Automatic Urban and Rural Network (AURN) LSO Manual - Part A

Version 1.2 - November 2022

We are the Environment Agency. We protect and improve the environment.

We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

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Updating and Version Control

This manual is a working document, intended to be updated when equipment or procedures change. This manual is provided in electronic format, and the latest version is available on the Health and Safety Database. If you are a Local Site Operator, it is your responsibility to ensure that you download and use the most up to date version

Version Control Table

Revision Date	Summary of Changes	Version Number
October 2021	Sections 1.2 and 3.2: minor changes to reflect post-Brexit legislative situation.	1.1
October 2021	Addition to include reference to the ALN	1.1
November 2022	No changes: version number updated for consistency with parts B and C of this Manual.	1.2

1. Introduction

This is the Local Site Operators' Manual for the AURN LSO Air Quality Network covering Carbon Monoxide (CO), Sulphur Dioxide (SO_2), Oxides of Nitrogen (NO_2), Ozone (O_3) and Particulate Matter ($PM_{2.5}$ and PM_{10}) monitored across the UK. Within the AURN there is a subset of sites in and around London, called the Automatic London Network (ALN). In this document, 'AURN' means the whole network, including ALN sites, unless specifically stated otherwise.

The AURN LSO Manual has been prepared for the Local Site Operators responsible for day to day operation of the AURN air quality monitoring sites and is based on original documentation written by Ricardo Energy and Environment. Its purpose is to provide the Local Site Operators (LSOs) with the information they need to operate the sites correctly.

This manual addresses on-site procedures to ensure uniform operation and maintenance of monitoring stations by different site operators and Equipment Support Units (ESUs).

The QA/QC procedures for the AURN are fully documented elsewhere (AEA Technology plc, 2009): these can be found here

And for all Environment Agency and Defra networks, here (Defra, 2016): https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1902040953_All_Networks_QAQC_Document_2012__Issue2.pdf

This manual has been split into four separate documents:

Part A provides advice specific to the LSO role, supporting how the role is to be carried out along with a brief overview of how the AURN works.

Part B contains all the work guidance: there is a separate section for every monitoring instrument within the AURN, and these sections provide a step by step guide on how to carry out calibration procedures.

A further 'Essential Background Reading' document has also been provided, which supports Part A and provides more in-depth information on the AURN as a whole. **It is important that new LSOs read this document prior to commencing work on the AURN.**

There are also several Appendices, which have been put together in a further document.

1.1. The AURN Hub

The AURN Hub is a website developed by the AURN QA/QC Unit. It is designed to give the various people and organisations involved in running the AURN access to the information they need, in one convenient location. Information of particular relevance to LSOs includes:

- all network reports
- intercalibration and service schedules

- an electronic copy of this manual

The screenshot below shows the home page of the Hub. Different topic areas are accessed via the menu options on the left hand side.

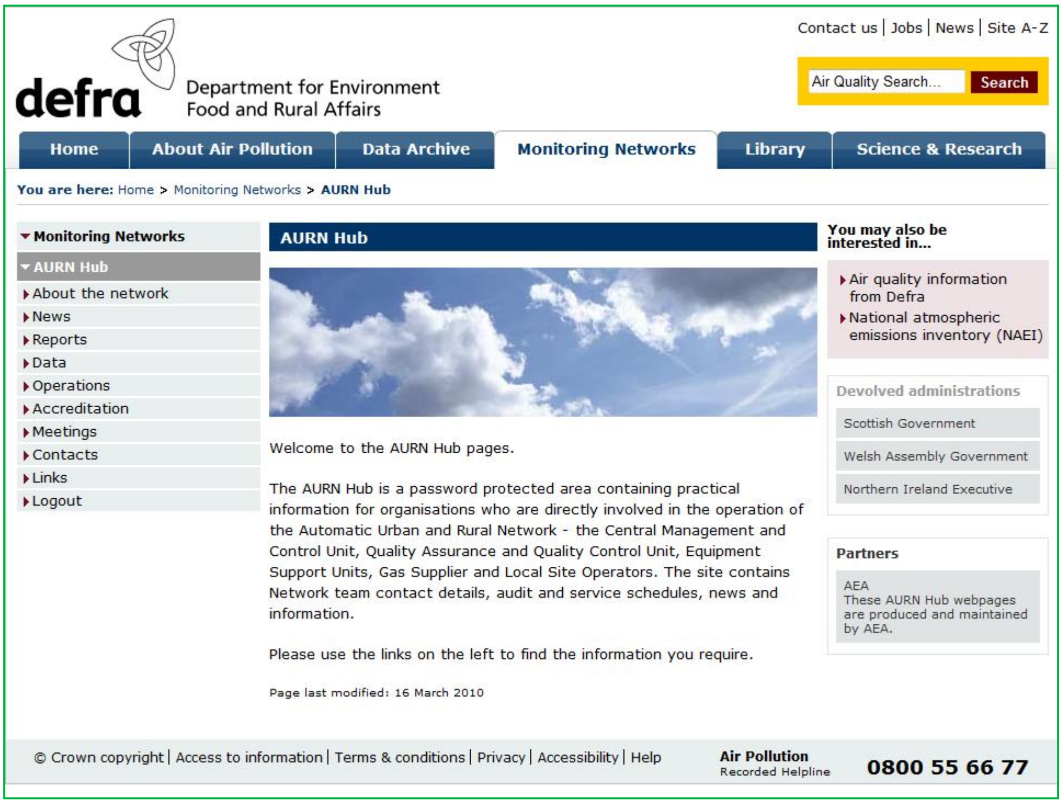

Figure 1 - AURN Hub

The AURN Hub login page is [here](#) . The Hub is password protected, and should only be used by network participants. For password assistance please contact [Ricardo's](#) Air Quality Monitoring Admin team at aqadmin@ricardo.com.

1.2. Objectives of the AURN Air Quality Network

The main objectives of the AURN are as follows:

- Fulfilling the UK's legal obligation to carry out air quality monitoring.
- Monitoring the UK's compliance with statutory air quality limit values, set by UK legislation and based on European Union legislation (European Commission, 2008).
- Providing information about air quality to the public.
- Providing information that can be used in local air quality review and assessments as required by the UK Air Quality Strategy.
- Helping us understand long-term trends in air pollution concentrations.
- Measuring the effectiveness of policies intended to control air pollution.

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

1.3. Locations of Monitoring Stations

Previous editions of this manual contained a map showing the locations of AURN sites. However, all this information is now available online. The Defra online air quality resource, UK-AIR [here](#) contains an interactive map [here](#) showing the locations of all AURN monitoring stations. (There is a link to this page from the Hub).

Figure 2 shows part of this map as an example.

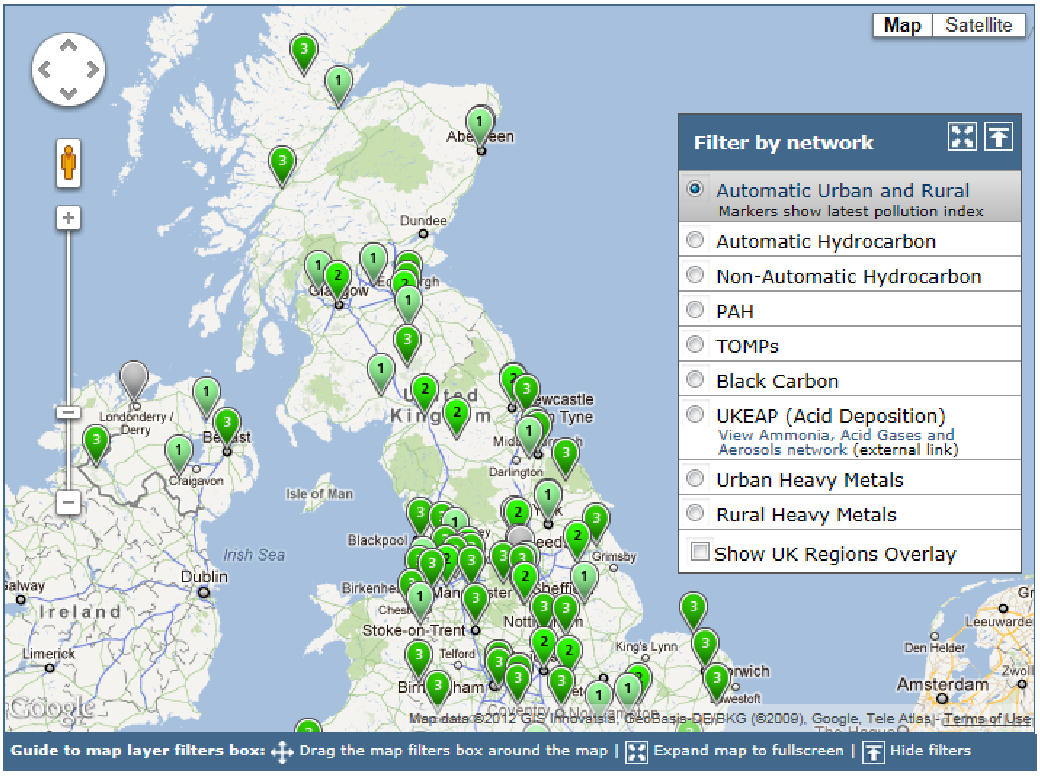

Figure 2 - Section of Interactive Site Map

You can see more details about each site, and access data summaries and information on background pollutant concentrations in the area, by clicking on its marker – see the example in Figure 3 for Hull Freetown.

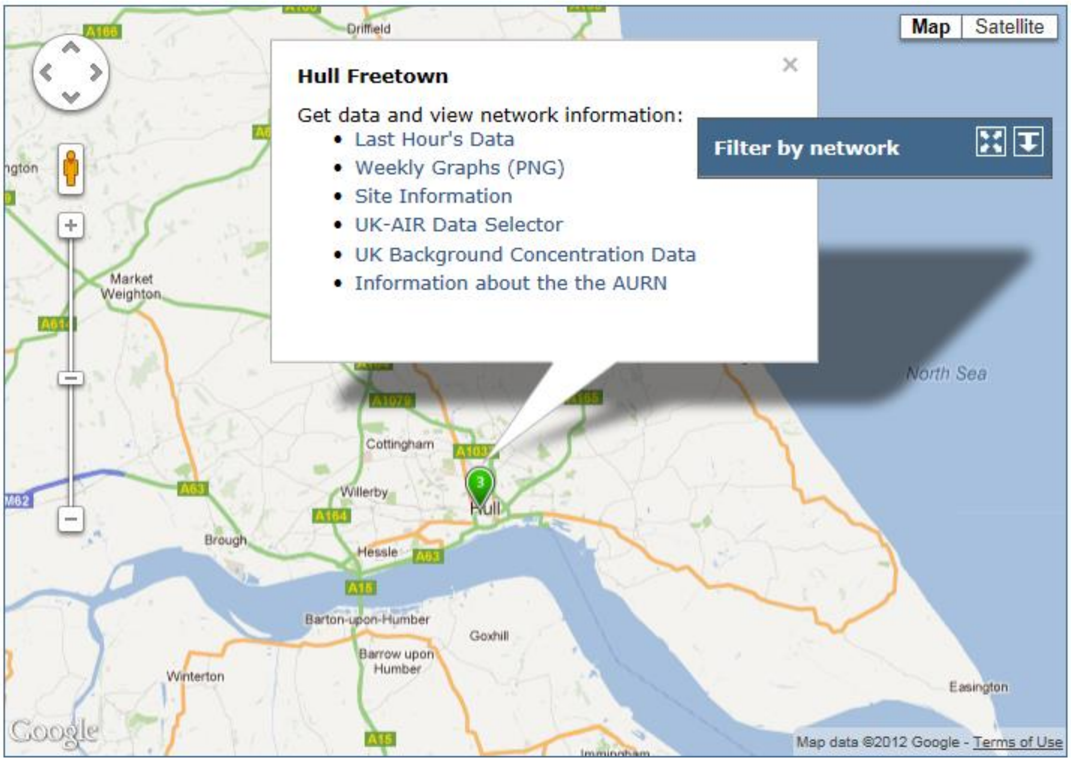

Figure 3 - Example: Information Menu for Hull Freetown

2. Roles and Responsibilities

2.1. Duties and Responsibilities of an LSO

As an LSO, 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 network (or site owner for affiliate[1] 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 Central Management Control Unit (CMCU) for EA owned sites, or site owners for local authority owned affiliate 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 CMCU for EA owned sites, or site owners for local authority owned affiliate 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

[1] AURN sites may either be: owned and fully funded by the Environment Agency, or 'affiliate' sites owned by other organisations such as local authorities. The differences are explained in the Background Reading document.

gases, COSHH and manual handling etc.) Any safety issues identified should be communicated to the network contractors immediately, as detailed in Section 6.

6. Routine instrument calibrations. These must be carried out on a 2-weekly basis for traffic-related sites, on a 4-weekly basis for urban background, urban industrial and suburban sites, and on a 3-monthly basis for rural and remote 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 (in electronic format: latest versions can be found on the 'Operations' page of the AURN Hub alongside this manual) and e-mail this to the QA/QC Unit and CMCU. **Note: please make sure you are using the most up to date version of the calibration sheet!**
- Make a note of anything unusual at the site, which could affect the monitoring results. For example 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. This is normally done routinely at each 2-weekly or 4-weekly calibration visit.
- For sites with Beta Attenuation Monitors (BAM), carry out leak testing at every routine visit, regular nozzle and vane cleaning, and tape changes when necessary.
- For a small number of sites which use gravimetric techniques to measure PM_{10} or $PM_{2.5}$, 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.
- For sites with Fidas optical particulate analysers, to carry out calibration checks on the analyser and ensure it is working within the operating parameters (if specifically requested to do so by the CMCU, this is not a routine requirement).
- For the small number of TEOM-FDMS sites, change the filter in the Filter Dynamic Measurement System (FDMS) when necessary. This done when the filter has reached 90% of maximum loading, and is requested by the network.

The details of how to carry out these tasks are provided in Part B of this manual. They vary depending on the type of 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 Central Processing Unit (CPU), CAS (code activated switch) logger and modem if necessary. However, as an LSO you will not be required to undertake major repair or maintenance of the equipment: this will be carried out by a dedicated Equipment Support Unit(s) (ESU), under a separate contract with CMCU.
8. **Attend and participate in site audits.** These are visits carried out by a member of the QA/QC team, either twice per year or (in the case of sites monitoring ozone) four times per year. 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 AURN 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 AURN site is set up (or affiliated), the LSOs are trained by the QA/QC unit. 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 separate "UK Air Quality Monitoring Networks Health and Safety Guidance" document (Ricardo Energy & Environment, 2020) – available on the AURN Hub link here, and the Health and Safety Database link here 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).
- Use the Health and Safety Database to check the 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 (trips and falls hazards, water ingress, etc.) to review whether it is safe to carry out work without risk to yourself or to members of the public, this should include a visual check of the ladder and ladder anchor bolts prior to use. Please refer to the Health and Safety Guidance for more information on risks at site.
- Follow the Cascade procedure (section 4 of the Health and Safety Guidance) and notify the Network Manager and the Health and Safety coordinator (Ricardo Energy & Environment, via aqsafety@ricardo.com), and any other relevant parties, of any new or site-specific risks.
- Follow advice from the Network Manager.
- Ensure contact details for your organisation are up to date and sent to the Network Manager.
- Other responsibilities as specifically identified in the LSO's contract.
- Comply with health and safety laws and regulations (see http://www.hse.gov.uk)

2.2. LSO Training

It is essential that you fully understand all the site operation procedures documented in this manual. The QA/QC Unit will undertake to train at least one LSO per site. 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 the QA/QC Unit 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 the QA/QC unit requests that they do so.

Each LSO trained by the QA/QC Unit 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 a network site and has either been originally trained or successfully audited by QA/QC Unit.
- 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 QA/QC Unit at the earliest possible opportunity, for example, during the 6-monthly intercalibration exercise or ad-hoc site audit.
- QA/QC Unit should be informed if training has taken place and the name of the newly trained LSO.

Formal retraining of LSOs by QA/QC Unit will only be mandatory if all the original trained LSOs have left the organisation.

3. Monitoring Instrumentation

3.1. Data Handling, Logging and Retrieval

3.1.1. Data Logging

Two methods of data logging are used in the AURN. 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 the CMCU 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 or analyser is programmed to trigger the daily analyser auto calibrations 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 data logger is connected to the CMCU’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.

3.1.2. Data Retrieval

The CMCU collect the data from each site on an hourly basis.

3.1.3. 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 testing carried out on the instrument, and the corresponding time constant identical to that used in the type test.

3.2. Units

Analysers for the gaseous pollutants NOx, SO_2 and O_3 provide an output in units of parts per billion (ppb) by volume (one part per billion is one part in 10^9). Carbon monoxide (CO) concentrations (which are usually higher) are output in units of ppm (parts per million or one part per 10^6).

Analysers for particulate matter provide an output in micrograms per cubic metre (µg m^{-3}).

For the purpose of reporting, the Air Quality Standards Regulations, like the Air Quality Directive (2008/50/EC) from which they were derived (European Commission, 2008) requires the ambient concentration of gaseous pollutants to be expressed in units of mass concentration, i.e. micrograms per cubic metre (µg m^{-3}), or milligrams 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.

4. Monitoring Station Infrastructure

4.1. 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.

4.1.1. 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.

4.1.2. Self-Contained Monitoring Sites

Where a number of air quality monitoring analysers are to be housed in stand-alone, self-contained cabinets of differing sizes depending on the location setting, the housing should be of adequate size to accommodate the instrumentation. The AURN contains a mix of larger walk-in housings, and smaller roadside cabinets. Each housing is typically supplied with:

- Internal electrical wiring and fittings;
- Air conditioning;
- Shelving/racking;
- Sampling inlets (usually in the roof), and tubing connecting these to the analysers;
- Gas cylinder storage area;
- Modem or Router to allow for mobile communications
- A fire extinguisher suitable for use on electrical equipment. All AURN sites must have a suitable fire extinguisher and it must be properly maintained.
- First Aid kit

The following information refers primarily to sites directly funded by the Environment Agency and housed in stand-alone self-contained cabins (of any size). Some local authority-owned affiliated sites and those housed in existing buildings may differ slightly in some aspects of the infrastructure.

4.1.3. 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) 18th Edition, 2018 (IET/British Standards Institute, 2018). 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 6 of the Health and Safety Guidance (Ricardo Energy & Environment, 2020), which is available from the AURN Hub link here and the Health & Safety Database link here.

4.1.4. 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 as far as possible. Due to the sensitivity of instrumentation to temperature fluctuations, the temperature control on the air conditioning unit should only need adjusting should the CMCU request an LSO do so.

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.

4.2. 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:

- 450ppb nitric oxide (NO) in nitrogen for urban monitoring stations.
- 450ppb sulphur dioxide (SO_2) in air for urban monitoring stations.
- 20ppm carbon monoxide (CO) in air for urban monitoring 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. This cylinder is supplied by BOC in the case of direct funded stations and the local authority in the case of affiliated sites. 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 (40 litre volume), or L50 (50 litre volume) if suitable. However, some sites where space is limited will supplied with L10 size cylinders.

Where sites have an external gas cylinder store (due to be installed during 2020-2021) the gas cylinders will be L10 due to space constraints.

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 and have passive ventilation in place. The provision of safe cylinder storage facilities is the responsibility of the CMCU / Management Unit. Safety Data Sheets for the supplied gases are provided on the AURN Hub, with links given in Appendix B (Safety Data Sheets for Gases).

4.3. Supply and Replacement of On-Site Gas Cylinders

See the work guide in section 14 of Part B of the LSO Manual which outlines in relation to delivery and replacement of on-site gas cylinders.

4.4. Sampling System

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 suitable sampling system must be used at all sites in the AURN.

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 or inverted funnel is used to prevent water from entering the inlet and potentially damaging the analysers.

At most AURN sites, the analysers sample ambient air through a single ¼" PTFE tube from the analyser through the roof to a weatherproof inlet funnel. Each analyser is connected directly to the inlet. It is important that there is a good seal around the PTFE tubing at the point where it passes through the wall or roof of the cabin or enclosure. If not properly sealed, 'indoor' air from inside the enclosure (which will be under slight positive pressure as air is continually being drawn through the analysers and vented into the enclosure) will leak out around the tubing, and could cause internal sampling. LSOs should check occasionally to make sure that there is a good seal around the inlet tube at the point where it passes through the wall or roof of the cabin or enclosure.

An inlet filter will be situated in between the sample inlet and the analyser, in order to protect each instrument from ingress of particulate matter. The location of filter housing will either be secured on the front panel of the instrument rack or at the back of the analyser connected to the sampling tubing. For some analysers (e.g. API and Serinus), the filter housing is internal, located behind the instrument's front panel. These filters need to be changed by the LSO during routine calibration. The filters are made of PTFE and are held in a PTFE-coated filter holder to ensure the sample gases are not lost during sampling.

4.4.1. Manifolds

Manifolds were once widely used in the AURN. However, they required regular cleaning and replacement, and there was a risk of sample loss if the manifold leaked or became dirty. Most were replaced with the system described above. However, a small number of affiliate sites still use a sampling manifold: the information below applies only to these.

The manifold is constructed from an inert material such as glass or Teflon (PTFE).

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 the table below.

Table 4.1 -Typical specifications for air sampling manifold

Parameter	Specification
Manifold material	Glass with Teflon fittings
Length	2500 mm
Internal Diameter	25mm
Flow rate	3 metres/second
Residence time	0.8 seconds
Pressure drop	0.25 inches H_2O
Blower speed	3000 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.

4.5. 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 PM sensor unit to an appropriate sampling inlet mounted externally on the roof.

Gravimetric samplers /SEQ are self-contained units are usually located externally of the monitoring enclosure.

4.6. Site Communication

At the majority of AURN stations communications are via a mobile 4G, GPRS, or GSM connection. Only a few rural remote sites are telephone lines in place and this is due to the poor signal strength for mobile communications. At the small number of sites with a gravimetric sampler, a second mobile connection is sometimes used.

4.7. Modems

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

- Mains power;

- A connection to the site telephone wall socket, (rural remote sites) 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.

4.8. 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 CMCU / 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 175, "Principles of Calibration".

5. Principles of Calibration

In order to ensure the data from the AURN 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 in the AURN. 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 gaseous pollutant analysers manually with documented and traceable calibration gas standards, and with clean 'zero air' either from a zero air cylinder or (now more commonly) a chemical scrubber (see section 5.1)
3. Network intercalibrations: three monthly for ozone, six monthly for all other pollutants. These exercises, performed by QA/QC Unit, ensure that measurements from all AURN 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. Check listed operational procedures for the fortnightly instrument calibrations are provided in Part B of this manual. The intercalibration exercises performed by the QA/QC unit are not described in detail in this manual but a summary is included in Part B.

5.1. 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.

5.1.1. NOx 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 chemical 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. The QA/QC unit verifies the integrity of on-site zero scrubbers during the routine six monthly audits by comparison to a certified zero air cylinder.

To check the "span" NO_2 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 NO_2 permeation tube. Zero air at a constant flow rate is passed across the tube which contains a quantity of pure liquid NO_2. The tube is enclosed in an oven maintained at constant temperature. Provided the flow rate and temperature are kept constant, the amount of NO_2 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 NO_2 calibration gas standard is also used for the autocalibration check.

5.1.2. SO_2 Analyser

Zero air (either from a cylinder of pure zero air, or generated by passing ambient air through a chemical 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 NOx analyser, except a permeation tube containing liquid SO_2 is used in the oven. Alternatively, on some analyser systems the SO_2 calibration gas standard is also used for the autocalibration check.

5.1.3. 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.

5.1.4. 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.

5.1.5. Production of Zero Air

Two methods of zero air production are used in the AURN. The first is through use of a cylinder of zero grade air. Alternatively, the zero air can be produced by drawing the sample airstream through scrubbers containing silica gel to remove water vapour, and Purafil^{TM}, Hopcalite^{TM} and activated charcoal, to catalytically remove pollutant species.

The consumable components in the zero air scrubber 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 the QA/QC Unit for these comparisons will previously have been compared to certified zero air cylinders. This is carried out by the QA/QC unit and is not the responsibility of the LSO.

5.1.6. Production of Span Calibration Gases

The gas standards supplier supplies gas cylinders containing calibration gas mixtures of NO, NO_2, SO_2, 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 in the AURN, 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 O_3 and particulate analysers, all calibrations which produce data scaling factors for these instruments will be carried out by the QA/QC Unit.

5.2. 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 'raw' units) 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 'raw' units, 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:

Instrument zero response = V_z

Instrument span response = V_S

Instrument calibration factor, $F = c/(V_S - V_z)$

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

$$Pollutant\ concentration = F(V_a - V_z)$$

Where V_a is the recorded 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 range in use. The linearity of the instrument is checked at six-monthly intervals by the QA/QC Unit.

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/NOx/NO_2 data is scaled from the calibration of the NO and NOx channels of the NOx analyser, using the NO in nitrogen transfer standard. This will directly output NO and NOx concentrations, with the NO_2 concentration being given by:

$$NO_2\ (ppb) = NOx\ (ppb) - NO\ (ppb)$$

An NO_2 in air calibration mixture will, however, be used as a cross-check on the NOx channel calibration and to ensure that the catalytic converter in the instrument efficiently reduces NO_2 to NO.

Conversion of concentrations to units of µg 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 of this manual.

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

5.3. 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:

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 - V_z 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.

5.4. Zero Checks on Particulate Analysers

It is possible to carry out a zero check on PM_{10} or $PM_{2.5}$ monitoring instruments by 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. This process is carried out by the QA/QC unit at the end of the inter-calibration audit. LSOs will be asked to return to site to remove the filters and replace the PM head, as appropriate by the CMCU. The PM heads will be left on site by the QA/QC unit and the filters should be left on site by the LSO once removed so that they are available for the next test.

5.5. 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 (SO_2) in air.
- Carbon monoxide: Carbon monoxide (CO) in air.

A second span check is undertaken on the nitrogen oxides analyser using a nitrogen dioxide (NO_2) in air mixture.

The gas standards supplier is responsible for supply and calibration of the standard gas mixtures. These standards are maintained and used by 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.

The QA/QC unit 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.

5.6. 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 the table below, 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 5.1 - "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

6. Health and Safety

A separate document, "UK Air Quality Monitoring Networks Health and Safety Guidance (Ricardo Energy & Environment, 2020)" has been produced, to provide consistent guidance for 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 via the AURN Hub Link here Local Site Operators are referred to this document and should read and familiarise themselves with all sections of it.

For further information on site safety contact the relevant Central Management and Control Unit (CMCU) or Local Authority Health & Safety Teams (affiliated sites).

7. References

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