site markers reflect pollution levels at the time this screen-print was taken – they do not have any other significance.

To see more details about each site, and access data summaries and information on background pollutant concentrations in the area, click on its marker.

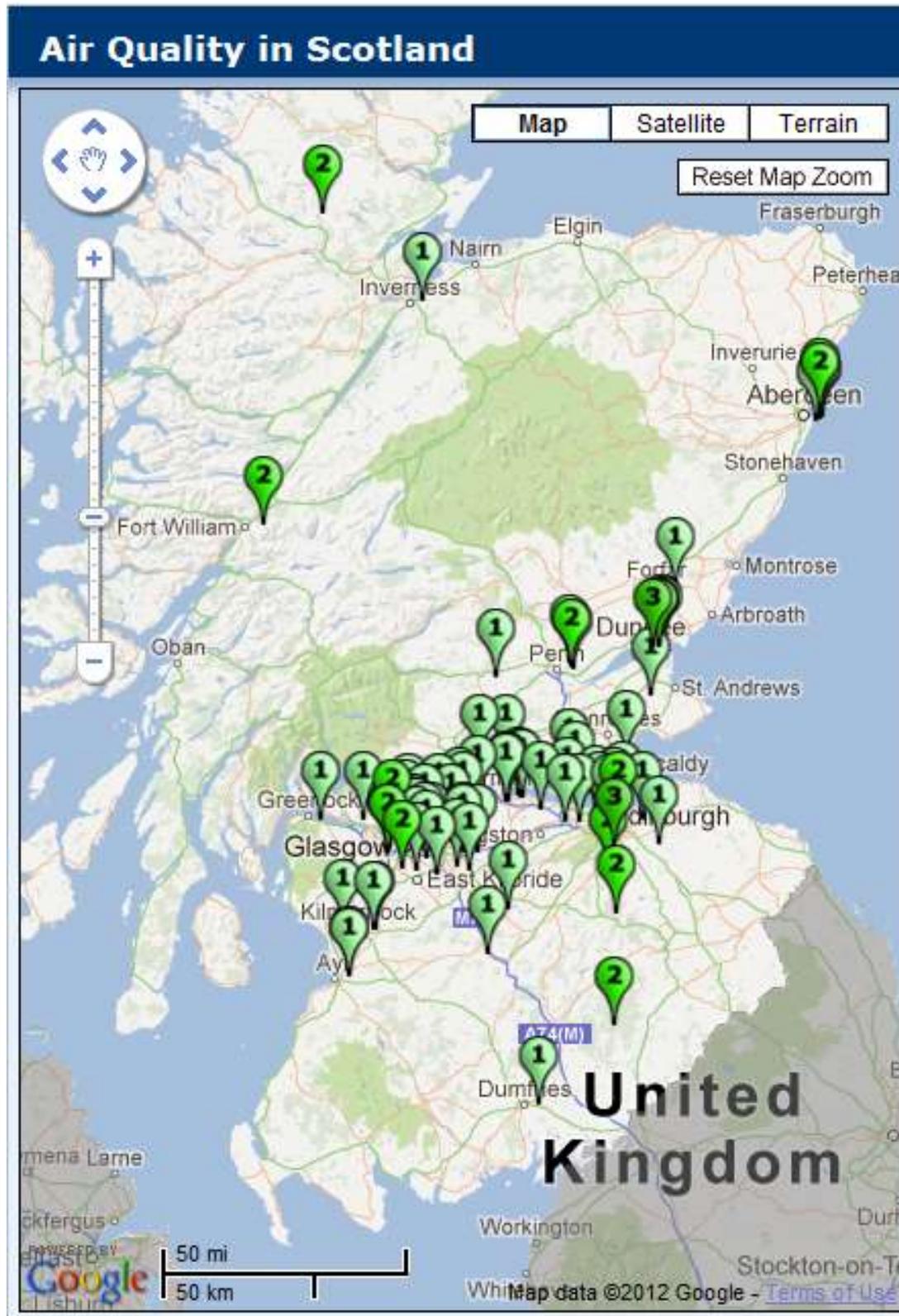


Figure 2-1 Section of Interactive Site Map

2.3 Pollutants Monitored

The Scottish air quality monitoring network monitors five pollutants: oxides of nitrogen (NO_x, which comprises nitric oxide (NO) and nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO), ozone (O₃) and suspended particulate matter (PM). Particulate matter is subdivided into two size fractions, PM₁₀ and PM_{2.5}. Information on the sources and effects of these pollutants is provided below.

2.3.1 Particulate Matter

Particulate matter (PM) is a complex mixture of organic and inorganic substances. Particles can be primary (emitted directly to the atmosphere) or secondary (formed by the chemical reaction of other pollutants in the air such as SO₂ or NO₂). Particles may arise from a wide variety of sources, man-made or natural. The main source of particles is combustion, e.g. vehicles and power stations. Other man-made sources include quarrying and mining activities, industrial processes, dust from construction work and particles from tyre and brake wear. Natural sources include wind-blown dust, sea salt, pollens, fungal spores and soil particles.

Particles found in ambient air range in size from a few nanometres (nm, or 10⁻⁹ m) to several hundred micrometres (µm, or 10⁻⁶ m) in diameter. Particle size is usually expressed in terms of its aerodynamic diameter. Two size fractions are measured: PM₁₀ and PM_{2.5}. PM₁₀ is the mass concentration (expressed in µg m⁻³) of PM that has a mean aerodynamic diameter of 10 µm. These particles are small enough to penetrate deep into the airways, carrying surface-absorbed harmful compounds into the lungs and increasing the risk of health effects. PM_{2.5} is of particular concern, as it can penetrate deeper into the lungs than PM₁₀ and is harder for the body to remove.

The range of health effects associated with PM is broad, but is predominantly related to the respiratory and cardiovascular systems. Susceptibility to the effects of PM may vary with health or age. There is little evidence to suggest a threshold below which no adverse health effects would be anticipated.

2.3.2 Oxides of Nitrogen

Nitrogen can form several oxides but only two are of interest in the context of air pollution. These are nitric oxide (NO) and nitrogen dioxide (NO₂), collectively referred to as NO_x. (Nitrous oxide, N₂O, is implicated in climate change, but does not appear to have significant health impacts at ambient concentrations and is not measured as an air pollutant by Scotland's air quality monitoring programme).

Combustion processes release a mixture of NO and NO₂, formed by oxidation of nitrogen in the air itself, as well as in the fuel. NO₂ is of concern because it is harmful to human health (it is a respiratory irritant). NO is not generally considered a pollutant at the concentrations found in ambient air: however, it is quickly oxidised to form more NO₂.

For the UK as a whole, approximately one third of all NO_x emissions (in 2010) originate from motor vehicles, with most of the remainder arising from power stations and other industrial sources. Since power station and industrial emissions are usually from high chimneys, away from city centres, motor vehicles represent by far the largest source of

low-level NO_x emission and therefore make the largest contribution (about 75% or more) to long term ground level concentrations in urban areas. For this reason, highest NO_x levels in cities are usually found at roadside locations.

2.3.3 Sulphur Dioxide

Sulphur dioxide (SO₂) is an acidic gas, formed by the oxidation of sulphur impurities in fuels during combustion processes, particularly of solid fuel and petroleum, which account for about 90% of SO₂ emissions. A very high proportion of UK emissions originate from power stations and industrial sources, although these are generally released at height by chimneys to achieve effective dispersion under normal conditions. Historically, domestic solid fuel use was once an important source of ground level SO₂ emissions. Atmospheric concentrations have decreased sharply, by over 90% in the past forty years, as a result of decreasing use of high sulphur coal and increasing use of abatement equipment in the industrial and power generation sectors.

SO₂ is a respiratory irritant and can cause constriction of the airways. It can also react with other pollutants in the atmosphere to produce secondary particulate matter (PM). Finally, at high concentrations it can damage plants, and through acid deposition (so-called “acid rain”) contribute to acidification of soils and waters.

2.3.4 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas produced when fuels containing carbon are burned with insufficient oxygen to fully oxidise the carbon present. Petrol engines used to emit significant amounts of CO but concentrations are now very low due to the introduction of catalytic converters on car exhausts. However, ambient carbon monoxide in urban areas results almost entirely from vehicle emissions. In urban areas, concentrations are highest at the kerbside and decrease rapidly with increasing distance from the road.

Carbon monoxide affects health by preventing the blood carrying oxygen around the body. People are more likely to be exposed to dangerous concentrations of CO indoors – for example, from a faulty heating appliance. Cigarette smoke is also a major source of exposure.

2.3.5 Ozone

Ozone (O₃) is a form of oxygen containing three atoms per molecule rather than the usual two. In the stratosphere (part of the upper atmosphere) O₃ is formed by the action of ultraviolet light on oxygen molecules. This produces the “ozone layer”, and at this level the gas has a beneficial effect by absorbing harmful ultraviolet solar radiation.

In the lower atmosphere, however, O₃ is an air pollutant. It is produced by the photochemical effect of sunlight on oxides of nitrogen and volatile organic compounds produced by motor vehicles and industry. These reactions take place over periods of several hours or even days. Once formed, O₃ can travel long distances, accumulate and reach high concentrations often far away from the sources of the original pollutants. For this reason, levels of O₃ in the air are often higher in rural areas. For example, it is often

the case that when O₃ levels are elevated in the South East of England, much of the O₃ has originated in continental Europe. O₃ concentrations are greatest in the summer (usually on hot, sunny, windless days) and lowest in the winter months.

Also, NO reacts with O₃ to form NO₂. This means NO emissions have a “scavenging” effect, reducing local concentrations of O₃. This often means that levels of ozone are low at roadside locations where levels of other pollutants are highest.

O₃ is an oxidising agent and acts as an irritant to the respiratory tract. It is also harmful to vegetation.

3 Roles and Responsibilities

3.1 Overview of operational structure

Scotland's air quality monitoring is not undertaken by a single organisation but by a number of organisations working together.

The customer is the Scottish Government. Ricardo-AEA are contracted by the Scottish Government to undertake quality assurance, quality control and data processing activities.

Day-to-day operation of each monitoring site is the responsibility of a Local Site Operator or LSO. These are often Local Authority staff members.

Maintenance and repair of the monitoring equipment, as well as supply of calibration gases, is usually carried out by an equipment support contractor working under contract to the site owner (Local Authority).

In the case of sites which are also part of the AURN, the LSO is usually a subcontractor to the organisation holding the contract with Defra for central management of the AURN. This organisation is termed the "Central Management and Control Unit" or CMCU. LSOs for sites within the AURN have specific additional responsibilities in relation to the CMCU – these are documented in the AURN's own LSO manual.

3.2 Duties and responsibilities of an LSO

As an LSO for a site in the Scottish air quality monitoring network, you have the following duties and responsibilities:

1. **Routine management of the site.** This means:
2. Keeping the site and its surroundings generally tidy and in a good state of repair. This includes informing the relevant organisation (the site owner, or else the CMCU in the case of AURN sites) if any repairs are needed to the site infrastructure (such as repair of a leaking roof or damage due to vandalism). You may be asked to carry out some simple or temporary repairs.
3. Inform the site owner (or CMCU for AURN sites) of issues such as overgrown shrubs or vegetation around the site.
4. Assisting with management of grass and vegetation around the site.
5. Inform the site owner (or CMCU for AURN sites) of any safety issues. The LSO will be responsible for ensuring that all work undertaken on site conforms to the relevant health and safety standards and legislation (such as working at heights, electrical safety, use of compressed gases, COSHH and manual handling etc.) Any safety issues identified should be communicated immediately to all relevant organisations – including Ricardo-AEA (who may need to visit the site as part of their QA.QC duties), the CMCU (in the case of AURN sites), service contractors, gas suppliers etc.
6. **Routine instrument calibrations.** These must be carried out on a 2-weekly basis for traffic-related sites, or a 4-weekly basis for other sites. You will need to -
 - Carry out calibrations of the analysers for gaseous pollutants, using the standard gas mixtures provided on site.

- Complete the relevant calibration sheet (provided by Ricardo-AEA) and e-mail this to Ricardo-AEA at the AQ Admin e-mail address provided (aqadmin@ricardo-aea.com).
- Make a note of anything unusual at the site, which could affect the monitoring results. This could be road works, building or demolition work nearby, evidence of a fire nearby, or changes to normal traffic flow.
- Change the particulate filters on the monitoring instrumentation for gaseous pollutants (these are the filters that prevent airborne particulate matter being drawn into the analyser, where it would affect the results). This is normally done routinely at each 2-weekly or 4-weekly calibration visit.
- Change the filter in the FDMS when necessary. This is not usually done at every visit but when the filter has reached 90% of maximum loading, and is requested by the QA/QC contractor.
- For Partisol sites (currently the only sites in Scotland with these are at Inverness and Auchencorth Moss), change the filter canister on a two-weekly basis. (This needs to happen on the same day of the week, every two weeks. Also exposure sheets must be completed and sent out, and filters returned to laboratory).

The details of how to carry out these tasks are provided in Section B of this manual. They vary depending on the manufacturer of the analyser.

7. **Emergency call-outs.** The LSO will also be required to provide an emergency call-out service in the event of equipment failure or malfunction. You may be asked to carry out simple diagnostic checks on the instruments, and to undertake basic repairs. You may also be required to carry out additional calibrations, and resetting of the CPU, logger and modem if necessary. However, as an LSO you will not be required to undertake major repair or maintenance of the equipment: this is usually carried out by a dedicated Equipment Support Unit contractor. It is the LSO's responsibility to ensure that a suitable contract is in place to cover necessary maintenance and repair, including emergency callouts.
8. **Attend and participate in twice-yearly site audits.** These are twice-yearly visits by a member of the QA/QC team at Ricardo-AEA. The purpose is partly to check that all the instrumentation is functioning correctly. However, the other purpose is to check that the LSO has the necessary skills and is carrying out calibrations etc. correctly. You may be asked to carry out some of your routine tasks by the site auditor. This is nothing to worry about, and it provides an opportunity to ask any questions you may have.
9. **Ensure that a suitably trained colleague is able to cover for you,** if you have to miss a routine calibration visit (for example, if you are on holiday, or off sick). This is a requirement of your organisation's contract with the CMCU. All sites **must** have at least two people trained to carry out LSO duties, for this reason.
10. **Train up your replacement LSO if necessary.** When a new site is set up (or affiliated), the LSOs are trained by Ricardo-AEA. However, from then on, it is the LSO organisation's responsibility to train up any replacements necessary. So, if you are unable to continue to act as an LSO (for example, if you are leaving your organisation), it will be the responsibility of you and/or your colleagues to train up your replacement.

11. **Health and Safety Responsibilities.** These are as listed in the “*UK Air Quality Monitoring Networks Health and Safety Guidance*” document² – available from Ricardo-AEA and available on the Health and Safety Database. Health and safety responsibilities of the LSO are as follows:

- Review risks and prepare a risk assessment for work carried out at each site, including transport to and from the site and the movement of gas cylinders into the site. (The risk assessment should be updated at least annually).
- Ensure actions are taken to mitigate the risks resulting from the risk assessment (e.g. purchase of safety equipment, display of H&S information at site, staff training and communication).
- Carry out a ‘take two’ risk assessment on arrival at the site. A ‘take two’ risk assessment is a short and simple visual check of the key risks to review whether it is safe to carry out work.
- Notify Ricardo-AEA of any new or site specific risks.
- Follow advice from the Ricardo-AEA Health and Safety Coordinator.
- Ensure contact details for your organisation are up to date and sent to Ricardo-AEA.
- Other responsibilities as specifically identified in the LSO’s contract. If your site is an AURN site there are specific responsibilities regarding reporting risks via the AURN Health and Safety Database: these will have been communicated separately.
- Comply with health and safety laws and regulations (see <http://www.hse.gov.uk>)

3.3 LSO Training

As an LSO, it is essential that you fully understand all the site operation procedures documented in this manual. Ricardo-AEA will undertake to train at least one LSO per site. Each LSO trained by Ricardo-AEA may subsequently train further local site operators under the following conditions:

- The LSO conducting the training has had at least six months operational experience at the site and has either been originally trained or successfully audited by a QA/QC auditor from Ricardo-AEA.
- An experienced LSO oversees the first one or two fortnightly calibrations conducted by the newly trained LSO.
- After being trained, the new LSO is audited by Ricardo-AEA at the earliest possible opportunity, for example, during the 6-monthly intercalibration exercise or ad-hoc site audit.
- Ricardo-AEA should be informed if training has taken place, and the name of the newly trained LSO.

Formal retraining of LSOs will only be mandatory if all the original trained LSOs have left the organisation.

4 Quality Assurance/Quality Control Objectives

Good data quality and high data capture rates are essential if the monitoring carried out in Scotland is to achieve its objectives. To ensure that data are sufficiently accurate, reliable and comparable, consistent data quality assurance/control (QA/QC) procedures are applied throughout the network.

Good QA/QC practice covers all aspects of network operation, including systems design and site selection, equipment evaluation, site operation, maintenance and calibration, data review and ratification. The successful implementation of each component of the QA/QC scheme is essential for the success of the programme.

The fundamental aims of a quality assurance/control programme are as follows:

- (i) The data obtained from measurement systems should be representative of ambient concentrations existing in each urban and rural area;
- (ii) Measurements must be accurate, precise and traceable;
- (iii) Data must be comparable and reproducible. Results from this geographically extended network must be internally consistent and comparable with international and other accepted standards;
- (iv) Results must be consistent over time; and
- (v) In order for seasonally or annually averaged measurements to be meaningful, an appropriate level of data capture is required throughout the year.

The National Measurement System (NMS) exists to provide a formal infrastructure for all measurements in the United Kingdom. At its core are primary standards held by the National Physical Laboratory, together with appropriate absolute or traceable metrology standards maintained at other designated laboratories. Essential requirements for conformity with the NMS are as follows:

- Measurement methods used must be of known performance and defined scope of application;
- All calibrations must be traceable through an unbroken chain to international standards (the SI system);
- Measurements should be made within a documented quality system;
- Where possible, measurements should be harmonised with those made by organisations both within and outside UK.

This manual describes the documented procedures and record-keeping systems necessary to ensure that on-site network operations comply with the overall QA/QC programme objectives specified above, and are also compatible with the requirements of the UK National Measurement System.

However, documenting the procedures alone is not enough: they must also be followed properly by everyone involved. To help ensure that this happens, Ricardo-AEA provide full training to LSOs. This training is intended to ensure that the site operators understand the monitoring techniques involved, and the network procedures required, to maintain a high standard of performance.

Compliance with documented procedures is also closely monitored by Ricardo-AEA during intercalibrations, audits of site operators and on-going data assessments. It is a requirement that LSOs must make themselves available for an intercalibration visit if a member of Ricardo-AEA requests that they do so.

5 Data Requirements

Not all the monitoring sites within the Scottish air quality monitoring network are used for monitoring compliance with EU directives on air quality. Only the AURN sites are used for this purpose. However, *all* sites in Scotland are operated according to the data capture and data quality targets set by European Union's Air Quality Directive (Directive 2008/50/EC)³. This Directive sets out data quality objectives regarding the maximum uncertainty of measurements and the minimum data capture. These are presented in Table 5-1.

Table 5-1 Measurement uncertainty objectives given in EU Air Quality Directives

Parameter	Uncertainty Continuous Measurement ¹	for Minimum Data Capture
NO ₂ , NO _x	15%	90%
SO ₂	15%	90%
Particulate Matter	25%	90%
CO	15%	90%
O ₃	15%	90%

The methodology for calculating uncertainties is specified by the European Committee for Standardisation (CEN – Comité Européen de Normalisation). Details are given in the relevant CEN documents.

New types of analysers must be tested to ensure they meet CEN standards. In the UK, this is carried out under MCERTS, the Environment Agency's Monitoring Certification Scheme that tests analysers to see whether they meet the CEN standards. Only those analysers that meet the CEN standards are shown to be equivalent to the reference method. In compliance with the European Directive, all analysers used in the AURN must be proven equivalent to the reference method as of June 2013. More information on the reference methods can be found in Section 7.

5.1 Data Capture

The data capture target for the Scottish air quality monitoring network is 90%. This is as specified in the EU Air Quality Directive. Again, although not all sites in Scotland are used for monitoring compliance with the Air Quality Directive, those sites that are also part of the AURN are used for this purpose, and all sites in Scotland are operated to the same data capture and data quality criteria.

¹ The percentages for uncertainty in the above table are given for individual measurements averaged over the period considered by the limit value (or target value in the case of ozone). For a 95% confidence interval. The uncertainty for the fixed measurements shall be interpreted as being applicable in the region of the appropriate limit value (or target value in the case of ozone).

Data loss in any network can result from a number of factors. The most important in practice are as follows:

- Analyser breakdown
- Site servicing
- Site relocation/up-grading
- Failure or leak of gas sampling system
- Data acquisition system failure
- Power cut or other site disruption
- Telephone line breakdown
- Operator error
- Vandalism
- Air conditioning faults
- Data rejection (after failing QA/QC criteria).

Automatic analysers carry out a daily automatic calibration. If properly designed and configured, these automatic calibrations should *not* result in loss of hourly average data. In well-run networks, the major failure mode will be analyser breakdown: these instruments are complex and 100% reliability cannot reasonably be expected. Data loss due to most other problems can be minimised by:

- Efficient data telemetry (enabling on-site problems to be identified rapidly)
- Backup data storage media on-site
- Rapid service, maintenance and repair
- Comprehensive and documented site operational protocols
- Regular application of these protocols
- Experienced site operators
- Proven site infrastructure and system backup, and
- The deployment of proven analyser types.

Detailed analysis of the reasons for loss of data is provided in the bi-annual and annual data ratification reports produced by Ricardo-AEA (available on the reports database on UK-AIR and the AURN Hub).

One of the main reasons for data loss is analyser breakdown. It is therefore important that LSOs have a suitable equipment support contract in place. (For AURN sites, this is a condition of the LSO's contract with the CMCU).

6 Site Selection

6.1 Site Location criteria: AURN sites

For sites which are part of the AURN, and therefore used to monitor the UK's compliance with the European Union Air Quality Directive 2008/50/EC (the Air Quality Directive)³, it is a requirement that each site meets the siting criteria set by this Directive. These are divided into two categories:

- “macro-scale” criteria, relating to the surroundings of the monitoring site, and the area of which it is representative, and
- “micro-scale” criteria, which relate to the positioning of the actual site and its inlet, taking into account factors such as distance from the kerb, and free flow of air to the inlet.

Sites within the AURN should meet these criteria, set out in Annex III of the Air Quality Directive.

In accordance with Directive 2008/50/EC, air quality need not be assessed at any locations situated within areas where members of the public do not have access and there is no fixed habitation. This includes factory premises and industrial installations where health and safety at work regulations apply. It also includes the carriageway and central reservations of roads except where there is normally pedestrian access to the central reservation.

One important siting criterion of the Air Quality Directive (and therefore of AURN sites) is that traffic urban monitoring sites must be at least 25m from any major road junction. However, for Local Authority sites being used for LAQM purposes only, this is not a requirement.

6.2 Site Location Criteria: Non-AURN sites

For sites which are not part of the AURN, sites should be selected according to the siting criteria set out in the Local Air Quality Management Technical Guidance, LAQM.TG(09) which can be found at <http://archive.defra.gov.uk/environment/quality/air/airquality/local/guidance/documents/tech-guidance-laqm-tg-09.pdf>.

Site selection is covered in Annex 1 of the Technical Guidance.

The siting criteria set out in the Technical Guidance are based upon the requirements of LAQM, and differ from those of the Air Quality Directive. In general, they are less prescriptive than those of the Directive. For example, it is perfectly acceptable to place monitoring sites within 25m of road junctions if there is relevant exposure. However, it should be noted that a monitoring site that does not meet the Directive siting criteria would not be eligible for incorporation into the AURN at a later date.

6.2.1 Site Selection – Practical Considerations

In addition to the above, there are a number of practical considerations to be taken into account:

- It should be practical for power and telephone connections to be made at the site;
- The site should be accessible for a lorry to deliver the housing (if necessary)
- It should be reasonably easy for gas cylinders to be delivered close to the site and transferred to the housing (or the building in which the site is located).
- The LSO should be able to gain access to the site whenever necessary.
- The site should be in an area where the risks of vandalism are minimal.
- Account should be taken of visual impact of the housing.

7 Monitoring Instrumentation

7.1 Selection of Monitoring Equipment

The selection of appropriate instruments is essential to the success of any monitoring network in achieving its stated objectives. The monitoring objectives require precise time-resolved measurements, necessitating the use of automatic analysers. The selection of instruments for the AURN (and therefore for the monitoring sites used in Scotland) was based on specific and proven analytical techniques for the pollutants measured (Table 7-1).

Table 7-1 Operating Principles of Automatic Analysers

Pollutant Measured	Operating Principle
O ₃	UV Absorption
NO/NO ₂	Chemiluminescence
SO ₂	UV Fluorescence
CO	IR Absorption
PM ₁₀ /PM _{2.5}	FDMS (Flow Dynamic Measurement System) BAM (Beta Attenuation Monitor) Gravimetric Sampler

These techniques represent the current state-of-the-art for automated monitoring networks and, with the exception of the automatic PM₁₀/PM_{2.5} analysers, are the Reference methods of measurement defined in the EU Directives.

7.1.1 CEN

The EU requirements for achieving appropriate data quality are stated by the European Committee for Standardisation (CEN – Comité Européen de Normalisation). These standards give the detailed performance specifications for reference monitoring methods and include methodologies for sampling, calibration and on-going QA/QC. The instrument performance specifications are incorporated into the Environment Agency's MCERTS (Monitoring Certification Scheme) and into other European product certification schemes, such as TÜV (Technischer Überwachungsverein – Technical Monitoring Association) in Germany. Typical performance specifications of analysers used in the AURN are given in Table 7-2 and have been taken from the following British Standards documents:

- Ambient air quality – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, BS EN 14211:2005⁵;
- Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence, BS EN 14212:2005⁶;
- Ambient air quality – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, BS EN 14625:2005⁷;
- Ambient air quality – Standard method for the measurement of the concentration of carbon monoxide by nondispersive infrared spectroscopy, BS EN 14626:2005⁸;

- Air quality – Determination of the PM₁₀ fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods BS EN 12341:1999⁹; and
- Standard gravimetric measurement method for the determination of PM_{2.5} mass fraction of suspended matter, BS EN 14907:2005¹⁰.

(Some of these standards are currently under review at the time of writing. This manual will be updated as necessary). As already mentioned in previous sections, as of 11th June 2003, only analysers that are proven to be equivalent to the reference method are allowed in the AURN. This requirement extends to non-AURN sites within the Scottish air quality network, as they must be operated to the same principles of QA/QC.

Table 7-2 Typical Specifications for Standard Gaseous Pollutant Analysers

Pollutant Measured by	NO ₂	SO ₂	O ₃	CO
Repeatability: Zero	2 µg m ⁻³	2.5 µg m ⁻³	2 µg m ⁻³	1.2 mg m ⁻³
At Limit Value	6 µg m ⁻³	8 µg m ⁻³	6 µg m ⁻³	3.5 mg m ⁻³
Linearity	4%	4%	4%	5%
Period of Unattended Operation	3 months	3 months	3 months	3 months
95% Response Time (max)	180 secs	180 secs	180 secs	180 secs

7.2 Accreditation

Ricardo-AEA holds UKAS (United Kingdom Accreditation Service) accreditation (UKAS Calibration Laboratory No. 0401) to ISO 17025 for the on-site calibration of the gas analysers (NO_x, CO, SO₂, O₃) used in Scotland's air quality monitoring, for flow rate checks on particulate analysers (PM₁₀ and PM_{2.5}), and for the determination of the spring constant, k₀, for the FDMS analyser.

The accredited procedures for analyser calibration include the following analyser checks:

- Noise
- Linearity
- Response time
- Converter efficiency
- SO₂ hydrocarbon interference, and
- Uncertainty evaluation.

Ricardo-AEA also holds UKAS accreditation for laboratory certification of NO, NO₂, CO and SO₂ gas cylinders, also for ozone photometers.

7.3 Principles of Operation

This section explains the principles of operation of the various types of automatic pollutant analysers used in Scottish air quality monitoring. The on-site analysers are usually housed in temperature controlled rack units which also contain the data logger and auto-calibration system, where installed. If there is a Partisol at the site, this may be in a separate cabinet. Block diagrams showing the main components of the analysers are included in this section. There may be slight operational differences between different analyser makes and models. However, the measurement methodology will be the same, and these are described below.

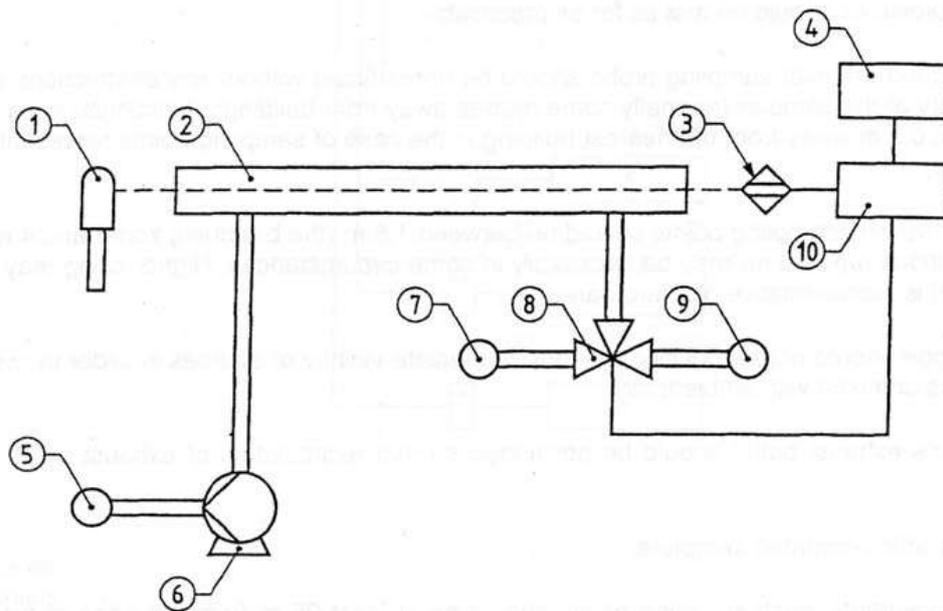
7.3.1 UV Absorption Ozone Analyser

Ambient air is drawn into the analyser by a pump, and passes through a reaction cell. Ultra-violet light of wavelength 254 nanometres ($1 \text{ nm} = 10^{-9} \text{ m}$) is passed through the sample. Ozone absorbs light of this wavelength, and this absorption is measured using a UV detector. An ozone-removing scrubber is used to provide a zero reference intensity. The analyser alternately measures the absorption I_0 of the air path with no ozone present and the absorption I_1 of the ambient sample. The concentration (c) is calculated using the Beer-Lambert equation:

$$I_1 = I_0 e^{-a/c}$$

where l = the length of the reaction cell, and a = the absorption coefficient at 254 nm.

The UV absorption analysers have a single reaction cell, and pneumatic valving to switch between zero and ambient air paths (see Figure 7-1). Ambient air is sampled using a pump unit. The analysers continually display current O_3 concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. An internal ozone generator and zero air scrubber are used to provide daily automatic check calibrations.



Key

1	Source 254 mm
2	Absorption Cell
3	Detector
4	Display
5	Exhaust
6	Pump
7	Reference in
8	Solenoid
9	Sample in
10	Digital Electronics

Figure 7-1 Schematic Diagram of Ozone Analyser

7.3.2 Chemiluminescent Oxides of Nitrogen Analyser

Nitric oxide (NO) in the sample air stream reacts with ozone (O₃) in an evacuated chamber to produce activated nitrogen dioxide (NO₂*). This then returns to its ground (unactivated) state, emitting a photon (chemiluminescence):

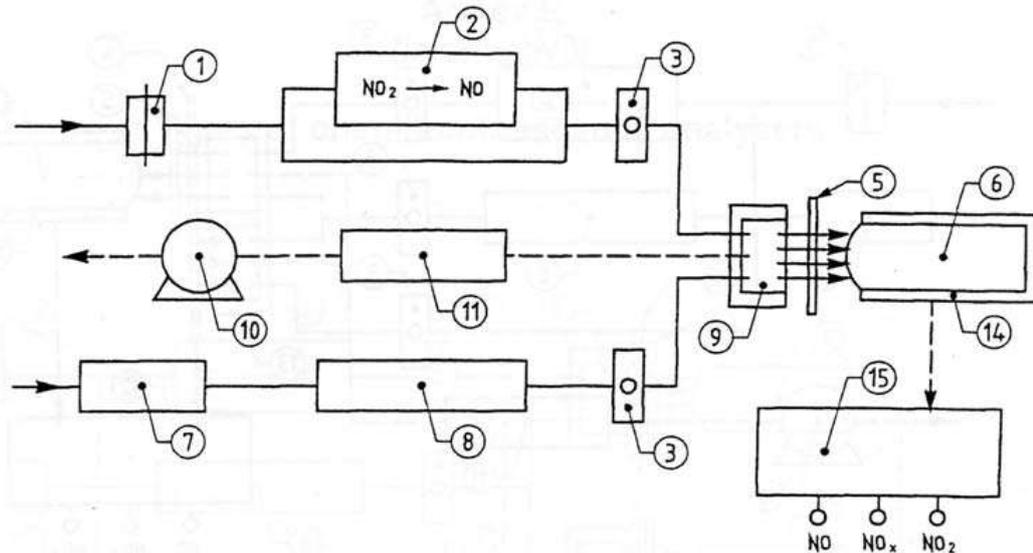


where O₂ = oxygen and hν = the energy of the photon of light emitted (h is Planck's constant and ν is its frequency).

The intensity of the chemiluminescent radiation produced depends upon the amount of NO in the sampled air. This is measured using a photomultiplier tube (PMT) or photodiode detector, so the detector output voltage is proportional to the NO concentration. The ambient air sample is divided into two streams; in one, ambient NO₂ is reduced to NO using a "molybdenum converter" (a molybdenum catalyst) before reaction. The molybdenum converter should be at least 95% efficient at converting NO₂ to NO. Separate measurements are made of total oxides of nitrogen NO_x (= NO + NO₂) and NO. The ambient NO₂ concentration is calculated from the difference (NO₂ = NO_x - NO).

The analysers are equipped with either a single or a double reaction chamber and PMT system. The main components of the analyser are shown in Figure 7-2. A solenoid valve is

used to alternatively switch between NO and NO_x (NO + NO₂) measurement typically at 15 second intervals. Ambient air is drawn through the system via a pump and drier unit. The analysers display current NO, NO₂ and NO_x concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. Either external gas cylinders or an internal permeation oven and zero air scrubber are used to provide daily automatic check calibrations.



Key

- 1 Particle filter
- 2 Converter
- 3 Flow rate controller
- 5 Optical filter
- 6 Photomultiplier tube
- 7 Drier
- 8 Ozone generator
- 9 Reaction chamber
- 10 Sampling pump
- 11 Ozone filter
- 14 Refrigerated housing
- 15 Controls NO-NO_x cycling

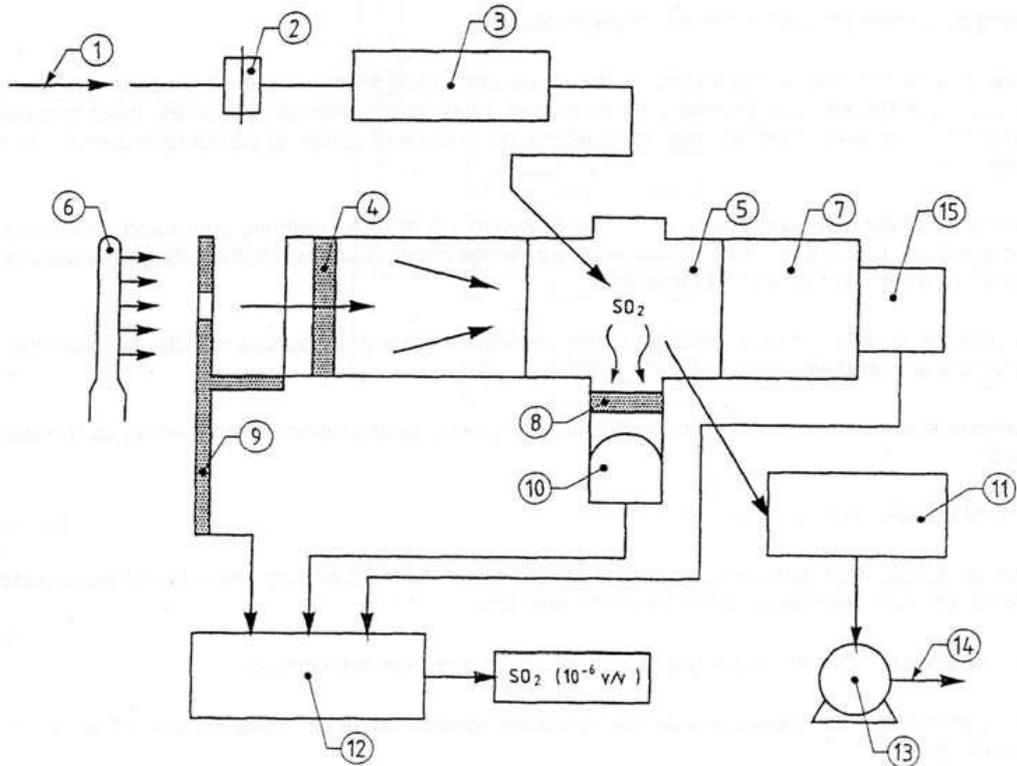
Figure 7-2 Schematic Diagram of Chemiluminescent NO_x Analyser

7.3.3 UV Fluorescence Sulphur Dioxide Analyser

Ambient air is exposed to UV light, which excites SO₂ molecules in the sample to higher but unstable excited states. These excited states decay, giving rise to the emission of secondary fluorescent radiation. The fluorescent radiation is detected by a photomultiplier tube, causing an output voltage proportional to SO₂ concentration. A permeable membrane “kicker” is used to remove interfering hydrocarbons before reaction.

These ultra violet fluorescence (UVF) analysers use a filtered UV source and PMT detection system. The main components of the analyser are shown in Figure 7-3. A UV detector is used to monitor the source radiation and compensate for fluctuations in UV energy. Ambient air is drawn through the system via a pump unit. The analysers continually display current SO₂ concentrations, and depending on the make and model of analyser other parameters can be

selected as necessary. Either external gas cylinders or an internal permeation oven and zero air scrubber are used to provide daily automatic check calibrations.



Key

- 1 Sample
- 2 Sampling inlet filter
- 3 Selective traps for interfering agents
- 4 Optical filter
- 5 Reaction chamber
- 6 UV lamp
- 7 Optical trap
- 8 Optical outlet filter
- 9 Modulator
- 10 Photomultiplier tube
- 11 Compensation pressure flowrate
- 12 Synchronous electronic amplification
- 13 Pump
- 14 Exhaust

Figure 7-3 Schematic Diagram of Sulphur Dioxide Analyser

7.3.4 IR Absorption Carbon Monoxide Analyser

Carbon monoxide (CO) absorbs infrared (IR) radiation in the 4.5 to 4.9 micrometres wavelength range ($\mu\text{m} = 10^{-6} \text{ m}$). The concentration of CO in a sample of air is measured by absorption. A reference detection system is used to alternately measure absorption due to CO in the ambient air stream, and absorption by interfering species. An infrared detector and amplification system produce output voltages proportional to the CO concentration. The concentration is derived from the Beer-Lambert relation described in Section 7.3.1 above for ozone.

The analysers used in the AURN (and throughout Scotland) are usually gas filter correlation infrared absorption analysers. They use a filter wheel to allow alternate measurement of total IR absorption, and that due to interfering species in the absorption band selected (see Figure 7-4). Alternatively, some CO analysers use the similar Non-Dispersive Infra-Red (NDIR) system. Here, differences in IR absorption between ambient air and reference gas (air with all CO removed) cause a metallic membrane in the detector to move back and forth in accordance with the alternating gas flow and CO concentration.

Ambient air is sampled using a pump unit. The analysers continually display current CO concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. An external carbon monoxide in air calibration cylinder and internal air scrubber or laser air cylinder are used to provide daily automatic check calibrations.

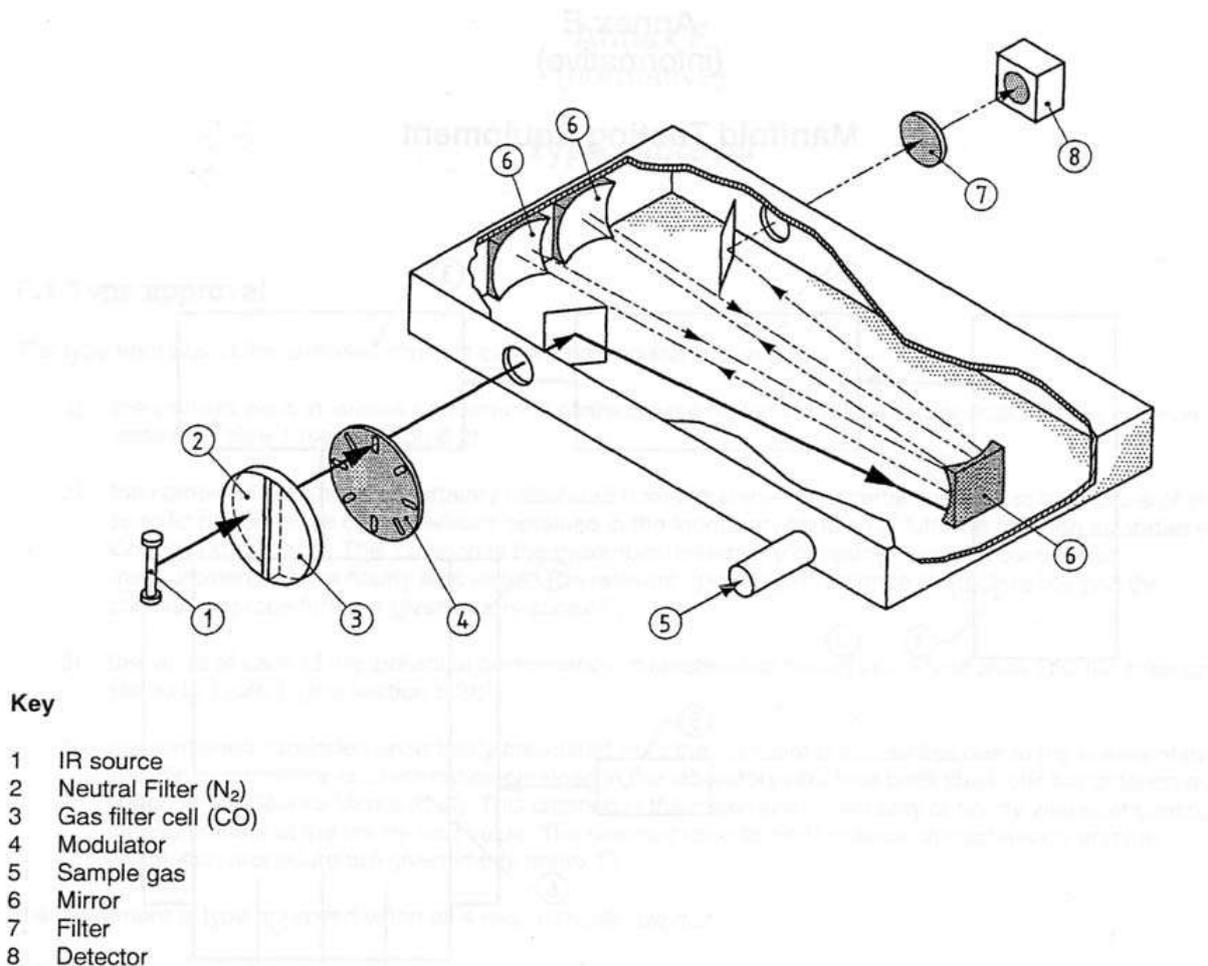


Figure 7-4 Diagram of Carbon Monoxide Analyser

7.3.5 Particulate Matter

In Scotland, two specific size fractions are monitored – PM₁₀ (the thoracic fraction), and PM_{2.5} (the high risk respirable size fraction). The same principles are used to monitor both: a size-selective inlet head or cyclone cut-off is used to ensure that only the required size fraction enters the particle analyser.

7.3.5.1 TEOM (Tapered Element Oscillating Microbalance)

All TEOM particulate analysers at AURN sites in Scotland and elsewhere have undergone modification by retrofitting with an FDMS unit. However, some non-AURN monitoring sites in Scotland still use the unmodified TEOM. This section explains the

operating principle of the TEOM, which is applicable to both the unmodified instrument and the FDMS analyser.

The tapered element oscillating microbalance (TEOM) system determines particulate concentration by continuously weighing particles deposited on a filter. The filter is attached to a hollow tapered element, which vibrates at its natural frequency of oscillation.

As particles progressively collect on the filter the frequency (f) changes by an amount proportional to the mass deposited (m):

$$m = k_0/f^2$$

where k_0 is a constant determined during calibration of the TEOM analyser.

The flow rate of air through the system is controlled using thermal mass flow controllers and automatically measured to determine mass concentration. The filter must be manually changed before the mass loading is at the maximum allowed by the system.

The TEOM analyser consists of a sample inlet head attached to the sensor unit, a control unit containing the mass flow controllers and system software and a carbon vane pump. The total flow of 16.67 litres per minute through the sampling head is divided using a flow splitter to give a main flow of 2 (or 3) litres per minute ($l \text{ min}^{-1}$) through the filter cartridge and an auxiliary flow of 14.67 (or 13.67) $l \text{ min}^{-1}$. The lower sample flow rate of 2 $l \text{ min}^{-1}$ is often selected to prolong filter lifetime, although the higher flow rate setting provides superior analyser response/noise characteristics, and is, therefore, to be recommended where possible.

The mass concentration, oscillation frequency, filter loading, flow rates, temperature and other diagnostic information can be displayed on the controller's LCD screen. In addition, mass concentration and filter loading are output to the data logger as analogue voltages or through the RS232 interface. The mass concentration is given at the reference conditions of 20°C (293 Kelvin) and 1 Atmosphere (101.3 KPa).

7.3.5.2 FDMS (Filter Dynamic Measurement System)

The TEOM analyser has a relatively high operating temperature, which is necessary to prevent condensation forming inside the unit. However, this can result in the loss of volatile components of the particulate matter, resulting in under-estimation of the ambient concentration.

The filter dynamic measurement system (FDMS) is a retrofit that can be applied to existing TEOM analysers. When added to the TEOM, the FDMS unit allows measurement of both non-volatile and volatile components of particulate matter (PM) and closely correlates with the gravimetric PM mass concentration, as measured with a reference sampler. All TEOM analysers within the AURN were retrofitted with FDMS units between 2008 and 2009.

The FDMS analyser consists of a sample inlet head attached to the FDMS unit, which is connected to the sensor unit, a control unit containing the mass flow controllers and system software, and a carbon vane pump. As with the TEOM, the FDMS samples ambient air with a flow rate of 16.67 $l \text{ min}^{-1}$ through the sampling head. Again, this flow is divided using a flow splitter to give a main flow of 3 $l \text{ min}^{-1}$ through the FDMS and filter cartridge, and an auxiliary flow of 13.67 $l \text{ min}^{-1}$.

In order to measure both volatile and non-volatile components of PM, the FDMS uses a switching valve to switch between a "base" measurement and "reference" measurement every six minutes. During the "base" measurement, the FDMS samples as a normal TEOM through the sensor unit filter and weighs the PM. During the "reference" measurement, the FDMS diverts the flow through a purge filter in order to remove all PM from the airstream and the filter is weighed again. The total PM measured during the 12-minute cycle is:

Mass Concentration = Base Concentration – Reference Concentration

During the “reference” measurement, any volatiles collected on the sensor unit filter may evaporate giving a negative mass concentration. This concentration is subtracted from the “base” measurement concentration to give the total PM present.

The mass concentration, base mass concentration, reference mass concentration, oscillation frequency, filter loading, flow rates, temperature and other diagnostic information can be displayed on the controller's LCD screen. In addition, mass concentrations, filter loading and other diagnostics are output to the data logger as analogue voltages or through the RS232 interface. The mass concentrations are given at ambient temperature and pressure.

The Local Site Operator is not required to calibrate the FDMS, but must change the tapered element filter and the purge filter as detailed the relevant site operations section. The auxiliary flow cartridge will be replaced once every six months as part of the service and maintenance procedure.

7.3.5.3 BAM (Beta Attenuation Mass Monitor)

This instrument measures mass density using the technique of beta radiation attenuation. A small beta source is coupled to a sensitive detector, which counts the beta particles. As the mass of particles increases the beta count is reduced. The relationship between the decrease in count and the particulate mass is computed according to a known relationship – the Beer-Lambert equation (previously shown in Section 7.3.1, in relation to the ozone analyser).

The BAM monitor consists of a paper tape filter located between a source of beta radiation and a radiation detector. A pump draws ambient air through the filter and the reduction in intensity of beta radiation measured at the detector is proportional to the mass of particulate deposited on the filter.

The calibration of the BAM is performed by measuring the absorption of a blank filter tape and a calibration control membrane with known absorption coefficient.

The monitor can be set to operate for ¼ to 24 hour cycles with intermediate averages if selected. The sampler will automatically take a measurement and feed the tape on if the filter loading reaches a pre-determined level.

When operated with a PM₁₀ sampling head, the monitor is set to operate at a flow rate of 16.7 l min⁻¹.

7.3.5.4 Gravimetric Sampler

This type of sampler involves the collection of particulate matter onto a filter, which is conditioned and weighed before and after sampling, and the deposited mass of PM determined.

Unlike the above types of particulate monitor, the gravimetric sampler is not truly an automatic analyser, because the filters require weighing before and after exposure.

The Partisol 2025 currently used in the AURN has been designed to meet regulatory monitoring requirements for PM₁₀, PM_{2.5} and other particulate fractions in the US, Europe and other countries. Filters are exposed for 24 hours (midnight GMT to midnight GMT) thus providing daily average concentration data. An active volumetric flow control system maintains a constant volume flow rate at a level specified by the user (16.7 l min⁻¹) incorporating a mass flow controller and ambient temperature and pressure sensors. This flow rate provides the requisite 1m³.hr⁻¹ volumetric flow for the sample head to maintain its size fraction separation. The sampler uses standard 47 mm filters. A filter storage and exchange system enables the instrument to collect daily samples for a period of up to 16 days before operator intervention is

required. The temperature of the collection filter is maintained to within 5°C of the outdoor ambient temperature.

Filters are conditioned in a temperature and humidity controlled environment for 48 hours before being weighed both pre and post exposure.

7.4 Data handling, logging and retrieval

7.4.1 Data Logging

Two methods of data logging are used. Either the analysers themselves contain data logging capabilities or, standalone loggers (which may be PCs) are used to scan the outputs of the analysers and record data. Both systems can be interrogated by remote data collection systems. The logger scans the analyser output approximately every 10 seconds and stores them as 15 minute averages in the logger memory.

The data logger is programmed to trigger the daily analyser autocalibrations using control signals which drive relays to initiate zero and span measurement cycles. Status inputs to the logger from analysers are used to monitor instrumental performance and detect error conditions.

The logger (or analyser) is connected through an RS232 serial interface to either

- an autodial-auto-answer modem operating at a data transmission rate of up to 9600 baud, or
- an IP-capable modem, for direct access via a web browser.

The datalogger is connected to Ricardo-AEA's central computer which automatically collects the logged data. This may be done via a landline connection, GPRS mobile phone connection or wireless broadband, or a combination of these. (In the case of AURN sites the data are collected by the CMCU).

7.4.2 Data Retrieval

Ricardo-AEA or the CMCU collect the data from each site on an hourly basis.

7.4.3 Adaptive/Kalman Filters

Many of the gaseous pollutant analysers use adaptive/Kalman filters. This technology is used to detect rapid changes in pollutant concentrations. The analyser changes its averaging time constantly, in order to match the changes in the profile of the ambient sample. This could affect the response characteristics of the analyser if the changes in pollutant concentration are not stable. It is important that the adaptive filtering is set in accordance with the setting used in the type approval tests carried out on the instrument, and the corresponding time constant set to 30 seconds.

7.5 Units

Analysers for the gaseous pollutants NO_x, SO₂ and O₃ provide an output in units of parts per billion (ppb) by volume (one part per billion is one part in 10⁹). Carbon monoxide concentrations (which are usually higher) are output in units of ppm (parts per million or one part per 10⁶).

Analysers for particulate matter provide an output in microgrammes per cubic metre (µg m⁻³).

For the purpose of reporting, the Air Quality Directive (2008//50/EC) requires the ambient concentration of gaseous pollutants to be expressed in units of mass concentration, i.e. microgrammes per cubic metre ($\mu\text{g m}^{-3}$), or milligrammes per cubic metre (mg m^{-3}) in the case of carbon monoxide.

The Directive also specifies that concentrations should be reported at a temperature of 20 °Celsius (293 Kelvin), and pressure of 101.3 kPa.

These requirements are therefore used within the AURN and at all other sites in Scotland.

8 Monitoring Station Infrastructure

8.1 Equipment Housing

Some monitoring stations are installed in stand alone, self-contained cabinets with an in-built air-conditioning unit, whilst others are sited in pre-existing buildings.

8.1.1 Sites installed in pre-existing buildings

Where the monitoring equipment is installed inside a pre-existing building, the LSO will need to make arrangements with relevant persons or organisations in order to ensure access to the site is available whenever necessary.

8.1.2 Self-contained Monitoring Sites

Where a number of air quality monitoring analysers are to be housed in stand-alone, self-contained cabinets, the housing should be of adequate size (typically 3.0 m x 2.0 m x 2.5 m high) to accommodate the instrumentation. Each housing is typically supplied with:

- Internal electrical wiring and fittings;
- Air conditioning;
- Shelving/racking;
- Sample intake manifold;
- Gas cylinder store;
- At least one telephone line for connection to modem and telephone handset (some sites). Many FDMS units are on mobile communications devices.
- A fire extinguisher, which must be suitable for use on electrical equipment and must be properly maintained.

The cabinet must be sufficiently robust to withstand deliberate criminal damage. As an example, a typical cabinet might be constructed of steel of 1.5 mm thickness to afford security, with the outer surface coated with glass-fibre reinforced plastic (GRP).

In Scotland, there are a number of smaller stand-alone monitoring cabinets. These compact monitoring cabinets (CMC's) are used at roadside locations where available space is an issue and usually only contain one or two analysers, typically for NO_x and PM. Each housing is typically supplied with:

- Internal electrical wiring and fittings;
- Air conditioning;
- Gas cylinder rack; and
- GSM modem.

The following information refers primarily to AURN sites directly funded by Defra and the Devolved Administrations, and housed in self-standing cabins. Some local authority-owned affiliated sites and those housed in existing buildings may differ slightly in some aspects of the infrastructure.

8.1.3 Electrical Systems

A 240V, 50Hz, 60 Amp electrical supply is provided to the housing. All internal electrical wiring and fittings conform to the Regulations for Electrical Installations (IEE Wiring Regulations) 17th Edition, 2011¹¹. Separate electrical circuits are provided for:

- Socket outlets;
- Air conditioning unit;

- Lighting; and
- Spare.

Sufficient standard UK 13 amp power sockets are available for the equipment plus spares. These are located so as to minimise accidental disturbance by site operators. The housings have internal fluorescent lighting and an emergency lighting system.

Requirements for electrical safety testing are given in section 10.1 “Electrical Safety”.

8.1.4 Air Conditioning

Freestanding monitoring station housings should be fully air conditioned in order to maintain a stable operating temperature of approximately 20-25°C within the enclosure. Typically, analysers can operate within a temperature range 15-35°C; however, in order to ensure a stable instrument response it is important to reduce the operating temperature variation to a minimum. It is also important that instrument calibrations are performed within a known, consistent and stable temperature range. Because a constant temperature must be maintained within the enclosure, doors must, whenever possible, be kept closed. The temperature control on the air conditioning unit should only need adjusting at the beginning of the summer and winter seasons.

The air conditioning unit must be able to maintain the internal temperature at 20-30°C with typically a 3 KW equipment load and an ambient temperature of up to 35°C.

The heat exchanger must be positioned where it cannot affect the ambient air being drawn in through the inlets.

8.2 Cylinder Storage

Many of the instruments are calibrated using standard gas mixtures. It is therefore necessary to keep compressed gas cylinders at the site, for this purpose. Depending on the number of analysers on site, there may be some or all of the following cylinders:

- 0.45ppm nitric oxide (NO) in nitrogen for urban monitoring stations or 0.2ppm nitric oxide (NO) in nitrogen for rural monitoring stations;
- 0.45ppm nitrogen dioxide (NO₂) in air for urban monitoring stations or 0.2ppm nitrogen dioxide (NO₂) in air for rural monitoring stations;
- 0.45ppm sulphur dioxide (SO₂) in air for urban monitoring stations or 0.15ppm sulphur dioxide (SO₂) in air for rural monitoring stations; and
- 20ppm carbon monoxide (CO) in air for urban monitoring stations. (CO is rarely monitored at rural stations).
- Zero air cylinders.

If there is a CO analyser, there also will be a 40ppm (approx) CO cylinder for the daily auto-calibration system. The calibration cylinders (and their regulators) listed above are supplied by the gas standards supplier.

The gas standards supplier will supply the largest practicable cylinder size for each site; this will usually be L40 size (i.e. 40 litre volume), or L50 if suitable. However, some sites where space is limited will be supplied with L10 size cylinders.

For safety, all cylinders **must** be supported securely during storage and use, and the cylinder storage area should be correctly labelled with the appropriate warning labels. The provision of safe cylinder storage facilities is the responsibility of the CMCU in the case of AURN sites, and of the Local Authority or site owner in other cases. Data sheets for the supplied gases are given in Appendix B (Safety Data Sheets for Gases).

8.3 Supply and Replacement of on-site gas cylinders

For AURN sites, it is the responsibility of the AURN gas standards supplier to ensure delivery of gas cylinders. For non-AURN sites, delivery of gas cylinders is usually included in a site service and maintenance contract. The gas supplier also supplies the daily CO autocal cylinders, and zero air cylinders, to some sites.

In the case of AURN sites, from the details given on the calibration spreadsheet completed by the LSO at each routine calibration visit, the gas standards supplier can see which cylinders are low and need replacing. The gas supplier will take an accredited cylinder from stock, contact the LSO and agree a convenient day and time for the cylinder delivery. It is intended that the delivery will be scheduled during a routine calibration visit. About an hour before the delivery, the driver will call ahead, so that the LSO has time to get there and receive the cylinder.

The gas standards supplier driver (or contractor) will deliver the full cylinder, and also take away any empty cylinders on the site, and return them to the owner. It is important that each cylinder, delivered or collected, is clearly recorded on the delivery note, by serial number.

In the case of non-AURN sites, the LSO will need to make their own arrangements for delivery and collection of gas cylinders and it will be their responsibility to ensure cylinders are replaced before the gas runs out.

The LSO will need to remove the gas pressure regulator from the empty cylinder and replace it on the new cylinder. Although this is a simple procedure, training is necessary to ensure it is carried out safely. This training will be provided by Ricardo-AEA where required. **Always wear safety glasses when changing cylinders and regulators, and protective footwear when moving cylinders.** The procedure is as follows:

- Ensure cylinder valve is fully turned off;
- Depressurise the regulator, by operating the purge valve on the system. The regulator will not unscrew safely when still under pressure;
- Unscrew the regulator using the spanner supplied. Note that BS4 and BS15 (all CO cylinders) are left hand threads i.e. are unscrewed anticlockwise. Left handed fittings are distinguished by notches cut in the fitting nut;
- Connect the regulator to the new cylinder, ensuring that the sealing washer is intact. When tightening the regulator, apply moderate force only; do not over-tighten;
- Close the regulator outlet valve (small knob) and gently open the cylinder valve; the inlet pressure gauge should rise. Turn the cylinder valve off, and check the regulator fitting for leaks, using "Snoop" leak detector if necessary;
- Purge the air from the regulator by allowing gas from the cylinder to flush out all air in the regulator and line through the purge valve - repeat twice. Air in the system may give false readings and cause the NO calibration gas to become unstable.
- If the system is on non-continuous operation, pressurise the regulator and close the cylinder valve. The regulator should be left in this pressurised state to ensure there is no ingress of ambient air. If the system is on continuous operation, leave the cylinder valve open, with the system under pressure.

Any problems encountered during this procedure should be reported to the gas standards supplier.

The Calibration Gas Supplier is also responsible for the gas pressure regulators. They will replace any damaged or faulty regulators: in the event that a regulator malfunctions or is damaged, please contact the Calibration Gas Supplier and they will arrange its repair or replacement.

Should there be a leak, or accidental discharge of gas, and the cylinder is empty, please phone **Air Liquide UK Ltd, (01737 462695)** for emergency advice.

For routine gas replacement, please contact Air Liquide directly on **01675 468901**. If the current cylinder is completely empty and you have not been contacted regarding replacement, please contact QA/QC Unit for advice.

8.4 Sampling System

The following applies only to sites fitted with a sampling manifold.

To ensure that the measurements made by the analyser are representative of the pollutant concentrations in the surrounding atmosphere, the sampled air must not be changed in any way by the process of transferring it from the inlet to the analysis cell of the instrument. For this reason, a manifold sampling system is used at most sites. The manifold is constructed from an inert material such as glass or Teflon (PTFE). The sample probe (inlet) extends vertically through the roof of the housing to a height of at least 0.5 m above the roof, thereby giving 360° unrestricted airflow. The location of the sample inlet is such that ambient sampling is not influenced by gas discharges from the instruments, calibration systems or adjoining installations such as the air conditioning unit. A simple rain hood is used to prevent water from entering the manifold.

The sampling manifold system has the following design specifications:

- Constructed of inert material;
- Inlet protection against rain, insects or large particulate matter;
- Demountable for cleaning;
- Sample residence time of less than 5 seconds between the inlet to the manifold and the inlet to the analysers;
- Minimum total flow through the manifold of 20 litres/minute;
- Pressure drop in the manifold system not exceeding 0.25" water; and
- Fitted with outlets for ¼" PTFE tubing for connection to analysers.

An independent suction motor is connected to the manifold to draw in a large excess volume of ambient air from which each analyser samples; the excess air is vented out of the hut. Typical specifications of the air-sampling manifold are given in Table 8-1.

Table 8-1 Typical specifications for air sampling manifold

Parameter	Specification
Manifold material	Glass with Teflon fittings
Length	2500 mm
Internal Diameter	25mm
Flow rate	3.2* metres/second
Residence time	0.8* seconds
Pressure drop	0.25* ins H ₂ O
Blower speed	3030 rpm

Although condensation in the manifold is unlikely to be a problem in the ambient conditions prevailing in the UK, a water trap has been included. The manifold is not heated, as this is usually only required in very high temperature/humidity operating conditions.

Ambient gas analysers are individually connected to the sample manifold via 1/4" PTFE (or equivalent) tube. The length of this tube is kept as short as possible and is usually between 1-2 metres. A PTFE filter is held in a PTFE-coated filter holder situated on the front panel of the instrument rack, in order to protect each instrument from ingress of particulate matter. (Another filter is situated at the back of each instrument, but this will only be changed at 6 monthly intervals by the instrument service technicians or QA/QC Unit. If, however, this is the only filter, it will need to be changed by the LSO during routine maintenance/calibration).

Increasingly, analysers sample ambient air through a single 1/4" PTFE tube from the analyser through the roof to a weatherproof inlet funnel. This arrangement has been put in place to minimise sample loss to dirty manifolds and to make maintenance (cleaning and replacement) much easier. Sites in the AURN have been upgraded, usually by extending tubes through the existing manifold system and sealing the ends to prevent room air contaminating the sample inlet. LSOs should check occasionally to make sure that there is no possibility for room air to contaminate the inlet.

8.5 Sample Inlet for Particulate Analyser

A separate sample port (approx 4 cm in diameter) in the roof of the housing is used to feed a sampling tube from the internal TEOM/FDMS/BAM sensor unit to the PM₁₀ inlet mounted externally on the roof. Because of the TEOM/FDMS measurement method, it is important for the sensor unit to be mounted on a sturdy platform which is independent from other activities, free from external vibration and, where practicable, isolated from mechanical noise.

Gravimetric samplers (Partisol 2025) are self contained units located externally of the monitoring enclosure.

8.6 Telephone Lines

There will be at least one telephone line to each site, but these may be fixed landline or mobile GPRS devices. Some sites may have a mixture of both. At some sites, an additional phone line may be installed for the gravimetric PM (Partisol) sampler.

8.7 Modems

The site modem is used for data communication between the remote central station and the site logger via the site telephone line. The modem requires:

- Mains power;
- A connection to the site telephone wall socket, or antenna in the case of mobile communications devices;
- a connection to the logger or analyser port; and
- Correct programming.

The modem program is held in a battery-backed store and should not require re-entry except after a prolonged power cut. Where sites have a history of modems locking up, a timer device may be used to reset it daily.

8.8 Auto-Calibration Facilities

The provision of a daily automatic calibration check on site analysers is an essential part of the overall monitoring quality assurance programme. These performance checks enable rapid remote detection of system faults via the telemetry system, and thereby minimise data loss through instrument malfunction.

The automatic calibration facility provides a zero and span check initiated either directly by the analyser, or by the data logger. The data recorded during the calibration are flagged and readily scrutinised by the Management Unit for evidence of faults. The daily calibration cycle is timed to minimise loss of ambient data. Details of the methods and auto-calibration standards used are given in section 9, "Principles of Calibration".

9 Principles of Calibration

In order to ensure the data are fit for purpose, the monitoring instruments (analysers) must be regularly calibrated. In the case of analysers for gaseous pollutants, this is done using traceable transfer gas calibration standards.

A three-tier system of calibration and analyser test procedures is used. The major parts of this system are as follows:

1. Daily automatic Internal Zero and Span (IZS) checks. This is a daily automatic calibration, which provides information on instrument response drifts, and act as a daily check on instrument performance. Results should not be used for data scaling, unless calibration gas is used for IZS.
2. Fortnightly manual calibrations (four-weekly at non-traffic sites). These are performed by the LSO, are used by the CMCU to scale raw pollution data from the instrument into meaningful concentration units. Instrument drifts are fully quantified, by calibrating analysers manually with documented and traceable calibration gas standards.
3. Network intercalibrations: three monthly for ozone, six monthly for all other pollutants. These exercises, performed by Ricardo-AEA, ensure that measurements from all sites are intercomparable. The intercalibrations also act as an independent audit of the system performance at each monitoring site. In this way, any site-specific problems which may have developed and remained undetected are fully quantified. In some cases, such as for ozone analysers, the data are directly scaled according to the results obtained from the network intercalibration.

This section describes the automatic calibration systems and techniques, and the gas standards to be used by local site operators in their fortnightly site calibrations. Checklisted operational procedures for the fortnightly instrument calibrations are provided in Part B of this manual. The intercalibration exercises performed by Ricardo-AEA are not described in detail in this manual but a summary is included in Part B.

9.1 Daily Automatic IZS Check Systems and Standards

Daily automatic analyser checks provide valuable information on the routine performance of analysers and any long term response drifts. The checks, consisting of two point zero and span checks, are controlled automatically by the data logger or analyser software, and do not normally need any adjustment. These checks usually take place around midnight.

The principles of operation of automatic internal zero and span (IZS) devices are given below for the different types of analyser. Some systems operate daily, whilst others may operate every two or three days.

9.1.1 NO_x Analyser

Zero air (that is, pure air free from pollutants) is passed into the reaction cell, to provide a check on the instrument's zero response. The zero air may be generated in one of two ways, depending on the type of instrument:

- by passing ambient air through purafil and charcoal scrubbers, or
- from a cylinder containing pure "zero air".

Where scrubbers are used to produce the zero air, these have a finite life. Eventually over time they would become exhausted, and the quality of the zero air would degrade. Using a zero air cylinder can give more consistent zero readings.

To check the "span" NO₂ response (that is, the response to a high concentration near to the maximum that the instrument can measure), a "span gas" is used. This is generated by an NO₂

permeation tube. Zero air at a constant flow rate is passed across the tube which contains a quantity of pure liquid NO₂. The tube is enclosed in an oven maintained at constant temperature. Provided the flow rate and temperature are kept constant, the amount of NO₂ which permeates from the tube into the air stream will be constant. The gas mixture thus produced then passes into the reaction cell to provide a span calibration response.

Alternatively, on some newer analyser systems the NO or NO₂ calibration gas standard is also used for the autocalibration check.

9.1.2 SO₂ Analyser

Zero air (either from a cylinder of pure zero air, or generated by passing ambient air through a charcoal scrubber) is passed through the reaction cell in order to test the instrument's zero response.

The span gas is produced in a similar way as for the NO_x analyser, except a permeation tube containing liquid SO₂ is used in the oven. Alternatively, on some analyser systems the SO₂ calibration gas standard is also used for the autocalibration check.

9.1.3 Ozone Analyser

Zero air is produced by an internal zero scrubber inside the analyser, and passed through the reaction cell.

Span gas is produced by the action of UV light in an ozone generator on the same zero airstream to produce ozone.

9.1.4 CO Analyser

Zero air (either from a cylinder of pure zero air, or generated by passing ambient air through a heated palladium/alumina catalyst) is passed through the reaction cell in order to test the instrument's zero response.

Span gas is supplied from a dedicated CO cylinder attached to the IZS span inlet on the equipment rack.

9.1.5 Zero Checks on Particulate Analysers

Because it is difficult to generate an air stream containing a specific concentration of particulate matter of the relevant size fraction (PM₁₀ or PM_{2.5}), it is not possible to provide a system to carry out daily automatic calibrations on the particulate analyser.

However, it is possible to carry out a zero check, and from time to time, PM₁₀ or PM_{2.5} monitoring instruments may be subject to zero checks by Ricardo-AEA. This involves fitting a filter on the inlet in place of the PM head for a period of a few days, so that the instrument samples particulate-free air over this period. LSOs may be asked to return to site to remove the filters and replace the PM head and (in the case of PM_{2.5} analysers) the sharp cut cyclone, as appropriate.

9.2 Transfer Standard Calibration Systems

As the fortnightly (or four-weekly) manual zero and span calibrations are used to scale the raw data into meaningful units, it is important that the calibration gases used are both stable and traceable to primary standards. The standard gas mixtures used are sometimes referred to as "on-site transfer standards". The following calibration gases are used:

- Nitrogen oxides: Nitric oxide (NO) in nitrogen.
- Sulphur dioxide: Sulphur dioxide (SO₂) in air.
- Carbon monoxide: Carbon monoxide (CO) in air.

A second span check is undertaken on the nitrogen oxides analyser using a nitrogen dioxide (NO₂) in air mixture.

The gas standards supplier is responsible for supply and calibration of the standard gas mixtures. These standards are maintained and used the LSO, as specified in this manual.

At every calibration visit, the LSO performs a two-point calibration. This involves determining the response of the analyser to the following:

1. A sample of air from which the pollutant to be determined has been removed (zero response)
2. A sample of air in which the pollutant to be measured is present, at an accurately known concentration (span response).

Data scaling factors are determined from these responses, and are used to convert raw voltage data into concentration units.

Ricardo-AEA verifies the integrity of on-site standards every six months, during the intercalibration exercise. These network intercalibrations employ an independent standard to determine zero and span response. This is done in order to quantify any change (drifts) in on-site calibration standards which may have occurred during the preceding six-month period. If standards are found to have undergone significant drifts, these will be replaced.

9.2.1 Production of Zero Air

Two methods of zero air production are used. At some sites a cylinder of zero grade air is used. This is now the preferred method. At others, zero air is produced by catalytically removing pollutant species from a sample airstream. For the second method, Ricardo-AEA has developed a zero air generator which consists of the following components.

1. Compressor to produce air sample.
2. Water drain to remove liquid water.
3. Needle valve to regulate airflow.
4. Silica gel to remove water vapour.
5. Hopcalite to remove CO
6. Purafil to remove NO
7. Activated charcoal to remove O₃, NO₂ and SO₂.
8. A particulate filter on the system outlet to ensure that no particulate matter, especially scrubber material, is "blown" into the analysers.

A diagram of the zero air generator is given in Figure 9-1.

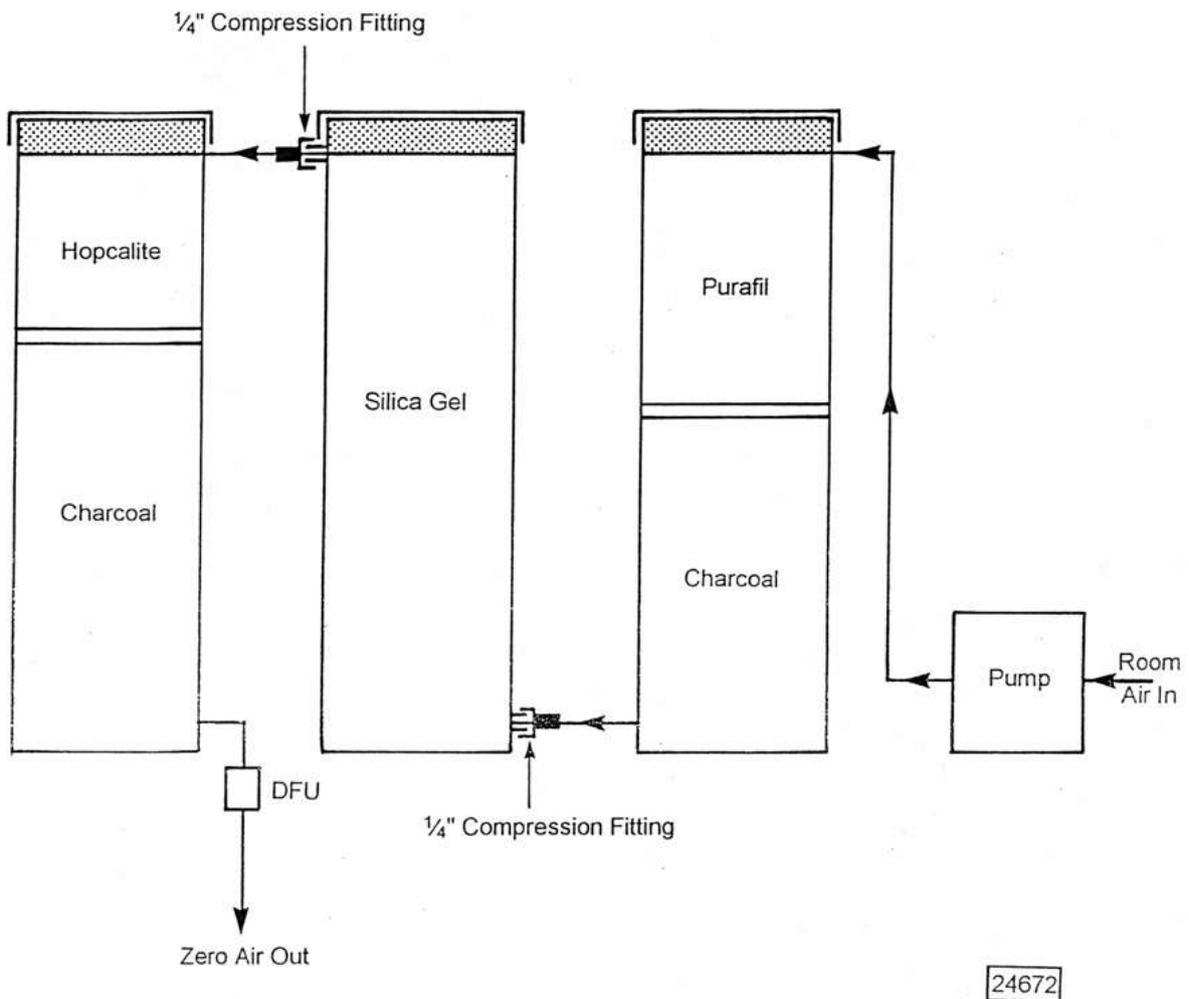


Figure 9-1 Zero Air Generator

Some sites use an "active" system, where air is forced through the scrubbers; others use a "passive" system in which air is drawn through the scrubbers by the analyser. The active system has the following advantages:

- the system is far less susceptible to leaks due to the positive pressure caused by the compressor along the flow path.
- the differences between output pressure and atmospheric pressure, i.e. overpressurisation in active and underpressurisation in passive systems, can be better regulated and controlled.

The consumable components in the zero air generator are changed routinely at six monthly intervals as part of the service. This will only be done after comparison with transfer zero standard at the QA/QC audit. The zero transfer standard used by Ricardo-AEA for these comparisons will previously have been compared to certified zero air cylinders. This is carried out by Ricardo-AEA and is not the responsibility of the LSO.

9.2.2 Production of Span Calibration Gases

The gas standards supplier supplies gas cylinders containing calibration gas mixtures of NO, NO₂, SO₂, and CO. These cylinders are purchased from a supplier which has demonstrated compliance with all relevant quality control procedures in the preparation of gas mixtures.

The cylinders are calibrated, prior to being installed on-site, at the gas standards supplier's gas calibration laboratory. To ensure traceability of measurements, all calibration gas standards are required to be calibrated by an organisation accredited to the requirements of ISO17025 by the United Kingdom Accreditation Service (UKAS).

Each cylinder is supplied with its own regulator. This minimises the possibility of ambient air or other calibration gases getting into the cylinder and contaminating the standard gas mixture inside. Therefore, regulators must not be removed from the cylinder under normal operating circumstances. Instructions on how to open and close cylinder/regulator supplies must be followed strictly (see the calibration instructions in the appropriate section of Part B for the instruments at the site).

Cylinders of compressed gas can be hazardous. They must be securely strapped to suitable supports to prevent the risk of them falling; this is especially important as regulators are to be left connected.

For all analysers, the span checks test the instrument's response to a concentration at the upper end of its operating range. This avoids introducing errors into the data scaling factors as a result of inconsistencies in analyser range ratios.

As there is, at present, no reliable and proven system for performing simple on-site two point calibrations on O₃ and particulate analysers, all calibrations which produce data scaling factors for these instruments will be carried out by Ricardo-AEA.

9.3 Utilisation of Calibration Data in Producing Scaled Pollution Data

As explained above, the two point calibration quantifies the analyser "zero" and "span" response. As the analyser gives an output signal which is recorded and averaged by the data logger, it is vital that zero and span factors are also taken as readings from the data logger (where used) and not solely by reading the instrument display.

The zero response, V_z , is the response in volts of the analyser when the pollutant species being measured is not present in the sample airstream. The span response, V_s is the response, again in volts, of the analyser to an accurately known concentration, c , in ppb, (parts per billion or 10^{-9}) or ppm, (parts per million or 10^{-6}) for CO, of the pollutant species. Both the zero and span responses will be taken on the concentration range at which the instrument normally operates. Instrument zero response and calibration factors are then calculated using these data as follows:

$$\text{Instrument zero response} = V_z$$

$$\text{Instrument span response} = V_s$$

$$\text{Instrument calibration factor, } F = c/(V_s - V_z)$$

Ambient pollution data are then calculated by applying these factors to logged voltage output signals as follows:

$$\text{Pollutant concentration} = F(V_a - V_z)$$

where V_a is the recorded voltage signal from the analyser sampling ambient air. Application of calibration data in this way assumes that the instrument response is linear over the whole concentration/voltage range in use. The linearity of the instrument is checked at six-monthly intervals by Ricardo-AEA.

The data scaling procedures detailed above are used for pollutants for which reliable transfer standards exist. In the case of ozone, however, the UV measurement technique is inherently more stable than the production of ozone concentrations in the ambient range. The fortnightly calibration of ozone analysers is therefore not used to produce data scaling factors.

Ambient NO/NO_x/NO₂ data is scaled from the calibration of the NO and NO_x channels of the NO_x analyser, using the NO in nitrogen transfer standard. This will directly output NO and NO_x concentrations, with the NO₂ concentration being given by:

$$\text{NO}_2(\text{ppb}) = \text{NO}_x(\text{ppb}) - \text{NO}(\text{ppb})$$

An NO₂ in air calibration mixture will, however, be used as a cross-check on the NO_x channel calibration and to ensure that the catalytic converter in the instrument efficiently reduces NO₂ to NO.

Conversion of concentrations to units of $\mu\text{g m}^{-3}$ or mg m^{-3} at the stated temperature and pressure of 20°C and 101.3 kPa may subsequently be undertaken. Details of the relevant conversion factors are given in Appendix D.

Exact (instrument-specific) procedures for instrument calibration are detailed in the relevant sections of Part B.

9.4 Use of Calibration Data over Extended Time Periods

Many air pollution analysers undergo some form of drift in sensitivity over time. This may be due to ageing of components such as photo-multiplier tubes, degradation of catalytic scrubbers, (e.g. ozone scrubbers), or drifts in electronic components.

It would be possible to routinely adjust instrument sensitivities to align the instrument with the on-site transfer standard. For the following reasons, however, such routine adjustments are not done in the AURN (and therefore not in the Scottish monitoring network):

1. As all instruments in the network are to be checked on a fortnightly or monthly basis, any drifts will be easily quantified by consideration of the calibration history of the instruments. It is most important, therefore that this calibration history is not destroyed.
2. The transfer standards themselves may drift from their original value. If this happened, and both the analyser and on-site standard were drifting, it would be impossible - having altered the analyser response - to produce a final validated data set. Drifts in the on-site standard will be quantified by QA/QC Unit intercalibration techniques at six monthly intervals.
3. Routine instrument adjustments may lead to unreliable data being produced as the instrument stabilises. Stabilisation periods may take many hours from the time of the adjustment and, with sites being calibrated/adjusted fortnightly or monthly, this could lead to an appreciable proportion of data being degraded in quality.

Calibration results therefore, serve only to scale ambient data. They are not be used to routinely adjust analyser response factors.

As the instruments will not be adjusted, the instrument zero response and calibration factors - Vz and F - will have to be updated in the CMCU and QA/QC Unit data processing system on a regular basis, following each calibration. For this reason, calibration records must be e-mailed to the CMCU and QA/QC Unit immediately after each on-site manual calibration.

9.5 Calibration During High Pollution Episodes

In order to prevent losing valuable pollution data, it is important to avoid calibrating the analysers during high pollution episodes.

Before starting the calibration, the LSO should check the ambient concentration displayed on the instrument's front panel. If any concentrations are above, or close to, the trigger levels given for each pollutant in Table 9-1, please do not proceed with the calibration for that pollutant. (It is alright to carry out the calibrations for the unaffected pollutants).

Pollutant episodes often last several hours or even days. To save a wasted journey, it may be useful to check on UK-AIR that the pollution episode appears to be over, before returning to the site to carry out the calibration that was delayed.

Table 9-1 "Trigger concentrations" indicating a Pollution Episode may be in Progress

Pollutant	Trigger Level (exceeded for ~ 1 hour)
O ₃	> ~70 ppb
NO ₂	> ~ 75 ppb
SO ₂	> ~ 90 ppb
CO	> ~ 5 ppm
PM ₁₀	> ~ 100 µg/m ³

10 Health and Safety

A separate document, “*UK Air Quality Monitoring Networks Health and Safety Guidance*”² has been produced, to provide consistent guidance for Defra contractors regarding health and safety (H&S) at air quality monitoring sites in the UK (the AURN and other networks). This forms the definitive guidance on health and safety, and is available at <http://aurnhub.defra.gov.uk/hnsdb/files/UK%20Air%20Quality%20Monitoring%20Networks%20Guidance%20Issue%206%20060612.pdf>. Local Site Operators are referred to this document.

This section has been included in the LSO manual to offer guidance on health and safety aspects of the duties of an LSO. However, it is included for *guidance only*: it is the responsibility of the LSO to put in place procedures for safe working, and to ensure that these are followed.

National safety regulations apply, in particular the Management of Health and Safety at Work Regulations (1999)¹² and the Health and Safety at Work etc. Act (1974)¹³. The latter applies to all persons connected with work done by the network, whatever their organisation. The Act requires that all employees while at work shall:

- “Take reasonable care for the health and safety of himself and other persons who may be affected by his acts or omissions at work; and”
- “As regards any duty or requirement imposed on his employer or any other person by or under any of the relevant statutory provisions to co-operate with him so far as is necessary to enable that duty or requirement to be performed or complied with.”

Employers shall conduct their work:

“In such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety.”

Also, as far as their own employees are concerned, employers shall:

- Provide and maintain “*plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health.*”
- Arrange “*for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;*”
- Provide “*such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of his employees;*”
- “*So far as is reasonably practicable as regards any place of work under the employer’s control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without risks.*”
- Provide and maintain “*a working environment for his employees that is, so far as is reasonably practicable, safe, without risks to health and adequate as regards facilities and arrangements for their welfare at work.*”

For further information on site safety please contact the relevant Management Unit (Ricardo-AEA, and the CMCU in the case of AURN sites).

10.1 Health and Safety Responsibilities of Local Site Operators

The specific Health and Safety responsibilities of LSOs are as follows:

- Review risks and prepare a risk assessment for work carried out at each site, including transport to and from the site and the movement of gas cylinders into the site. (Risk assessments should be reviewed and updated at least annually).
- Ensure actions are taken to mitigate the risks resulting from the risk assessment (e.g. purchase of safety equipment, display of H&S information at site, staff training and communication).
- Use the health and safety database to check safety status of the site before each visit.
- Carry out a 'take two' risk assessment on arrival at the site. A 'take two' risk assessment is a short and simple visual check of the key risks to review whether it is safe to carry out work.
- Notify the QA/QC Unit and the Ricardo-AEA Project Health and Safety coordinator of any new or site specific risks.
- Follow advice from the QA/QC and the Ricardo-AEA Project Health and Safety Coordinator.
- Ensure contact details for your organisation are up to date and sent to the Network Managers
- Other responsibilities as specifically identified in the LSO's contract.
- Comply with health and safety laws and regulations (see <http://www.hse.gov.uk>.)

10.2 Risk Assessments

Each monitoring station should have an up to date risk assessment that covers, in detail, all health and safety risks associated with the site. This risk assessment should be **reviewed and updated at least annually**. Risk assessments should include, but are not necessarily limited to the following:

- Fire hazards
- Lone working
- Driving and travel
- Slips, trips and falls
- Manual handling
- Use of electrical tools and equipment
- Use of gas cylinders
- Substances hazardous to health (COSHH)
- Site-specific risks (animals, water, machinery, personal safety etc)
- Weather

Risk assessments are specific not only to the monitoring site but also to each organisation, dependent on the organisation's equipment, staff, internal health and safety procedures, and responsibilities for work at the site. Therefore, each organisation should have a risk assessment for every site that they attend or manage.

It is a good idea to use a standard monitoring site risk assessment as a starting point but the risks at each site will be different and therefore it is necessary to consider each site separately and generate a risk assessment for each site individually.

Further information, and an example risk assessment (which can be used as a template) is given in the "UK Air Quality Monitoring Networks Health and Safety Guidance"².

10.3 Electrical Safety

The electrical supply to the monitoring station, and all fixed circuits, must be fully tested at least every five years. Testing of portable electrical appliances (PAT testing) must be carried out annually. At Local Authority sites, the individual site owners are responsible for making suitable arrangements for safe operation of electrical equipment and to comply with the law. These tests are usually carried out by the Equipment Support Unit. Electrical safety inspections of all monitoring equipment are undertaken on a regular basis during site servicing.

At AURN sites owned and fully funded by Defra and the Devolved Administrations, it is the responsibility of the CMCU to arrange both fixed circuit testing and annual PAT testing. Where Local Authority-owned equipment is installed at an otherwise Defra/DA's funded site, it is the owner's responsibility to arrange electrical testing of the equipment not covered by Defra funding.

10.4 Safety with Compressed Gas Cylinders

10.4.1 Safe Storage of Gas Cylinders

All cylinders **must** be supported securely during storage and use at all times. They should be strapped to a suitable support and never left unsupported. This is especially important because the regulators are left in place.

The cylinder storage area should be correctly labelled with the appropriate warning labels. The provision of safe cylinder storage facilities at AURN sites is the responsibility of the CMCU or Management Unit. At other sites it is the responsibility of the site owner.

Safety data sheets for the supplied gases are given in Appendix B.

10.4.2 Safety when Changing Cylinders

When an empty cylinder is replaced, the LSO will need to remove the gas regulator and replace it on the new cylinder. Although this is a simple procedure, compressed gas can be dangerous, so Ricardo-AEA will provide training to ensure it is carried out safely. **Always wear safety glasses when changing cylinders and regulators.**

As well as the potential hazards associated with compressed gas, the cylinders are heavy. Take great care when handling cylinders, which should not be lifted.

10.5 Work at Height

PM analysers have an inlet head that requires periodic cleaning. The LSO will need to use steps or a ladder to remove the inlet head for cleaning, and to replace it afterwards. Such work is covered by the Work at Height Regulations (2005)¹⁴.

Local Site Operators are referred to the Health and Safety Executive's guidance on safe use of ladders which can be found at <http://www.hse.gov.uk/pubns/indg402.pdf>.

10.6 Lone Working

It is the LSO's responsibility to implement safe working procedures. These should include precautions to minimise the risks associated with lone working (in circumstances where it is necessary for an LSO to visit a monitoring site alone). The following precautions should be included (although this is not an exhaustive list):

- Ensure someone at your office knows where you are going and when you will be expected back.
- Take a mobile phone with you: ensure it is charged and that there is someone available to call for help if necessary.
- However, avoid carrying any other valuables.
- Carry out site visits during daylight.
- If you feel threatened (e.g. by a member of the public acting suspiciously or behaving in a hostile way), leave and re-schedule the visit.
- Keep in regular contact with a colleague at your office if you are out for a long period or are visiting several sites.

10.7 Other Hazards

10.7.1 Indicating Silica Gel

The indicating silica gel found in zero air scrubbers should all be of the orange type. There should be no blue silica gel at any AURN sites: this was phased out some time ago, as the blue colour (cobalt chloride) is considered harmful. It is possible there may be some Scottish sites still using blue silica gel. If you find any blue silica gel, it must be disposed of as hazardous waste.

The dust from silica gel is hazardous. There should normally be no need to handle silica gel. However, if any silica gel is spilt, (for example, if a zero air scrubber is broken) do not attempt to deal with it but contact the ESU.

10.7.2 Health and Safety Considerations for the Met One BAM

The BAM contains a small, sealed radioactive source of beta radiation (carbon 14, or ^{14}C). This is the source of the beta particles used in the measurement process. Carbon 14 is a radioactive material and is therefore dangerous if it gets *inside* the body (if swallowed, inhaled or absorbed through the skin). That is not a risk here, because the source is sealed and safely contained inside the BAM. For this reason, **you must not attempt to access, modify or remove the BAM's sealed beta source for any reason.**

It has been found that, when the door of the BAM's case is open, a detectable amount of beta radiation emerges from the BAM, through the slit between the tape and the source, probably having been scattered by the tape and the material on it.

Beta radiation consists of fast moving electrons. The beta radiation from ^{14}C is of relatively low energy; it cannot penetrate through the case of the BAM, can only travel around 22 cm through air, and – most importantly - cannot penetrate even the outer layer of your skin.

However, it is known that direct exposure of the lens of the eye to beta radiation can increase the risk of developing the eye condition of cataracts (where the lens becomes opaque). This is a known risk for people whose eyes are directly and frequently exposed to beta radiation (such as health professionals regularly carrying out certain medical imaging procedures), and there exists an occupational exposure limit specifically for the lens of the eye.

When carrying out BAM maintenance tasks such as nozzle cleaning or tape changing, the operator will have the door open and may have their eyes close to the tape slit. While it is currently our understanding that any risk is very small, (because of the low energy of the beta radiation, and because such tasks are infrequent and do not take long), as a precaution we are recommending that safety glasses are worn when carrying out such tasks. Beta particles will not be able to pass through the plastic material they are made of.

We are therefore making the following recommendations to Local Site Operators and others who carry out work on a BAM1020 that involves opening its door:

1. We remind you **not to attempt to access, modify or remove the BAM's sealed beta source for any reason.**
2. It is recommended (but not essential) to **wear safety glasses when working on the BAM 1020 with its door open.** As well as offering more than adequate protection for the extremely small risk of any long-term eye damage from exposure to radiation the beta source, this will also minimise any other risk of eye injury from other maintenance activities such as cleaning nozzles etc.

Safety glasses are already provided at All SAQD monitoring stations that have BAMs (because they are necessary for other work at the sites).

Part B – Site Operational Procedures

The following sections (11-24) contain the details of the procedures LSOs will need to carry out at each routine site visit.

These procedures are different for different types of monitoring instrumentation. You will need to follow the procedures applicable to the type of instrument at the site(s) you look after.

At many sites, all the gaseous pollutant analysers will be of the same make. However, this is not always the case, so you may need to refer to more than one section within Part B.

Each type of particulate analyser (TEOM, FDMS and BAM) has been given a separate section here. If your site contains a particulate analyser as well as analysers for gaseous pollutants, please refer to the relevant particulate analyser section as well.

The instrument-specific sections are followed by information on the following:

- The Calibration Sheet (which is used for all types of instrument)
- Site Audits and Intercalibrations
- Non-routine Site Visits
- Troubleshooting.

11 API Equipment - Site Operational Procedures

11.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

1. Pre calibration checks;
2. Changing the particulate monitor filter (if applicable);
3. Calibration of analysers;
4. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Procedures associated with particle analysers (PM_{2.5} or PM₁₀) are covered in a separate section.

Calibration procedures differ from instrument to instrument, but the basic principle is common to all analyser types, with the exception of the particulate analyser. As described in Section 9 of the main document (Principles of Calibration), weekly calibrations take the form of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC unit, in combination with the 6 monthly instrument intercalibration and servicing exercise.

Each analyser must be calibrated exactly *as found*. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

There may be a mixture of different makes of analyser on site, and reference to other sections of the LSO Manual may be necessary. The instructions for any particle analyser (TEOM, FDMS, Partisol or BAM) will also be found elsewhere.

Acting only on advice from the QAQC or ESU, instrument adjustments may be performed to optimise analyser sensitivity. If such adjustments are found to be necessary, the instrument will be recalibrated after a suitable initial stabilisation period typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours and hence, ideally the instrument should be recalibrated after say a further 24 hours. The QAQC will advise on this. It is not anticipated that instrument adjustments of this sort will occur frequently.

The following sections of manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made. However, the sequence in which zero and span calibrations are performed is not critical.

The exact specification of the calibration systems at each monitoring may differ slightly. The control of gas delivery into the analysers may use an excess flow meter, or an in-line critical orifice restricting the pressure. Training in the use of these systems is provided by the QA/QC Unit as required.

11.2 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of each analyser and the chart trace to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O₃ >~70 ppb, NO₂ >~75 ppb, SO₂ >~90 ppb and CO >~5 ppm). If an episode is occurring, phone QAQC before proceeding any further.
2. Take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the toolkit at the site is complete.

11.3 Pre-calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibrationsheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QAQC if any are not correct before proceeding with the calibration.

11.3.1 CO Analyser

The API 300 CO analyser has a 2-line alphanumeric display and 3 status LED display lights on the front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", with the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on pre-calibrationchecklist.
2. If the red FAULT light is on, a warning message has been generated and is still active; due to some instrument operating parameter falling outside preset ranges. If the FAULT light is on, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on pre-calibrationchecklist. When all parameters on the pre-calibrationchecklist have been noted, press the test button once more. This will display the current time on the instrument display.

11.3.2 NOx Analyser

The API 200 NOx analyser has a 2-line alphanumeric display and 3 status LED display lights on the front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", with the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on pre-calibrationchecklist.
2. If the red FAULT light is on, a warning message has been generated and is still active; due to some instrument operating parameter falling outside preset ranges. If the FAULT

light is on, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.

3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on pre-calibration checklist. When all parameters on the pre-calibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

11.3.3 SO₂ Analyser

The API 100 SO₂ analyser has a 2 line alphanumeric display and 3 status LED display lights on front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on pre-calibration checklist.
2. If the red FAULT light is on, a warning message has been generated and is still active; due to some instrument operating parameter falling outside of the preset levels. If the FAULT light is on, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on pre-calibration checklist. When all parameters on the pre-calibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

11.3.4 Ozone Analyser

The API 400 O₃ analyser has a 2 line alphanumeric display and 3 status LED display lights on front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on pre-calibration checklist.
2. If the red FAULT light is on, a warning message has been generated and is still active; due to some instrument operating parameter falling outside of the preset levels. If the FAULT light is on, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on pre-calibration checklist. When all parameters on the pre-calibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

11.3.5 Air Sampling Manifold (where fitted)

Record the following checks on the pre-calibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the rack and that these connections are secure and leak-tight.

11.3.6 Modem (where fitted)

Check that the AA, TR and MR red lights are displayed on the modem and record on the pre-calibration checklist.

11.3.7 Zero Air Generator

Check the condition of the scrubbers, two of which are self indicating; silica gel turns from orange to clear and purafil from purple to brown as it becomes exhausted. A diagram of the zero air generator has been shown earlier, in Figure 9-1.

1. Check that at least 25% of the silica gel is still orange. If less than 25% of the silica gel is orange please contact the QAQC: **do not change the silica gel yourself as it can give off a harmful dust.**
2. Check that at least 25% of the purafil is still purple. If less than 25% of the purafil is purple, note on the calibration record sheet, but continue with calibration.
3. Check that all connections are secure and tight.

11.3.8 Changing the Silica Gel

It is no longer necessary for the LSO to change the silica gel. This is carried out by either the QA/QC unit or the ESU.

11.3.9 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform QAQC before proceeding with calibration. If all correct, proceed to the next section.

11.4 Analyser Calibration Procedure

Results of the calibration will be taken from both the data logger display (if present) and the instrument's display and recorded on the calibration record sheets.

When closing the gas cylinder valves, care should be taken not to overtighten the valves on the gas regulator. Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

In order to have a full and complete set of instructions for each analyser, instructions for opening gas cylinder valves are contained within the calibration procedure for each analyser. However, when all analysers are being calibrated, it will be advantageous for all cylinders to be opened at the same time, after ensuring that the needle valves in the cabinet are closed. All cylinders can then be closed at the same time at the end of the calibration session.

11.4.1 Analyser Stability Criteria

Analysers with A and E suffix (i.e. M100A, M200E, etc.) have a built in stability function. This can be accessed by pressing the "TEST" button on the front panel until "STABIL" or "NOx STABIL", as appropriate, is displayed. During calibration, if this value is close to zero (< 1 ppb for NO, NOx and O₃, < 2 ppb for SO₂ and < 0.5 ppm for CO) then the analyser can be considered to have stabilised.

11.4.2 CO Analyser

The two-point calibration of a carbon monoxide analyser is carried out as follows:

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch CO "out of service" by pressing the "Cal" button on the front panel **once** only. This allows calibration data to be flagged. Do not press "Cal Z" or "Cal S". The Cal light should now turn on and Sample light switch off.
3. Uncap the CO zero air inlet situated on the front of the instrument rack, or where a zero air cylinder is supplied, connect the tubing and turn the cylinder on.
4. If fitted, turn the CO inlet selection valve from "CO AMBIENT" to "CO WEEKLY ZERO / SPAN".
5. Connect the zero air generator to this zero air inlet. Plug in or switch on zero air generator. Check that flow indicator shows a flow of 1.9 ± 0.1 litres per minute. Adjust if necessary using the tap on the output of the zero air generator. Where a zero air cylinder is used, ensure there is sufficient pressure or flow as appropriate.
6. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes
7. Record three consecutive CO readings from the data logger and/ or instrument display, i.e. after 3 ten-second updates on the data logger display.
8. Switch off the zero air generator and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then with a spanner, tighten further by one quarter turn.
9. Open CO in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not attempt to use the cylinder if the pressure indicated is less than 300 psi. In this event contact QAQC.
10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) valve. Slowly open the regulator outlet (left hand) valve fully.
11. By gradually turning the CO calibration gas control valve inside the hut, adjust the flow through the flow meter to produce $1.0 (\pm 0.1)$ litres per minute.
12. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute.
13. Record three consecutive CO readings from the data logger and/ or instrument display.
14. If fitted, turn the CO inlet selection valve from "CO WEEKLY ZERO / SPAN" to "CO AMBIENT".
15. In the following order, fully close the CO calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QAQC should be informed.
16. By comparison with previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~ 0.25 ppm from the

previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QAQC.

17. Change the CO sample inlet filter, following the instructions given in section 11.5.
18. Switch the CO out-of-service control to "off" by pressing "Exit". The sample light will begin to flash until the end of the current 15-minute mean.

11.4.3 NOx Analyser

The two-point calibration of the nitrogen oxides analyser is carried out as follows:

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch NOx "out of service" by pressing the "Cal" button on the front panel **once** only. This allows calibration data to be flagged. Do not press "Cal Z" or "Cal S". The Cal light should now turn on and Sample light switch off.
3. Uncap NOx zero air inlet situated on the front of the instrument rack, or where a zero air cylinder is supplied, connect the tubing and turn the cylinder on.
4. Connect the zero air generator to the zero air inlet of the nitrogen oxides analyser. Plug in or switch on zero air generator. Check that flow indicator shows a flow of 1.9 ± 0.1 litres per minute. Adjust if necessary using the tap on the output of the zero air generator. Where a zero air cylinder is used, ensure there is sufficient pressure or flow as appropriate.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. The "Stab" value should be less than 1ppb.
6. Record three consecutive sets of NOx, NO and NO₂ readings from the data-logger and/ or instrument display, i.e. after 3 ten second updates on the data logger display.
7. Switch off the zero air generator/cylinder and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then, with a spanner, tighten further by one quarter turn.
8. Open NO in nitrogen cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not attempt to use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QAQC.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) valve. Slowly open the regulator outlet (left hand) valve fully.
10. By gradually turning the NO calibration gas control valve inside the hut, adjust the flow through the flow meter to produce 1.0 (± 0.1) litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute. Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
12. Record three sets of NOx, NO and NO₂ readings from the data logger and instrument display. The readings should be taken as close as possible to each other, but need not be in consecutive 10 sec periods if this is not possible. The NO signal should be similar to the NOx signal, and show a large deflection from the zero point previously obtained. The NO₂ signal should be close to zero.
13. In the following order, fully close the NO calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QAQC should be informed.
14. Turning now to the NO₂ in air calibration cylinder, repeat steps 8 to 13
15. Record three sets of NOx, NO and NO₂ readings from the data logger and instrument display. The readings should be taken as close as possible to each other, but need not be

in consecutive 10 sec periods if this is not possible. Verify that the readings are reasonable: the NO signal should be close to that obtained while performing the zero calibration, with the NO_x and NO₂ signals showing approximately the same large deflection from this zero point.

16. Repeat step 13.
17. By comparison with previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than ~4 ppb from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QAQC.
18. Change the NO_x analyser sample inlet filter following the instructions given in section 11.5.
19. Switch the NO_x back in service by pressing "Exit". The sample light will begin to flash until the end of the current 15-minute mean

11.4.4 SO₂ Analyser

The two-point calibration of a sulphur dioxide analyser is carried out as follows:

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch SO₂ to "out of service" by pressing the "Cal" button on the front panel **once** only. This allows calibration data to be flagged. Do not press "Cal Z" or "Cal S". The Cal light should now turn on and Sample light switch off.
3. Uncap the SO₂ zero air inlet situated on the front of the instrument rack, or where a zero air cylinder is supplied, connect the tubing and turn the cylinder on.
4. Connect the zero air generator/cylinder to this zero air inlet. Plug in or switch on zero air generator. Check that flow indicator shows a flow of 1.9 ± 0.1 litres per minute. Adjust if necessary using the tap on the output of the zero air generator. Where a zero air cylinder is used, ensure there is sufficient pressure or flow as appropriate.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred by checking the "Stab" value is less than 1ppb.
6. Record three consecutive SO₂ readings from the instrument display, i.e. after 3 ten second updates on the data logger display.
7. Switch off the zero air generator/cylinder and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then with a spanner, tighten further by one quarter turn.
8. Open SO₂ in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not attempt to use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QAQC.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) value. Slowly open the regulator outlet (left hand) valve fully.
10. By gradually turning the SO₂ calibration gas control valve inside the hut, adjust the flow through the flow meter to produce $1.0 (\pm 0.1)$ litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute. Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
12. Record three consecutive SO₂ readings from the data logger and/ or instrument display. The signal should show a large deflection from the zero point previously obtained.
13. In the following order, fully close the SO₂ calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous

setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.

14. By considering previous calibration results obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~4 ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
15. Change the SO₂ sample inlet filter, following the instructions given in section 11.5.
16. Switch the SO₂ back into service by pressing the "Exit" button. The sample light will begin to flash until the end of the current 15-minute mean.

11.4.5 Ozone Analyser

There is no longer a requirement for the LSO to perform the two point calibration of the ozone analyser during each site visit. The analyser performs an internal zero/span daily, and this is adequate for data ratification purposes. Calibrations for scaling ratified data are carried out every three months by the QA/QC Unit using a photometer.

11.4.6 Where a web-logger is installed

1. The two-point calibration of the API analyser with a web-logger is carried out as follows:
2. Record the instrument number and instrument running range on the calibration record sheet.
3. Switch Analyser "out of service" by pressing the "Cal" button on the front panel once only. This allows calibration data to be flagged. Do not press "Cal Z" or "Cal S". The Cal light should now turn on and Sample light switch off.
4. Locate the Web-logger and hold the <Zero> button until the red light illuminates.
5. (Note only one button can be switched on at any one time)
6. Allow the analyser to stabilise on zero air. (The button will automatically switch off after 2-3 minutes)
7. Record three consecutive sets of readings from the data-logger or Instrument display (depending on site configuration), allow 1-2 minutes between each set of readings.
8. Allow the analyser to stabilise on zero air. The "Stab" value should be less than 1ppb.
9. Repeat process if readings did not stabilise.
10. Press and hold button until red light illuminates if an auto-calibration cylinder is being used to calibrate the analyser. If a cylinder is being manually connected to be used for the calibration, press and hold <SERVICE> button until red light illuminates.
11. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
12. Check flow of site cylinder, regulator secondary pressure should read approximately 15 psi. To adjust flow slowly turn pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve. Note that the pressure regulator dials should remain at their setting while button is illuminated, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
13. Allow the analyser to stabilise on this sample. (Note the button will automatically switch off after 2-3 minutes) Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
14. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings. The signal should show a large deflection from the zero points previously obtained.
15. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10

mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.

16. Change the analyser sample inlet filter following the instructions given in section 11.5
17. The light should now be off, If not allow 2-3 minutes for it to turn off automatically. If using the <SERVICE> button, Press and hold button until red light switches off.
18. All three red lights should be turned off.
19. Switch the analyser back in service by pressing "Exit". The sample light will begin to flash until the end of the current 15-minute mean.

11.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack will be changed on a monthly basis at background sites and fortnightly at roadside sites. In the event of a filter appearing badly soiled, the site operator shall inform the QAQC. Most API analysers have the filter mounted inside the front panel, which hinges down to allow access. Some API-equipped sites have the sample filter holder mounted on the front panel.

Detailed instructions for sample inlet filter changing (panel-mounted holder):

1. Unscrew 2 brass nuts on filter holder.
2. Lift top cover of filter holder off bottom section.
3. Remove "O" ring and used filter.
4. Inspect filter for signs of excessive soiling and inspect "O" ring.
5. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
6. Replace "O" ring in filter holder.
7. Replace top of filter holder and secure with brass nuts. The brass nuts should be hand tightened.

11.6 Post calibration Checks, Safety and Security Inspection

As the Scottish Network reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive noise or cyclic response changes etc. Information on analyser performance over very short time periods is important, as this will alert network managers as to whether instrumentation faults are developing.

Performing calibration checks at weekly intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

In addition, seemingly unimportant occurrences, such as an analyser air pump being noisy, may be indicative that the unit is liable to malfunction; this should be reported by the operator.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the postcalibration check sheet must be completed as follows:

1. All checks detailed in section 11.3 must now be repeated and recorded on the postcalibration check sheet as follows:

-
- CO Analyser
 - NO_x Analyser
 - SO₂ Analyser
 - Ozone Analyser
 - TEOM/FDMS (not required when filter not changed)
 - Air Sampling Manifold (not required if pre-calibration was OK)
 - Modem
2. Complete the final check section of the postcalibration check sheet.
 3. Complete the calibration end time.
 4. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.
 5. Check that the roof area and fittings are secure. *If you have had to access the roof, to clean the inlet of a particulate analyser, check that there are no loose items left on the roof and then stow the ladder safely inside the hut.*
 6. Check that all cylinders except the CO autocal cylinder are firmly closed and the cylinder store locked.
 7. Ensure the cabinet is clean and tidy.
 8. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at agadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

12 Thermo Fisher I Series Equipment - Site Operational Procedures

12.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

1. Pre calibration checks;
2. Changing the particulate monitor filter (if applicable);
3. Calibration of analysers;
4. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Procedures associated with particle analysers (PM_{2.5} or PM₁₀) are covered in a separate section.

Local site operators will be trained in all aspects of normal equipment operation by the QA/QC, and in the relevant calibration procedures by the QA/QC Unit. Operators must retain copies of instrument manuals at each site, and are required to familiarise themselves with normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is common to all analyser types, with the exception of the particulate analyser. As described in Section 9 of the main document, routine calibrations take the form of a simple two-point calibration. More detailed instrument tests are undertaken by the QA/QC Unit, in combination with the 6-monthly instrument intercalibration and servicing exercises.

Each analyser must be calibrated *exactly as found*. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Acting only on advice from the QA/QC, instrument adjustments may be performed to optimise analyser sensitivity. If such adjustments are found to be necessary, the instrument will be recalibrated after a suitable initial stabilisation period typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours and hence, ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this. It is not anticipated that instrument adjustments of this sort will be required frequently.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for both routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made. However, the sequence in which zero and span calibrations are performed is not critical.

The exact specification of the calibration systems at each monitoring may differ slightly. The control of gas delivery into the analysers may use an excess flow meter, or an in-line critical orifice restricting the pressure. Training in the use of these systems is provided by the QA/QC Unit as required.

12.2 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of each analyser to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O_3 >~70 ppb, NO_2 >~75 ppb, SO_2 >~90 ppb and CO >~5 ppm). If an episode is occurring phone QA/QC before proceeding any further.
2. Start up the electronic calibration sheet on your computer, or take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit is complete.
5. The analysers can be switched out of service by either:
 - pressing "Menu", scrolling down to "Instrument controls" and selecting "Service mode". Switch the service mode on by pressing "Return". Press "▶" to return to the main screen. A spanner should appear on the bar on the screen. If the spanner does not appear, the QA/QC should be telephoned upon arrival. This will allow them to ensure that calibration data is not disseminated as ambient data or:
 - If displayed, press the "SERV" key on the main screen to enter service mode. Switch the service mode on by pressing "Return". Press "▶" to return to the main screen. A spanner should appear on the bar on the screen. If the spanner does not appear, the QA/QC should be telephoned upon arrival. This will allow them to ensure that calibration data is not disseminated as ambient data

12.3 Pre-calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a value to be recorded in the pre-calibrationspreadsheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

In case of difficulty operating the logger contact your QA/QC who will be able to offer assistance.

12.3.1 CO Analyser

The Thermo Electron model 48i CO analyser has a LCD display which, in all operating modes, shows the current CO concentration.

1. Check the display and record the current CO concentration in the pre-calibration checklist, and check the analyser is in service mode-see Section 12.2 ("Preparation")
2. Record any fault warnings/unusual display status.
3. Access the analysers alarm status from the primary screen by using the Alarm and arrow keys. Note any alarms displayed. To return to the primary screen press "▶"
4. Access the instrument operating parameters by pressing the "DIAGS" key. scroll down, using the arrow and enter keys, to access and record all of the required temperature, pressure and flow parameters in the pre-calibration checklist. To return to the primary screen press "▶"

12.3.2 NOx Analyser

The Thermo Electron model 42i Nitrogen Oxides analyser has a LCD display which, in all operational modes shows the current NO , NO_2 and NO_x concentration.

1. Check the display and record the current NO, NO₂ and NO_x concentrations in the pre-calibration checklist and check the analyser is in "service" mode - see Section 12.2 ("Preparation").
2. Record any alarms/unusual display status. Press "Alarms" and note any displayed.
3. Access the analysers alarm status from the primary screen by using the Alarm and arrow keys. Note any alarms displayed. To return to the primary screen press "▶"
4. Access the instrument operating parameters by pressing the "DIAGS" key.scroll down, using the arrow and enter keys, to access and record all of the required temperature, pressure and flow parameters in the pre-calibration checklist. To return to the primary screen press "▶"

12.3.3 SO₂ Analyser

The Thermo Electron model 431 SO₂ analyser has a LCD display which, in normal operation shows the current SO₂ concentration.

1. Check the display and record the current SO₂ concentration on the pre-calibration checklist and check the analyser is in service mode mode - see Section 12.2 ("Preparation").
2. Record any alarms/unusual display status.
3. Access the analysers alarm status from the primary screen by using the Alarm and arrow keys. Note any alarms displayed. To return to the primary screen press "▶"
4. Access the instrument operating parameters by pressing the "DIAGS" key.scroll down, using the arrow and enter keys, to access and record all of the required temperature, pressure and flow parameters in the pre-calibration checklist. To return to the primary screen press "▶"

12.3.4 Ozone Analyser

The Thermo Electron model 49i O₃ analyser has a LCD display which, in normal operation shows the current O₃ concentration.

1. Check the display and record the current O₃ concentration on the pre-calibration checklist and check the analyser is in service mode – see Section 12.2 ("Preparation").
2. Record any alarms/unusual display status.
3. Access the analysers alarm status from the primary screen by using the Alarm and arrow keys. Note any alarms displayed. To return to the primary screen press "▶"
4. Access the instrument operating parameters by pressing the "DIAGS" key.scroll down, using the arrow and enter keys, to access and record all of the required temperature, pressure and flow parameters in the pre-calibration checklist. To return to the primary screen press "▶"

12.3.5 Zero Air Generation

Zero air may be provided by chemical scrubber towers (with or without a pump), or using a zero air cylinder. For scrubber-equipped sites at which all pollutants are measured, two zero towers will be present; check the condition of the scrubber materials in the canisters, two of which are self indicating; silica gel turns from orange to clear and purafil from purple to brown as it becomes exhausted.

1. Check that at least 25% of the silica gel is still orange. If less than 25% of the silica gel is orange please contact the QA/QC: **do not change the silica gel yourself as it can give off a harmful dust.**
2. Check that at least 25% of the purafil is still purple. If less than 25% of the purafil is purple, note on the calibration record sheet, but continue with calibration.
3. Check the tubing from the canisters is secure and the lid is tight.

12.3.6 Changing the Silica Gel

It is no longer necessary for the LSO to change the silica gel. This is carried out by either the QA/QC unit or the ESU.

12.3.7 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform QA/QC before proceeding with calibration.

If all correct, proceed to the next section.

12.4 Analyser Calibration Procedure

Results of the calibration will be taken from either the data logger display (if fitted) or the instrument's display for recording on the calibration record sheets.

When closing the calibration gas cylinder valves, care should be taken not to over tighten the valves on the gas regulator. Over tightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

12.4.1 CO Analyser

The two point calibration of the carbon monoxide analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Switch CO "out of service" control to on. This allows calibration data to be flagged. Methodologies for flagging calibration data vary between systems, in case of difficulty consult your QA/QC.
3. If necessary, locate the inlet line to the CO analyser, and disconnect it from the manifold.
4. This step is different depending on whether the zero air at the site is provided by a scrubber or from a zero air cylinder. **At scrubber equipped sites:** connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the orange silica gel and the black hopcalite. The silica gel end should be open to the environment, the hopcalite end connected to the instrument. **At cylinder equipped sites:** set the calibration valve to "Zero" and turn on the zero air gas cylinder. Ensure there is sufficient gas flow to the analyser (where possible)
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.
6. Record three consecutive CO readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
7. Remove the zero air canister from the inlet line, or turn off the cylinder.
8. If necessary, connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the carbon monoxide (CO) in air calibration gas cylinder. (Cylinder-equipped sites) Set the calibration valve to "Span"
9. Open the CO in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute.

11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute.
12. Record three consecutive CO readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
13. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
14. By considering previous calibration results (if present) obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 10 mV (~0.5 ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
15. Change the CO analyser sample inlet filter, following the instructions given in section 12.5.
16. If necessary, reconnect the ambient sample line to the analyser. Turn the calibration valve to "Ambient"
17. Switch the CO analyser back into service by exiting the service mode when the analyser has fallen to ambient levels. Access the "Service Mode" as described in section 12.2 and switch service mode off. The spanner should disappear from the bar on the screen.

12.4.2 NOx Analyser

The two point calibration of the Nitrogen Oxides analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Press the out-of-service switch so that the calibration data is flagged.
3. If necessary, locate the inlet line to the NOx analyser, and disconnect it from the manifold.
4. This step is different depending on whether the zero air at the site is provided by a scrubber or from a zero air cylinder. **At scrubber equipped sites:** connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the pink Purafil and the black charcoal. The Purafil end should be open to the environment, the charcoal end connected to the instrument. **At cylinder equipped sites:** set the calibration valve to "Zero" and turn on the zero air gas cylinder. Ensure there is sufficient gas flow to the analyser (where possible).
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.
6. Record three consecutive sets of NOx, NO, NO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each set of readings.
7. Remove the zero air canister from the inlet line, or turn off the zero air cylinder.
8. If necessary, connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the nitric oxide (NO) in nitrogen calibration gas cylinder. Turn the calibration valve to "NO Span"
9. Open the NO in nitrogen cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute.

11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute.
12. Record three consecutive sets of NO_x , NO, NO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each set of readings. The signal should show a large deflection from the zero points previously obtained.
13. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
14. Turning now to the NO₂ in air calibration cylinder, repeat steps 8 to 13.
15. Record three sets of NO_x , NO and NO₂ readings from the data-logger or instrument display (depending on site configuration). Allow 10 seconds between each set of readings.
16. Verify that the readings are reasonable: the NO signal should be close to that obtained while performing the zero calibration, with the NO_x and NO₂ signals showing approximately the same large deflection from this zero point.
17. Repeat step 13.
18. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
18. Change the NO_x analyser sample inlet filter following the instructions given in section 12.5.
19. Reconnect the ambient sample line to the analyser. Turn Calibration valve to "Ambient"
20. Switch the NO_x analyser back into service by exiting the service mode when the analyser has fallen to ambient levels. Access the "Service Mode" as described in section 12.2 (Preparation) and switch service mode off. The spanner should disappear from the bar on the screen.

12.4.3 SO₂ Analyser

The two point calibration of the Sulphur Dioxide analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Press the out-of-service switch to allow calibration data to be flagged. Methodologies for flagging calibration data vary between systems, in case of difficulty consult your QA/QC.
3. If necessary, locate the inlet line to the SO₂ analyser, and disconnect it from the manifold.
4. This step is different depending on whether the zero air at the site is provided by a scrubber or from a zero air cylinder. **At scrubber equipped sites:** connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the pink Purafil and the black charcoal. The Purafil end should be open to the environment, the charcoal end connected to the instrument. **At cylinder equipped sites:** set the calibration valve to "Zero" and turn on the zero air gas cylinder. Ensure there is sufficient gas flow to the analyser (where possible)
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.
6. Record three consecutive SO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
7. Remove the zero air canister from the inlet line.
8. Connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the sulphur dioxide (SO₂) in air calibration gas cylinder. Turn the calibration valve to "Span"

Open the SO₂ in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.

9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute.
10. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute.
11. Record three consecutive SO₂ readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
12. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
13. By considering previous calibration results (if present) obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 10 mV (~ 4 ppb) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
19. Change the SO₂ analyser sample inlet filter, following the instructions given in section 12.5.
14. Reconnect the ambient sample line to the analyser. Turn calibration valve to "Ambient"
15. Switch the SO₂ analyser back into service by exiting the service mode when the analyser has fallen to ambient levels. Access the "Service Mode" as described in section 12.2 (Preparation) and switch service mode off. The spanner should disappear from the bar on the screen.

12.4.4 Ozone Analyser

There is no longer a requirement to perform the two point calibration of the ozone analyser during each site visit. The analyser performs an internal zero/span daily, and this is adequate for data ratification purposes.

12.4.5 Where a web-logger is installed

The two point calibration of the Thermo analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Switch analyser "out of service" control to on. This allows calibration data to be flagged. Methodologies for flagging calibration data vary between systems, in case of difficulty consult your QA/QC.
3. If necessary, locate the inlet line to the analyser, and disconnect it from the manifold.
4. Locate the Web-logger and hold the <Zero> button until the red light illuminates.
5. (Note only one button can be switched on at any one time)
6. Allow the analyser to stabilise on zero air. (The button will automatically switch off after 2-3 minutes)
7. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings.
8. Repeat process if readings did not stabilise.

9. Press and hold button until red light illuminates if an auto-calibration cylinder is being used to calibrate the analyser. If a cylinder is being manually connected to be used for the calibration, press and hold <SERVICE> button until red light illuminates.
10. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
11. Check flow of site cylinder, regulator secondary pressure should read approximately 15 psi. To adjust flow slowly turn pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve. Note that the pressure regulator dials should remain at their setting while button is illuminated, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
12. Allow the analyser to stabilise on this sample. (Note the button will automatically switch off after 2-3 minutes)
13. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings. The signal should show a large deflection from the zero points previously obtained.
14. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
15. Change the analyser's sample inlet filter following the instructions given in section 12.5
16. The light should now be off, If not allow 2-3 minutes for it to turn off automatically. If using the <SERVICE> button, Press and hold button until red light switches off.
17. All three red lights should be turned off.
18. Switch the analyser back into service by exiting the service mode when the analyser has fallen to ambient levels. Access the "Service Mode" as described in section 12.2 (Preparation) and switch service mode off. The spanner should disappear from the bar on the screen.
19. Hold down the <Service> button until red light illuminates.

12.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front panel of the instrument rack will be changed on a monthly or fortnightly (roadside sites only) basis at all sites. If a filter appears unusually dirty, please inform the QA/QC.

Detailed instructions for sample inlet filter changing:

1. Unscrew the orange locking ring on filter holder.
2. Lift top cover of filter holder off bottom section.
3. Inspect filter for signs of excessive soiling and inspect "O" ring (if fitted). Inspect the perimeter of the filter holder for signs of wear and the effectiveness of the filter holder clip.
4. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
5. Replace top of filter holder and secure with orange locking ring.
6. Check that Teflon lines to filter holder are well secured.

12.6 Changing the daily CO cylinder.

The CO analyser uses a second cylinder to perform daily checks on the performance of the instrument. The LSO will need to replace this cylinder periodically.

1. If not already fitted, connect the regulator to the cylinder using the spanner provided. Ensure that the regulator is tightly fitted to the cylinder (The CO regulator has a left hand thread).

2. The regulator must be purged. To do this briefly open the main cylinder valve and close it again. Open the regulator output valve. The sound of escaping gas should be heard and the 'cylinder' pressure gauge should fall rapidly. If it does not fall check that the main cylinder valve is fully turned off. When the gas present in the regulator has fully vented the regulator should be closed once more. This should be repeated twice leaving the regulator closed.
3. Connect the Teflon tubing from the analyser span input to the output of the regulator.
4. Open the cylinder main valve by turning it fully anticlockwise. Check that there are no leaks from around the regulator seals, using the "SNOOP" leak detecting solution provided. Tighten the regulator, if necessary. Record the cylinder pressure from the right hand dial.
5. Adjust the regulator secondary pressure to 15 psi, as read from the left hand dial, by turning the regulator pressure control (right hand) valve.
6. Switch CO "out of service" control to "on". This allows calibration data to be flagged. Methodologies for flagging calibration data vary between systems, in case of difficulty consult your QA/QC.
7. Press the span button on the front of the analyser.
8. Fully open the cylinder main valve. Slowly open the regulator output valve to allow gas to flow to the analyser. Adjust the regulator secondary pressure to 15 psi, as read from the left hand dial, by turning the regulator pressure control (right hand) valve.
9. Regulate the flow using the regulator output such that the excess flow is around 100 l/hour.
10. Note the span value on the analyser front panel. This should be within 10% of the value of the cylinder. If not contact the QA/QC.
11. Press measure to return to sampling ambient air. Switch the CO "out-of-service" control to "off" when the analyser has fallen to ambient levels.

12.7 Post calibration Checks, Safety and Security Inspection

As the Scottish Network reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

In addition, seemingly unimportant occurrences, such as an analyser air pump being noisy, may be indicative that the unit is liable to malfunction; this should be reported by the operator.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the postcalibration check sheet must be completed as follows:

1. All pre-calibration checks detailed in section 12.3 must now be repeated and recorded on the postcalibration check sheet as follows:
 - CO Analyser
 - NOx Analyser

-
- SO₂ Analyser
 - Ozone Analyser
 - FDMS or other particulate analyser if applicable (not required when filter not changed)
 - Air Sampling Manifold (not required if pre-calibration was OK)
 - Modem
2. Compare the results of the post calibration checks to the pre-calibration values. If there are any large unexpected changes notify the QA/QC.
 3. Complete the final check section of the post calibration check sheet. If no out of service switches are present telephone the QA/QC to notify them that the calibration is complete so that they may restore data dissemination.
 4. Complete the calibration end time.
 5. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation that may lead to members of the public or LSO personnel being at risk.
 6. Check that the roof area and fittings are secure. *If you have had to access the roof, to clean the inlet of a particulate analyser, check that there are no loose items left on the roof and then stow the ladder safely inside the hut.*
 7. Check that all cylinders except the autocal cylinders are firmly closed and all cylinders are secure. Many sites with Thermo i-series analysers use cylinders for autocalibration, and these should be left switched on.
 8. Ensure the cabinet is clean and tidy.
 9. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

13 Monitor Labs 98 Series Equipment - Site Operational Procedures

13.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

5. Pre calibration checks;
6. Changing the particulate monitor filter (if applicable);
7. Calibration of analysers;
8. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is the same for all analyser types, except the particulate analyser. Routine calibrations consist of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC Unit personnel, in combination with the 6 monthly instrument inter- calibration and servicing exercises.

Each analyser must be calibrated exactly as it is found. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Occasionally, the QA/QC may advise the LSO to carry out an instrument adjustment, to optimise analyser sensitivity. It is not likely that this will need to be done frequently. If such adjustments are necessary, the instrument will be recalibrated after a suitable initial stabilisation period of typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours. Ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. The sequence in which zero and span calibrations are performed is not critical. However, apart from this, it is essential that the procedures are followed exactly as written, for both routine and non-routine site visits.

13.2 Preparation

1. On arrival at the site, check the pollutant levels on the front panel of each analyser to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O_3 >~70 ppb, NO_2 >~75 ppb, SO_2 >~90 ppb and CO >~5 ppm). If an episode is occurring phone the QA/QC before proceeding. You may be advised to delay the calibration until the episode is over.
2. Take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time. This can be done directly into the spreadsheet (on a laptop), or written onto a paper printout of the spreadsheet (Appendix D), and entered electronically back at your office.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit (if provided) is complete.

- 5. If “out of service switches” are not fitted at the site the QA/QC should be telephoned upon arrival. This will allow them to ensure that calibration data is not disseminated as ambient data.**

13.3 Pre-calibration Checks

In this section, a number of initial visible checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration sheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

13.3.1 CO Analyser

The Monitor Labs model ML9830 CO analyser has a liquid crystal display which in normal operation shows the current CO concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the ‘primary screen’. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analyser’s internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press EXIT twice.

13.3.2 NOx Analyser

The Monitor Labs model ML9841A NOx analyser has a liquid crystal display which in normal operation shows the current NO concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the ‘primary screen’. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analyser’s internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press EXIT twice.

13.3.3 SO₂ Analyser

The Monitor Labs model ML9850 SO₂ analyser has a liquid crystal display which in normal operation shows the current SO₂ concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analysers internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press EXIT twice.

13.3.4 Ozone Analyser

The Monitor Labs model ML9850 O₃ analyser has a liquid crystal display which in normal operation shows the current O₃ concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analysers internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press EXIT twice.

13.3.5 Air Sampling Manifold (where fitted)

Record the following checks on the pre-calibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the instruments and that these connections are secure and leak-tight.

In the case of a passive manifold sampling system (i.e. tubing from an inverted funnel) check that the tubing from the funnel is connected to the sample inlet port at the back of the

instruments and that these connections are secure and leak tight. Check that the end of the sample tubing is just inside the lip of the funnel. Check the sample lines for visible obstructions and kinks and that the funnel is orientated so as to prevent rainwater entering the tubing.

13.3.6 Modem (where fitted)

Check that the lights on the modem are lit, the 25 way connector is secure, and the phone line is plugged into the BT socket. Record on the pre-calibration checklist.

13.3.7 Data Logger (where fitted)

Perform the following logger checks and record the results on the pre-calibration check list.

The logger clock is displayed on the screen. This clock is automatically updated to agree with the network central computer clock, each time data is collected from the site by telemetry. Check that the date and time displayed are correct to within 5 minutes of the current time GMT. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time. Note that the network operates on GMT throughout the year and the clocks are not adjusted for BST.

13.3.8 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform QA/QC before proceeding with calibration. If all correct, proceed with the calibration.

13.4 Analyser Calibration Procedure

Results of the calibration will be taken from either the data logger display (if fitted) or the instrument's display for recording on the calibration record sheets. The display is to be used to determine that the instrument has fully stabilized in its response to the gas sample being introduced at its inlet.

When closing the calibration gas cylinder valves, care should be taken not to overtighten the valves on the gas regulator. Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

13.4.1 Analyser Stability Criteria

The ML98XX series analysers show both an instantaneous and an average concentration on the front panel display. By examining both of these values, the analyser stability can be assessed. During calibration, if both values are the same (± 2 ppb for NO, NO_x, SO₂ and O₃ and ± 0.1 ppm for CO) then the analyser can be considered to have stabilised.

13.4.2 CO Analyser

A two point calibration of the carbon monoxide analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Switch the CO "SERVICE" control to "OUT". This allows calibration data to be flagged. The "SERVICE" switch is mounted on the secondary panel behind the instrument front panel. To access this panel grasp the front top corners of the front panel and pull forward. The panel will pop loose and pivot forward.
3. Locate the inlet line to the CO analyser, and disconnect it from the manifold.

4. Connect the zero air line so that the analyser is now sampling air from the zero air cylinder.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.
6. Record three consecutive CO readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
7. Remove the zero air from the inlet line.
8. Connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the carbon monoxide (CO) calibration gas cylinder.
9. Open the CO calibration gas cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from the tag on the cylinder, and enter these on the calibration spreadsheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute. Verify that the readings do not fluctuate by more than 0.2ppm on the analyser front panel.
12. Record three consecutive CO readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
13. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
14. Check that the results from this calibration are consistent with those of the previous calibration. The zero value should not differ by more than 10 mV (~ 0.5 ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
15. Change the CO analyser sample inlet filter, following the instructions given in part 13.5 of this section.
16. Reconnect the ambient sample line to the analyser.
17. Switch the CO "SERVICE" control to "IN" when the analyser has fallen to the ambient levels seen prior to the calibration.

13.4.3 NOx Analyser

A two point calibration of the NOx analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Switch the NOx "SERVICE" control to "OUT". This allows calibration data to be flagged. The "SERVICE" switch is mounted on the secondary panel behind the instrument front panel. To access this panel grasp the front top corners of the front panel and pull forward. The panel will pop loose and pivot forward.
3. Locate the inlet line to the NOx analyser, and disconnect it from the manifold.
4. Connect the zero air to the inlet line so that the analyser is now sampling air from the zero air cylinder
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.

6. Record three consecutive sets of NO_x , NO, NO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each set of readings.
7. Remove the zero air from the inlet line.
8. Connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the nitric oxide (NO) in nitrogen calibration gas cylinder.
9. Open the NO in nitrogen cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from the tag on the cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute
11. Record three consecutive sets of NO_x , NO, NO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each set of readings. The signal should show a large deflection from the zero points previously obtained.
12. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
13. Turning now to the NO₂ in air calibration cylinder, repeat steps 8 to 12.
14. Record three sets of NO_x , NO and NO₂ readings from the data-logger or instrument display (depending on site configuration). Allow 10 seconds between each set of readings.
15. Verify that the readings are reasonable: the NO signal should be close to that obtained while performing the zero calibration, with the NO_x and NO₂ signals showing approximately the same large deflection from this zero point.
16. Repeat step 12.
17. Check that the results from this calibration are consistent with those of the previous calibration. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
18. Change the NO_x analyser sample inlet filter following the instructions given in part 13.5 of this section.
19. Reconnect the ambient sample line to the analyser.
20. Switch the NO_x "SERVICE" control to "IN".

13.4.4 SO₂ Analyser

A two point calibration of the SO₂ analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument number on the calibration record sheet.
2. Switch the SO₂ "SERVICE" control to "OUT". This allows calibration data to be flagged. The "SERVICE" switch is mounted on the secondary panel behind the instrument front

- panel. To access this panel grasp the front top corners of the front panel and pull forward. The panel will pop loose and pivot forward.
3. Locate the inlet line to the SO₂ analyser, and disconnect it from the manifold.
 4. Connect the zero air to the inlet line so that the analyser is now sampling air from the zero air cylinder.
 5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes.
 6. Record three consecutive SO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
 7. Remove the zero air from the inlet line.
 8. Connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the sulphur dioxide (SO₂) in air calibration gas cylinder.
 9. Open the SO₂ in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration spreadsheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
 10. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve adjusting the flow through the excess flow meter to produce 1.0 ± 0.1 litres per minute.
 11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to maintain 1.0 litre per minute.
 12. Record three consecutive SO₂ readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
 13. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
 14. Check that the results from this calibration are consistent with those of the previous calibration. The zero value should not differ by more than 10 mV (~ 4 ppb) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
 15. Change the SO₂ analyser sample inlet filter, following the instructions given in part 13.5 of this section.
 16. Reconnect the ambient sample line to the analyser.
 17. Switch the SO₂ "SERVICE" control to "IN".

13.4.5 Ozone Analyser

1. Record the instrument number on the calibration record sheet.
2. Switch the O₃ "SERVICE" control to "OUT". This allows calibration data to be flagged. The "SERVICE" switch is mounted on the secondary panel behind the instrument front panel. To access this panel grasp the front top corners of the front panel and pull forward. The panel will pop loose and pivot forward.
3. Change the O₃ analyser sample inlet filter, following the instructions given in part 13.5 of this section.
4. Switch the O₃ "SERVICE" control to "IN".

13.4.6 12.4.6 Where a web-logger is installed

A two point calibration of the ML analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Switch the analyser "SERVICE" control to "OUT". This allows calibration data to be flagged. The "SERVICE" switch is mounted on the secondary panel behind the instrument front panel. To access this panel grasp the front top corners of the front panel and pull forward. The panel will pop loose and pivot forward.
3. Locate the Web-logger and hold the <Zero> button until the red light illuminates. (Note only one button can be switched on at any one time)
4. Allow the analyser to stabilise on zero air. (The button will automatically switch off after 2-3 minutes)
5. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings.
6. Allow the analyser to stabilise on zero air. The "Stab" value should be less than 1ppb.
7. Repeat process if readings did not stabilise.
8. Press and hold button until red light illuminates, if an auto-calibration cylinder is being used to calibrate the analyser. If a cylinder is being manually connected to be used for the calibration, press and hold <SERVICE> button until red light illuminates.
9. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
10. Check flow of site cylinder, regulator secondary pressure should read approximately 15 psi. To adjust flow slowly turn pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve. Note that the pressure regulator dials should remain at their setting while button is illuminated, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
11. Allow the analyser to stabilise on this sample. (Note the button will automatically switch off after 2-3 minutes) Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
12. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings. The signal should show a large deflection from the zero points previously obtained.
13. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
14. Change the analyser sample inlet filter following the instructions given in section 13.5
15. The light should now be off, If not allow 2-3 minutes for it to turn off automatically. If using the <SERVICE> button, Press and hold button until red light switches off.
16. All three red lights should be turned off.
17. Switch the "SERVICE" control to "IN" when the analyser has fallen to the ambient levels seen prior to the calibration.

13.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the rear of the instruments must be changed on a fortnightly basis at all sites. If a filter appears unusually dirty, inform the QA/QC.

Detailed instructions for sample inlet filter changing:

1. Unscrew the fasteners on filter holder.
2. Lift top cover of filter holder off bottom section.
3. Remove "O" ring (if fitted) and used filter.
4. Inspect filter for signs of excessive soiling and inspect "O" ring (if fitted). Inspect the perimeter of the filter holder for signs of wear and the effectiveness of the filter holder clip. Adjust the tension of the sprung retaining wire if necessary.
5. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
6. Replace "O" ring in filter holder (if fitted).
7. Replace top of filter holder and secure.
8. Check that Teflon lines to filter holder are well secured.

13.6 Changing the daily CO cylinder (Where fitted)

The CO analyser uses a second cylinder to perform daily checks on the performance of the instrument. Because of this, it will be necessary for LSOs to replace this cylinder periodically.

1. If not already fitted, connect the regulator to the cylinder using the spanner provided. Ensure that the regulator is tightly fitted to the cylinder (The CO regulator has a left hand thread).
2. The regulator must be purged. To do this briefly open the main cylinder valve and close it again. Open the regulator output valve. The sound of escaping gas should be heard and the 'cylinder' pressure gauge should fall rapidly. If it does not fall check that the main cylinder valve is fully turned off. When the gas present in the regulator has fully vented the regulator should be closed once more. This should be repeated twice leaving the regulator closed.
3. Connect the Teflon tubing from the analyser to the output of the regulator.
4. Open the cylinder main valve by turning it fully anticlockwise. Check that there are no leaks from around the regulator seals, using the "SNOOP" leak detecting solution provided. Tighten the regulator, if necessary. Record the cylinder pressure from the right hand dial.
5. Adjust the regulator secondary pressure to 15 psi, as read from the left hand dial, by turning the regulator pressure control (right hand) valve. Slowly open the regulator outlet valve (left hand) fully.
6. Turn the CO "SERVICE" control to "OUT", allowing data to be flagged.
7. Press the span button on the front of the analyser. A click should be heard as the solenoid valve opens.
8. Fully open the cylinder main valve. Slowly open the regulator output valve to allow gas to flow to the analyser. Adjust the regulator secondary pressure to 15 psi, as read from the left hand dial, by turning the regulator pressure control (right hand) valve.
9. Regulate the flow using the regulator output such that the excess flow is around 100 l/hour.
10. Note the span value on the analyser front panel. This should be within 10% of the value of the cylinder. If not contact the QA/QC.
11. Press measure to return to sampling ambient air. When the measured values have returned to ambient levels switch the "SERVICE" switch to "IN" to allow data collection to resume.

13.7 Post calibration Checks, Safety and Security Inspection

As the Scottish Network reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post calibration spreadsheet must be completed as follows:

1. All pre-calibration checks detailed in section 13.3 must now be repeated and recorded on the post calibration spreadsheet as follows:

- (i) CO Analyser
- (ii) NO_x Analyser
- (iii) SO₂ Analyser
- (iv) Ozone Analyser
- (v) TEOM (not required when filter not changed)
- (vi) Air Sampling Manifold (not required if pre-calibration was OK)
- (vii) Modem
- (viii) Data Logger

Compare the results of the post calibration checks to the pre-calibration values. If any there are any large unexpected changes notify the QA/QC.

2. Complete the final check section of the post calibration spreadsheet if no out of service switches are present telephone the QA/QC to notify them that the calibration is complete so that they may restore data dissemination.

3. Complete the calibration end time.

4. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.

5. Check that the roof area and fittings are secure, that there are no loose items left on the roof and stow any site ladder safely inside the monitoring station Do not go on the roof if there are no safety railings present, check with QA/QC if in doubt.

6. Check that all cylinders except the CO auto cal cylinder are firmly closed and all cylinders are secure.

7. Ensure the cabinet is clean and tidy.

8. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (This e-

mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

14 Monitor Labs 98 Series Equipment With Envidas Data Logger - Site Operational Procedures

14.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

1. Pre calibration checks;
2. Changing the particulate monitor filter (if applicable);
3. Calibration of analysers;
4. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is the same for all analyser types, except the particulate analyser. Routine calibrations consist of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC Unit personnel, in combination with the 6 monthly instrument inter- calibration and servicing exercises.

Each analyser must be calibrated exactly as it is found. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Occasionally, the QA/QC may advise the LSO to carry out an instrument adjustment, to optimise analyser sensitivity. It is not likely that this will need to be done frequently. If such adjustments are necessary, the instrument will be recalibrated after a suitable initial stabilisation period of typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours. Ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. The sequence in which zero and span calibrations are performed is not critical. However, apart from this, it is essential that the procedures are followed exactly as written, for both routine and non-routine site visits.

14.2 Preparation

1. On arrival at the site, check the pollutant levels on the front panel of each analyser to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document ($O_3 > \sim 70$ ppb, $NO_2 > \sim 75$ ppb, $SO_2 > \sim 90$ ppb and $CO > \sim 5$ ppm). If an episode is occurring, phone QA/QC before proceeding further. Usually, the QA/QC will advise delaying the calibration until the episode is over.
2. Take a new set of check and calibration spreadsheets and enter Site, Date and Operator and Start Time. This can be done directly into the spreadsheet (on a laptop), or written onto a paper printout of the spreadsheet, and entered electronically back at your office.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit (if provided) is complete.

14.3 Pre calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration spreadsheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

14.3.1 CO Analyser

The Monitor Labs model ML9830 CO analyser has a liquid crystal display which in normal operation shows the current CO concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analyser's internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre calibration checklist. To return to the primary screen press EXIT twice.

14.3.2 NOx Analyser

The Monitor Labs model ML9841A NOx analyser has a liquid crystal display which in normal operation shows the current NO concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre calibration checklist. Telephone the CMCU if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analysers internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre calibration checklist. To return to the primary screen press EXIT twice.

14.3.3 SO₂ Analyser

The Monitor Labs model ML9850 SO₂ analyser has a liquid crystal display which in normal operation shows the current SO₂ concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure

condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analysers internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre calibration checklist. To return to the primary screen press EXIT twice.

14.3.4 Ozone Analyser

The Monitor Labs model ML9850 O₃ analyser has a liquid crystal display which in normal operation shows the current O₃ concentration, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing SELECT when the cursor is flashing in the MAIN MENU option. Use the down arrow to move the cursor to the SYSTEM FAULTS option and then press SELECT. To return to the primary screen press EXIT twice.
3. Access the analysers internal parameters from the primary screen by pressing SELECT when the cursor is flashing in the MAIN MENU option. Using the down arrow move the cursor to the INSTRUMENT STATUS option and then press SELECT. Note the values of the parameters on the pre calibration checklist. To return to the primary screen press EXIT twice.

14.3.5 Air Sampling Manifold (where fitted)

Record the following checks on the pre calibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the instruments and that these connections are secure and leak-tight.

In the case of a passive manifold sampling system (i.e. tubing from an inverted funnel) check that the tubing from the funnel is connected to the sample inlet port at the back of the instruments and that these connections are secure and leak tight. Check that the end of the sample tubing is just inside the lip of the funnel. Check the sample lines for visible obstructions and kinks and that the funnel is orientated so as to prevent rainwater entering the tubing.

14.3.6 Modem (where fitted)

Check that the lights on the modem are lit, the 25 way connector is secure, and the phone line is plugged into the BT/relevant socket. Record the pre calibration checklist.

14.3.7 Data Logger

The ENVIDAS logger is a fully integrated data-logger and system controller. There are few controls or indicators for the operator to interface with, therefore the operator is only required to observe and record the status of each pollutant channel.

1. Open the door on the front of the ENVIDAS logger module.
2. Observe (and record on the pre-calibration checks form) the status of the indicator lights for each pollutant channel.
3. Close the door on the logger module.

If any of the pollutant channels are switched to any state other than 'SAMPLE' (ie 'ZERO', 'SPAN', 'FILTER' or 'SERVICE') the management unit should be informed.

14.3.8 Completion of Pre calibration Checks

If any of the above checks are not correct, inform QA/QC before proceeding with calibration. If all correct, proceed to the next section.

14.4 Analyser Calibration Procedure

Results of the calibration will be taken from the instrument's display for recording on the calibration record spreadsheets. When closing the calibration gas cylinder valves, care should be taken not to overtighten the valves on the gas regulator. Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

14.4.1 Analyser Stability Criteria

The ML98XX series analysers show both an instantaneous and an average concentration on the front panel display. By examining both of these values, the analyser stability can be assessed. During calibration, if both values are the same (± 2 ppb for NO, NO_x, SO₂ and O₃ and ± 0.1 ppm for CO) then the analyser can be considered to have stabilised.

14.4.2 CO Analyser

The following two point calibration of the carbon monoxide analyser is to be undertaken during each site visit (or in the rare event of an analyser adjustment). The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record spreadsheet.
2. Open the door on the front of the ENVIDAS logger module and press the relevant button to set the CO analyser to 'ZERO'. This sets the solenoid valves to introduce zero gas to the analyser whilst also flagging the data as calibration data and not to be used.
3. Allow the analyser to stabilise on zero air for at least 10 minutes.
4. Record three consecutive CO readings from the instrument display, allowing 10 seconds between each reading.

5. On the front of the ENVIDAS logger module press the relevant button to set the CO analyser to 'SPAN'. This sets the solenoid valves to introduce span gas to the analyser whilst also flagging the data as calibration data and not to be used.
6. Read the cylinder pressure of the CO in air calibration cylinder from the right hand dial and cylinder number from the label on the cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi (approx. 20 bar). In this event contact QA/QC immediately.
7. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. When stabilised, the concentration displayed on the analyser front panel should not vary by more than 0.2ppm.
8. Record three consecutive CO readings from the instrument display. The signal should show a large deflection from the zero point previously obtained.
9. Check that the results from this calibration are consistent with those of the previous calibration. The zero value should not differ by more than ~0.5 ppm from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
10. Change the CO analyser sample inlet filter, following the instructions given in part 14.5 of this section.
11. On the front of the ENVIDAS logger module press the relevant button to set the CO analyser to 'SAMPLE' when the analyser has fallen to the ambient levels seen prior to the calibration.

14.4.3 NOx Analyser

The following two point calibration of the NOx analyser is to be undertaken during each site visit (or in the rare event of an analyser adjustment). The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Open the door on the front of the ENVIDAS logger module and press the relevant button to set the NOx analyser to 'ZERO'. This sets the solenoid valves to introduce zero gas to the analyser whilst also flagging the data as calibration data and not to be used.
3. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred, i.e. the NOx and NO concentrations displayed on the instrument front panel vary by no more than 2 ppb.
4. Record three consecutive sets of NOx, NO, NO₂ readings from the instrument display, allow 10 seconds between each reading.
5. On the front of the ENVIDAS logger module press the relevant button to set the NOx analyser to 'SPAN'. This sets the solenoid valves to introduce span gas to the analyser whilst also flagging the data as calibration data and not to be used.
6. Read the cylinder pressure of the NO in nitrogen calibration cylinder from the right hand dial and cylinder number from the label on the cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi (approx. 20 bar). In this event contact QA/QC immediately.
7. Allow the analyser to stabilise on this sample for at least 10 minutes. Verify that stabilisation has taken place, i.e. the NOx and NO concentrations not varying by more than 2ppb on the analyser front panel.
8. Record three consecutive sets of NOx, NO, NO₂ readings from the instrument display. The signal should show a large deflection from the zero point previously obtained.
9. Check that the results from this calibration are consistent with those of the previous calibration. The zero value should not differ by more than 4 ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.

10. Change the NO_x analyser sample inlet filter, following the instructions given in part 14.5 of this section.
11. On the front of the ENVIDAS logger module press the relevant button to set the NO_x analyser to 'SAMPLE' when the analyser has fallen to the ambient levels seen prior to the calibration.

14.4.4 SO₂ Analyser

The following two point calibration of the SO₂ analyser is to be undertaken during each site visit (or in the rare event of an analyser adjustment). The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Open the door on the front of the ENVIDAS logger module and press the relevant button to set the SO₂ analyser to 'ZERO'. This sets the solenoid valves to introduce zero gas to the analyser whilst also flagging the data as calibration data and not to be used.
3. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred, i.e. the SO₂ concentration displayed on the instrument front panel does not vary by more than 2 ppb.
4. Record three consecutive SO₂ readings from the instrument display, allow 10 seconds between each reading.
5. On the front of the ENVIDAS logger module press the relevant button to set the SO₂ analyser to 'SPAN'. This sets the solenoid valves to introduce span gas to the analyser whilst also flagging the data as calibration data and not to be used.
6. Read the cylinder pressure of the SO₂ in air calibration cylinder from the right hand dial and cylinder number from the label on the cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi (approx. 20 bar). In this event contact QA/QC immediately.
7. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Verify that stabilisation has occurred, i.e. the SO₂ concentration displayed on the instrument front panel does not vary by more than 2 ppb.
8. Record three consecutive SO₂ readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
9. Check that the results from this calibration are consistent with those of the previous calibration. The zero value should not differ by more than ~4 ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
10. Change the SO₂ analyser sample inlet filter, following the instructions given in part 14.5 of this section.
11. On the front of the ENVIDAS logger module press the relevant button to set the SO₂ analyser to 'SAMPLE' when the analyser has fallen to the ambient levels seen prior to the calibration.

14.4.5 Ozone Analyser

The ozone analyser does not require calibration. The procedure is as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Change the O₃ analyser sample inlet filter, following the instructions given in part 14.5 of this section.

14.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack must be changed on a fortnightly basis at all sites. If a filter appears unusually dirty, inform the QA/QC.

Detailed instructions for sample inlet filter changing:

1. Unscrew the front of the filter holder.
2. Lift the top cover of the filter holder off the bottom section.
3. Inspect filter for signs of excessive soiling. Inspect the perimeter of the filter holder for signs of wear and the effectiveness of the filter holder clip.
4. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
5. Replace top of filter holder and secure.
6. Check that Teflon lines to filter holder are well secured.

14.6 Changing the daily CO cylinder. (Where fitted)

Some network sites use separate cylinders for weekly calibration and daily autocalibration. This is not the case for ENVIDAS equipped monitoring stations, so there will be no need to change a daily CO cylinder.

14.7 Post calibration Checks, Safety and Security Inspection

As the Scottish Network reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert network managers and the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator.

The operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post calibration check spreadsheet must be completed as follows:

1. All checks detailed in section 14.3 must now be repeated and recorded on the post calibration check spreadsheet as follows:
 - (ix) CO Analyser
 - (x) NO_x Analyser
 - (xi) SO₂ Analyser
 - (xii) Ozone Analyser
 - (xiii) TEOM (not required when filter not changed)
 - (xiv) Air Sampling Manifold (not required if pre calibration was OK)
 - (xv) Modem
 - (xvi) Data Logger

-
2. Compare the results of the post calibration checks to the pre calibration values. If any there are any large unexpected changes notify the QA/QC
 3. Complete the final check section of the post calibration check spreadsheet if no out of service switches are present telephone the QA/QC to notify them that the calibration is complete so that they may restore data dissemination.
 4. Complete the gas cylinder pressure table at the end of the calibration spreadsheets.
 5. Complete the calibration end time.
 6. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.
 7. Check that the roof area and fittings are secure, that there are no loose items left on the roof and stow any site ladder safely inside the monitoring station.
 8. Check that all cylinders except the CO autocal cylinder are firmly closed and all cylinders are secure.
 9. Ensure the cabinet is clean and tidy.
 10. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (These e-mail addresses are provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

15 CM20XX Casella Monitor Equipment – Site Operational Procedures

15.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

1. Pre calibration checks;
2. Changing the particulate monitor filter (if applicable);
3. Calibration of analysers;
4. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is the same for all analyser types, except the particulate analyser. Routine calibrations consist of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC Unit personnel, in combination with the 6 monthly instrument inter- calibration and servicing exercises.

Each analyser must be calibrated exactly as it is found. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Occasionally, the QA/QC may advise the LSO to carry out an instrument adjustment, to optimise analyser sensitivity. It is not likely that this will need to be done frequently. If such adjustments are necessary, the instrument will be recalibrated after a suitable initial stabilisation period of typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours. Ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. The sequence in which zero and span calibrations are performed is not critical. However, apart from this, it is essential that the procedures are followed exactly as written, for both routine and non-routine site visits.

15.2 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of each analyser and the chart trace (if available) to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O_3 >~70 ppb, NO_2 >~75 ppb, SO_2 >~90 ppb and CO >~5 ppm). If an episode is occurring phone the QA/QC before proceeding any further.
2. Take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit (if provided) is complete.
5. If out of service switches are not fitted at the site the QA/QC should be telephoned upon arrival. This will allow them to ensure that calibration data is not disseminated as ambient data.

15.3 Pre-calibration Checks

In this section, a number of initial visible checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration sheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the CMCU if any are not correct, before proceeding with the calibration.

15.3.1 CO Analyser

The Casella Monitor model CM2030 CO analyser has a TFT colour display which in normal operation shows the current CO concentration, a time series graph displaying the previous 10 minutes of concentration data, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the SYSTEM FAULTS option and then press the ENTER button, which located in the centre of the arrow keys. To return to the primary screen press the HOME button.
3. Access the analyser's internal parameters from the primary screen by pressing SELECT when the MAIN MENU option is highlighted on the primary screen. Using the arrow keys move the cursor to the INSTRUMENT STATUS option and then press ENTER. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press HOME.

15.3.2 NOx Analyser

The Casella Measurement model 2041 NOx analyser has a TFT colour display which in normal operation shows the current NOx, NO₂ and NO concentrations, a time series graph displaying the previous 10 minutes of NO₂ concentration data, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the SYSTEM FAULTS option and then press the ENTER button, which located in the centre of the arrow keys. To return to the primary screen press the HOME button.
3. Access the analyser's internal parameters from the primary screen by pressing SELECT when the MAIN MENU option is highlighted on the primary screen. Using the arrow keys move the cursor to the INSTRUMENT STATUS option and then press ENTER. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press HOME.

15.3.3 SO₂ Analyser

The Casella Monitor model CM2050 SO₂ analyser has a TFT colour display which in normal operation shows the current SO₂ concentration, a time series graph displaying the previous 10 minutes of concentration data, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the SYSTEM FAULTS option and then press the ENTER button, which located in the centre of the arrow keys. To return to the primary screen press the HOME button.
3. Access the analyser's internal parameters from the primary screen by pressing SELECT when the MAIN MENU option is highlighted on the primary screen. Using the arrow keys move the cursor to the INSTRUMENT STATUS option and then press ENTER. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press HOME.

15.3.4 Ozone Analyser

The Casella Monitor model CM2010 O₃ analyser has a TFT colour display which in normal operation shows the current O₃ concentration, a time series graph displaying the previous 10 minutes of concentration data, the operation mode of the analyser, time of day, date and a main menu option. This display is termed the 'primary screen'. If a failure condition is detected, a fault will be displayed on the status line above the operating mode line. If there are multiple failures, the failure at the top of the list will be displayed on the status line. When this failure clears, the next failure on the list will be displayed. The entire list of failures is displayed on the SYSTEM FAULTS menu screen.

1. Check the display and record the current readings and the current time on the pre-calibration checklist. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
2. If any fault messages are displayed, record these. Access to the faults list is by pressing the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the SYSTEM FAULTS option and then press the ENTER button, which located in the centre of the arrow keys. To return to the primary screen press the HOME button.
3. Access the analyser's internal parameters from the primary screen by pressing SELECT when the MAIN MENU option is highlighted on the primary screen. Using the arrow keys move the cursor to the INSTRUMENT STATUS option and then press ENTER. Note the values of the parameters on the pre-calibration checklist. To return to the primary screen press HOME.

15.3.5 Modem (where fitted)

Check that the lights on the modem are lit, the 25 way connector is secure, and the phone line is plugged into the BT socket. Record on the pre-calibration checklist.

15.3.6 Data Logger (where fitted)

Perform the following logger checks and record the results on the pre-calibration check list. The logger clock is displayed on the screen. This clock is automatically updated to agree with the network central computer clock, each time data is collected from the site by telemetry. Check that the date and time displayed are correct to within 5 minutes of the current time GMT. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time. Note that the network operates on GMT throughout the year and the clocks are not adjusted for BST.

15.3.7 Zero Air Generation

If the zero air is produced using a scrubber, check the condition of the scrubber materials in the canisters, two of which are self indicating; silica gel turns from orange to clear and purafil from purple to brown as it becomes exhausted.

1. Check that at least 25% of the silica gel is still orange. If less than 25% of the silica gel is orange note on the calibration record sheet and contact the QA/QC, but continue with calibration. **Do not change the silica gel yourself as it can give off a harmful dust.**
2. Check that at least 25% of the purafil is still purple. If less than 25% of the purafil is purple, note on the calibration record sheet, but continue with calibration.
3. Check the tubing from the canisters is secure and the lid is tight.

If a zero air cylinder gas is used, note the gas pressure in the calibration sheet.

15.3.8 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform QA/QC before proceeding with calibration. If all correct, proceed to the next section.

15.4 Analyser Calibration Procedure

Results of the calibration will be taken from either the data logger display (if fitted) or the instrument's display for recording on the calibration record sheets. The on-site chart recorder (if present) is to be used to determine that the instrument has fully stabilized in its response to the gas sample being introduced at its inlet.

When closing the calibration gas cylinder valves, care should be taken not to overtighten the valves on the gas regulator. Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

In order to have a full and complete set of instructions for each analyser, instructions for opening gas cylinder valves are contained within the calibration procedure for each analyser. However, when all analysers are being calibrated, in practice it is usually better to open all cylinders at the same time, after ensuring that any needle valves in the cabinet are closed. All cylinders can then be closed, if necessary, at the same time at the end of the calibration session.

15.4.1 CO Analyser

The two point calibration of the carbon monoxide analyser will be undertaken during each site visit or in the rare event of an analyser adjustment. The calibration will be carried out as follows:

1. Record the instrument serial number on the calibration record sheet.

2. Switch the CO "SERVICE" control to "OUT OF SERVICE". This allows calibration data to be flagged. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the "OUT OF SERVICE MENU" option and then press the ENTER button. Press ENTER to highlight the IN SVC/OUT SVC option for switching the analyser out of service and use the arrow key to change the option to "OUT SVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should appear on the status line.
3. Now **EITHER** -
 - Connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the orange silica gel and the black hopcalite. The silica gel end should be open to the environment, the hopcalite end connected to the instrument.

OR

 - If a zero air cylinder is used then open the cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact CMCU immediately. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (± 0.1) litres per minute.
4. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred i.e. the CO concentration should not vary more than 0.2 ppm in 10 minutes which can also be confirmed by the concentration plot on the analyser primary screen.
5. Record three consecutive CO readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
6. Remove the zero air canister from the inlet line or fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the CMCU should be informed.
7. Depending on site configuration, it might be necessary to connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the carbon monoxide (CO) in air calibration gas cylinder. If not necessary, continue to next step.
8. Open the CO in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (± 0.1) litres per minute.
10. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time (if a flow meter is present). Adjust the flow, if necessary, to maintain 1.0 litre per minute. Verify that stabilisation has taken place i.e. the CO concentration should not vary more than 0.4 ppm in 10 minutes, which can also be confirmed by the concentration plot on the analyser primary screen.

11. Record three consecutive CO readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
12. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
13. Compare with previous calibration results to satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 10 mV (~0.5 ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
14. Change the CO analyser sample inlet filter, following the instructions given in part 15.5 of this section.
15. Reconnect the ambient sample line to the analyser.
16. Switch the CO "SERVICE" control to "IN SERVICE" when the analyser has fallen to the ambient levels seen prior to the calibration. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the OUT OF SERVICE MENU option and then press the ENTER button. Press ENTER to highlight the INSVC/OUTSVC option and use the arrow key to change the option to "INSVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should disappear from the status line.

15.4.2 NOx Analyser

The two point calibration of the oxides of nitrogen analyser will be undertaken during each site visit or in the rare event of an analyser adjustment. The calibration will be carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Switch the NOx "SERVICE" control to "OUT OF SERVICE". This allows calibration data to be flagged. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the "OUT OF SERVICE MENU" option and then press the ENTER button. Press ENTER to highlight the INSVC/OUTSVC option for switching the analyser out of service and use the arrow key to change the option to "OUTSVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should appear on the status line.
3. Now **EITHER**:
 - Connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the orange silica gel and the black hopcalite. The silica gel end should be open to the environment, the hopcalite end connected to the instrument.

OR

- If a zero air cylinder is used then open the cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (± 0.1) litres per minute.
4. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred i.e. the NOx/NO concentrations should not vary

- more than 2 ppb in 10 minutes, which can also be confirmed by the concentration plot on the analyser primary screen.
5. Record three consecutive NO_x, NO and NO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading, which can also be confirmed by the concentration plot on the analyser primary screen.
 6. Remove the zero air canister from the inlet line or fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
 7. Depending on site configuration, it might be necessary to connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the Nitric Oxide (NO) in nitrogen calibration gas cylinder. If not necessary, continue to next step.
 8. Open the NO in nitrogen cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
 9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. In this event contact QA/QC immediately. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (±0.1) litres per minute.
 10. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time (if a flow meter is present). Adjust the flow, if necessary, to maintain 1.0 litre per minute. Verify that stabilisation has taken place i.e. the NO_x/NO concentrations should not vary more than 4 ppb in 10 minutes, which can also be confirmed by the concentration plot on the analyser primary screen.
 11. Record three consecutive NO_x, NO and NO₂ readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
 12. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
 13. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 10 mV (~0.5 ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
 14. Change the NO_x analyser sample inlet filter, following the instructions given in part 15.5 of this section.
 15. Reconnect the ambient sample line to the analyser.
 16. Switch the NO_x "SERVICE" control to "IN SERVICE" when the analyser has fallen to the ambient levels seen prior to the calibration. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the OUT OF SERVICE MENU option and then press the ENTER button. Press ENTER to highlight the INSVC/OUTSVC option and use the arrow key to change the option to "INSVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should disappear from the status line.

15.4.3 SO₂ Analyser

The two point calibration of the sulphur dioxide analyser will be undertaken during each site visit or in the rare event of an analyser adjustment. The calibration will be carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Switch the SO₂ "SERVICE" control to "OUT OF SERVICE". This allows calibration data to be flagged. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the "OUT OF SERVICE MENU" option and then press the ENTER button. Press ENTER to highlight the INSVC/OUTSVC option for switching the analyser out of service and use the arrow key to change the option to "OUTSVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should appear on the status line.
3. Either:
 - Connect the zero air canister to the inlet line so that the analyser is now sampling air through the zero air canister. The zero air scrubber to be used is the one containing the orange silica gel and the black hopcalite. The silica gel end should be open to the environment, the hopcalite end connected to the instrument.

OR

- If a zero air cylinder is used then open the cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (±0.1) litres per minute.
4. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred i.e. the SO₂ concentration should not vary more than 2 ppb in 10 minutes, which can also be confirmed by the concentration plot on the analyser primary screen.
 5. Record three consecutive SO₂ readings from the data-logger or instrument display (depending on site configuration), allow 10 seconds between each reading.
 6. Remove the zero air canister from the inlet line or fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
 7. Depending on site configuration, it might be necessary to connect one end of the excess flow meter to the inlet line, the other end to the regulator attached to the sulphur dioxide (SO₂) in air calibration gas cylinder. If not necessary, continue to next step.
 8. Open the SO₂ in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
 9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (right hand) valve. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning the pressure control (left hand) valve. If a flow meter is fitted, a further adjustment of the gas flow can be made. In this case use the output needle valve to adjust the output flow to approximately 1 (±0.1) litres per minute.
 10. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the excess flow measured by the flow meter remains stable during this time (if a flow meter is present). Adjust the flow, if necessary, to maintain 1.0 litre per minute.

- Verify that stabilisation has taken place i.e. the SO₂ concentration should not vary more than 4 ppb in 10 minutes, which can also be confirmed by the concentration plot on the analyser primary screen.
11. Record three consecutive SO₂ readings from the data logger or instrument display (depending on site configuration). The signal should show a large deflection from the zero point previously obtained.
 12. In the following order, fully close the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
 13. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 10 mV (~0.5 ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
 14. Change the SO₂ analyser sample inlet filter, following the instructions given in part 15.5 of this section.
 15. Reconnect the ambient sample line to the analyser.
 16. Switch the SO₂ "SERVICE" control to "IN SERVICE" when the analyser has fallen to the ambient levels seen prior to the calibration. To access the SERVICE menu press the ENTER button when the MAIN MENU option is highlighted on the primary screen. Use the arrow keys to move the cursor to the OUT OF SERVICE MENU option and then press the ENTER button. Press ENTER to highlight the INSVC/OUTSVC option and use the arrow key to change the option to "INSVC". Press ENTER again and the HOME button to return to the primary screen – "OUT OF SERVICE" should disappear from the status line.

15.4.4 Ozone Analyser

There is no longer a requirement for the LSO to perform the two point calibration of the ozone analyser during each site visit. The analyser performs an internal zero/span daily, and this is adequate for data ratification purposes. Calibrations for scaling ratified data are carried out every three months by the QA/QC Unit using a photometer.

15.4.5 Where a web-logger is installed

A two point calibration of the ML analyser is undertaken during each site visit or in the rare event of an analyser adjustment. The calibration is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. Turn the analyser 'OUT OF SERVICE'; select <MAIN MENU> <OUT OF SERVICE MENU> change analyser to 'OUT SVC'.
3. Locate the Web-logger and hold the <Zero> button until the red light illuminates. (Note only one button can be switched on at any one time)
4. Allow the analyser to stabilise on zero air. (The button will automatically switch off after 2-3 minutes)
5. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings.
6. Allow the analyser to stabilise on zero air. The "Stab" value should be less than 1ppb.
7. Repeat process if readings did not stabilise.
8. Press and hold button until red light illuminates, if an auto-calibration cylinder is being used to calibrate the analyser. If a cylinder is being manually connected to be used for the calibration, press and hold <SERVICE> button until red light illuminates.

9. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
10. Check flow of site cylinder, regulator secondary pressure should read approximately 15 psi. To adjust flow slowly turn pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve. Note that the pressure regulator dials should remain at their setting while button is illuminated, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
11. Allow the analyser to stabilise on this sample. (Note the button will automatically switch off after 2-3 minutes) Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
12. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings. The signal should show a large deflection from the zero points previously obtained.
13. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
14. Change the analyser sample inlet filter following the instructions given in section 15.5
15. The light should now be off, If not allow 2-3 minutes for it to turn off automatically. . If using the <SERVICE> button, Press and hold button until red light switches off.
16. All three red lights should be turned off.
17. Switch the analyser 'OUT OF SERVICE' to 'IN SVC' when the analyser has fallen to the ambient levels seen prior to the calibration.

15.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack must be changed on a fortnightly basis at all sites. If a filter appears unusually dirty, inform the QA/QC.

Detailed instructions for sample inlet filter changing:

7. Unscrew the front of the filter holder.
8. Lift the top cover of the filter holder off the bottom section.
9. Inspect filter for signs of excessive soiling. Inspect the perimeter of the filter holder for signs of wear and the effectiveness of the filter holder clip.
10. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
11. Replace top of filter holder and secure.
12. Check that Teflon lines to filter holder are well secured.

15.6 Post-calibration Checks, Safety and Security Inspection

As the Scottish Network reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert network managers and the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post calibration check sheet must be completed as follows:

1. All checks detailed in section 15.3 must now be repeated and recorded on the post calibration check sheet as follows:
 - CO Analyser
 - NO_x Analyser
 - SO₂ Analyser
 - Ozone Analyser
 - TEOM FDMS (not required when filter not changed)
 - Air Sampling Manifold (not required if pre-calibration was OK)
 - Modem
 - Data Logger
2. Compare the results of the post calibration checks to the pre-calibration values. If any there are any large unexpected changes notify the QA/QC
3. Complete the final check section of the post calibration check sheet if no out of service switches are present telephone the QA/QC to notify them that the calibration is complete so that they may restore data dissemination.
4. Complete the calibration end time.
5. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.
6. Check that the roof area and fittings are secure, that there are no loose items left on the roof and stow any site ladder safely inside the monitoring station.
7. Check that all cylinders except the CO autocal cylinder are firmly closed and all cylinders are secure.
8. Ensure the cabinet is clean and tidy.
9. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

16 Horiba Equipment 360 Series, Site Operational Procedures

16.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

5. Pre calibration checks;
6. Changing the particulate monitor filter (if applicable);
7. Calibration of analysers;
8. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is the same for all analyser types, except the particulate analyser. Routine calibrations consist of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC Unit personnel, in combination with the 6 monthly instrument inter-calibration and servicing exercises.

Each analyser must be calibrated exactly as it is found. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Occasionally, the QA/QC may advise the LSO to carry out an instrument adjustment, to optimise analyser sensitivity. It is not likely that this will need to be done frequently. If such adjustments are necessary, the instrument will be recalibrated after a suitable initial stabilisation period of typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours. Ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. The sequence in which zero and span calibrations are performed is not critical. However, apart from this, it is essential that the procedures are followed exactly as written, for both routine and non-routine site visits.

16.2 Preparation

1. On arrival at the site, check the pollutant levels on the front panel of each analyser to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O_3 >~70 ppb, NO_2 >~75 ppb, SO_2 >~90 ppb and CO >~5 ppm). If an episode is occurring, phone the QA/QC before proceeding further. Usually, the QA/QC will advise delaying the calibration until the episode is over.
2. Take a new set of check and calibration spreadsheets and enter Site, Date and Operator and Start Time. This can be done directly into the spreadsheet (on a laptop), or written onto a paper printout of the spreadsheet, and entered electronically back at your office.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit (if provided) is complete.

16.3 Pre-calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration spreadsheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

16.3.1 CO Analyser

The APMA-360 CO analyser has a multi-line alphanumeric display that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition, control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Pressing any key on the analyser front panel will turn the screen on again. A blinking cursor on the display disappears after 10 minutes of inactivity, to redisplay the cursor press the up or down arrows.

1. In normal operation, the analyser should be displaying the current ambient CO concentration. The Mode field will show "EXT", the correct time and date should be displayed on the top line of the display. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. If the ALARM indicator is present on the display, it is possible that a system malfunction has occurred. The ALARM codes that have occurred can be viewed by pressing the function key under the ALARM indicator. If the ALARM indicator is present view the individual ALARM codes and note them. Not all ALARM codes indicate system malfunction - several (LINE, AIC and MAINT) indicate operational status and require no action. Record the various codes on the pre-calibration checklist. Afterwards press EXIT to return to the concentration overview screen.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. Press the MENU function key to access the MAIN menu. Using the up and down arrows highlight the MAINTENANCE menu, press EXEC to enter this menu. Using the up and down arrows highlight the ANALOGUE INPUT menu, press EXEC to enter this menu. Record the cell pressure and sample flow on the pre-calibration checklist. Return to the concentration overview screen by pressing the EXIT key to quit the various menus.

16.3.2 NOx Analyser

The APNA-360 NOx analyser has a multi-line alphanumeric display that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Pressing any key on the analyser front panel will turn the screen on again. A blinking cursor on the display disappears after 10 minutes of inactivity, to redisplay the cursor press the up or down arrows.

1. In normal operation, the analyser should be displaying the current ambient NO, NO₂ and NO_x concentration, the Mode field will show "EXT", and the correct time and date should be displayed on the top line of the display. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. If the ALARM indicator is present on the display then it is possible that a system malfunction has occurred. The ALARM codes that have occurred can be viewed by pressing the function key under the ALARM indicator. If the ALARM indicator is

- present view the individual ALARM codes and note them. Not all ALARM codes indicate system malfunction, several (LINE, AIC and MAINT) indicate operational status and require no action. Record the various codes on the pre-calibration checklist. Afterwards press EXIT to return to the concentration overview screen.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. Press the MENU function key to access the MAIN menu. Using the up and down arrows highlight the MAINTENANCE menu, press EXEC to enter this menu. Using the up and down arrows highlight the ANALOGUE INPUT menu, press EXEC to enter this menu. Record the detector pressure and sample flow on the pre-calibration checklist. Return to the concentration overview screen by pressing the EXIT key to quit the various menus.

16.3.3 SO₂ Analyser

The APSA-360 SO₂ analyser has a multi-line alphanumeric display that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Pressing any key on the analyser front panel will turn the screen on again. A blinking cursor on the display disappears after 10 minutes of inactivity, to redisplay the cursor press the up or down arrows.

1. In normal operation, the analyser should be displaying the current ambient SO₂ concentration, the Mode field will show "EXT", the correct time and date should be displayed on the top line of the display. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. If the ALARM indicator is present on the display then it is possible that a system malfunction has occurred. The ALARM codes that have occurred can be viewed by pressing the function key under the ALARM indicator. If the ALARM indicator is present view the individual ALARM codes and note them. Not all ALARM codes indicate system malfunction, several (LINE, AIC and MAINT) indicate operational status and require no action. Record the various codes on the pre-calibration checklist. Afterwards press EXIT to return to the concentration overview screen.
3. The analyser monitors several important pieces of information about its current operation. Of these sample flow and various reaction cell parameters are of particular interest. Press the MENU function key to access the MAIN menu.
4. Using the up and down arrows highlight the MAINTENANCE menu, press EXEC to enter this menu. Using the up and down arrows highlight the ANALOGUE INPUT menu, press EXEC to enter this menu. Record the detector pressure and sample flow on the pre-calibration checklist. Return to the concentration overview screen by pressing the EXIT key to quit the various menus.

16.3.4 Ozone Analyser

The APOA-360 O₃ analyser has a multi-line alphanumeric display that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Pressing any key on the analyser front panel will turn the screen on again. A blinking cursor on the display disappears after 10 minutes of inactivity, to redisplay the cursor press the up or down arrows.

1. In normal operation, the analyser should be displaying the current ambient O₃ concentration, the Mode field will show "EXT", the correct time and date should be displayed on the top line of the display. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. If the ALARM indicator is present on the display then it is possible that a system malfunction has occurred. The ALARM codes that have occurred can be viewed by pressing the function key under the ALARM indicator. If the ALARM indicator is present view the individual ALARM codes and note them. Not all ALARM codes indicate system malfunction, several (LINE, AIC and MAINT) indicate operational status and require no action. Record the various codes on the pre-calibration checklist. Afterwards press EXIT to return to the concentration overview screen.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. Press the MENU function key to access the MAIN menu. Using the up and down arrows highlight the MAINTENANCE menu, press EXEC to enter this menu. Using the up and down arrows highlight the ANALOGUE INPUT menu, press EXEC to enter this menu. Record the detector pressure and sample flow on the pre-calibration checklist. Return to the concentration overview screen by pressing the EXIT key to quit the various menus.

16.3.5 Air Sampling Manifold (where fitted)

Record the following checks on the pre-calibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing. If the manifold is HORIBA supplied the LED on the blower casing should be lit.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the rack and that these connections are secure.

16.3.6 Modem (where visible/fitted)

Check that the modem is powered and record on the pre-calibration checklist.

16.3.7 Data Logger (where fitted)

Air monitoring stations differ in that some record data from analysers using a discrete data logger (often recording analyser analogue output voltages), whereas other stations record data on the analysers internal logging system. Exact procedures are dependent on the type of logger present; contact your QA/QC for specific instructions.

16.3.8 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform the QA/QC before proceeding with calibration. If all correct, proceed to the next section.

16.4 Analyser Calibration Procedure

Results of the calibration will be taken from both the data logger display (if present) and the instrument's display and recorded on the calibration spreadsheets. When closing the gas cylinder valves, take care not to overtighten the valves on the gas regulator: overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The

main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder. Where autocalibration systems use solenoid valve switching of the site cylinders (as opposed to permeation devices) the cylinders should be left on after calibration.

In order to have a full and complete set of instructions for each analyser, instructions for opening gas cylinder valves are contained within the calibration procedure for each analyser. However, when all analysers are being calibrated, in practice it will be better to open all cylinders at the same time, after ensuring that any needle valves in the cabinet are closed. All cylinders can then be closed, if necessary, at the same time at the end of the calibration session.

16.4.1 CO Analyser

The two-point calibration of a carbon monoxide analyser is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. The analyser is automatically flagged as "out of service" when a calibration is activated. This prevents calibration data being disseminated as ambient concentrations.
3. If the display is blank press any key to activate it.
4. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
5. Use the green INC (increment) and DEC (decrement) buttons (up and down arrows) to toggle the MODE field from EXT to LOCAL.
6. Press the Function key under the MENU command on the instrument display, this displays the instruments MAIN menu.
7. Ensure that CALIBRATION is highlighted (use the DEC and INC buttons to toggle through the menu options if it isn't).
8. Press the function button under the EXEC command on the instrument display (this EXECutes the highlighted menu option, in this case taking us to the CALibration menu)
9. Ensure the cursor is highlighting the LINE field. Use the INC or DEC keys to toggle the value of the LINE field from MEASure (measuring ambient) to ZERO. This places the analyser into a zero calibration, causing the analyser to sample from the site zero air scrubber.
10. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Ensure that the reading on the front panel of the analyser has stabilised (the value should not vary by more than $\pm 0.2\text{ppm}$)
11. Record three consecutive CO readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
12. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
13. Use the INC or DEC keys to toggle the value of the LINE field from ZERO to SPAN. This places the analyser into a span calibration, causing the analyser to sample from the site CO calibration cylinder.
14. Allow the analyser to stabilise on span gas for at least 10 minutes. Ensure that the reading on the front panel of the analyser has stabilised (the value should not vary by more than $\pm 0.4\text{ppm}$)
15. Record three consecutive CO readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.

16. Use the INC or DEC keys to toggle the value of the LINE field from SPAN to MEAS. This places the analyser into its ambient sampling mode, causing the analyser to sample ambient air from the from the site sample manifold.
17. Press the function button under the EXIT command on the instrument display (this EXITs from the CALIBRATION menu returning the instrument to the MAIN menu).
18. Press the function button under the EXIT command on the instrument display (this EXITs from the MAIN menu returning the instrument to the concentration display). An ALARM will be shown (indicating that a calibration has been completed, this should clear in ~3 minutes).
19. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
20. Use the green INC or DEC buttons (up and down arrows) to toggle the MODE field from LOCAL to EXT.
21. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analysers pre-calibration checks as a rough indication of ambient values, bearing in mind that at strongly traffic-related sites these concentrations may vary over fairly short timescales).
22. By considering previous calibration results obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~0.25 ppm from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the Q/QC.
23. Change the CO sample inlet filter, following the instructions given in section 16.5.
24. The analyser will now be back in service.

16.4.2 NOx Analyser

The two-point calibration of the oxides of nitrogen analyser is carried out as follows:

1. Record the instrument serial number on the calibration spreadsheet.
2. The analyser is automatically flagged as "out of service" when a calibration is activated. This prevents calibration data being disseminated as ambient concentrations.
3. If the display is blank press any key to activate it.
4. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
5. Use the green INC (increment) and DEC (decrement) buttons (up and down arrows) to toggle the MODE field from EXT to LOCAL.
6. Press the Function key under the MENU command on the instrument display, this displays the instruments MAIN menu.
7. Ensure that CALIBRATION is highlighted (use the DEC and INC buttons to toggle through the menu options if it isn't).
8. Press the function button under the EXEC command on the instrument display (this EXECutes the highlighted menu option, in this case taking us to the CALibration menu).
9. Ensure the cursor is highlighting the LINE field. Use the INC or DEC keys to toggle the value of the LINE field from MEASure (measuring ambient) to ZERO. This places the analyser into a zero calibration, causing the analyser to sample from the site Zero air scrubber.
10. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. The reading on the front panel of the analyser has stabilised (the value should not vary by more than ± 2 ppb)

11. Record three consecutive NO_x, NO and NO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
12. Read the NO cylinder pressure from right hand dial and cylinder number from neck of cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
13. Use the INC or DEC keys to toggle the value of the LINE field from ZERO to SPAN. This places the analyser into a span calibration, causing the analyser to sample from the site NO calibration cylinder.
14. Allow the analyser to stabilise on span gas for a period of not less than 10 minutes. Ensure that the reading on the front panel of the analyser has stabilised (the value should not vary by more than ± 2 ppb)
15. Record three consecutive NO_x, NO and NO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display. The NO signal should be similar to the NO_x signal, showing a large deflection from the zero point, previously obtained. The NO₂ signal should be close to zero.
16. Repeat steps 13 to 15 using the on-site NO₂ calibration cylinder. The NO signal should be close to that obtained while performing the zero calibration. The NO_x and NO₂ signals should show the same approximate large deflection.
17. Use the INC or DEC keys to toggle the value of the LINE field from SPAN to MEAS. This places the analyser into its ambient sampling mode, causing the analyser to sample ambient air from the from the site sample manifold.
18. Press the function button under the EXIT command on the instrument display (this EXITs from the CALIBRATION menu returning the instrument to the MAIN menu).
19. Press the function button under the EXIT command on the instrument display (this EXITs from the MAIN menu returning the instrument to the concentration display). An ALARM will be shown (indicating that a calibration has been completed, this should clear in ~3 minutes).
20. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
21. Use the green INC or DEC buttons (up and down arrows) to toggle the MODE field from LOCAL to EXT.
22. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analysers pre-calibration checks as a rough indication of ambient values, bearing in mind that at strongly traffic related sites these concentrations may vary over fairly short timescales).
23. By considering previous calibration results obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~4ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
24. Change the NO_x sample inlet filter, following the instructions given in section 16.5
25. The analyser will now be back in service.

16.4.3 SO₂ Analyser

The two-point calibration of a sulphur dioxide analyser is carried out as follows:

1. Record the instrument serial number and instrument running range on the calibration record sheet.
2. The analyser is automatically flagged as "out of service" when a calibration is activated. This prevents calibration data being disseminated as ambient concentrations.

3. If the display is blank press any key to activate it.
4. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
5. Use the green INC (increment) and DEC (decrement) buttons (up and down arrows) to toggle the MODE field from EXT to LOCAL.
6. Press the Function key under the MENU command on the instrument display, this displays the instruments MAIN menu.
7. Ensure that CALIBRATION is highlighted (use the DEC and INC buttons to toggle through the menu options if it isn't).
8. Press the function button under the EXEC command on the instrument display (this EXECutes the highlighted menu option, in this case taking us to the CALibration menu).
9. Ensure the cursor is highlighting the LINE field. Use the INC or DEC keys to toggle the value of the LINE field from MEASure (measuring ambient) to ZERO. This places the analyser into a zero calibration, causing the analyser to sample from the site Zero air scrubber.
10. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. The reading on the front panel of the analyser has stabilised (the value should not vary by more than ± 2 ppb)
11. Record three consecutive SO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
12. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
13. Use the INC or DEC keys to toggle the value of the LINE field from ZERO to SPAN. This places the analyser into a span calibration, causing the analyser to sample from the site NO_x calibration cylinder.
14. Allow the analyser to stabilise on span gas for a period of not less than 10 minutes. If Ensure that the reading on the front panel of the analyser has stabilised (the value should not vary by more than ± 2 ppb)
15. Record three consecutive SO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
16. Use the INC or DEC keys to toggle the value of the LINE field from SPAN to MEAS. This places the analyser into its ambient sampling mode, causing the analyser to sample ambient air from the from the site sample manifold.
17. Press the function button under the EXIT command on the instrument display (this EXITs from the CALIBRATION menu returning the instrument to the MAIN menu).
18. Press the function button under the EXIT command on the instrument display (this EXITs from the MAIN menu returning the instrument to the concentration display). An ALARM will be shown (indicating that a calibration has been completed, this should clear in ~3 minutes)
19. Use the white cursor keys on the instrument front panel to position the flashing cursor over the MODE field on the instrument display.
20. Use the green INC or DEC buttons (up and down arrows) to toggle the MODE field from LOCAL to EXT.
21. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analyser's pre-calibration checks as a rough indication of ambient values).
22. By considering previous calibration results obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~4ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during

- the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
23. Change the SO₂ sample inlet filter, following the instructions given section 16.5. The analyser will now be back in service.

16.4.4 Ozone Analyser

1. Record the instrument serial number and instrument running range on the calibration spread sheet.
2. Change the O₃ sample inlet filter, following the instructions given in section 16.5.
3. The analyser will now be back in service.

16.4.5 Where a web-logger is installed

The two-point calibration of the API analyser with a web-logger is carried out as follows:

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch Analyser "out of service" by changing the MODE from <EXT> to <LOCAL> and flicking the sitc
3. Locate the Web-logger and hold the <Zero> button until the red light illuminates.
4. (Note only one button can be switched on at any one time)
5. Allow the analyser to stabilise on zero air. (The button will automatically switch off after 2-3 minutes)
6. Record three consecutive sets of readings from the data-logger or Instrument display (depending on site configuration), allow 1-2 minutes between each set of readings.
7. Allow the analyser to stabilise on zero air. The "Stab" value should be less than 1ppb.
8. Repeat process if readings did not stabilise.
9. Press and hold button until red light illuminates if an auto-calibration cylinder is being used to calibrate the analyser. If a cylinder is being manually connected to be used for the calibration, press and hold <SERVICE> button until red light illuminates.
10. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration sheet. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact QA/QC immediately.
11. Check flow of site cylinder, regulator secondary pressure should read approximately 15 psi. To adjust flow slowly turn pressure control (right hand) valve. Slowly open the regulator outlet (left hand) valve. Note that the pressure regulator dials should remain at their setting while button is illuminated, if a marked decrease is observed there is a leak in the system, and the QA/QC should be informed.
12. Allow the analyser to stabilise on this sample. (Note the button will automatically switch off after 2-3 minutes) Verify that stabilisation has taken place by checking the "Stab" value is less than 1ppb.
13. Record three consecutive sets of readings from the data-logger or instrument display (depending on site configuration), allow 1-2 minutes between each set of readings. The signal should show a large deflection from the zero points previously obtained.
14. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
15. Change the analyser sample inlet filter following the instructions given in section 11.5
16. The light should now be off, If not allow 2-3 minutes for it to turn off automatically. If using the <SERVICE> button, Press and hold button until red light switches off.
17. All three red lights should be turned off.
18. Switch the analyser back in service by pressing "Exit". The sample light will begin to flash until the end of the current 15-minute mean.

16.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack must be changed on a fortnightly basis at all sites. If a filter appears unusually dirty, please inform the QA/QC.

Detailed instructions for sample inlet filter changing:

1. Open the analyser front panel by pulling the knob (front right), the analyser panel swings open with a door action hinged on the left.
2. The sample filter is situated on the centre or right of the analyser unit, mounted in a vertical orientation for ease of access.
3. Turn the filter cover anticlockwise and then remove.
4. Remove the sample filter.
5. Inspect filter for signs of excessive soiling and inspect the gasket and o-ring to ensure they are not damaged.
6. Take clean filter from box and insert into the filter holder (being careful not to dislodge or lose the gasket and o-ring under the sample filter). On the APMA and APNA (CO and NOX) the notched face of the gasket should be pointing outwards. Otherwise leaks will occur.
7. Replace the filter cover.

16.6 Post-calibration Checks, Safety and Security Inspection

As the Scottish Network will report time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive noise or cyclic response changes etc. Information on analyser performance over very short time periods is important, as this will alert network managers as to whether instrumentation faults are developing.

Performing calibration checks at fortnightly intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post calibration check sheet must be completed as follows:

1. All checks detailed in section 16.3 must now be repeated and recorded on the post calibration spreadsheet as follows:
 - CO Analyser;
 - NOx Analyser;
 - SO₂ Analyser;
 - Ozone Analyser;
 - Air Sampling Manifold (not required if pre-calibration was OK);
 - Modem;
 - Data Logger (where applicable)
2. Complete the final check section of the post calibration check sheet.
3. Complete the calibration end time.

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4. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.
 5. Check that the roof area and any fittings are secure. If you have had to access the roof (to clean the inlet of a particulate analyser – see relevant instructions), check that there are no loose items left on the roof and then stow the ladder safely inside the hut.
 6. Where applicable check that all cylinders are firmly closed and the cylinder store locked (Note: if the cylinders are used for autocalibration purposes, via solenoid control, the cylinders must be left on).
 7. Ensure the cabinet is clean and tidy.
 8. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com . (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

17 Horiba Equipment 370 Series Site Operational Procedures,

17.1 Introduction

The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

9. Pre calibration checks;
10. Changing the particulate monitor filter (if applicable);
11. Calibration of analysers;
12. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is the same for all analyser types, except the particulate analyser. Routine calibrations consist of a simple two-point calibration. More detailed instrument tests are undertaken by QA/QC Unit personnel, in combination with the 6 monthly instrument inter-calibration and servicing exercises.

Each analyser must be calibrated exactly as it is found. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Occasionally, the QA/QC may advise the LSO to carry out an instrument adjustment, to optimise analyser sensitivity. It is not likely that this will need to be done frequently. If such adjustments are necessary, the instrument will be recalibrated after a suitable initial stabilisation period of typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours. Ideally the instrument should be recalibrated after a further 24 hours. The QA/QC will advise on this.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. The sequence in which zero and span calibrations are performed is not critical. However, apart from this, it is essential that the procedures are followed exactly as written, for both routine and non-routine site visits.

17.2 Preparation

1. On arrival at the site, check the pollutant levels on the front panel of each analyser to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values as discussed in Section 9.5 of the main document (O_3 >~70 ppb, NO_2 >~75 ppb, SO_2 >~90 ppb and CO >~5 ppm). If an episode is occurring, phone the CMCU before proceeding further. Usually, the QA/QC will advise delaying the calibration until the episode is over.
2. Take a new set of check and calibration spreadsheets and enter Site, Date and Operator and Start Time. This can be done directly into the spreadsheet (on a laptop), or written onto a paper printout of the spreadsheet, and entered electronically back at your office.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit is complete.

17.3 Pre calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration spreadsheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

17.3.1 CO Analyser

The APMA-370 CO analyser has a full graphic LCD touch screen that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition, control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes: touching the LCD touch screen will turn the screen back on.

1. In normal operation, the analyser should be displaying the current ambient CO concentration, the Mode field showing "MEAS", the correct time and date should be displayed on the top line of the display, and the padlock symbol showing it as locked. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. The alarm indicator is a small LED light situated to the bottom left of the LCD display. This should be showing green if everything is OK with the analyser. If the LED is showing red then it is possible that a system malfunction has occurred. To view this fault select the "alarm" button on the touch screen display and note down the fault onto the calibration sheet. To exit Alarm page select "Close" on the display.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. To find these parameters you must first unlock the front screen by selecting the "Padlock" symbol situated top right of the LCD touch screen display.
4. Next select "key Unlock", then insert the password of "1234" and select "Set". The padlock symbol will now appear open and a spanner icon will flash showing that the analyser is out of service. The Alarm indicator will also turn red.
5. To access Pre Calibration Parameters first select the "Menu" button, then scroll using the cursor icon to the "Maintenance" page, and select "Analog Input".
6. From here take down all appropriate parameters (stated in the pre calibration sheet) found within "Analog Output 1/2" and "Analog Output 2/2". Select "Close" until you return to the front screen.

17.3.2 NOx Analyser

The APMA-370 NOx analyser has a full graphic LCD touch screen that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition, control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Touching the LCD touch screen will turn the screen back on.

1. In normal operation, the analyser should be displaying the current ambient NO, NO₂ and NO_x concentration, the Mode field will show "MEAS", and the correct time and date should be displayed on the top line of the display, and the padlock symbol showing it as locked. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. The alarm indicator is a small LED light situated to the bottom left of the LCD display. This should be showing green if everything is OK with the analyser. If the LED is showing red then it is possible that a system malfunction has occurred. To view this fault select the

- “alarm” button on the touch screen display and note down the fault onto the calibration sheet. To exit Alarm page select “Close” on the display.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. To find these parameters you must first unlock the front screen by selecting the “Padlock” symbol situated top right of the LCD touch screen display.
 4. Next select “key Unlock”, then insert the password of “1234” and select “Set”. The padlock symbol will now appear open and a Spanner Icon will flash showing that the analyser is out of service. The Alarm indicator will also turn red.
 5. To access Pre Calibration Parameters first select the “Menu” button, then scroll using the cursor icon to the “Maintenance” page, and select “Analog Input”.
 6. From here take down all appropriate parameters (stated in the pre calibration sheet) found within “Analog Output 1/2” and “Analog Output 2/2”. Select “Close” until you return to the front screen

17.3.3 SO₂ Analyser

The APMA-370 SO₂ analyser has a full graphic LCD touch screen that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition, control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser automatically turns the screen off when no key has been pressed for 30 minutes. Touching the LCD touch screen will turn the screen back on.

1. In normal operation, the analyser should be displaying the current ambient SO₂ concentration, the Mode field showing "MEAS", the correct time and date should be displayed on the top line of the display, and the padlock symbol showing it as locked. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. The alarm indicator is a small LED light situated to the bottom left of the LCD display. This should be showing green if everything is OK with the analyser. If the LED is showing red then it is possible that a system malfunction has occurred. To view this fault select the “alarm” button on the touch screen display and note down the fault onto the calibration sheet. To exit Alarm page select “Close” on the display.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. To find these parameters you must first unlock the front screen by selecting the “Padlock” symbol situated top right of the LCD touch screen display.
4. Next select “key Unlock”, then insert the password of “1234” and select “Set”. The padlock symbol will now appear open and a Spanner Icon will flash showing that the analyser is out of service. The Alarm indicator will also turn red.
5. To access Pre Calibration Parameters first select the “Menu” button, then scroll using the cursor icon to the “Maintenance” page, and select “Analog Input”.
6. From here take down all appropriate parameters (stated in the pre calibration sheet) found within “Analog Output 1/2” and “Analog Output 2/2”. Select “Close” until you return to the front screen.

17.3.4 Ozone Analyser

The APMA-370 O₃ analyser has a full graphic LCD touch screen that, via a system of menus, can display a variety of analyser information such as pollutant concentration and system error messages. In addition, control of the calibration of the site analyser is undertaken via the system calibration menu. A screen saver function on the analyser

automatically turns the screen off when no key has been pressed for 30 minutes. Touching the LCD touch screen will turn the screen back on.

1. In normal operation, the analyser should be displaying the current ambient O₃ concentration, the Mode field will show "MEAS", and the correct time and date should be displayed on the top line of the display, and the padlock symbol showing it as locked. Check the status of the analyser display and record the various parameters on the pre-calibration checklist.
2. The alarm indicator is a small LED light situated to the bottom left of the LCD display. This should be showing green if everything is OK with the analyser. If the LED is showing red then it is possible that a system malfunction has occurred. To view this fault select the "alarm" button on the touch screen display and note down the fault onto the calibration sheet. To exit Alarm page select "Close" on the display.
3. The analyser monitors several important pieces of information about its current operation. Of these, sample flow and various reaction cell parameters are of particular interest. To find these parameters you must first unlock the front screen by selecting the "Padlock" symbol situated top right of the LCD touch screen display.
4. Next select "key Unlock", then insert the password of "1234" and select "Set". The padlock symbol will now appear open and a spanner icon will flash showing that the analyser is out of service. The Alarm indicator will also turn red.
5. To access Pre Calibration Parameters first select the "Menu" button, then scroll using the cursor icon to the "Maintenance" page, and select "Analog Input".
6. From here take down all appropriate parameters (stated in the pre calibration sheet) found within "Analog Output 1/2" and "Analog Output 2/2". Select "Close" until you return to the front screen.

17.3.5 Air Sampling Manifold (where fitted)

Record the following checks on the pre-calibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing. If the manifold is HORIBA supplied the LED on the blower casing should be lit.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the rack and that these connections are secure.
- 4.

17.3.6 Modem (where visible/fitted)

Check that the modem is powered and record on the pre-calibration checklist.

17.3.7 Data Logger (where fitted)

Air monitoring stations differ in that some record data from analysers using a discrete data logger (often recording analyser analogue output voltages), whereas other stations record data on the analysers internal logging system.

Exact procedures are dependent on the type of logger present, contact your QA/QC for specific instructions.

17.4 Analyser Calibration Procedure

Results of the calibration will be taken from both the data logger display (if present) and the instrument's display and recorded on the calibration spreadsheets. When closing the gas cylinder valves care should be taken not to overtighten the valves on the gas regulator.

Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder. Where autocalibration systems use solenoid valve switching of the site cylinders (as opposed to permeation devices) the cylinders should already be on before calibration starts and should be left on.

In order to have a full and complete set of instructions for each analyser, instructions for opening gas cylinder valves are contained within the calibration procedure for each analyser. However, when all analysers are being calibrated, in practice it will usually be best to open all cylinders at the same time, after ensuring that any needle valves in the cabinet are closed. All cylinders can then be closed, if necessary, at the same time at the end of the calibration session.

17.4.1 CO Analyser

The two-point calibration of a carbon monoxide analyser is carried out as follows:

1. Record the instrument serial number on the calibration spreadsheet.
2. The analyser is automatically flagged as "out of service" when the analyser is unlocked. This prevents calibration data being disseminated as ambient concentrations.
3. On the LCD touch screen display select "CAL", then "MEAS", then "ZERO". Select "SET" to initiate the zeroing of the analyser.
4. Note the concentrations down after 6 minutes or after the readings have stabilised (the value should not vary by more than ± 0.2 ppm)
5. Record three consecutive CO readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
6. Before initiating the Span cycle, record the cylinder pressure from the dial closest to the cylinder head and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
7. Initiate the Span sequence by selecting "ZERO" on the Cal front screen, then "SPAN" on the LCD touch screen display. Select "SET" to initiate SPAN sequence.
8. Allow the analyser to stabilise on span gas for a period of not less than 6 minutes or after the analyser has stabilised (the value should not vary by more than ± 0.4 ppm).
9. Record three consecutive CO readings from the data logger (where present) and instrument display, i.e. after thirty-second intervals record the value from the analyser display.
10. To exit calibration menu select "SPAN", then "MEAS", then "SET", then "CLOSE" to go back to front screen.
11. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analysers pre-calibration checks as a rough indication of ambient values, bearing in mind that at strongly traffic related sites these concentrations may vary over fairly short timescales).
12. By considering previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~ 0.25 ppm from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
13. Change the CO sample inlet filter, following the instructions given in section 17.5.

17.4.2 NO_x Analyser

The two-point calibration of the oxides of nitrogen analyser will be carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. The analyser is automatically flagged as "out of service" when the analyser is unlocked. This prevents calibration data being disseminated as ambient concentrations.
3. On the LCD touch screen display select "CAL", then "MEAS", then "ZERO". Select "SET" to initiate the zeroing of the analyser.
4. Note the concentrations down after 6 minutes or after the readings have stabilised (the value should not vary by more than ± 2 ppb). Also note down the instrument gain values for zero and span. These are situated under "ZERO" and "SPAN" on the Cal front page beside "SPAN CONC."
5. Record three consecutive NO_x, NO, and NO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
6. Before initiating the Span cycle, record the cylinder pressure from the dial closest to the cylinder head and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi. In this event contact the QA/QC.
7. Initiate the Span sequence by selecting "ZERO", then "SPAN" on the LCD touch screen display. Select "SET" to initiate SPAN sequence.
8. Allow the analyser to stabilise on span gas for a period of not less than 6 minutes or after the analyser has stabilised (the value should not vary by more than ± 2 ppb).
9. Record three consecutive NO_x, NO, and NO₂ readings from the data logger (where present) and instrument display, i.e. after thirty-second intervals record the value from the analyser display.
10. Repeat steps 1 to 9 using the on-site NO₂ calibration cylinder. The NO signal should be close to that obtained while performing the zero calibration. The NO_x and NO₂ signals should show the same approximate large deflection.
11. To exit calibration menu select "SPAN", then "MEAS", then "SET", then "CLOSE" until back to front screen.
12. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analysers pre-calibration checks as a rough indication of ambient values, bearing in mind that at strongly traffic related sites these concentrations may vary over fairly short timescales).
13. By comparison with previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~ 4 ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.

Change the NO_x sample inlet filter, following the instructions given in section 17.5.

17.4.3 SO₂ Analyser

The two-point calibration of a sulphur dioxide analyser is carried out as follows:

1. Record the instrument serial number on the calibration record sheet.
2. The analyser is automatically flagged as "out of service" when the analyser is unlocked. This prevents calibration data being disseminated as ambient concentrations.
3. On the LCD touch screen display select "CAL", then "MEAS", then "ZERO". Select "SET" to initiate the zeroing of the analyser.
4. Note the concentrations down after 6 minutes or after the readings have stabilised (the value should not vary by more than ± 2 ppb).

5. Record three consecutive SO₂ readings from the data logger (where present) and instrument display, i.e. after thirty second intervals record the value from the analyser display.
6. Before initiating the Span cycle, record the cylinder pressure from the dial closest to the cylinder head and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300psi. In this event contact the QA/QC.
7. Initiate the Span sequence by selecting "ZERO", then "SPAN" on the LCD touch screen display. Select "SET" to initiate SPAN sequence.
8. Allow the analyser to stabilise on span gas for a period of not less than 6 minutes or after the analyser has stabilised (the value should not vary by more than ± 2 ppb).
9. Record three consecutive SO₂ readings from the data logger (where present) and instrument display, i.e. after thirty-second intervals record the value from the analyser display.
10. To exit calibration menu select "SPAN", then "MEAS", then "SET", then "CLOSE" until back to front screen.
11. Check that the analyser returns to normal ambient concentrations (you can use the value you recorded during the analysers pre-calibration checks as a rough indication of ambient values, bearing in mind that at strongly traffic related sites these concentrations may vary over fairly short timescales).
12. By comparison with previous calibration results, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than ~ 4 ppb from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. If the results of this are also unsatisfactory, contact the QA/QC.
13. Change the SO₂ sample inlet filter, following the instructions given in section 17.5.

17.4.4 Ozone Analyser

1. Record the instrument serial number on the calibration spreadsheet.
2. The analyser is automatically flagged as "out of service" when the analyser is unlocked. This prevents calibration data being disseminated as ambient concentrations.
3. Change the O₃ sample inlet filter, following the instructions given in section 17.5.

17.5 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack must be changed on a fortnightly basis at all sites. If a filter appears unusually dirty, please inform the QA/QC.

Detailed instructions for sample inlet filter changing:

1. Open the analyser front panel by pressing down right side of the panel (front right), the analyser panel swings open with a door action hinged on the left.
2. The sample filter is situated on the centre or right of the analyser unit, mounted in a vertical orientation for ease of access.
3. Turn the filter cover anticlockwise and then remove.
4. Remove the sample filter.
5. Inspect filter for signs of excessive soiling and inspect the gasket and o-ring to ensure they are not damaged.
6. Take clean filter from box and insert into the filter holder (careful not to dislodge/lose the gasket and o-ring under the sample filter). On the APMA and APNA (CO and NO_x) the notched face of the gasket should be pointing outwards. Otherwise leaks will occur.
7. Replace the filter cover.

17.6 Post calibration Checks, Safety and Security Inspection

As the Scottish Network will report time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive noise or cyclic response changes etc. Information on analyser performance over very short time periods is important, as this will alert network managers as to whether instrumentation faults are developing.

Performing calibration checks at fortnightly intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

The operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post calibration check spreadsheet must be completed as follows:

1. All checks detailed in section 17.3 must now be repeated and recorded on the post calibration check spreadsheet as follows:
 - CO Analyser
 - NOx Analyser
 - SO2 Analyser
 - Air Sampling Manifold (not required if pre-calibration was OK)
 - Modem
 - Data Logger (where applicable)
2. Complete the final check section of the post calibration check sheet. Ensure that the Analyser is back in "Mode: MEAS" on the front screen.
3. Put the analyser back into service (if not done so already) by selecting the "Padlock" icon in the top right of the touch screen, select "Key Lock", then "Close". This will bring you back to the front screen.
4. Complete the calibration end time.
5. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to deterioration in data quality. Immediate action must be taken to rectify any situation, which may lead to members of the public or monitoring personnel being at risk.
6. Check that the roof area and any fittings are secure, that there are no loose items left on the roof and then stow the ladder safely inside the hut.
7. Where applicable check that all cylinders are firmly closed and the cylinder store locked (Note: if the cylinders are used for autocalibration purposes, via solenoid control, the cylinders must be left on).
8. Ensure the cabinet is clean and tidy.
9. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

18 R&P TEOM 1400, Site Operational Procedures

18.1 Introduction

This document describes LSO procedures for the TEOM analyser. The regular site visits carried out by the LSOs are a major factor in ensuring high quality data from the Scottish Network. The following jobs are done during these site visits:

1. Pre calibration checks;
2. Changing the particulate monitor filter (if applicable);
3. Calibration of analysers;
4. Post calibration checks, safety and security inspection.

As well as these routine jobs, there will sometimes be a need for non-routine site visits – for example in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. LSOs must keep copies of instrument manuals at each site, and will need to make sure they understand the normal operating principles and characteristics of the instrumentation.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for both routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made.

If your site also contains analysers for gaseous pollutants, in addition to the TEOM, you will also need to refer to the operational procedures for the relevant type of analysers.

18.2 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of the TEOM to see if an episode is occurring (PM_{10} concentration $> 100 \mu g m^{-3}$). If so, please phone the QA/QC. Do not proceed with the calibration as this will result in valuable data from the episode being lost.
2. Take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit (if provided) is complete.

If the instrument has no “out of service” switch, contact the QA/QC. This will allow them to ensure that calibration data are not disseminated as ambient data.

18.3 Initial Checks for the TEOM

A number of initial visual checks must be made on the equipment before carrying out any further tasks. If at a site with other analysers for gaseous pollutants, these will form part of the “pre-calibration” checks. Some checks require a tick and some require a value to be recorded on the pre-calibration sheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct, before proceeding with the calibration.

The R & P TEOM instrument has a 4 line display screen, as shown in Figure 18-1. The top line is fixed, and displays, from left to right, current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time.

The other 3 lines of the display can be used to scroll through a list of 16 information lines displaying various parameters. Use the cursor keys on the keypad to scroll up ↑ and down ↓. Two lights marked "POWER" and "STATUS" are also visible on the front panel.

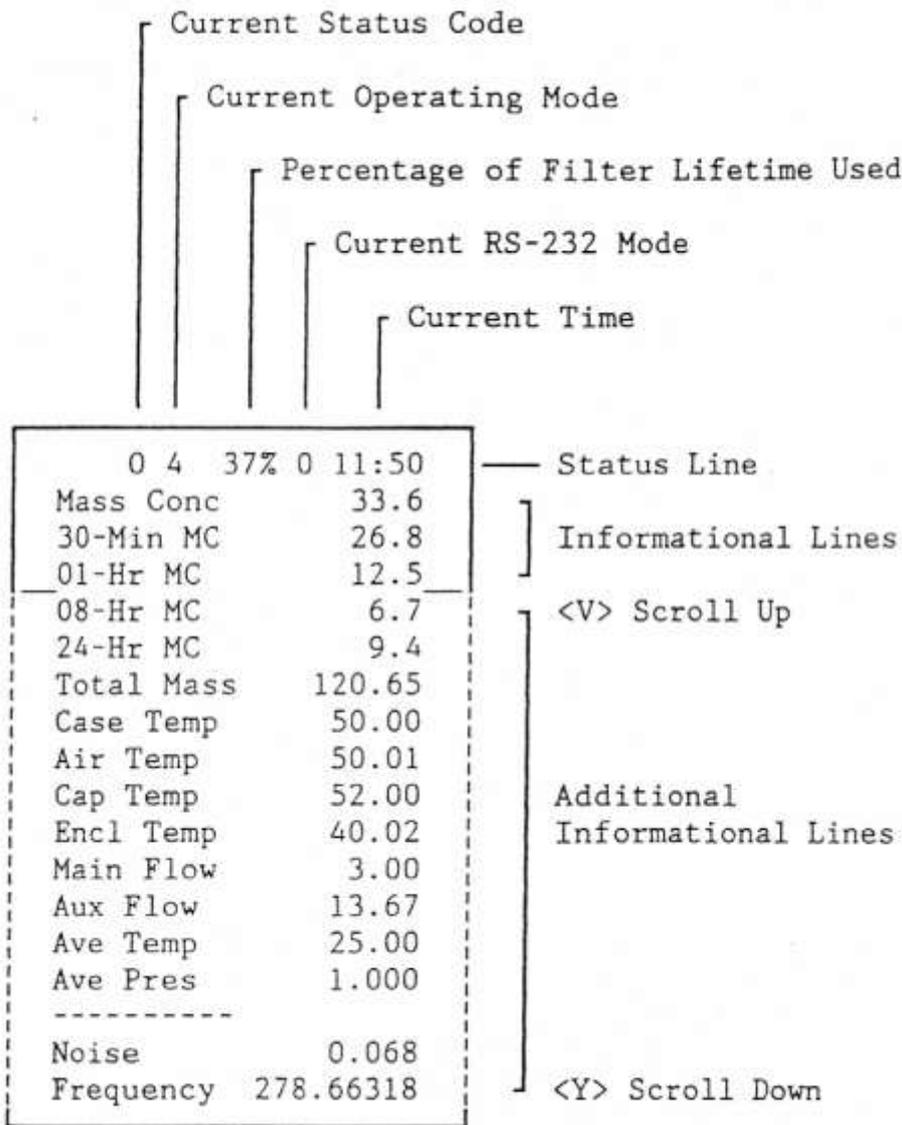


Figure 18-1 TEOM Display Panel

Record the following information on the pre-calibration checklist:

1. In normal operation, the "POWER" switch will be on and the "STATUS" light off.
2. Check these and record on the pre-calibration checklist.
3. Record current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time from the top line of the display.
4. Telephone the QA/QC if the time displayed differs by more than 5 minutes from Greenwich Mean Time.
5. Record the first three information lines in the appropriate space on the pre-calibration checklist.
6. Press ↓ to scroll through all information lines and record the information.

7. Press ↑ to return to the top of the information lines.
8. Carry out a visual check that the PM₁₀ head is intact.

18.3.1 Modem (where fitted)

Check that the lights on the modem are lit, the 25 way connector is secure, and the phone line is plugged into the BT socket. Record on the pre-calibration checklist. It is likely that the communications for the TEOM are incorporated into that for the other site analysers.

18.3.2 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform QA/QC before proceeding with calibration. If all correct, proceed to next section.

18.4 TEOM Particulate Monitor

The TEOM particulate monitor filter cartridge must be changed every 2 or 4 weeks (as advised by your QA/QC) or when the "percentage of filter lifetime used", as shown on the top line of the instrument display is 80% or greater. It is recommended that the TEOM filter cartridge box is stored in the sensor unit of the TEOM analyser so they are pre-conditioned before they are changed with existing filters.

Whenever the filter cartridge is changed, the PM₁₀ head must be cleaned as detailed below. The analyser requires at least one hour to stabilise after filter cartridge changing. Therefore, if the site also contains gaseous pollutant analysers, it is recommended that the PM₁₀ head should be cleaned first, then the gas analysers can be calibrated while you are waiting for the TEOM to stabilise.

18.4.1 Cleaning the PM₁₀ Head

The PM₁₀ head is located on the sample inlet tube above the roof of the monitoring station. To access the PM₁₀ head you will need to use the ladder. Take great care that the ladder is positioned correctly and is secure before stepping onto it. Extra care should be taken if raining as the roof of the station may be slippery when wet. Delay this job if adverse weather conditions (such as ice or snow) mean that it is not safe to use the ladder.

The PM₁₀ inlet needs to be cleaned each time the TEOM filter cartridge is changed, to ensure optimal performance. The cleaning materials required are a small brush, lint free tissues, cotton buds, Decon 90 (1% in H₂O), silicon grease, and distilled water. All components are to be cleaned by soaking Decon 90 on lint-free tissues or cotton buds as appropriate. The component should then be rinsed with distilled water to remove any Decon 90, and dried.

18.4.2 Removing the PM₁₀ Head

1. Switch the TEOM "out of service" switch to ON. If no switch has been explicitly fitted the 'Data Stop' button must be pressed.
2. Carefully lift the complete PM₁₀ head assembly from the TEOM inlet tube.
3. Protect the inlet tube so that rain, snow or dirt cannot enter at any time whilst the head is removed, and take the head inside the monitoring station.
4. Separate the upper and lower inlet halves by unscrewing (counter-clockwise) the acceleration assembly from the collector assembly (see Figure 18-2).

18.4.3 Cleaning the Acceleration Assembly

1. Mark the upper and lower plates of the assembly with a pencil so that the unit can be correctly aligned on reassembly.
2. Unscrew the four Philips screws from the top plate and remove the top plate and four spacers.
3. Clean the top plate, deflector cone, insect screen, internal walls and the underside plate.
4. Inspect the large diameter o-ring for wear and replace if necessary. Wipe any grease off with a tissue, and apply a thin coating of fresh silicon grease to the o-ring and the aluminium threads.
5. Careful reassemble, using the pencil marks to align the top and bottom plates.

18.4.4 Cleaning the Collector Assembly

1. Clean the walls, the three vent tubes and the base of the assembly with a lint-free cloth soaked in Decon 90. Rinse with distilled water.
2. Use cotton buds and Decon 90 to clean the three vent tubes, base of the assembly and weep hole in the collector plate where the moisture runs out to the moisture trap. Rinse with distilled water.
3. Disconnect rain jar assembly from lower collector plate assembly. Clean inside brass tube with cotton buds and Decon 90. Rinse with distilled water.
4. Remove the rain jar and clean. For units with a cork sealing ring inside the cap of the jar, put a thin coating of silicon grease on the gasket and install the jar. If the sealing gasket is neoprene, no silicon grease is required.
5. Reconnect rain jar assembly to lower collector assembly. Ensure rain jar is sitting vertically.
6. Inspect the two inlet tube o-rings for wear and replace if necessary. Wipe off any grease present, and apply a thin coating of fresh silicon grease to the o-rings.
7. Clean the internal threads of the assembly with Decon 90 on a lint-free tissue.

18.4.5 Replacing the Head

1. Screw the Acceleration and Collector assemblies together until the threads are hand tight. DO NOT OVER-TIGHTEN.
2. Place the complete assembly back onto the TEOM inlet tube.

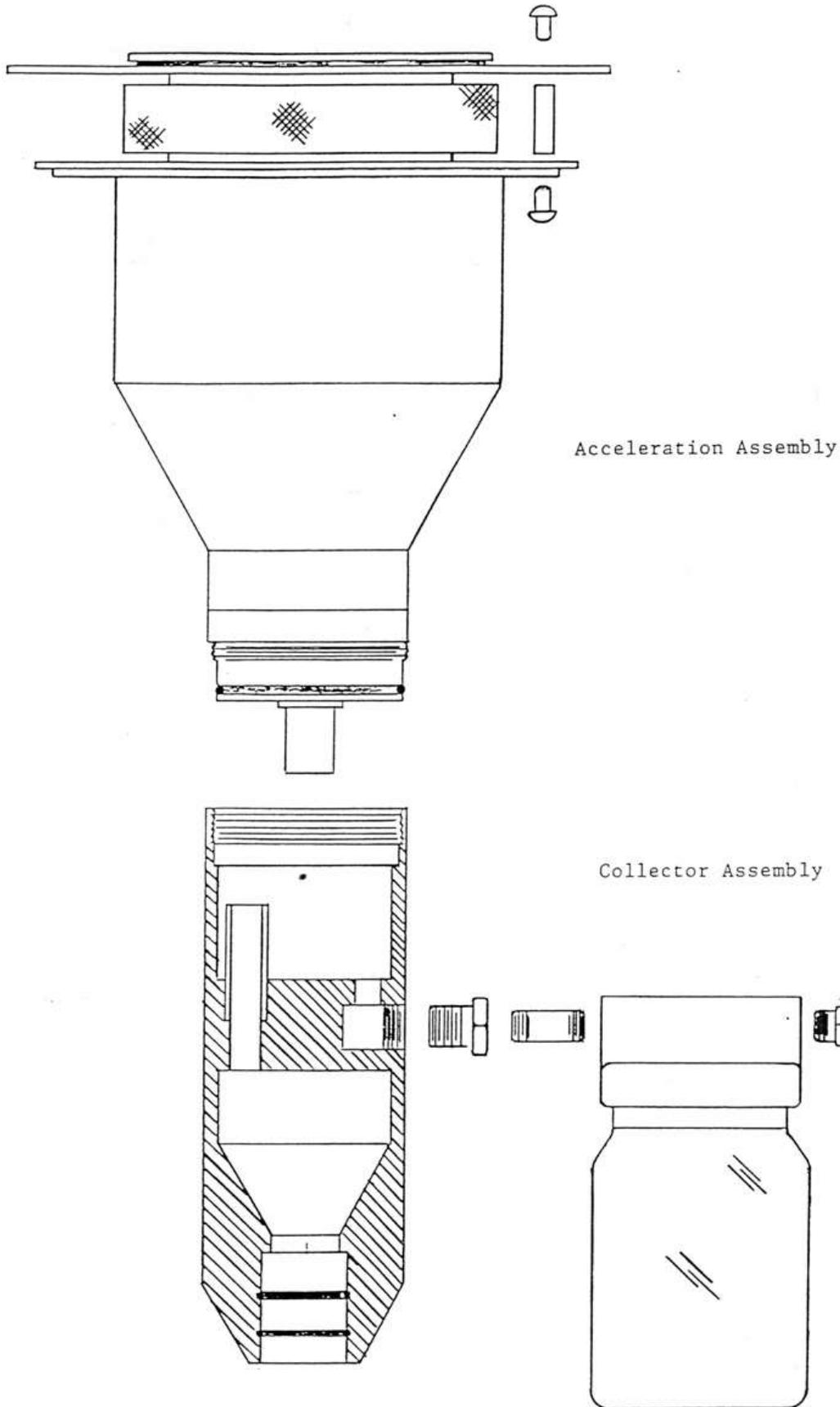


Figure 18-2 TEOM PM₁₀ Sampling Inlet

18.4.6 Filter Cartridge Exchange Procedure

1. Refer to Figure 18-3 when following the instructions for filter exchange. It is recommended that the TEOM filter cartridge box is stored in the sensor unit of the TEOM analyser so they are pre-conditioned before changing. Inform the QA/QC when the site stock of unused filters gets down to four.
2. Check that the TEOM 'out of service' switch/'Data Stop' button is ON.
3. Open the door of the TEOM sensor unit.
4. Carefully lift the handle of the mass transducer to swing the transducer into its filter changing position and expose the filter.
5. Carefully insert the filter exchange tool under the filter cartridge so that the filter disk is between the fork and the upper plate of the tool (with the hub of the filter between the tines of the lower form). Gently lift the filter from the tapered element with a straight pull - DO NOT TWIST OR PULL SIDEWAYS.
6. Discard the exposed cartridge and wipe clean the exchange tool with a tissue.
7. Use the exchange tool to remove a new cartridge from the box - DO NOT TOUCH THE FILTER WITH YOUR FINGERS. Note that the box of new filters should be stored inside the TEOM sensor unit, to maintain them at a constant temperature.
8. Hold the new filter in line with the tapered element and lightly insert the hub of the filter onto the tip of the tapered element. Apply a gentle downward pressure to set the filter firmly in place (Figure 18-4) and then carefully retract the exchange tool. Problems with excessive response noise may be experienced if the filter is not seated correctly and firmly on the tip of the tapered element. The filter should, therefore, be positioned with particular care.
9. Gently move the horizontal handle downwards to close the mass transducer; allow the springs to pull it closed for the last centimetre.
10. Close the door of the TEOM sensor unit.
11. After 5 minutes, open the sensor unit and mass transducer again and push down on the filter with the base of the exchange tool. This is to ensure that no movement of the cartridge has occurred during heating of the transducer.
12. Close the door of the TEOM sensor unit.
13. Press <F1> on the TEOM control unit. The TEOM will move through its operational modes as internal parameters stabilise. Check the noise value at the bottom of the display reads <0.1 after 10 minutes. If this is not the case reseal the filter. If this does not reduce the 'noise' sufficiently return to step 1 and repeat the whole procedure. If this is not successful inform the QA/QC immediately.
14. Switch the TEOM 'out of service' switch to 'off'. If no out of service switches are fitted the TEOM will return to service automatically on reaching mode 4. If this is not successful inform the QA/QC immediately.

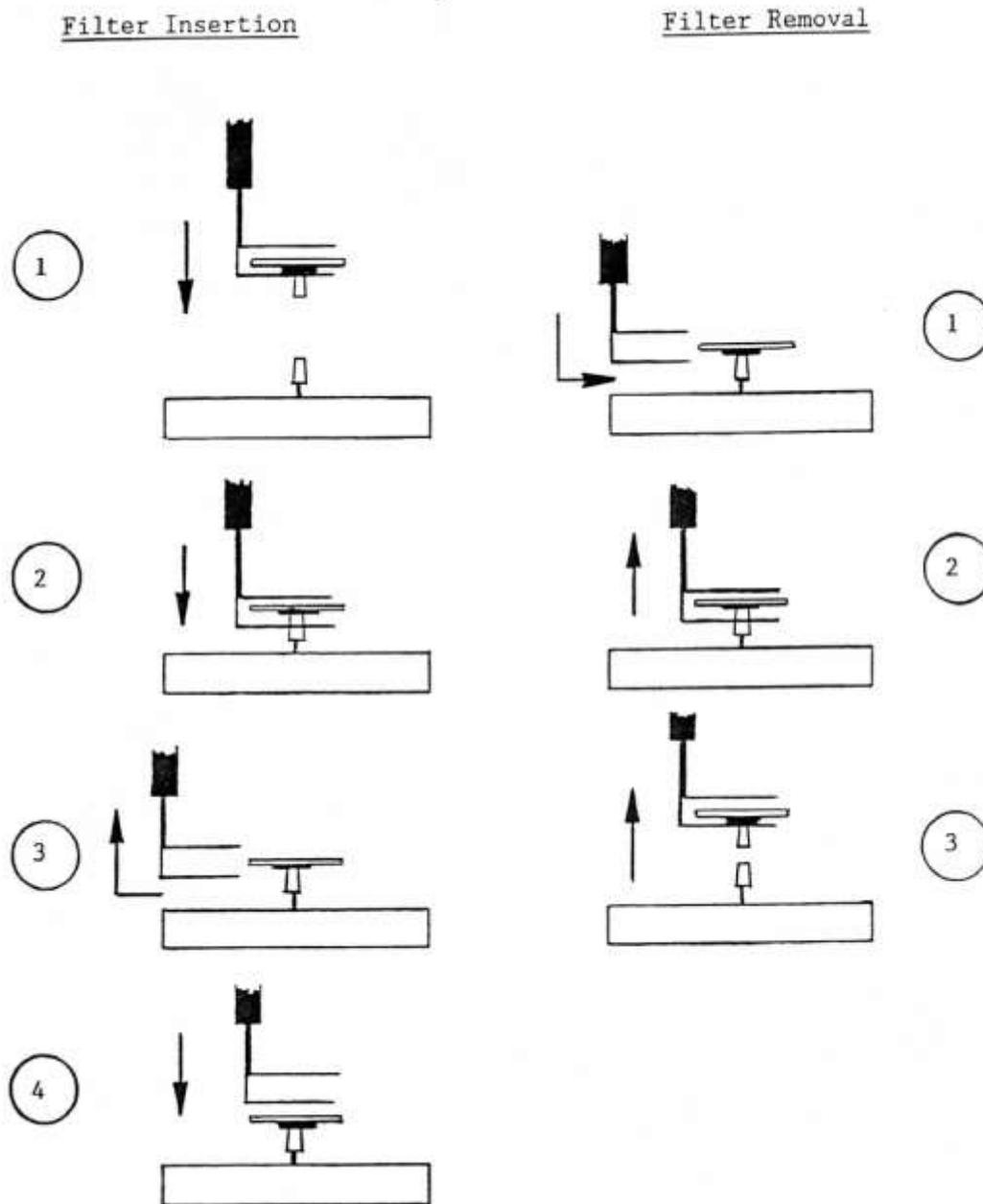


Figure 18-3 TEOM Filter insertion and removal

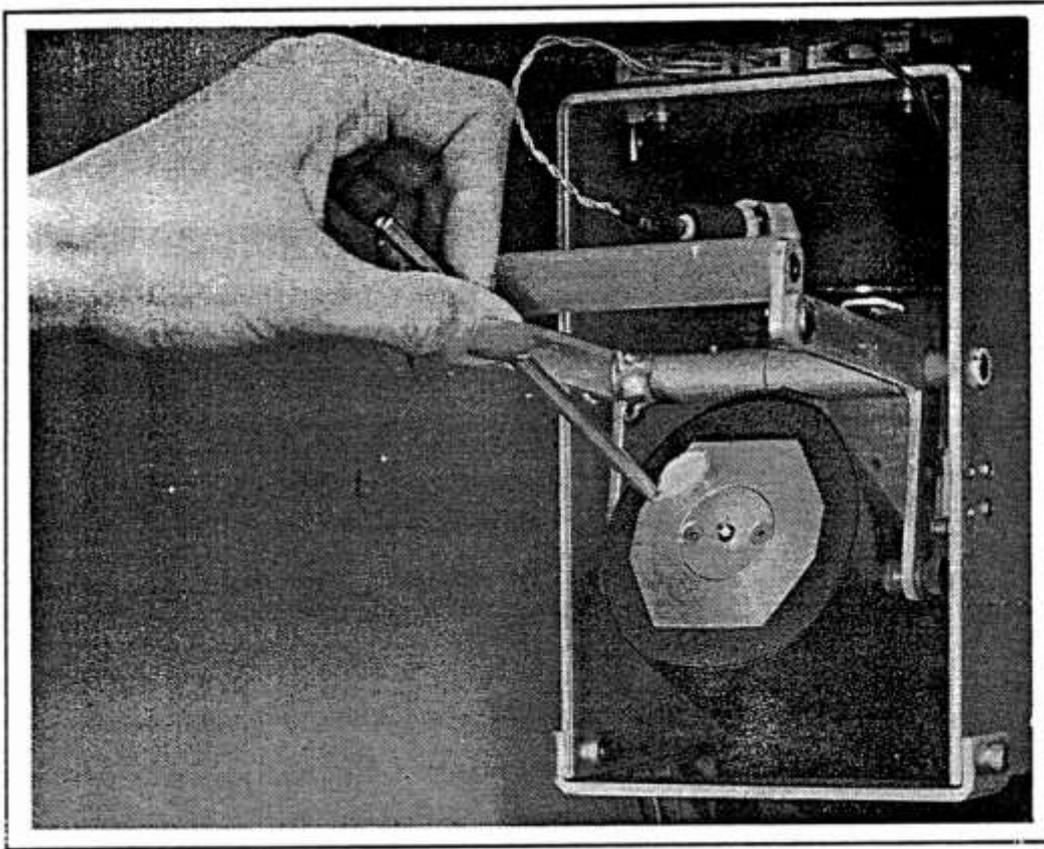


Figure 18-4 TEOM Filter Installation (with Mass Transducer in open position)

18.5 Final Checks, Safety and Security Inspection

As the AURN reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post-calibration check sheet must be completed as follows:

1. All pre-checks for the TEOM detailed in section 18.3 must now be repeated and recorded on the post-calibration check sheet.
2. Complete the final check section of the post-calibration check sheet. If "out of service" switches are not fitted telephone the QA/QC to notify them that the visit is complete so that they may restore data dissemination.
3. Complete the calibration end time.

-
4. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation which may lead to members of the public or monitoring personnel being at risk.
 5. Check that the roof area and any fittings are secure. If you have had to access the roof (to clean the inlet of a particulate analyser – see relevant instructions), check that there are no loose items left on the roof and then stow the ladder safely inside the hut.
 6. Where applicable check that all cylinders are firmly closed and the cylinder store locked (Note: if the cylinders are used for autocalibration purposes, via solenoid control, the cylinders must be left on).
 7. Ensure the cabinet is clean and tidy.
 8. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

19 TEOM FDMS Analysers, Site Operational Procedures

19.1 Introduction

A major factor in ensuring high quality from the Scottish Network will be the regular visits to each monitoring site carried out by locally based personnel.

This section sets out procedures to be followed by Local Site Operators in carrying out the tasks necessary to support the operation of the Thermo TEOM 1400AB / 8500 FDMS (Filter Dynamic Measurement System) equipment used to undertake gravimetric monitoring of airborne particulate concentrations of PM_{10} and, where relevant $PM_{2.5}$, at sites in the UK. It outlines procedures required for the changing of sensor unit and purge filters, together with the routine maintenance of the equipment necessary for continued optimal performance. It is essential that the procedures be followed as written, for routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made.

Together with these routine functions, there may be instances when non-routine site visits will be necessary, in the event of instrument or system malfunction.

Local site operators have been trained in all aspects of normal equipment operation by the QA/QC unit. Operators must retain copies of instrument manuals at each site, and are required to familiarise themselves with normal operating principles and characteristics of the instrumentation.

If your site also contains analysers for gaseous pollutants, in addition to the FDMS, you will also need to refer to the operational procedures for the relevant type of analysers.

19.2 Operational procedures

The FDMS unit provides particulate matter (PM) measurement that closely correlates with gravimetric PM mass concentration, as measured with the EU Reference Sampler. The FDMS system accounts for volatile PM that may not be detected by earlier TEOM models. The device provides high-resolution PM mass concentration readings for both short-term averages (one hour) as well as 24-hour averages. The system's basic output consists of a 1-hour average mass concentration (in $\mu\text{g m}^{-3}$) of PM updated every six minutes.

The FDMS unit automatically measures mass concentrations ($\mu\text{g m}^{-3}$) that include both non-volatile and volatile PM components.

The FDMS instrument calculates PM mass concentration average based upon independent measurements of "base" and "reference" mass concentrations (see numbered points 3 and 4 in the list below). The analyser constantly samples ambient air, using a switch valve to change the path of the main flow every six minutes. The sampling process consists of alternate sample and reference (filtered) air streams passing through the exchangeable filter in the TEOM mass sensor.

Figure 19-1 gives a schematic of the process, which is described below.

1. The analyser draws air through the PM₁₀ head in the same way as a basic TEOM and then splits the excess flow through the Auxiliary Mass Flow Controller.
2. The main flow then passes through a new module – a permeation dryer - which removes water from the airstream. The air then reaches a switching valve.
3. For six minutes, the air passes directly into the sensor unit, where PM is collected on the filter and weighed. This is identical to the method used in the TEOM 1400AB, except that the air is dried and the FDMS operates at 30°C, rather than 50°C. The flow of air for this part of the cycle is marked in green in Figure 19-1. The average concentration over this 6 minutes, is the “base” measurement of the 12-minute cycle.
4. The switching valve then diverts the air through to a purge filter, marked in blue in Figure 19-1. The main flow air passes through the drier as before, but then passes into a cooled chamber, which is held at 4°C. The air then passes through a filter, which retains all the PM in the airstream, but allows any gases to pass through. This scrubbed, zero air is then returned to the sensor unit, where it is sampled normally, to provide a baseline measurement. The average concentration over this 6 minutes is the “reference” measurement of the 12-minute cycle.
5. During the reference cycle, any volatile particulates that were collected during the base measurement cycle can evaporate from the sensor filter. This means that the reference cycle average is usually a small negative value, as material has been lost from the filter. The reference cycle measurement can also, on occasion be slightly positive, if gases are absorbed by PM on the filter cartridge. The FDMS uses the average base and reference concentrations to calculate an overall mass concentration for the 12 minute cycle, according to the following example equation:

Mass Concentration = Base Concentration - Reference Concentration.

(example: Base = 25 µgm⁻³, Reference=-2.6 µgm⁻³) Mass Concentration = 25 - (-2.6) = 27.6 µgm⁻³

The exchangeable purge filter can provide a time-integrated particulate matter sample that can be used for subsequent chemical analysis.

System Schematic

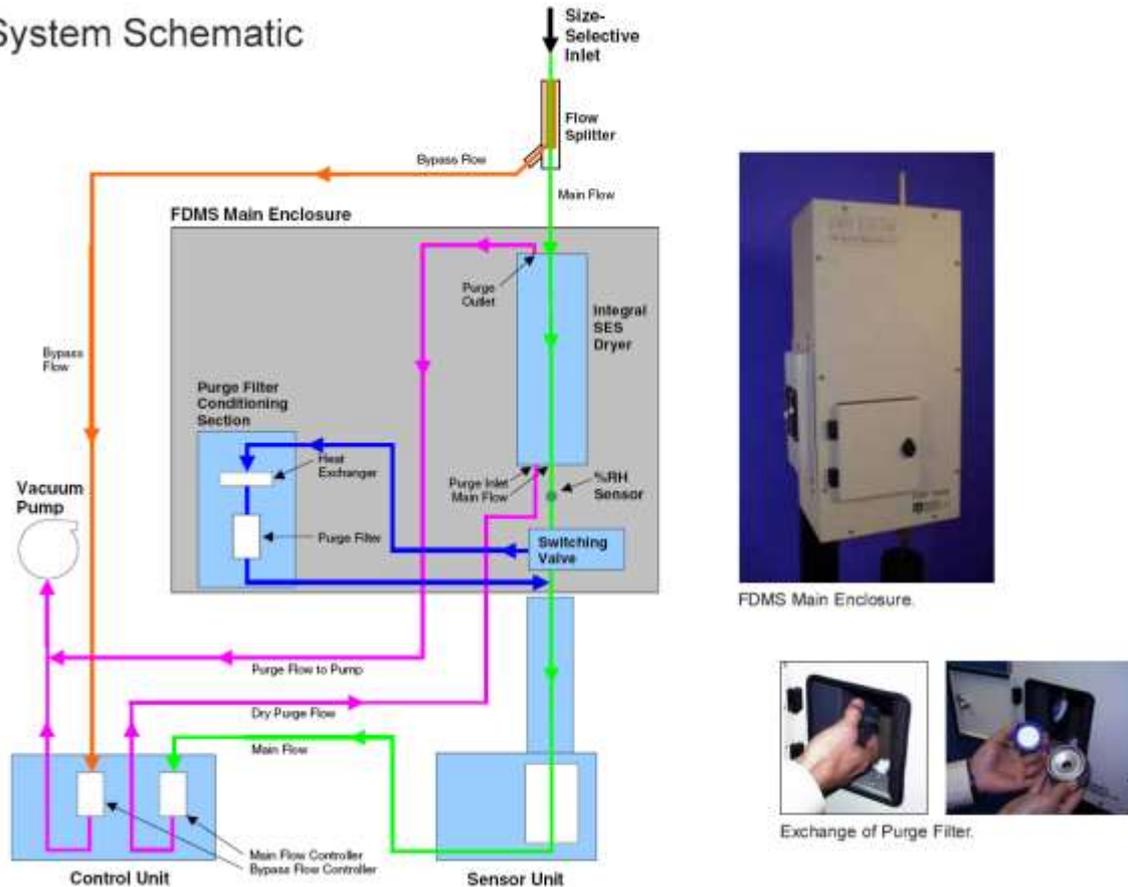


Figure 19-1 Analyser Schematic, showing 1st generation FDMS unit (B type drier)

19.2.1 TEOM FDMS Pre-Checks

The R & P TEOM FDMS instrument has a 4 line display screen, as shown in Figure 19-2. The top line displays, from left to right, current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time. This top line is fixed, whilst the other 3 lines of the display can be used to scroll through a list of information lines displaying various parameters. Use the cursor keys on the keypad to scroll up and down.

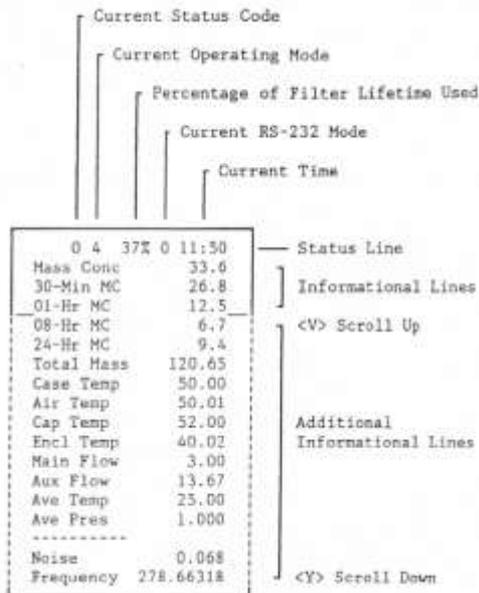


Figure 19-2 TEOM front panel display

Two lights marked "POWER" and "STATUS" are also visible on the front panel.

Record the following checks on the pre-calibration checklist.

1. In normal operation, the "POWER" switch will be on and the "STATUS" light off. Check these and record on the pre-calibration checklist.
2. Check that the power supply to the FDMS unit (8500 module) is intact by confirming that the cooler is working properly by placing a hand close to the fan on the side (1st generation FDMS) or rear (2nd generation FDMS) of the module. A steady air stream should be felt.
3. Open the front door of the FDMS module and check that the filter holder and sample tube are connected securely (1st generation only – access to the connections is not possible on the 2nd generation modules).
4. Record current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time from the top line.
5. Record the first three information lines in the appropriate space on the pre-calibration checklist.
6. Press ↓ to scroll through all information lines and record the information.
7. Press ↑ to return to the top of the information lines.
8. Record the pump vacuum measurement. This must be between –20 and –30 in Hg. CMCU must be informed if the result is outside these limits.



19.2.2 TEOM FDMS Routine Maintenance

Two filters need to be changed routinely on the TEOM FDMS unit:

- Sensor Unit filter (normal TEOM filter in the sensor unit)
- Purge filter located in the FDMS main enclosure

The TEOM sensor unit filter and the purge filter in the FDMS main enclosure must be changed together when the "percentage of filter lifetime used", as shown on the top line of the instrument display is 90% or greater. The filters supplied for the TEOM purge filters must only be used for this purpose. The sample inlet filters supplied for the other analysers must NOT be used. It is recommended that the filter boxes are stored in the sensor unit of the TEOM analyser so they are pre-conditioned before they are changed with existing filters. Whenever the filters are changed, the PM₁₀ head must be cleaned as detailed below. Since the analyser requires at least one hour to stabilise after filter cartridge changing, it is recommended that this operation be undertaken before the calibration of the gas analysers.

19.2.3 Cleaning the PM₁₀ Head

The PM₁₀ head is located on the sample inlet tube above the roof of the monitoring station. Use the ladder, with due regard to personal safety, to gain access to the cabinet roof. Extra care should be taken if raining as the roof of the cabinet may be slippery when wet. Ingress of rain into the sample inlet must be avoided, and consideration should be given to postponing cleaning the head if this is likely.

The PM₁₀ inlet (Figure 19-3) needs to be cleaned each time the TEOM FDMS filters are changed to ensure optimal performance. The cleaning materials required are a small brush, lint free tissues, cotton buds, Decon 90 (1% in H₂O), silicon grease, and distilled water. All components are to be cleaned by soaking Decon 90 on lint-free tissues or cotton buds. The component should then be rinsed with distilled water to remove any Decon 90 and wiped dry with a lint-free tissue.

19.2.4 Removing the PM₁₀ Head

1. Switch the TEOM FDMS "out of service" switch to ON. For sites without out of service switches, press the <Data Stop> button on the instrument front panel. This will flag any subsequent data as invalid.
2. Carefully lift the complete PM₁₀ head assembly from the TEOM inlet tube.
3. Protect the inlet tube so that rain, snow or dirt cannot enter at any time whilst the head is removed, and take the head inside the monitoring cabinet.

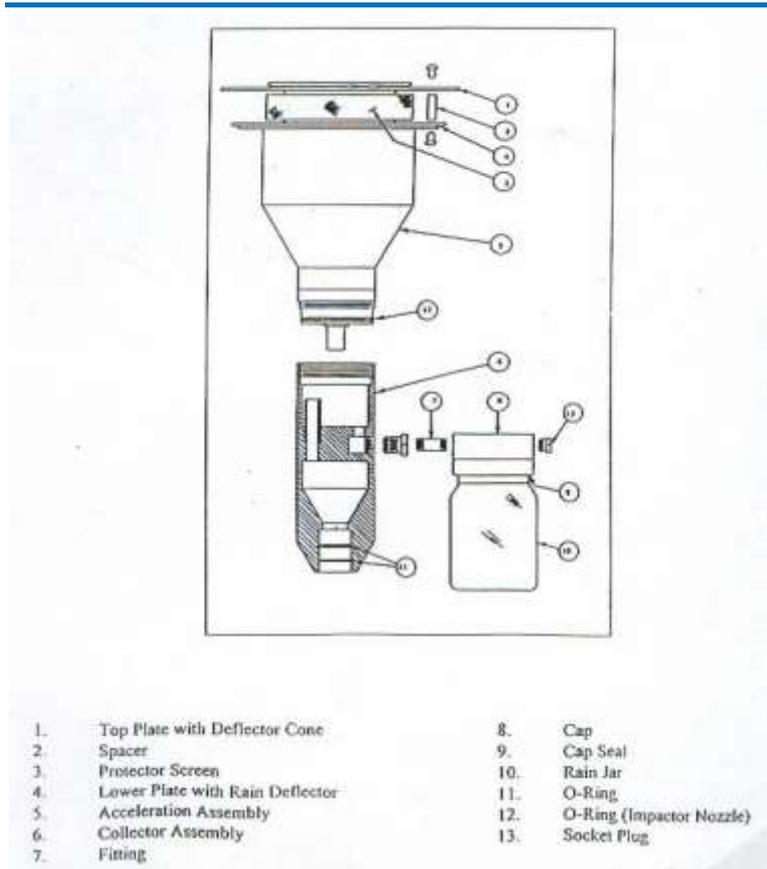


Figure 19-3 *PM₁₀ inlet assembly*

19.2.5 Cleaning the Acceleration Assembly

1. Mark the upper and lower plates of the assembly with a pencil so that the unit can be correctly aligned on reassembly.
2. Unscrew the four Philips screws from the top plate and remove the top plate and four spacers.
3. Clean the top plate, deflector cone, insect screen, internal walls and the underside plate.
4. Inspect the large diameter o-ring for wear and replace if necessary. Wipe any grease off with a tissue, and apply a thin coating of fresh silicon grease to the o-ring and the aluminium threads.
5. Carefully reassemble, using the pencil marks to align the top and bottom plates.

19.2.6 Cleaning the Collector Assembly

1. Clean the walls, the three vent tubes and the base of the assembly with a lint-free cloth soaked in Decon 90. Rinse with distilled water.
2. Use cotton buds and Decon 90 to clean the three vent tubes, base of the assembly and weep hole in the collector plate where the moisture runs out to the moisture trap. Rinse with distilled water.
3. Disconnect rain jar assembly from lower collector plate assembly. Clean inside brass tube with cotton buds and Decon 90. Rinse with distilled water.
4. Remove the rain jar and clean. For units with a cork sealing ring inside the cap of the jar, put a thin coating of silicon grease on the gasket and install the jar. If the sealing gasket is neoprene, no silicon grease is required.

5. Reconnect rain jar assembly to lower collector assembly. Ensure rain jar is sitting vertically.
6. Inspect the two inlet tube o-rings for wear and replace if necessary. Wipe off any grease present, and apply a thin coating of fresh silicon grease to the o-rings.
7. Clean the internal threads of the assembly with Decon 90 on a lint-free tissue.

19.2.7 Replacing the Head

1. Screw the Acceleration and Collector assemblies together until the threads are hand tight. DO NOT OVER-TIGHTEN
2. Place the complete assembly back onto the TEOM FDMS inlet tube.

19.2.8 TEOM Sensor Unit Filter Exchange Procedure

1. Refer to Figure 19-4 and Figure 19-5 when following the instructions for filter exchange. It is recommended that the TEOM sensor unit filter box is stored in the sensor unit of the TEOM analyser so they are preconditioned before changing
2. Check that the TEOM 'out of service' switch is ON. For sites without out of service switches, press the <Data Stop> button on the instrument front panel. This will flag any subsequent data as invalid.
3. Open the door of the TEOM sensor unit.
4. Carefully lift the clip on the front of the mass transducer to allow the transducer to open into its filter changing position and expose the filter.
5. Carefully insert the filter exchange tool under the used filter cartridge so that the filter disk is between the fork and the upper plate of the tool (with the hub of the filter between the tines of the lower form). Gently lift the filter from the tapered element with a straight pull - DO NOT TWIST OR PULL SIDEWAYS.
6. Check with Management Unit whether the filter cartridge is to be sent off for analysis. If so place in storage, otherwise discard the exposed cartridge and wipe clean the exchange tool with a tissue.
7. There are two storage locations in the transducer unit that hold fresh filter cartridges. Use the exchange tool to remove one of these - DO NOT TOUCH THE FILTER SURFACE WITH YOUR FINGERS.
8. Hold the new filter in line with the tapered element and lightly insert the hub of the filter onto the tip of the tapered element. Apply a downward pressure to set the filter firmly in place and then carefully retract the exchange tool. Problems with excessive response noise may be experienced if the filter is not seated correctly and firmly on the tip of the tapered element. The filter should, therefore, be positioned with particular care. Using the exchange tool, take a new filter cartridge from the box and place it in the empty storage location in the transducer unit.
9. Return the mass transducer to the closed position and reseal the clip to secure it in position.
10. Close the door of the TEOM sensor unit.
11. After 5 minutes, open the sensor unit and mass transducer again and push down on the filter with the base of the exchange tool. This is to ensure that no movement of the cartridge has occurred during heating of the transducer.
12. Close the door of the TEOM sensor unit.



Figure 19-4 Transducer unit (open position)

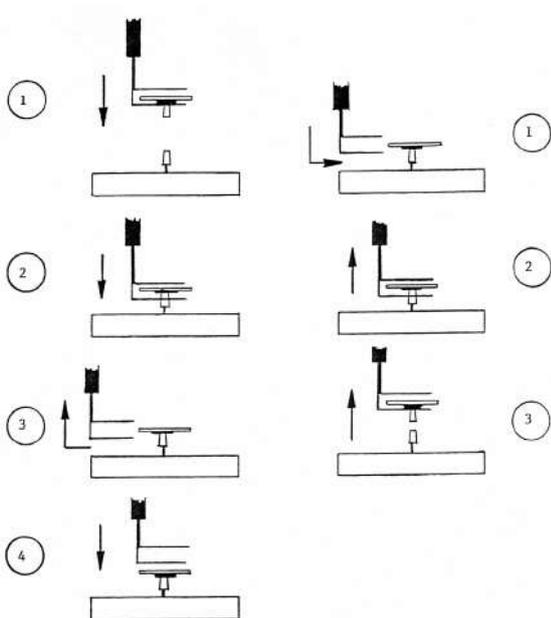
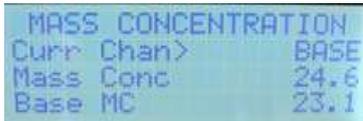


Figure 19-5 Cartridge insertion and removal

19.2.9 Purge Filter Exchange Procedure

Refer to the information diagrams in the margin and also Figure 19-1, Figure 19-5, Figure 19-6 and Figure 19-7 when following the instructions for changing the purge filter. The 47mm purge filter situated in the 8500 module must be replaced every time a TEOM filter in the sensor unit is changed, to ensure optimal performance of FDMS. The filter is cooled to 4°C. **Only EMFAB / Pallflex TX40 filters are to be used – sample inlet filters from gaseous analysers are not suitable.**

It is advisable to have a pre-prepared purge filter and cartridge assembly ready to swap into the 8500 unit. This will minimise the time that the cold surfaces are exposed to room air and reduces the possibility of water condensing in the tubing.



MASS CONCENTRATION
Curr Chan> BASE
Mass Conc 24.6
Base MC 23.1



C Drier



B Drier

1. Check that the TEOM 'out of service' switch is ON. Press **14** and then **Enter** on the TEOM control unit keyboard. This will bring up a special display showing the current operating mode of the FDMS. **The unit MUST be in BASE mode before proceeding**, if not, **either**: wait until it changes from REF mode to BASE mode (up to 6 minutes), **or**: press F8 on the keypad to force the valve to change operating position.
2. Switch the power to the FDMS module **OFF** to lock the system in BASE mode. The power can be switched off on the rear panel using the switch above the power cord.
3. Open small door located on the FDMS module
4. (1st generation modules only) Disconnect the quick connect fitting, from the filter holder on the left side of the compartment.
5. Unscrew the filter holder from the chiller and locate the blue filter cassette with 47mm filter
6. Remove the blue filter cartridge and replace with a new pre-prepared one. Make sure to install the 47mm filter into the cassette so that the woven side of the filter paper is face down on the foil. Place the cartridge into the holder with the foil back against the inner chamber and the filter facing upwards.
7. Check with Management Unit whether 47mm filter is to be sent off for analysis. If so place in refrigerated storage, otherwise discard.
8. Using a tissue, carefully wipe away any moisture that might be present in and around the filter chamber making sure no loose fibres or tissue are left behind. Check the condition of the 'V' seal and if damaged either replace it or report it to QA/QC.
9. Install filter holder back into chiller and connect the quick-connect fitting onto the filter holder (1st generation modules only). Shut door.
10. Switch the power to the FDMS module **ON**. **Check that this restarts the fan**. Confirming that the cooler is working properly. The fan is located on the side (1st generation FDMS) or rear (2nd generation FDMS) of the module. A steady air stream should be felt.
11. Turn on the FDMS unit again. Press <F1> on the TEOM control unit and allow one hour for system to reset.
12. Switch the TEOM 'out of service' switch to 'off'.
13. After one hour check that TEOM mass concentration returns to ambient levels. Scroll down to view the frequency value and examine how stable the response is. If very high or negative concentrations are displayed, or if the frequency value is not stable (i.e. if it changes by more than 0.001Hz in a 2 minute

period), reseal the tapered element filter cartridge (see section 19.2.8) and press <F1> again, waiting for a further hour for the analyser to return to normal operation. If the instrument still does not return to normal operation, contact QA/QC.



Figure Figure 19-7 C type Purge filter

19.2.10 Cleaning the PM_{2.5} Sharp Cut Cyclone (SCC) (where fitted)

PM_{2.5} analysers have an additional module placed in the sample stream to remove particulate matter larger than 2.5 microns. This unit is called a sharp cut cyclone (SCC), shown in Figure 19-8. In addition to the routine cleaning of the PM₁₀ sample inlet, it will be necessary for local site operators to clean the SCC used on FDMS units measuring PM_{2.5}.

Holding the SCC unit upright in the position which it has been removed from its 'plug-in' position, pull the 180° size separation unit from the side of the main accelerator chamber.

The separation unit can be cleaned simply by blowing into the orifice at the top of the unit.

Unscrew the knurled plug on the side of the SCC and clean the walls of the main accelerator chamber with a lint free cloth soaked in Decon 90. Wipe clean with a dry lint-free tissue.

Once cleaned, refit the knurled plug, push the separation unit back into position on the accelerator chamber and re-locate the SCC unit into its plug-in position.



Figure 19-8 Sharp Cut Cyclone - PM_{2.5} shown in stand alone profile and in conjunction with a PM₁₀ sampling head

20 FIDAS 100/200/300 Site Operational Procedures

20.1 Introduction

This section describes LSO procedures for the FIDAS 100/200/300, which may be included in a site equipped with any make of gaseous analysers.

The regular visits to each monitoring site, carried out by the LSO, are an important factor in ensuring high quality data is obtained from the SAQD Network. These site visits will allow the following functions to be undertaken:

1. Pre calibration checks;
2. Calibration of analysers;
3. Post calibration checks, safety and security inspection.

Occasionally you may also have to carry out non-routine site visits, in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. Operators must keep copies of instrument manuals at each site, and ensure they fully understand the normal operating principles and characteristics of the instrumentation.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for both routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made.

This section will cover the main procedures that a local site operator will have to undertake for a FIDAS.

20.2 Operational procedures

20.2.1 Pre-calibration Checks

In this section, a number of initial visual checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration spreadsheet. Complete all the checks for all the analysers and ancillary equipment. Calibration results should be recorded on a dedicated electronic spreadsheet and sent to CMCU and QA/QC. The electronic sheet should preferentially be used on site, to minimise the risk of errors, but if suitable facilities are not available, the results can be recorded on paper for subsequent transfer to the spreadsheet in the office.

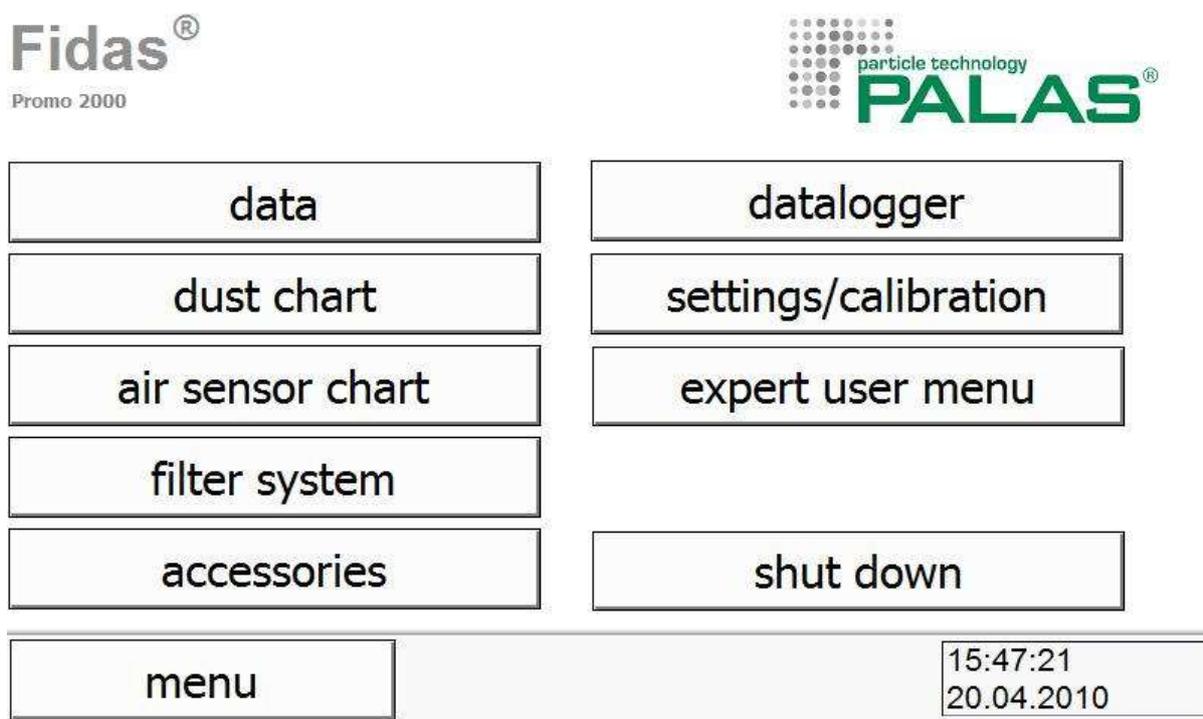
When all checks are complete, inform the CMCU if any are not correct, before proceeding with the calibration.

Before carrying out the pre-calibration checks the Envirollogger must be placed into Service Mode. Press the 'service' button located on the envirollogger – Red light should illuminate. The Envirollogger is now in service mode.



FIDAS analyser

The FIDAS analyser has a touch screen front panel, the main start screen display is shown below.



The user can change from one display option to another by using the touch display.

Press the 'data' icon on top left of the screen. This will allow the user to see the current data overview. Record the current readings from the front panel and the current time on the pre calibration checklist. Telephone the ESU if the time displayed differs by more than 5 minutes from Greenwich Mean Time.

Dust

- PM 1
- PM 2,5
- PM 4
- PM 10
- PM total (total mass concentration)
- Cn: Particle concentration in P/cm³

Air sensors:

- Relative humidity
- Temperature
- Barometric pressure NOTE: Pressure is displayed as hPa which is the same as mBar.

To return to the home page press 'menu'.

PM diagnostics

Press 'device status' to access the PM diagnostics page. Check the display and record the current readings in the pre calibration checklist.



To note down the flow sensor offset value -

1. From the main menu - select Expert User Menu on the front screen of the instrument
2. On keypad enter 1 then – (minus) and press Accept.
3. Select Sensor/calibration then sensor/calibration on the next screen.
4. Select Flow Sensor offset Measurement in bottom right corner of screen. This button may not be present on all analysers.
5. Note down the offset value in the calibration sheet. NOTE: Offset will only be visible for 5 seconds before returning to previous screen.
6. Select menu twice
7. Then select "Auto" button and then select the green "Fidas 200" button. This will put the analyser back into service mode and state "Device Ready" in green.

NOTE - Calibration of the FIDAS should only be carried out at ambient temperatures between 5 and 35 °C.

20.2.2 Completion of Pre-calibration Checks

If any of the above checks are not correct, inform ESU before proceeding with calibration. If all correct, proceed to the next section.

20.2.3 Analyser Calibration Procedure

Results of the calibration will be taken from the instrument's display for recording on the calibration record sheets.

The two point calibration of the FIDAS analyser is undertaken during each site visit. The calibration is carried out as follows:

20.2.4 To zero FIDAS

The following steps are needed to carry out a zero test on the FIDAS.

1. Remove head located in head cage using the allen key provided.



(FIDAS head – HEPA filter)

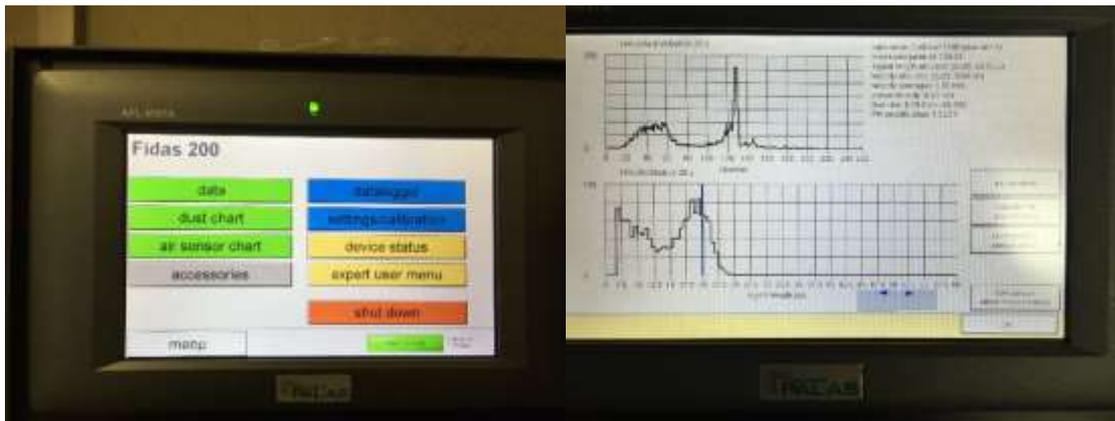
2. Connect the HEPA filter to inlet, making sure it is a tight fit around inlet.
3. With the HEPA filter connected, Press 'Data' on front screen of the instrument.
4. Wait approximately 20 seconds
5. All readings should go down to zero. P/cm should go straight to zero, ug/cm³ takes about 20 minutes. Note down all the values on the calibration spreadsheet.
6. Remove the HEPA filter and place in box provided.
7. Keep head detached from inlet for next calibration process.
8. Press 'menu' on analyser front screen to return to the homepage.

(Keep head detached from inlet for next calibration procedure)

20.2.5 To span FIDAS

The following steps are needed to carry out a span test on the FIDAS.

1. Press Expert User Menu on the front screen of the instrument



2. On keypad enter 1 then – (minus) and press Accept.
3. Press Sensor Calibration, then on sub menu press Sensor calibration again
4. With the head still detached, go to sample inlet located on the roof and connect long silicone tubing to the sample inlet.
5. Shake the 'Cal Dust' bottle to get cloud inside the bottle. Remove the lid and put the end of tubing into the cloud and straight back out. DO NOT put tubing in too far.
6. On the top right of the instrument screen, - *Calibration Cal Dust 1100 peak at 130* Measured Peak at xxx.xx (note down this value). The result must be within the range 128.5 to 131.5. Cal dust 1500 peak at 142. The result must be within the range 141 and 143.
7. If the LSO spreadsheet flags up an error Says "Calibration failed". Redo the calibration. If the second result also falls outside the acceptable ranges, contact your ESU
8. Press Menu to return to home page.
9. Place the head back on the Inlet and tighten the screws using the allen key provided.

20.2.6 Post-calibration checks

Repeat the PM diagnostics section and note down all values in the Post calibration section on the calibration sheet. This includes the flow sensor offset value.

After noting down the **flow sensor offset** value, press the 'menu' button twice. Follow the below steps to place the analyser into 'operation auto mode'

Under Operation Modus

1. Press Auto
2. Press FIDAS 200
3. Check Device Status, operation. The analyser is now sampling.



20.2.7 Post-calibration Checks, Safety and Security Inspection

As the AURN reports time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive analyser noise or cyclic response changes. Information on analyser performance over very short time periods is important, as this will alert network managers and the QA/QC Unit as to whether instrumentation faults are developing.

Performing calibration checks at regular scheduled intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

In addition, seemingly unimportant occurrences, such as an analyser air pump being noisy, may be indicative that the unit is liable to malfunction; this should be reported by the operator.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the post-calibration check sheet must be completed as follows:

10. Compare the results of the post calibration checks to the pre-calibration values. If there are any large unexpected changes notify the CMCU.
11. The Envirologger must be placed back **out** of Service Mode. Press the 'service' button located on the envirologger – Red light should disappear. The Envirologger is now collecting data.
12. Complete the final check section of the post-calibration check sheet. Check all analysers are back in service/operation mode.
13. Complete the calibration end time.
14. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality.

Immediate action must be taken to rectify any situation that may lead to members of the public or LSO personnel being at risk.

15. Check that the roof area and fittings are secure. *If you have had to access the roof, to clean the inlet of a particulate analyser, check that there are no loose items left on the roof and then stow the ladder safely inside the hut.*
16. Ensure the cabinet is clean and tidy.
17. Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at aqadmin@ricardo.com. (These e-mail addresses are provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

21 Beta Attenuation Monitor Model 1020 Site Operational Procedures

21.1 Introduction

This document describes LSO procedures for the Beta Attenuation Monitor model 1020 (BAM), which may be included in a site equipped with any make of gaseous analysers.

The regular visits to each monitoring site, carried out by the LSO, are an important factor in ensuring high quality data is obtained from the Scottish Network. These site visits will allow the following functions to be undertaken:

- (1) Pre-calibration checks;
- (2) Changing the particulate monitor filter (if applicable);
- (3) Post-calibration checks, safety and security inspection.

Occasionally you may also have to carry out non-routine site visits, in the event of apparent instrument or system malfunction.

Local site operators will be trained in all aspects of normal equipment operation and in the relevant calibration procedures by the QA/QC Unit. Operators must keep copies of instrument manuals at each site, and ensure they fully understand the normal operating principles and characteristics of the instrumentation.

The following sections of the manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for both routine and non-routine site visits, to ensure that reliable and accurate air quality measurements are made.

This section will cover the main procedures that a local site operator will have to undertake for a BAM 1020. These are as follows

- Pre and Post diagnostic checks
- Cleaning of Inlet Head
- Cleaning the acceleration chamber
- Cleaning the collector assembly
- Cleaning the Nozzle and vane
- Cleaning SCC
- Filter Tape installation
- LSO call out faults

21.1.1 Health and Safety Considerations for the Met One BAM

The BAM contains a small, sealed radioactive source of beta radiation (carbon 14, or ^{14}C). This is the source of the beta particles used in the measurement process. Carbon 14 is a radioactive material and is therefore dangerous if it gets *inside* the body (if swallowed, inhaled or absorbed through the skin). That is not a risk here, because the source is sealed and safely contained inside the BAM. For this reason, **you must not attempt to access, modify or remove the BAM's sealed beta source for any reason.**

It has been found that, when the door of the BAM's case is open, a detectable amount of beta radiation emerges from the BAM, through the slit between the tape and the source, probably having been scattered by the tape and the material on it.

Beta radiation consists of fast moving electrons. The beta radiation from ^{14}C is of relatively low energy; it cannot penetrate through the case of the BAM, can only travel around 22 cm through air, and – most importantly - cannot penetrate even the outer layer of your skin.

However, it is known that direct exposure of the lens of the eye to beta radiation can increase the risk of developing the eye condition of cataracts (where the lens becomes opaque). This is a known risk for people whose eyes are directly and frequently exposed to beta radiation (such as health professionals regularly carrying out certain medical imaging procedures), and there exists an occupational exposure limit specifically for the lens of the eye.

When carrying out BAM maintenance tasks such as nozzle cleaning or tape changing, the operator will have the door open and may have their eyes close to the tape slit. While it is currently our understanding that any risk is very small, (because of the low energy of the beta radiation, and because such tasks are infrequent and do not take long), as a precaution we are recommending that safety glasses are worn when carrying out such tasks. Beta particles will not be able to pass through the plastic material they are made of.

We are therefore making the following recommendations to Local Site Operators and others who carry out work on a BAM1020 that involves opening its door:

1. We remind you **not to attempt to access, modify or remove the BAM's sealed beta source for any reason.**
2. It is recommended (but not essential) to **wear safety glasses when working on the BAM 1020 with its door open.** As well as offering more than adequate protection for the extremely small risk of any long-term eye damage from exposure to radiation the beta source, this will also minimise any other risk of eye injury from other maintenance activities such as cleaning nozzles etc.

Safety glasses are already provided at All SAQD monitoring stations that have BAMs (because they are necessary for other work at the sites).

21.2 BAM Main Menu and Key Board Functions

The "Main Menu" and keyboard are shown in Figure 21-1 below, followed by a description of the keyboard functions.

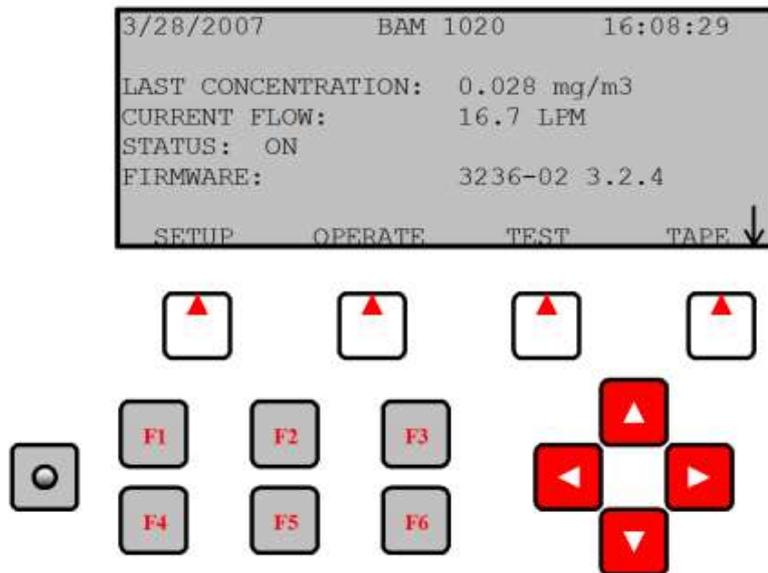


Figure 21-1 Main Menu and Keyboard lay out

21.2.1 Soft Keys:

Directly beneath the display are four white buttons called “soft-keys” or “hot-keys”. These are dynamic keys whose function changes in response to a menu option displayed directly above each key on the bottom row of the display. Whatever menu option is displayed above one of these keys is the function which that key will perform in that particular menu. These are used throughout the entire menu system for a wide variety of functions. For example, changes/updates made within a menu are usually not saved unless a SAVE soft-key is pressed. EXIT is also another common soft-key function.

21.2.2 Arrow (Cursor) Keys:

The four red arrow keys are used to scroll up, down, left, and right to navigate in the menu system, and to select items or change fields on the screen. The arrow keys are also often used to change parameters or increment/decrement values in the menu system.

21.2.3 Contrast Key:

The key with a circular symbol on it is for adjusting the light/dark contrast on the LCD display. Press and hold the key until the desired contrast is achieved. It is possible to over-adjust the contrast and make the entire display completely blank or completely dark, so be careful to set it to a visible level or it may appear that the unit is not operating.

21.2.4 Function Keys F1 to F6:

The function keys serve as shortcuts to commonly used menu screens, and can be safely pressed at almost any time without interrupting the sample cycle. The F keys are only functional from the main menu screen or for entering passwords. The factory default password is F1, F2, F3, F4.

F1 Current:

This key is a shortcut to the OPERATE > INST screen, used to display the instantaneous data values that are being measured by the BAM-1020. The F1 key can be used without interrupting a sample cycle.

F2 Average:

This key is a shortcut to the OPERATE > AVERAGE screen, used to display the latest average of the data recorded by the BAM-1020. The F2 key can be used without interrupting a sample cycle.

F3 Error Recall:

This key allows the user to view the errors logged by the BAM-1020. The errors are sorted by date. The last 12 days which contain error records are available, and up to the last 100 errors can be viewed. The F3 key can be used without interrupting a sample cycle.

F4 Data Recall:

This key allows the user to view the data stored in the BAM-1020, including concentrations, flow, and all six external channels. The data is sorted by date, and the user can scroll through the data hour-by-hour using the soft-keys. Only the last 12 days which contain data records are available in this menu. The F4 key can be used without interrupting a sample cycle.

F5 Transfer Module:

This key is used to copy the memory contents to an optional transfer storage module to retrieve the digital data without a computer. This function is rarely used. Met One recommends downloading the data with a laptop, computer or modem connection.

F6 (Blank):

This key is not assigned a data function.

21.3 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of each analyser) to see if an episode is occurring i.e. PM_{10} levels during the last hour are about $100\mu g/m^3$
2. Using the most up to date electronic calibration sheets provided enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the site toolkit is complete.

If “out of service” switches are not fitted at the site the QA/QC should be telephoned upon arrival. This will allow them to ensure that calibration data is not disseminated as ambient data.

21.4 Pre and Post Calibration checks

In this section, a number of initial visible checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the pre-calibration sheet. Complete

all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the QA/QC if any are not correct.

To obtain the required information use the various key pad functions on the monitor front panel (i.e. soft keys and Arrow keys)

If any of the above checks are not correct, inform QA/QC before proceeding.

21.5 Modem (where fitted)

Check that the light on the modem is flashing and all connections are secure. Record on the pre-calibration checklist provided.

21.6 Cleaning the PM₁₀ Head

The PM₁₀ head is located on the sample inlet tube above the roof of the monitoring station. Use the ladder, with due regard to personal safety, to gain access to the monitoring station roof. Extra care should be taken if raining as the roof of the station may be slippery when wet.

The PM₁₀ inlet needs to be cleaned each time the filter tape is changed to ensure optimal performance. The cleaning materials required are a small brush, lint free tissues, cotton buds, Decon 90 (1% in H₂O), silicon grease, and distilled water. All components are to be cleaned by soaking Decon 90 on lint-free tissues or cotton buds as appropriate. The component should then be rinsed with distilled water to remove any Decon 90.

21.7 Cleaning the Collector Assembly (Monthly)

1. Clean the walls, the three vent tubes and the base of the assembly with a lint-free cloth soaked in Decon 90. Rinse with distilled water.
2. Use cotton buds and Decon 90 to clean the three vent tubes, base of the assembly and weep hole in the collector plate where the moisture runs out to the moisture trap. Rinse with distilled water.
3. Disconnect rain jar assembly from lower collector plate assembly. Clean inside brass tube with cotton buds and Decon 90. Rinse with distilled water.
4. Remove the rain jar and clean. For units with a cork sealing ring inside the cap of the jar, put a thin coating of silicon grease on the gasket and install the jar. If the sealing gasket is neoprene, no silicon grease is required.
5. Reconnect rain jar assembly to lower collector assembly. Ensure rain jar is sitting vertically.
6. Inspect the two inlet tube o-rings for wear and replace if necessary. Wipe off any grease present, and apply a thin coating of fresh silicon grease to the o-rings.
7. Clean the internal threads of the assembly with Decon 90 on a lint-free tissue.

21.8 Cleaning the Acceleration Assembly (Quarterly)

1. Mark the upper and lower plates of the assembly with a pencil so that the unit can be correctly aligned on reassembly.
2. Unscrew the four Philips screws from the top plate and remove the top plate and four spacers.
3. Clean the top plate, deflector cone, insect screen, internal walls and the underside plate.

4. Inspect the large diameter o-ring for wear and replace if necessary. Wipe any grease off with a tissue, and apply a thin coating of fresh silicon grease to the o-ring and the aluminium threads.
5. Careful reassemble, using the pencil marks to align the top and bottom plates.

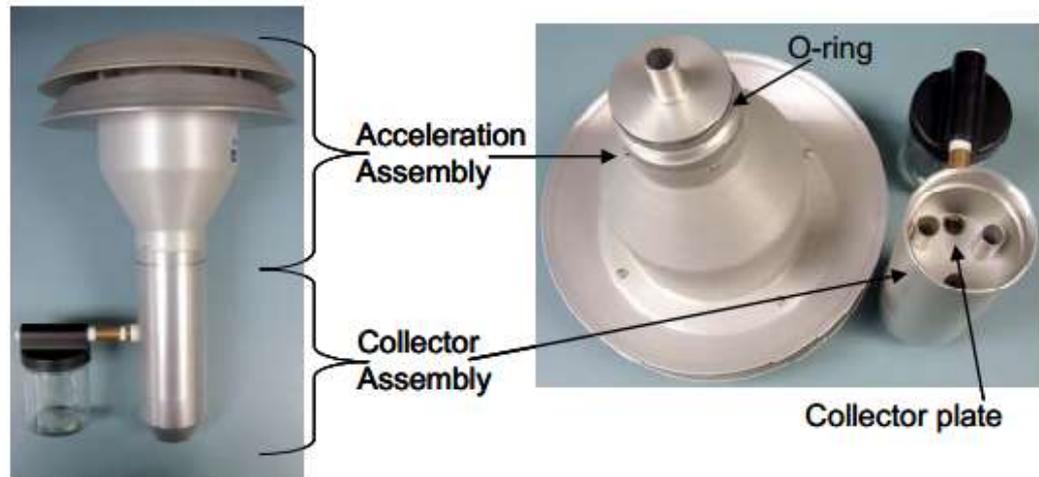


Figure 21-2 The PM_{10} inlet head

21.9 Clean the Nozzle and Vane

Regularly cleaning the BAM-1020 nozzle helps prevent leak and optimizing data accuracy. Monthly cleaning (and at every filter tape change) has generally proven adequate for this procedure, but more frequent cleaning may be necessary in some environments.

High leak values normally indicate a build-up of filter material at or near the nozzle/filter paper interface, compromising the interface “seal”, allowing air to be drawn in around the nozzle perimeter. Left uncorrected, the accuracy of the measurements can be affected and, in some situations, negative concentration values and/or low correlation with reference equipment may result.

When the nozzle is lowered, the downward pressure on these pieces of filter material can punch a hole in the tape (Figure 21-3, right panel). A puncture in the tape allows the beta particles to pass through without attenuation. This defect may reduce the post-sample count, and, in situations of low ambient PM concentrations, may cause this count to be larger than the pre-sample count, resulting in a negative concentration.

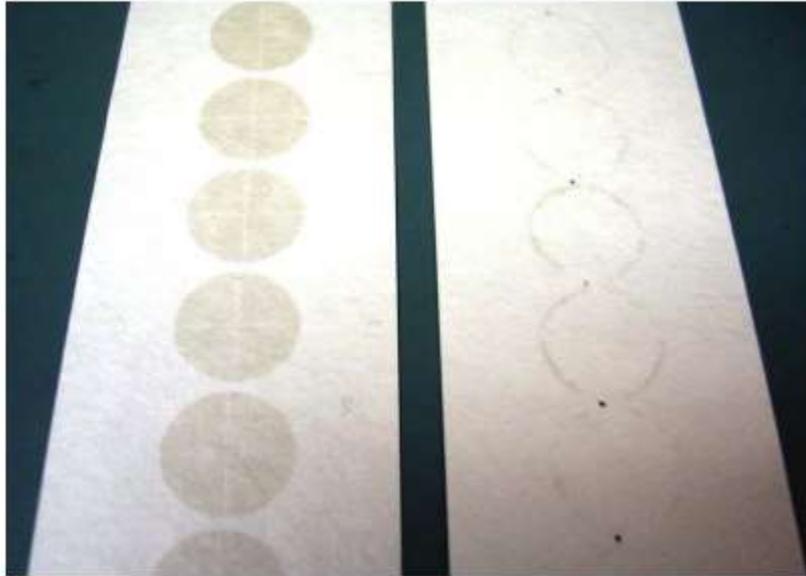


Figure 21-3 Filter tape from a BAM-1020 with a clean nozzle and vane (left) and from a poorly maintained unit (right), where debris accumulation under the nozzle has punched a hole in the tape and caused the nozzle to leak, creating the halo effect. (Photo courtesy of Met One)

21.9.1 Nozzle and Vane Cleaning Procedure

The following steps are needed to clean the nozzle and vane. Refer to the photos in Figure 21-4.

1. Raise the nozzle in the TEST > PUMP menu. Remove the filter tape (if installed) from the nozzle area. It is not necessary to completely remove the tape from the spools.
2. With the nozzle up, use a small flashlight to inspect the cross-hair vane.
3. Clean the vane with a cotton-tipped applicator and isopropyl alcohol. Hardened deposits may have to be carefully scraped off with the wooden end of the applicator or a dental pick or similar tool.
4. Lower the nozzle in the TEST > PUMP menu. Lift the nozzle with your finger and insert another cotton swab with alcohol between the nozzle and the vane. Let the nozzle press down onto the swab with its spring pressure (Figure 21-4 left panel).
5. Use your fingers to rotate the nozzle while keeping the swab in place. A few rotations should clean the nozzle lip.
6. Repeat the nozzle cleaning until the swabs come out clean.
7. Inspect the nozzle lip and vane for any burrs which may cause leaks or tape damage.



Figure 21-4 A cotton-tipped applicator and isopropyl alcohol are used to clean the BAM-1020 nozzle and vane (left panel). A view of the nozzle, sampled filter tape, and filter tape support vane are shown in the right panel.

21.10 Clean Sharp Cut Cyclone (SCC) (PM_{2.5} only)

The Sharp Cut Cyclone (SCC) - Figure 21-5 - is an essential component of the inlet system. It needs to be diligently maintained or it will corrode. Disassemble and clean the SCC following these steps:

1. Remove the SC from its installed position in the instrument.
2. Pull off the side transfer tube. If it is too tight to remove by hand, pry it off with a rigid plastic lever. Care should be taken to not damage the two O-ring seals.
3. Unscrew the top cap and the grit pot.
4. Use alcohol wipes, or if unavailable, a dampened cloth, to remove all visible deposits.
5. These deposits are most likely to be found at the bottom of the cone (located beneath the grit pot) and inside the grit pot.
6. Inspect all O-rings for shape and integrity. If at all suspect, replace. Lubricate all O-rings with light grease. It is important to well lubricate the transfer tube to avoid difficult disassembly.
7. Clean hands with alcohol wipe or similar media.
8. Assemble in reverse order and reinstall.

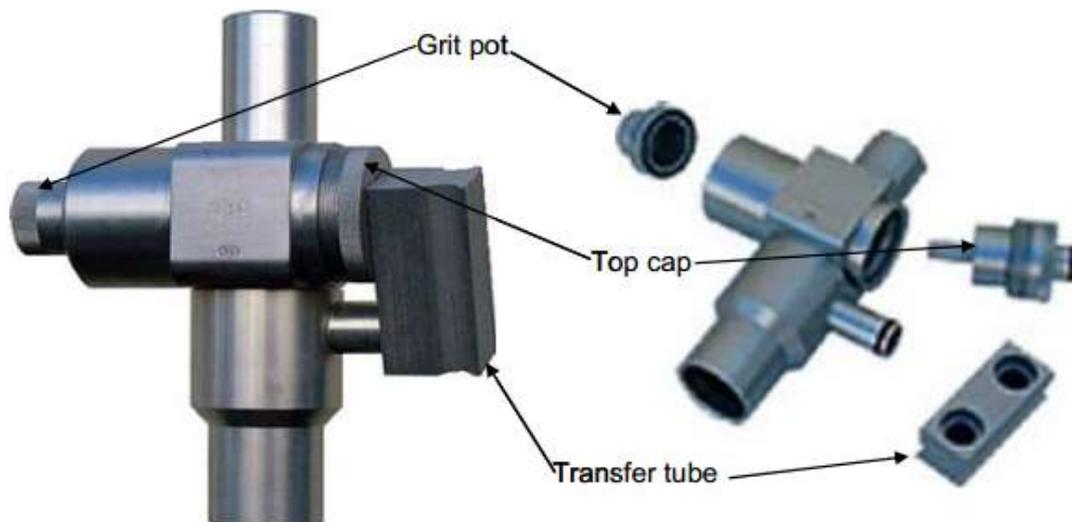


Figure 21-5 $PM_{2.5}$ Sharp Cut Cyclone

21.11 Filter Tape Installation

A roll of filter tape must be loaded into the BAM-1020 for sampling. One roll of tape should last approximately two (2) months under normal operation. It is important to have several spare rolls of tape available to avoid data interruptions. It is the responsibility of the site operator to have at least one spare roll ready for installation. If there are no spare filter tapes please inform the QA/QC.

The tape should be changed when it approaches the end of the roll based on visual inspection during each site visit by the site operator.

Filter tape should never be “flipped over” or re-used! This will result in measurement problems.

Loading a roll of filter tape is achieved by using the following steps and referring to Figure 21-6. Gloves must be worn whilst installing new tape.

1. From the MAIN MENU screen, press the <TAPE> soft key to enter the TAPE menu (Note: This is not the same as the TEST > TAPE menu). If the nozzle is not in the UP position, press the <TENSION> soft-key to raise the nozzle.
2. Lift the rubber pinch roller assembly and latch it in the UP position (see Numbers 5 and 7 in Figure 21-6). Unscrew and remove the two clear plastic spool covers.
3. An empty core tube **MUST** be installed on the left (take-up) reel hub. This provides a surface for the used tape to spool-up on. Met One supplies a plastic core tube to use with the first roll of tape. After that, you can use the empty core tube left over from your last roll (right reel hub) to spool-up the new roll. Never fasten the filter tape to the aluminum hub.
4. Load the new roll of filter tape onto the right (supply) reel, and route the tape through the transport assembly as shown in Figure 21-6 below. Attach the loose end of the filter tape to the empty core tube with cellophane tape or equivalent.
5. If the tape change is a result of a tape break do not replace with entirely new spool unless it is close to being empty. Remove used filter tape from the left hand spool and attach loose end to the empty core tube.
6. Rotate the tape roll by hand to remove excess slack, and then install the clear plastic spool covers. The covers will clamp the rolls to the hubs to prevent slipping.

-
7. Align the filter tape so that it is centered on all of the rollers. Newer units have score marks on the rollers to aide in visually centering the tape.
 8. Unlatch and lower the pinch roller assembly onto the tape. The BAM will not function if the pinch rollers are latched up, and it has no way of automatically lowering the roller assembly!
 9. Press the <TENSION> soft-key in the TAPE menu. The BAM-1020 will set the tape to the correct tension and alert you if there was an error with the process.
 10. While still in the TAPE menu, press the <SELF TEST> soft key. The BAM-1020 has a built-in self-test function which automatically tests most of the tape control and flow systems of the unit. (The self-test can also be used if the operator suspects a problem with the unit.) The tests will take a couple of minutes, and the BAM-1020 will display the results of each tested item with an OK or a FAIL tag (see Figure 20-2). If all of the test items are OK, the status will show SELF TEST PASSED as shown in the drawing below. If any item fails, the status will show ERROR OCCURRED. If an error or Failed status occurs, address the item identified, and perform the SELF TEST again. If the problem cannot be resolved, call the QA/QC.
 11. Press the <EXIT> soft key to return to the main menu. The BAM will automatically begin normal sampling operations at the top of the next hour.

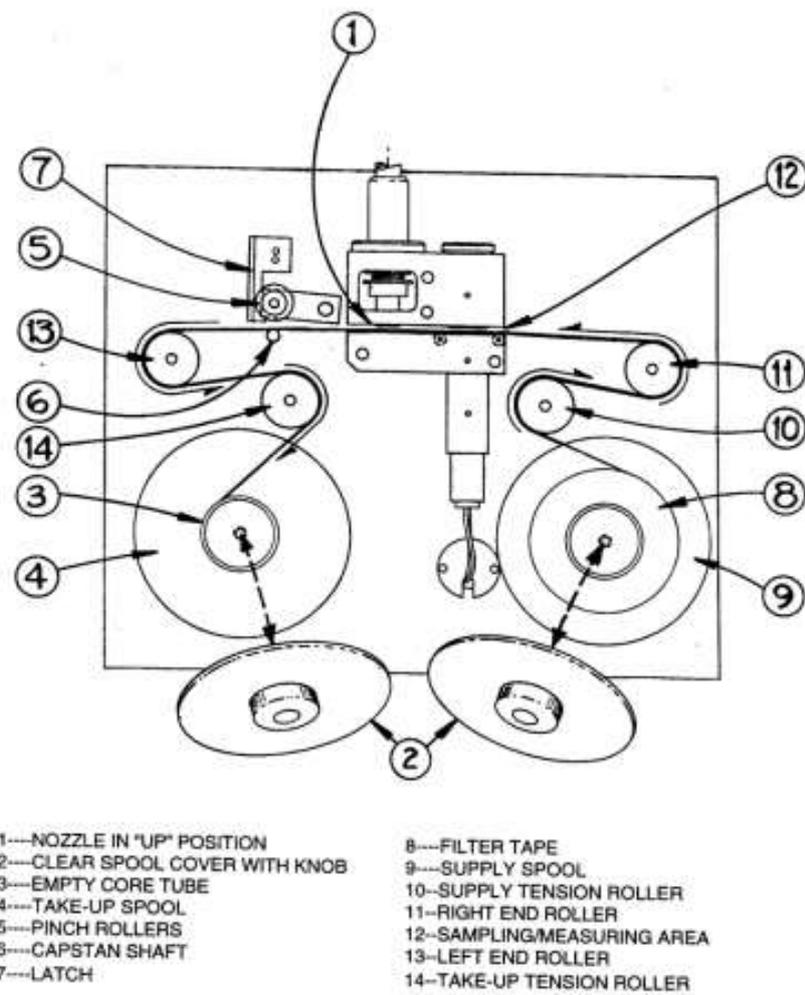


Figure 21-6 Filter tape changing procedures

21.12 BAM Error Codes

Table 20-1 below gives a list of possible BAM error codes that LSO may see when on site. Also given are actions that the LSO may carry out while on site to test the monitor. These however should only be undertaken after contacting the QA/QC.

Table 20-1 BAM 1020 Error Codes and Actions

E	Telemetry reset, indicates that the system time was reset. This may occur after a power outage. Check to see that date and time (GMT) are correct through SETUP option.
U	Telemetry fault, indicates a fault with the remote telemetry system. Check to see if telemetry connections are secure and the light on the modem is flashing.
I	Internal error. NCAR. Contact QA/QC
L	Power failure; Make sure unit is on. Check power lead is not loose or damaged at back of BAM. If power has been interrupted to BAM check date and time is corrected. If not reset clock through SETUP.
R	Reference membrane stuck, membrane motor timed out without completing extension/withdrawal of membrane. Contact QA/QC and or ESU
N	Nozzle stuck, nozzle motor timed out; Manually test using TEST/PUMP/Nozzle UP and DOWN. Look for deposits on nozzle lip. Clean if required
F	Flow error, flow <10 or >20 lpm; Perform manual flow audit using Test/PUMP/Pump ON. If flow is <10LPM, check line to pump for obstructions or crimps in line. If Zero flow is greater than 1LPM, check for deposits on nozzle lip.
p	Pressure error, pressure drops more than 300 mmHg during the cycle or the reference mass flow deviates more than $\pm 5\%$; Check line to pump for breaks in line and leaks in inlet and pump connections to instrument.
D	Deviant membrane density, indicates that the reference membrane was out of limits by more than $\pm 3\%$; NCAR. Contact QA/QC
C	Count error, any count is <10000. NCAR. Contact QA/QC
T	Tape error, any tape breakage or tape motor movement error; Check that there is tape and install new roll if needed, check for tears in tape and retape if needed, advance tape several positions and watch movement using Test/PUMP/Tape Advance.

Key to abbreviations

NCAR= No corrective action required

ESU = Engineer Support Unit

22 Calibration Sheets

The calibration spreadsheet (Figure 1-1) is the recommended method of recording calibration and diagnostics information for LSOs. The software allows all information collected during the calibration to be readily used to improve the quality of the validated and ratified data. The spreadsheet is specifically designed to be read automatically by software at the QA/QC Unit so as to minimise the risk of transcription errors. The spreadsheet should work with all versions of Microsoft Excel from 2003 onwards. It may not work correctly in OpenOffice. The required calibration information is automatically transferred into the write-protected "NETCEN" tab ready for automatic upload at the QA/QC Unit.

AQ Monitoring Station - Site Visit Summary

Send to: aqadmin@aeat.co.uk

Contact Details: Martin Davies
AEA
0870 190 6451
martin.davies@aeat.co.uk

Site Name:

Name of LSO / ESU

Date of Visit

Time of Visit: (hh:mm) (GMT/BST)

Reason For Visit:

Equipment attended to:

	Fault on arrival?	Attended to?	Fault on leaving?
All			
NOx Analyser			
CO Analyser			
SO2Analyser			
O3 Analyser			
PM10 Analyser			
PM2.5 Analyser			
Aircon unit			
Other			

Other: Please specify:

Figure 1-1 Opening screen for the Calibration Spreadsheet v1.01

Information is entered in a series of tabs (Figure 21-2) that follow a similar format to the traditional paper forms. The site is selected from a list, eliminating the risk of misidentification of the site. Revised versions of the sheet will be issued as appropriate upon the commissioning of new sites. There is a facility to record free text as necessary.

It is recommended that you take a laptop with you to the site if possible, and complete the spreadsheet as you carry out the calibration. If you do not have access to a laptop, or if it is not feasible to take it on site visits, the spreadsheets may be copied, for example, into Word, printed out and the paper copy completed on site. An example of the NETCEN tab is given in Appendix D. However, when you return to your office it is important to transfer the data from the paper copy into the original electronic version of the spreadsheet, and then e-mail this to the QA/QC Unit.

Always e-mail the actual spreadsheet to the QA/QC unit; please do not fax or scan the paper copy to them. This is because the QA/QC Unit's data handling software **reads the data directly from the spreadsheet**. It cannot read from a faxed or scanned copy.

To use the spreadsheet:

1. Open the file and select the Intro page (if not already selected)
2. Enter all the basic info: Select your site from the drop down menu, enter your name, date and time and select the reason for visit from the drop down menu.
3. Select the Pre Cal page. Confirm that there is no pollution episode occurring before proceeding. For the analysers you have on site, select the analyser types from the drop down menus. A series of specific diagnostic parameters will then appear – having consulted the relevant sections of the LSO Manual, enter the required values as appropriate. Scroll down for the PM diagnostics tables. It is possible some software versions on analysers may display slightly different parameters-if you can't find a specific value, just leave the box blank.
4. A typical example of a checklist awaiting completion is shown in Figure 21-2.

Pre-Calibration Checklist:

Is a Pollution Episode in Progress? (y/n)

Select analysers on site:

<p>NOx Horiba 370</p> <p>Analysers OK Serial Number LED green</p> <p>Actual Time Time Date Mode</p> <p>Alarm Present? List alarms</p> <p>Signal (NO) Signal (NOx) Detector Pump Ambient Sample DC 24V DC 5V</p>	<p>O3 API</p> <p>Analysers OK Serial Number Sample LED on Cal LED on Fault LED off Actual Time: Time: Range: Stabil: O3 Meas: O3 Ref: O3 Gen: O3 Drive: VAC: Sample Pressure: Sample Flow: Sample Temp: Photo Lamp Temp: IZS Temp: IZS Flow: O3 Gen Temp: Orifice Temp: DCPS: Slope: Offset:</p>	<p>CO Thermo 1 Series</p> <p>Analysers OK Serial Number</p> <p>Actual time Time</p> <p>Fault Present? List Faults</p> <p>CO Range CO BKG CO Coeff Internal Temp Chamber Temp Pressure Sample Flow S/R ratio AGC Intensity Motor Speed</p>	<p>SO2 ML / ME</p> <p>Analysers OK Serial Number</p> <p>Actual Time Time</p> <p>Fault Present? List Faults</p> <p>Instr Gain Gas Flow Gas Pressure Ref Voltage Conc Voltage Analog Supply Digital Supply Ground Offset High Voltage Lamp Current Version</p>
---	--	---	--

<p>PM10 TEOM FDMS</p> <p>Power on Status light off Serial Number</p> <p>Current Status Code: Current Operating Mode: % Filter Lifetime Used: Current RS232 Mode: Actual Time: Current time: Mass Conc: 30-Min MC: 01-Hour MC: 08-Hour MC: 24-Hour MC: Total Mass: Case Temp: Air Temp: Cap Temp: Encl Temp: Main Flow: Aux Flow: Ave Temp: Ave Press: Noise: Frequency: Pump Vacuum:</p>	<p>PM2.5 BAM</p> <p>Power on Status light off Serial Number Actual Time Time</p> <p>cycle mode force maint fault polarity split deltatap reset polarity mult offset flow ambp tape p rh heater delta t s/no</p>
--	---

Figure 21-2 Pre-calibration Checklist

5. Select the Cal page. Turn on any Status Flags or out of service switches (consult the LSO Manual for details) and click on the box next to the “Turn all status flags on:” message. The calibration tables will now appear. If the monitoring station records data through an external datalogger, click the “External Datalogger present?” box, for another set of tables to appear. If printing out a copy to take to site, click on the “Turn all status flags on” first so that the tables appear on your print out.
6. Perform zero and cylinder calibrations as described in the LSO Manual. NOx, SO₂ and ozone values should be entered in ppb (value typically between 0 and 1000ppb) and CO in ppm. Once each calibration point is stable, take three replicate measurements for each pollutant species at about 1 minute apart – this will help to prove that the analyser has stabilised. See Figure 21-3.

Calibration

Turn all status flags on: External Datalogger present?

Zero (Analyser Front Panel)

	1	2	3	
NOx:				(ppb/ppm)
NO:				(ppb/ppm)
CO:				(ppb/ppm)
SO2:				(ppb/ppm)
O3:				(ppb/ppm)

Cal Cylinder (Analyser Front Panel)

	1	2	3	
NOx:				(ppb/ppm)
NO:				(ppb/ppm)
NO2:				(ppb/ppm)
CO:				(ppb/ppm)
SO2:				(ppb/ppm)
O3:				(ppb/ppm)

NO2 Cylinder (Analyser Front Panel)

	1	2	3	
NOx:				(ppb/ppm)
NO:				(ppb/ppm)
NO2:				(ppb/ppm)

Cylinders

	Cyl no	Pressure	Units	
NO:				(psi/bar)
NO2:				(psi/bar)
Weekly CO:				(psi/bar)
Daily CO:				(psi/bar)
Weekly SO2:				(psi/bar)
Zero:				

Change All Gas Analyser Filters: (y/n)

TEOM PM10 Filters Changed?: (y/n)

PM10 Heads Cleaned?: (y/n)

TEOM PM2.5 Filters Changed?: (y/n)

PM2.5 Heads Cleaned?: (y/n)

Comments

NOx:

CO:

SO2:

O3:

Scroll

Figure 21-3 Calibration page

7. Enter all the cylinder details, including cylinder number, pressure and units, not forgetting any zero and Daily CO cylinders that may be present at site
8. Once the calibration is complete, return the calibration gases to their as-found condition and change the sample inlet filters.
9. Change the FDMS analyser filters and clean the heads only if instructed to do so by the Management Unit.
10. Enter any comments you have in the boxes provided at the bottom of the Cal page
11. Select the Post Cal page and fill in the appropriate diagnostics.
12. Select the Final Page. Complete all the questions, enter the end time and fill in any final comments.

-
13. The Save File button will automatically save the spreadsheet with a unique file name "Site Name dd-mm-yy.xls". The file will be saved in the default folder for Excel file saves. To change this folder, in Excel 2007 on, go to "Office Button", Excel Options, Save and change the default file location. For earlier versions of Excel, go to Tools, Options, General and change the default file location.
 14. Press the Save File button and close Excel. Email the file to the contacts on the Intro page.

Remember to reset all status flags and turn all cylinders off as normal.

Upon completion of the calibration and on returning to your office, e-mail the Local Site Operator (LSO) Calibration Sheet to the QA/QC Unit at agadmin@ricardo-aea.com. (This e-mail address is provided on the calibration sheet, which will be updated if they change). Keep a copy, so that there is a backup calibration history of all the instruments.

23 Site Audits and Intercalibration Visits

An important part of the QA/QC programme for the Scottish network are the audits and intercalibration visits. All sites will be visited for audit and intercalibration service as detailed below. The QA/QC unit is also responsible for the training of LSOs. Site audit/intercalibration schedules normally starting in the first week of December and June and lasting approximately 10 weeks. During these periods QA/QC staff will contact LSOs to arrange for entry to the monitoring stations and if necessary for the LSO to attend for audit purposes.

23.1 Site Audits

In order to ensure that proper procedures, as detailed in this manual, are being carried out, the QA/QC Unit will audit sites as part of the site intercalibrations.

During site audits, which may or may not coincide with a normal weekly/fortnightly calibration visit, the site operator must be present if requested and be able to produce for the QA/QC Unit all records relating to the site operation. The site operator may be asked to demonstrate any routine site operational procedure and show that this can be competently carried out.

In addition, short notice or unannounced audits may also be performed. The QA/QC Unit reserves the right to visit sites as often as is necessary to ensure that correct procedures are being followed.

23.2 Intercalibration Visits

Every six months (three months for ozone analysers) the QA/QC Unit will undertake detailed checks on analyser performance and calibration prior to the sites being serviced by the ESU. As noted above, the QA/QC Unit will also use their visit to audit site records and LSO procedures.

It is not the purpose of this manual to describe fully operations to be undertaken at these intercalibration visits, but the sections below indicate the scope and range of the functions to be performed. During the intercalibration exercise these will include:

1. Full network intercomparison covering all pollutants and analyser types;
2. Production of ozone data scaling factors by performing reference ozone photometer intercalibrations at all sites;
3. Verification of site transfer gas standard integrity;
4. Calibration of the particulate analyser electronic, flow measurement, and mass measurement systems.
5. Analyser operational performance tests.

On completion of the intercalibration site visit, the QA/QC Unit will report any problems identified (e.g. failed NOx converter) immediately, to the LSO – this is now usually done by e-mail. Full details and results of the intercalibrations are reported in conjunction with the data ratification reports.

24 Non-routine Site Visits

Data from the Scottish Network is inspected daily by the QA/QC. Full consideration will be given to ambient pollution levels being measured, and the range of available autocalibration and instrument status data.

If "suspect" data is identified from a particular monitoring site, the QA/QC will first carry out a series of checks, remotely. If these checks indicate a possible instrument or infrastructural malfunction, the Local Site Operator will be asked to visit the site and investigate the problem.

By considering ambient and autocalibration data, the QA/QC will often be able to diagnose the problem remotely. The LSO will then be told what further manual tests, if any, to carry out on-site.

It is not possible to anticipate all potential problems, but basic guidelines for fault diagnosis are given in the "Troubleshooting" section.

Having carried out the tests requested, the LSO should convey their results to the QA/QC and await further instructions.

The LSO may then be asked to perform basic remedial actions to rectify any faults (for example, ensuring electrical supplies to the instruments). Local site operators are not expected to carry out repairs requiring detailed knowledge of the instrument's operation. These more serious problems will be referred to the ESU.

If there is an FDMS instrument at the site, the LSO may be asked to perform tasks such as reseating the filters to reduce signal noise, changing the filters, or checking the pump vacuum (this is not always possible remotely).

When the LSO has carried out any tests or basic repairs, it is their responsibility to fully document these actions, and the results. Once the problem has been rectified, the QA/QC may ask the LSO to carry out a routine calibration, according to the standard procedures. As with routine calibrations, the results must be forwarded to the QA/QC Unit as soon as possible in order to allow data to be scaled correctly.

Similarly, all action taken by the ESU will be documented and forwarded to the QA/QC Unit. In the event of the instrument being repaired on site, it will be the responsibility of the ESU to recalibrate the instrument after a suitable stabilization period. If, however, the instrument is removed and repaired off-site, a calibration must be undertaken by the ESU before removal (where possible).

Any replacement instruments must be calibrated by the ESU upon installation. The documentation forwarded to the QA/QC Unit must show clearly that this is a replacement instrument, and the time allowed between instrument power up and calibration must be recorded.

From time to time, particulate monitoring instruments may be subject to zero checks by the QA/QC unit, as detailed in section 9.1.5 of the main document. This involves fitting a filter on the inlet in place of the PM head for a period of a few days, so that the instrument is sampling particulate-free air. The LSO may be asked to return to site to remove the filters and replace the PM head and sharp cut cyclone (for PM_{2.5} analysers) as appropriate.

24.1 On-site Procedures in the Event of Non-Routine Site Visits

It is impossible to list here every possible problem and its solution. However, it is generally possible to systematically test the measurement chain in order to discover the cause of the problem and effect its solution.

The non-routine call-out of site operators will be at the request of the QA/QC, who will supply information on which piece of equipment has malfunctioned, together with relevant fault symptoms and possible causes.

It is very important that all checks and remedial action carried out are fully documented.

The LSO will not need to carry out tests on analysers or ancillary equipment which have not been reported as faulty. As far as possible, the site should be left "free running" to maintain instrument response continuity and maximise data capture.

On-site problems, when they occur, generally fall into six categories:

- (a) Loss of mains or telephone connection to the site. This will be detected by QA/QC being completely unable to contact the site by telemetry.
- (b)Analyser malfunction. This will generally affect data from only one analyser.
- (c) Data-logging or telemetry malfunction. This may have the same symptoms as (a) above, or may result in normal line connection to the site but inability to receive any meaningful data.
- (d) Autocalibration malfunction.
- (e) Site vandalism.
- (f) Air conditioning faults
- (g) Replacement or reseating of TEOM and FDMS filters

25 Troubleshooting

This section provides examples of common problems and faults that may arise during the routine operation or calibration of the automatic analysers. In some cases the faults are easy to correct, but sometimes a call-out visit from the Equipment Support Unit may be required. If a fault is identified, QA/QC should be informed immediately and they will advise whether or not the corrective measure needs to be performed by experienced service engineers. No instrument adjustments should be performed by the LSO unless acting on the advice of the QA/QC.

This section first gives basic on-site test procedures, then covers the following topics in more detail:

- Sampling Faults
- Calibration Drift
- High Noise or Erratic Response
- Site cylinder gas
- Spurious Data
- Figure 24-1 and Figure 24-2 - examples of internal sampling
- Figure 24-3 and Figure 24-4 - examples of erratic data after poor filter change
- Auto-calibration Run-ons
- Figure 24-5 Auto-Calibration Run-on for a NO_x Instrument.

25.1 On-site Test Procedures

25.1.1 Loss of mains or telephone connection.

1. Verify that mains power is being supplied to all site circuits, i.e. lighting, air conditioning, and instrument circuits.
2. Verify that the telephone connection to the data-logger modem line is working. Initiate two way test of line, i.e. make an outgoing call and receive an incoming call.
3. In the case of mains failure having occurred, the complete site operation should be thoroughly checked subsequent to reconnection. Many electronic units are susceptible to losing their program after mains failure.

25.1.2 Analyser malfunction

1. Is the analyser receiving mains power? Check for blown fuses in the electricity supply unit, the instrument plug and the current protect fuse on the instrument itself.
2. Verify that the analyser is properly connected to the data-logger (where fitted) and/or the modem. Check all communications leads are firmly attached at each end.
3. Is the instrument sampling ambient air? Check that:
 - a. the manifold system is functioning and is not blocked in any way;
 - b. the instrument is connected solely to the manifold, and is not sampling from autocalibration units or indoor air;
 - c. the instrument pump is functioning;
 - d. there are no obvious restrictions to air flow through the instrument, ensuring the instrument flow rates fall within manufacturer guidelines
 - e. sample inlet filter holders are closed, tightly and not leaking.
4. Having verified that the instrument samples ambient air, the introduction of span gas through the ambient inlet should produce a detectable response from the system.
5. Perform the routine instrument checks on the instrument, as described in the relevant section within Part B of this document, to verify optimum performance of the analyser.

6. Connect a calibration gas cylinder to the instrument and conduct a calibration check following the procedures detailed in the relevant section of Part B.
7. Having allowed the appropriate stabilisation times, observe the reading on the instrument front panel. If this shows that the analyser has responded to the calibration gas, as would normally be expected, the problem does not lie in the actual measurement process.
8. Verify that the analyser response on the data logger or front panel is normal.

25.1.3 Data-logging or telemetry malfunction

1. Are the datalogger and modem receiving mains power? Check for blown fuses or trips in the electricity supply unit, the equipment plugs and the current protect fuses on the equipment itself.
2. Verify that the cables connecting logger to modem and modem to BT phone socket are in place and are not damaged in any way.
3. Verify that the logger set-up programme has not become corrupted by checking carefully the display screen.
4. You may be asked to observe the modem display while telemetry communications from QA/QC to the site are being attempted.

25.1.4 IZS Unit Malfunction

QA/QC will advise on the need for checking Internal Zero and Span (IZS) units, if problems are identified.

25.1.5 Site Vandalism

Record details of site vandalism and report them to the relevant QA/QC (and to the police if serious criminal damage has occurred).

If the sampling manifold is damaged it is important to note whether the damage occurs above or below the roof level. A sketch to show exactly where breakages occur should be provided. The QA/QC will advise on temporary repairs, where possible.

25.2 Sampling Faults

Symptom	Possible Cause	Check/Action
No response signal	Power cut or mains disconnected	Ensure cables are properly connected Air conditioning unit thermal cut-out may have triggered the power to be switched off
	No sample flow	Check flow meter reading low Check vacuum gauge reading low Check pump not working or disconnected Check filter holder not sealed Check sample flow reading Check analyser is in sample mode
	Component malfunction e.g. ozonator fault lamp fault electronics problem defective photomultiplier tube	Check analyser diagnostics or fault warning messages
	Date and time is out of sync after power outage.	Check date and time on front panel.
	Loss of Firmware	Check front panel is showing usual data. Blank screen may indicate loss of firmware
Internal sampling, Smoothed or dampened response, no diurnal variation (see Figure 24-1 and Figure 24-2)	Sample line disconnected	Check that the sample line is securely connected to the sample inlet port at the back of the analyser or rack
	Leak in sample inlet filter holder	Check seal on sample inlet filter Check sample inlet filter housing is finger tight Check all parts of the filter housing has been installed properly
	Leak from inside the analyser itself e.g. leaking permeation drier hydrocarbon kicker reaction cell pneumatic lines IZS solenoid valve	Check for sample flow and vacuum gauge for an indication. Check all plumbing lines are tight.
Low Sample flow	Dirty/overloaded Filter	Check filter to see if it is overloading or dirty. Change if required. Sample flow should return to normal.
	Blockage in sample line	Disconnect sample line from inlet at back of analyser. If flow returns to normal then there is a possible blockage in the sample line. Contact QA/QC.
	Faulty pump	Check to see if there are any holes or kinks in pump tubing. Listen to here if there the pump is noisier than usual.

25.3 Calibration Drift

Symptom	Possible cause	Check/Action
Span response unstable or differs by more than 10% from previous manual calibration	Calibration gas not left on long enough for response to stabilise	Concentrations should not vary by more than +/- 2ppb
	Analyser not completely warmed up after repair	Allow analyser sufficient time to warm up and stabilise (usually 2-3 hours)
	Insufficient flow of calibration gas	Check excess flow and/or cal system connections are tight
	Calibration gas cylinder unstable or nearly empty	Check gas supply. Site gas cylinder pressure should be above 300psi. If not inform QA/QC.
	Analyser adjustment, repair or service has taken place	Check site records and ESU documentation
	Calibration cylinder changed	Check calibration cylinder number
	Backing paper inserted or left on the Teflon sample filter	Check filter holder
	Teflon filter clogged or contaminated (possibly by charcoal from zero air scrubber)	Visual inspection of filter paper for dirt or blockage
	Leak in sampling system causing dilution of the calibration gas	Check sample flow and vacuum. A low vacuum indicates a leak or defective pump
	Incorrect analyser response range (usually seen as half or double the expected calibration value)	Check analyser range setting

Zero response unstable	Zero air scrubber exhausted	Check condition of scrubber materials: silica gel (orange okay, clear used) Purafil (purple okay, brown used)
	Zero air cylinder empty or close to empty	Check cylinder pressure. If below 300ppb inform QA/QC for replacement
	Loose connection or filter housing	Check filter housing and all zero sample line connections are secure
Falling NO ₂ span response during calibration	Molybdenum converter fault	Check calibration screen to see if NO ₂ span response is steadily falling during the calibration. Alternatively take span readings at 2, 10 and 20 minute intervals to see if the response falls Check diagnostics to see if there is converter temperature fault
	Molybdenum converter material has been consumed	Full converter test required and replacement converter needed
	NO ₂ gas cylinder nearly empty.	Check cylinder pressure
	Unstable calibration source. NO ₂ cylinders are often subject to changes in concentration	Verify stability of calibration source (recalibration of cylinder required)
Unusually slow response time to span gas	Sample capillary or solenoid blocked	Check sample flow rate and vacuum. A high vacuum indicates a blockage.
Auto-calibration span low or falling day by day	NO ₂ /SO ₂ permeation tube or autocal cylinder empty. Check for IZS fault on front panel	Check for IZS fault on front panel. Check concentration of autocal cylinder and if autocal cylinder is turned on.
Zero baseline stepping	Automatic zero adjustment causing step changes in the zero baseline at uncontrolled times	Check that the analyser's automatic zero adjustment function is deactivated.

25.4 High Noise or Erratic Response

Symptom	Possible cause	Check/Action
High noise response seen as rapid fluctuations in the mV response	Analyser range incorrectly set	Check that the analyser operating range has not been changed
	Sample pump not operating smoothly	Check sample flow and listen to pump for any indication of irregular pumping action
	Component failure	Check instrument diagnostics
TEOM FDMS high noise or response cycling See Figure 24-3 and Figure 24-4.	Filter seated incorrectly. Wrong type of Filter used. FDMS filter not changed or changed incorrectly	Re-seat filter on tapered element and Change FDMS filter at same time following instructions give within LSO manual. Change both TEOM and FDMS filters following instructions give within LSO manual. Check TEOM filter is the correct type using documentation provided
Negative ambient response	Change in site temperature. CO and SO ₂ analysers may be sensitive to an increase or decrease in rack or cabin temperature	Check site temperature and air-conditioning unit
	For FDMS negative response could be a result of poor filter change	Re-seat filter on tapered element and Change FDMS filter at same time following instructions give within LSO manual.
Intermittent response problem	Component malfunction e.g. faulty lamp, chopper motor or gas filter correlation wheel	Check analyser diagnostics

25.5 Site Gas Cylinders

Symptom	Possible cause	Check/Action
Site cylinder running out of gas quickly	Cylinder left on	Check cylinder is turned off before leaving site not just the regulator valves.
	Regulator not connected properly	Ensure regulator is properly connected to the site cylinder
		Ensure connections to sample line are secure
	Check sealing washer is connect to regulator and has not perished	
Oxidation of NO cylinders	Contamination, manufacturing defect or poor installation of cylinder	Leave regulator pressurised
		When installing the cylinder, check that the cal system is in calibration mode. This enables any gas mixture, caused by installing the regulator, to be vented out.
		Check cal system tubing. Cal system may require stainless steel tubing instead of PTFE

25.6 Spurious Data

Symptom	Possible cause	Check/Action
High concentration spikes seen at unusual times e.g. high ozone during the night	Interference problem	O ₃ - ensure 1 micron sample filters are used in the sample filter holder SO ₂ - check performance of the hydrocarbon kicker.
	Irregular auto calibration span	Check timing of autocalibrations
High concentrations during high temperature periods	High temperatures causing elevated baseline response	Check instrument is not over-heating. Check air conditioning unit and vents
Spurious high PM ₁₀ concentrations – often followed by periods of low negative response	These may be genuine episodes due to bonfire night celebrations or other phenomena such as dust storms	Compare data with other nearby monitoring sites(data available on the Web)
Negative NO ₂ data recorded during episode periods – usually only seen at roadside sites	Instrument response may be too slow for rapidly fluctuating concentrations	Check instrument set up is appropriate for the site environment

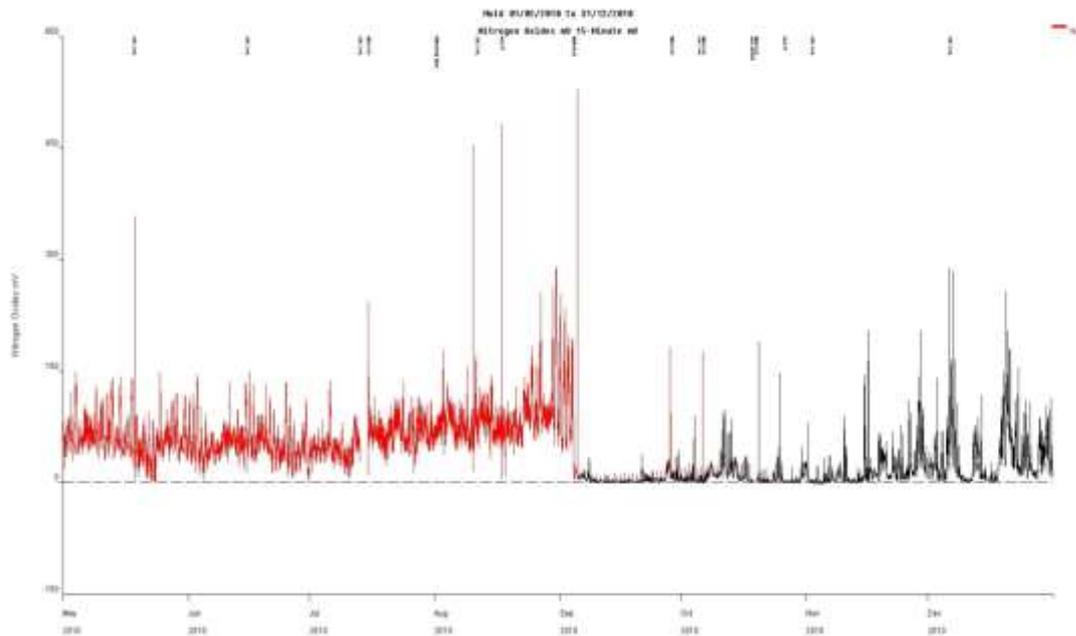


Figure 24-1 Examples of internal sampling

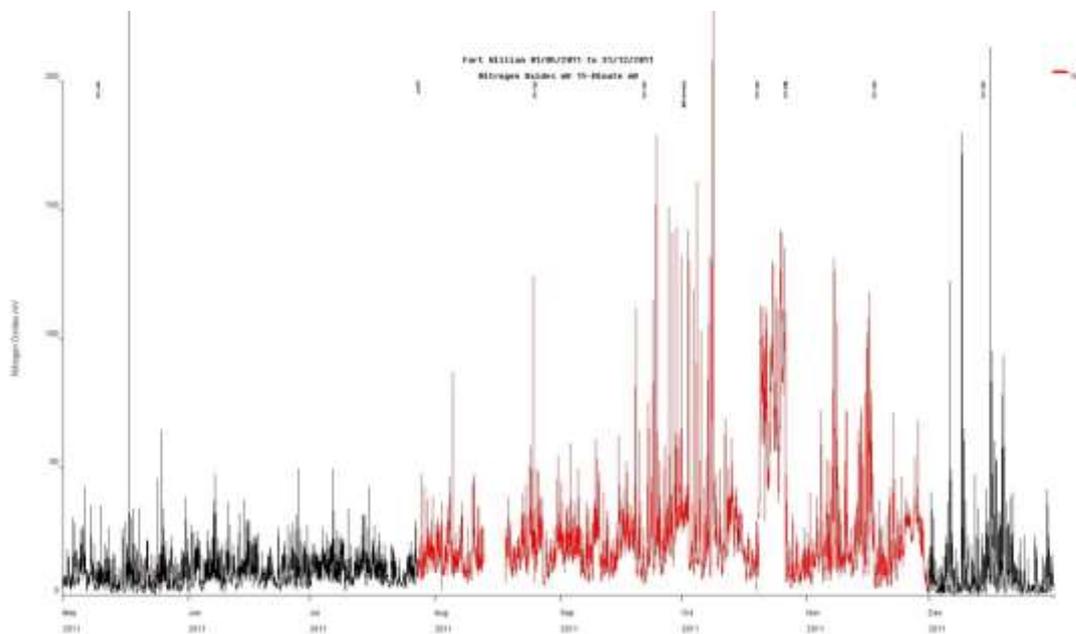


Figure 24-2 Further examples of internal sampling

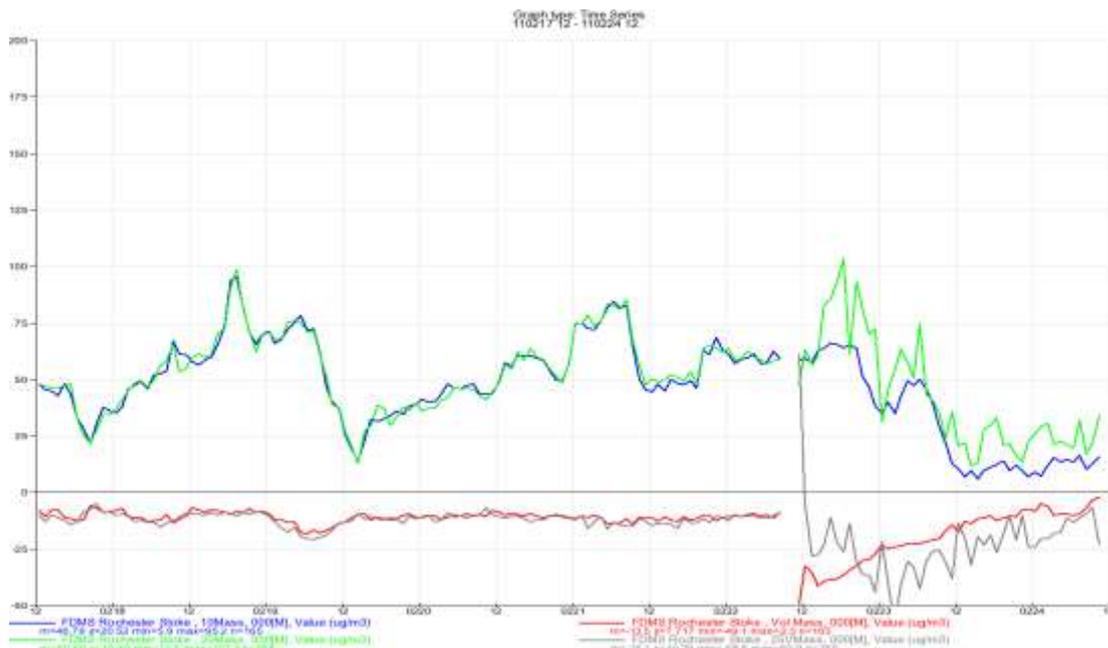


Figure 24-3 Examples of erratic data after poor filter change

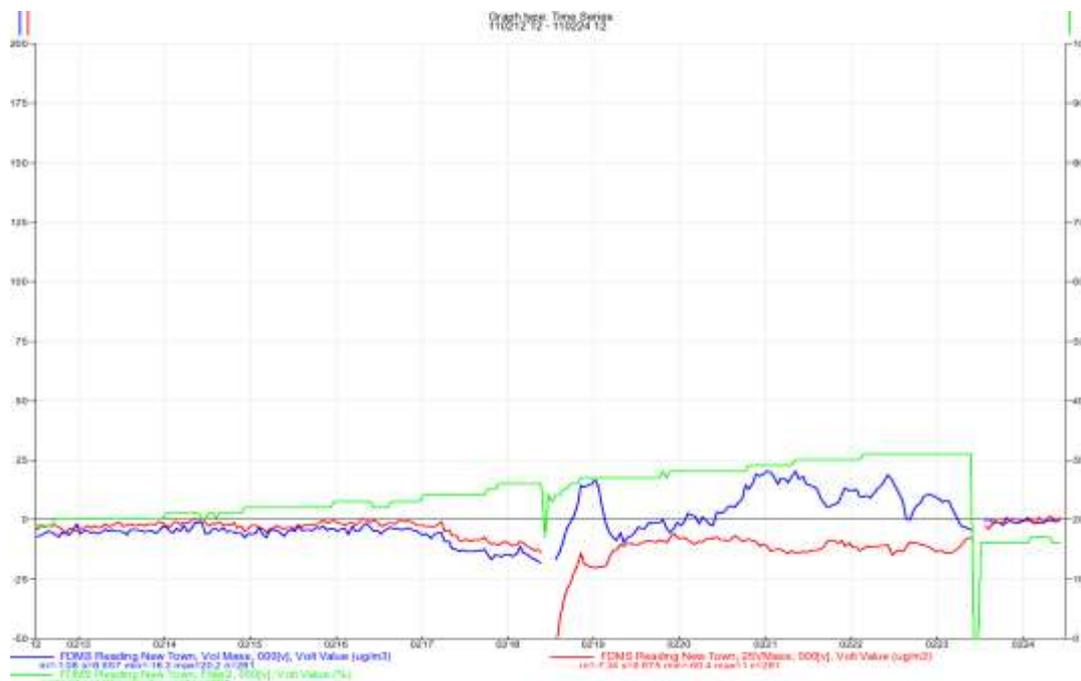


Figure 24-4 Further Examples of erratic data after poor filter change

25.7 Auto-Calibration Run-ons

Most instruments in the Scottish Network perform an automatic calibration cycle every night/ every 3 days. Zero gas and then span calibration gas are introduced into the instruments between the times of 0045 and 0115. The resultant readings for these gases are used to identify instrument breakdowns or excessive drifts. Data during the calibration cycle are flagged as zero and span measurements and are not used to calculate the reported ambient measurements.

A problem can occur if the solenoid valves in the pneumatic system do not close fully after the cycle. Calibration gas may then leak into the instrument during the ambient measurement period. The fault can be identified by calculating the diurnal variation of concentrations during this period (i.e. calculating the average concentration for each 15-minute period).

Figure 24-5 shows the average diurnal cycle of 15-minute and hourly average NO₂ concentrations at Belfast Centre. Hourly averages, which are the basic reporting time period for the AURN, are calculated from at least three valid 15-minute concentrations. This example shows that the calibration gas introduced between 0045 and 0115 remained in the instrument until about 0200. The ambient measurements between 0130 and 0200 are therefore invalid and must be removed during data ratification. If this correction is required throughout a year, one hour out of twenty-four will be lost which is 4% of the annual data capture. This can be a serious source of data loss when the target data capture is 90%.

ESUs should ensure solenoid valves are cleaned and free from leaks during the service to minimise this effect.

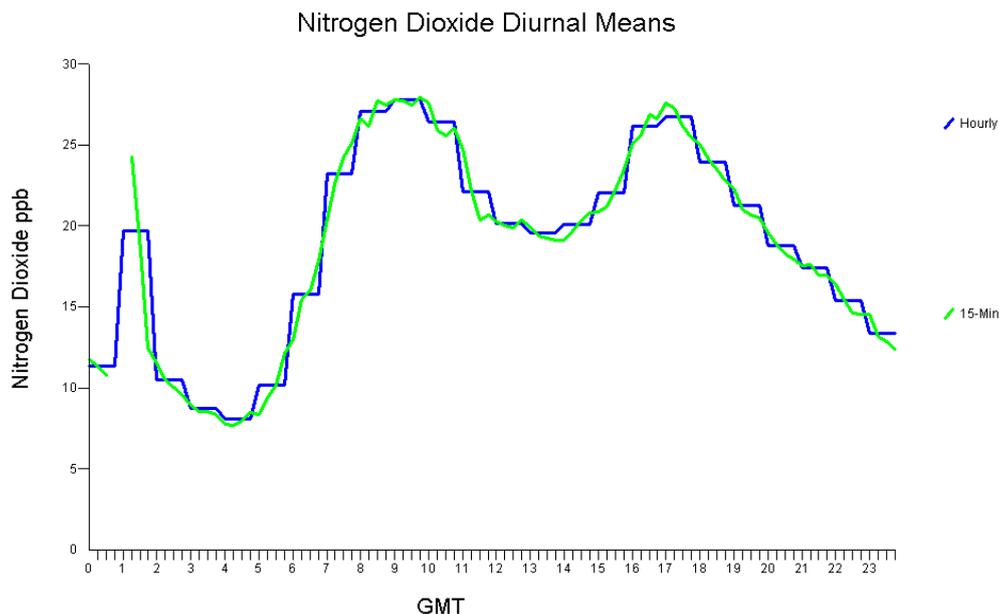


Figure 24-5 Auto-Calibration

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Appendices

Appendix A - Example of Service Contract Specification

Appendix B – Safety Data Sheets for Gases

Appendix C – Glossary of Abbreviations and Conversion Factors

Appendix D– Calibration Sheet

Appendix E– Equipment Support Unit Procedures

Appendix A - Example of Service Contract Specification

Example Specification for the Servicing and Maintenance of Air Quality Monitoring Equipment

Routine Service and Maintenance

It is a requirement of the AURN to achieve a minimum data capture of 90% for all pollutants across all sites, over the period of a calendar year. The service and maintenance procedures adopted, and the resources dedicated to them, must be sufficient to guarantee the required data capture target.

Routine servicing of all instruments and equipment at each site is to be carried out on a six-monthly basis. The service visits are to be conducted in co-ordination with the QA/QC six-monthly audit visits, and must be completed within a timetable determined by the QA/QC and the site owner. A schedule of service visits must be provided to QA/QC Unit and the site owner in advance.

The ESU will be responsible for ensuring that all work they undertake on site conforms to the relevant health and safety standards and legislation (such as, working at heights, electrical safety, use of compressed gases, COSHH and manual handling etc.).

Routine service visits are to include full instrument servicing according to the manufacturer's recommendations. During the service, a number of important equipment tests must be undertaken. To achieve these, the ESU must own, or have access to, the following test equipment:

- a calibrated ozone photometer able to perform a six point test of an ozone analyser in the range 0 to 250 ppb.
- a gas blender / dilution system able to perform a NO_x converter test at NO₂ concentrations of 300 and 500 ppb, as well as undertake a six point linearity test across the operating ranges of the NO_x, CO and SO₂ analysers.

These analyser tests must be undertaken every six months, at the scheduled service exercise. Further guidance on the scope of work to be undertaken can be obtained by reference to Part A of this document (the Site Operator's Manual, provided by the Network QA/QC unit, available on the SAQD website).

Where a sample manifold is fitted, it must to be completely dismantled and cleaned every six months. The manifold blower must also be dismantled, cleaned and lubricated. All PTFE lines which are exposed to ambient air, up to the first Sample Inlet Filter, are to be replaced every six months. The ESU will also be required to service and maintain the Zero Air Generator (ZAG) pumps. If requested by QA/QC or the site owner, the ESU will also be required to change the PTFE lines between the ZAG and the instruments and between the calibration gas cylinders and the instruments.

At the time of the first site service, and thereafter on an annual basis, PAT testing of all analysers and associated peripherals must be conducted and a suitable certificate issued and provided to the site owner. Testing and certification of the electrical supply circuit is recommended on a five yearly basis and must be carried out at least once during the period of this contract, and a suitable certificate issued and provided to the site owner.

All routine service visits are to be fully documented and completed in accordance with procedures described within the Site Operator's Manual (issued by the QA/QC Unit) and the ESU Procedure Manual. Documentation must describe in detail any necessary equipment adjustments, modifications or repairs. The relevant Pre and Post-Calibration Checklists are to be completed and faxed or emailed to both the site owner and the QA/QC Unit at the earliest opportunity, and within 7 days at latest. ESUs should use their own electronic spreadsheet or paper record systems but these are to be agreed with the QA/QC units in advance.

Emergency Service and Maintenance

In the event of equipment malfunction between routine service visits, the appointed ESU will be required to carry out emergency repairs. The emergency call-out will be issued by the site owner. During normal working hours (Mon-Fri, 0830-1730 hrs) emergency call-outs will be notified by telephone and confirmed by fax or e-mail.

It is a requirement that the ESU attends site and effects repairs within 48 hours after receiving notification from the site owner. If the faulty equipment cannot be repaired within the required timescale, then a replacement unit should be fitted. Specific procedures related to emergency call-outs are detailed within the Site Operator's Manuals and the ESU Procedure Manual as prepared by Network CMCU. This 48-hour response is required for all working days of the year, excluding weekends and Public Holidays. In all cases the ESU must confirm to the QA/QC and site owners that they have received the call-out, and that the required response is under way.

As a general guide, the following circumstances may give rise to an emergency call-out:

- electronic or pneumatic instability of the instruments
- autocalibration checks outside of acceptable tolerances
- instruments operating outside of manufacturers specifications
- manual calibration checks outside of acceptable tolerances
- malfunctions identified with the sample manifold, data logging or gas calibration systems
- malfunction of the air conditioning unit.

Whilst these criteria provide guidance on call-out procedures, emergency call-outs will be issued at the sole discretion of the Site owner. ESU's should note that a calibrated ozone photometer and/or NOx converter test equipment may be required during an emergency call out visit for ozone or NOx analysers respectively.

All emergency call-out visits must be fully documented and reports must describe all equipment malfunctions, repairs or replacements. In the event that instrument adjustments are necessary which affect its response, these must be agreed in advance with the Network QA/QC Unit, and be accompanied by the relevant Pre and Post-Calibration Checklists and Calibration Records. Documentation must be e-mailed to both the site owner and the QA/QC Unit as soon as possible, and within 7 days at latest.

Supply of consumables

The ESU will be required to provide and maintain adequate consumable supplies for all monitoring stations within the relevant part of the Network. This will include, for example, supplies of chart paper, Sample Inlet Filters, TEOM filters, permeation tubes, degreasing agents for sample head cleaning (Decon 90) etc. Additional supplies of consumables are to be despatched to the site owner within 5 working days of notification by the site owner. Any consumable sent to or left at sites (especially any cleaning agents) must be in clearly marked containers.

Air Conditioning Units

Many of the Network monitoring stations are equipped with air conditioning units, and the ESU will be responsible for the service and maintenance of these units, to ensure adequate operation. Both routine (6-monthly) servicing and emergency call-out should be provided for.

Other site equipment

The ESU should include for the annual testing and replacement (if required) of fire extinguisher units, first aid kits and any ladders at each site. Suitable certificates or other evidence of testing must be supplied to the site owners.

Spares and calibration equipment

The ESU will be expected to provide replacement equipment within the stated response timescale, should any equipment fault not be rectifiable.

Immediately before any repair, adjustment, or replacement of an analyser, it is essential that the instrument is calibrated (if possible) in an 'as found' state using the on-site calibration gases. In the case of ozone analysers, this calibration must be completed against a reference photometer.

Gravimetric Samplers

The gravimetric samplers will be subject to the same routine and emergency service and maintenance requirements as detailed above.

Appendix B - Safety Data Sheets for Gases

Appendix C – Glossary of Abbreviations and Conversion Factors

ppm	parts per million
PM ₁₀	Particulate Matter - the mass fraction of particles collected by a sampler with a 50% inlet cut-off at aerodynamic diameter 10µm
QA/QC	Quality Assurance and Control
SO ₂	Sulphur Dioxide
TEOM	Tapered Element Oscillating Microbalance
UKAS	United Kingdom Accreditation Service
UV	Ultra-violet
µm	micrometres

µg m⁻³ or µg/m³ microgrammes per cubic metre

Conversion Factors – (at 293K and 101.3 kPa)

Nitric oxide

$$1 \text{ ppb} = 1.25 \text{ µg/m}^3 \quad 1 \text{ µg/m}^3 = 0.8 \text{ ppb}$$

Nitrogen dioxide

$$1 \text{ ppb} = 1.91 \text{ µg/m}^3 \quad 1 \text{ µg/m}^3 = 0.523 \text{ ppb}$$

Total oxides of nitrogen (NO_x)

$$\text{NO}_x \text{ in } \text{µg/m}^3 \text{ is expressed as NO}_2 \text{ i.e. } (\text{NOppb} + \text{NO}_2\text{ppb}) \times 1.91 = \text{NO}_x \text{ µg/m}^3$$

Sulphur dioxide

$$1 \text{ ppb} = 2.66 \text{ µg/m}^3 \quad 1 \text{ µg/m}^3 = 0.38 \text{ ppb}$$

Ozone

$$1 \text{ ppb} = 2.0 \text{ µg/m}^3 \quad 1 \text{ µg/m}^3 = 0.5 \text{ ppb}$$

Carbon monoxide

$$1 \text{ ppm} = 1.16 \text{ mg/m}^3 \quad 1 \text{ mg/m}^3 = 0.86 \text{ ppm}$$

Appendix D– Calibration Sheet

Site Calibration and Instrument Checklist

Site Operator

Date Time (hh:mm GMT)

Code: Reason for visit:

Instrument Calibration

	Zero			Span						
			Logger	Instrument		Logger	Instrument			
			(if present)	Front panel		(if present)	Front panel	Cyl No	Cyl Pressure	Cyl Concentration
	Instrument No	Range	mV	ppb or CO ppm	Range	mV	ppb or CO ppm	psi or Bar	ppb	
NOx										
NO										
NOx										
NO										
CO										
SO2										
O3										
D CO										
Zero										

PM10 Filter / Tape Changed? Y/N

PM10 Head Cleaned? Y/N

PM2.5 Filter / Tape Changed? Y/N

PM2.5 Head Cleaned? Y/N

Sample Filter Changed? Y/N

NOx

CO

SO2

O3

Flow Test? Y/N

NOx

CO

SO2

O3

Appendix E– Equipment Support Unit Procedures

G.1 Introduction

This section is provided as background information. It provides additional details on the duties and responsibilities of the Equipment Support Unit (ESU).

Monitoring systems can only be relied on to operate satisfactorily and reliably for extended periods of time if they are properly supported and maintained. In the AURN, the maintenance and support of the analysers and associated site infrastructure is undertaken by a number of ESUs, which are usually equipment manufacturers, distributors or service agents.

ESUs are appointed and managed by the Management Units for Defra and the DAs funded sites. In the case of affiliated sites, however, the local authority itself may be directly responsible for arranging the service and maintenance contract. An example ESU contract specification is included in Appendix A for reference for affiliated site owners who appoint their own ESU.

Service and maintenance is of vital importance to the successful operation of the Network. As there are several different ESUs involved in the network, it is important to ensure that consistent operating procedures are followed, in order to achieve satisfactory data quality and capture rates throughout the network.

In order to ensure ESUs have sufficient resources (manpower and equipment) to carry out the work correctly, they may be subject to audit by the CMCU and/or the QA/QC Unit. The ESUs are expected to retain suitable and sufficient records of staff training, competence, equipment records (including proof of traceability) and service sheets for each contracted site visit.

A full technical description of the equipment service and maintenance procedures is not provided here, as these will differ from instrument to instrument and will be carried out following the manufacturer's recommendations. Instead, this section of the manual contains the basic operating guidelines for ESUs, describing the required service and maintenance support for the equipment used in the AURN.

The main tasks performed by ESUs are as follows:

- (i) Routine equipment service (6-monthly)
- (ii) Non-routine maintenance and breakdown repairs (emergency call-out)

Each of these tasks is described in more detail in the following sections. ESUs are also expected to attend the annual LSO meeting organised by the CMCU.

G.2 General Considerations for ESU Site Visits

The following considerations must be adhered to at all sites during both routine ESU service and emergency call-out visits:

1. On arrival at the site, check the pollutant levels on the analyser front panels to see if an episode is occurring (i.e. pollution levels are above or close to the trigger values set out in Section 9.5). In the event of a pollution episode taking place contact the Management Unit before proceeding.
2. While analysers are being serviced or under test of any kind, activate the logger status switches (or "out-of-service" switches) to ensure that the analyser response outputs are not treated as ambient data. Reset the switches at the end of the visit. If no such mechanism for flagging data as invalid exists, then the Management Unit should be

contacted and instructed to stop dissemination of the data until such time as the tests/service are complete.

Before each six-month service exercise, the ESU should make arrangements with the QA/QC unit to have their photometer(s) calibrated against the network reference instrument. The QA/QC unit will contact all ESU's and request them to make photometers available for calibration one month prior to the start of the intercalibration exercise. ESUs are responsible for taking their photometers to the QA/QC Unit by arrangement for this work to be carried out.

G.3 Routine Equipment Service and Maintenance

Routine service and maintenance of the equipment at each site is carried out every six months, in conjunction with the QA/QC Unit intercalibration exercise. The servicing usually begins in January and July each year and is completed in accordance to a site visit schedule determined by the QA/QC and Management Units or Local Authority.

The ESUs must provide a timetable for the site service visits and this made available on the AURNHUB prior to each 6-monthly service exercise.

The service is carried out in three stages:

- pre-service analyser tests and calibration,
- equipment servicing,
- post-service analyser calibration and tests.

Details of these procedures are as follows:

G.3.1 Pre-Service instrument checks and calibration

Immediately before the analysers are switched off-line for servicing, a full site calibration is undertaken together with basic analyser performance tests (See Table G.1 below). The pre-service calibration is required to ensure that the analysers are functioning correctly prior to the service and that up-to-date calibration factors for the instruments are obtained for data scaling purposes.

Table G.1 Pre-service Procedures

Procedure	Details
Pre-service analyser calibration	The analysers are calibrated in full accordance with the site operator's manual using the on-site gas calibration standards. The results are recorded on the routine calibration sheets and should be clearly marked as PRE-SERVICE results.
Ozone photometer calibration	The ozone analyser is calibrated against a reference photometer. A two-point calibration (at 0 and 200 ppb) is used to determine whether the agreement is to within $\pm 5\%$. If the result is outside $\pm 5\%$, then a full multi-point calibration (5 points and a zero) must be performed in order to provide a more accurate determination of the response deviation for data scaling purposes.
NOx converter efficiency	<p>This test is undertaken to determine whether the converter needs replacing prior to service. Any reduction in converter efficiency will result in an under-estimation of measured NO₂ concentration. If the converter efficiency is found to be below 95% then the converter should be replaced.</p> <p>Converter efficiency is tested as follows:</p> <p>A high concentration of NO is diluted by zero air in a mixing vessel to a level near the upper range limit of the analyser. The response from the NO and NO_x channels are recorded. The ozone generator is activated to oxidise a proportion of the NO present in the mixing vessel to NO₂. The converter efficiency is then determined from the relative change in NO_x and NO outputs.</p>

If the service is started within 14 days of the QA/QC intercalibration visit and the QA/QC unit did not identify any significant problems with the analysers (NO_x converter efficiency was found to be >95%, ozone analyser found to be within $\pm 5\%$ of the reference photometer calibration), then these tests need not be repeated by the ESU.

G.3.2 Site Servicing

Routine service and maintenance of the instruments at each site is carried out according to the equipment manufacturer's recommendations. The visit also provides the opportunity to check, repair and/or replace many items of site infrastructure. Service details are given in Table G.2 below. Typical procedures carried out during routine service and maintenance include:

- replacement of all consumable components (e.g filters, scrubber materials, o-rings)
- dismantling and cleaning of optical and other components
- checking the integrity of the sampling system and pneumatic systems
- lubrication of moving parts
- checking and replacing batteries
- electrical safety checks on analysers and ancillary site equipment (ie PAT testing in accordance with 'IEE Code of Practice for In-service Inspection and Testing of Electrical Equipment') on an annual basis.
- testing and certification of the electrical supply circuit is recommended on a 5-yearly basis. Contact CMCU for details.

- annual testing and replacement (if necessary) of fire extinguisher units, first aid kits and any ladders at each site.

Table G.2 General Servicing Procedures

Procedure	Details
Instrument servicing	The analysers are serviced according to the manufacturer's recommended procedures. NOTE: The ozone analyser must be serviced first, in order to allow sufficient time for it to warm up and stabilise before recalibration.
Other equipment	Other associated equipment used on site is serviced according to manufacturer's recommendations including, where applicable: autocalibration facilities loggers modems
Sample manifold	The sample manifold and manifold fan are completely dismantled and cleaned. All PTFE sample lines exposed to ambient air, and up to the first sample inlet filter, are cleaned or replaced. All other PTFE tubing is cleaned. If no manifold, sample line teflon tubing is to be completely replaced.
Zero air cylinders/generators	For some sites the ESU will service and maintain the Zero Air Generator (ZAG) pumps, although QA/QC Unit is responsible for replacement of the ZAG consumables every 6 months. Zero cylinders will be supplied on the same basis as span cylinders. If requested by the CMCU the ESU will also change the PTFE lines between the ZAG and the instruments, and between the calibration gas cylinders and the instruments.
Air conditioning units	Service and maintenance of these units is carried out according to the manufacturer's recommendations, either by the ESU or other contracted service engineer.

Ozone analysers must be set up with a slope of 1.00 and offset of 0 following calibration. Should this not result in accurate readings, this must be investigated before leaving site.

G.3.3 Post-Service Calibration and Analyser Performance Tests

The process of servicing the instruments and associated equipment will usually change the response of the instrument from that obtained prior to service. For this reason, the instruments must be correctly configured and recalibrated before ambient sampling commences. After-service calibration and performance tests are therefore carried out to ensure that the equipment servicing has been successful and that the analysers are correctly set up for the next six months of operation. Post-service procedures are given in Table G.3 below.

Table G.3 Post-service Procedures

Procedure	Details
Leak tests	After service, the analyser's sampling and associated pneumatic systems are tested to ensure that no leaks are present.
Analyser reconfiguration	After a suitable stabilisation time (usually 24 hours) the NO _x , SO ₂ and CO analysers are reconfigured to show agreement with the gas calibration cylinders. The ozone analyser is adjusted to agree with a reference photometer.
12-hour span drift test	The analysers are left overnight to sample span gas from the autocalibration system in order to determine any response drift. It may be necessary to ensure that the chart recorder is on an appropriate range to record the traces. In the case of the CO analyser and analyser systems which use gas cylinders for the autocalibration system, to conserve autocalibration gas, the instrument can be left sampling periodically between autocalibration, span and zero (e.g. once per hour).
Linearity test	A multi-point calibration of the analyser is carried out using five sample gas concentrations, evenly distributed across the analyser's normal running range, and a zero point. The span gas is generated using a high concentration gas species diluted with zero air. The analyser response is then plotted against the concentration of the span gas generated to give a measure of linearity.
NO _x converter efficiency	This test only needs to be carried out if the converter has been replaced, adjusted or repaired during service.
Noise levels	The zero and span response noise are examined during tests or calibrations to ensure that they are within the manufacturer's specifications. The response noise can be easily quantified from the chart and logger outputs.
Response time	The response time for the analyser to reach 90% of its final value is examined during calibration. This can be readily quantified from the chart traces.
Kalman/Adaptive filtering	It is the preference of the QA/QC unit that this function is disabled for all analysers, and the corresponding time constant set to 30 seconds, which is a reasonable compromise between quick response and low noise.
Post-service analyser calibration	Before leaving the site, the NO _x , SO ₂ and CO analysers are calibrated in full accordance with the site operator's manual using the on-site gas calibration standards. A multi-point (five points and a zero in the range 0-250 ppb) calibration of the ozone analyser against the reference photometer is also performed. All calibration results are recorded on the routine calibration sheets and should be clearly marked as POST-SERVICE results.

G.4 Documentation of Service Visits

Routine service visits must be fully documented and describe in detail any adjustments modification or repairs undertaken. Results of the analyser tests performed during the service are recorded on the "Analyser Performance Test" form provided, or with any other electronic or paper system which has previously been agreed with the QA/QC and Management Units. The service records, together with the pre and post-service calibration sheets, are e-mailed to

the Management Unit and QA/QC Unit at the earliest opportunity and within 7 days at the latest.

Contact details are given in on the AURN Hub.

G.5 Emergency Call-out Visits

In the event of equipment breakdown or site problem, the ESU is required to carry out an emergency repair (or call-out) visit. Emergency call-outs are initiated by the management units or local authority responsible for the site. The ESU is normally only called out to a site following an initial investigation by the local site operator. If the problem cannot be resolved by the site operator, then the ESU will be contacted.

In general, the ESU will be requested to attend the site in circumstances in which:

- Instrument malfunction affects data quality or loss of data;
- There is electronic or pneumatic instability of an instrument;
- Auto calibration checks are outside of acceptable tolerances as determined by the Management Unit;
- Instruments are not operating within the manufacturer's specifications;
- Manual calibration checks are outside acceptable tolerance limits, as determined by the Management Unit;
- Malfunctions are occurring with the sample manifold, data logging/telemetry or gas calibration systems.

The ESU is usually required to attend site and effect repairs within 48 hours of being notified by telephone or, e-mail. Call-out arrangements may, however, vary slightly depending on the agreement between the organisations involved. In many cases, the requirement for weekend cover by the ESU is not requested. It is important, however, that ESUs have adequate manpower and equipment spares provision to ensure that 90% data capture targets can be met.

The procedures undertaken during emergency call-outs are given in Table G.4 below.

Table G.4. Emergency call-out procedures

Procedure	Details
"As-found" calibration	Immediately before repair, adjustment or replacement of the analyser, it is calibrated "as-found" using the on-site calibration gas. This calibration is very important as it may give an indication of the effect of the response fault on ambient measurements; it is usually during periods when the analyser performance is suspect or faulty that the quality of the data recorded is of most concern. Note: If a problem with the ozone analyser is suspected, then the ESU must take a reference photometer to the site and calibrate the analyser before and after repair.
Repair	The fault is rectified as appropriate.
Post-repair calibration	The analyser must be allowed sufficient time to warm up after repair, adjustment or replacement. It is then calibrated using the on-site gas calibration standards. The serial number of any analysers being removed or installed must be clearly noted on the calibration records.

G.6 Documentation of Emergency Call-out Visits

All analyser checks and repairs carried out by the ESU must be carefully documented. For every emergency call-out visit a "Service Engineer's Emergency Call-out" form, or the form/spreadsheet agreed with the QA/QC and Management Units, is completed giving full details of the remedial action undertaken. Where appropriate, diagrams or flow-schematics illustrating faults or repairs (e.g. damage to glass sample manifolds or location of sample leak) should also be included as these are useful for data ratification purposes. The emergency call-out form, together with any before and after repair calibration records must be emailed to the Management Unit and QA/QC Unit as soon as possible, and within 7 days at the latest.

G.7 Ad-hoc ESU Visits

It may, from time-to-time, be necessary for the ESU to undertake site visits between servicing to perform analyser checks or carry out modifications. Instrument modifications or repairs which will affect the calibrations of the analysers must not be carried out during these visits without prior agreement of the Management Unit. If adjustments or repairs are agreed, then the same calibration and reporting procedures, as carried out during an emergency call-out visit, should be followed.

G.8 Use of On-site Calibration Gas Standards

The gas standards supplier is responsible for the supply and verification of the on-site gas calibration cylinders. These standards are an expensive resource and as such should not be used for any other purpose other than those stated below.

- "as-found" calibrations either before service or repair
- post-service or repair calibrations
- post-service reconfiguration of the analysers to agree with the standards

Site calibration cylinders should not be used for long-term response drift, linearity tests or as a general source of test gas during servicing or repair without prior agreement of the gas standards supplier.

G.9 Photometer Calibration

All photometers used within the AURN are required to be calibrated traceable to a Reference Photometer. All ESU's must attend a calibration exercise arranged by QA/QC Unit twice a year for this purpose.



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