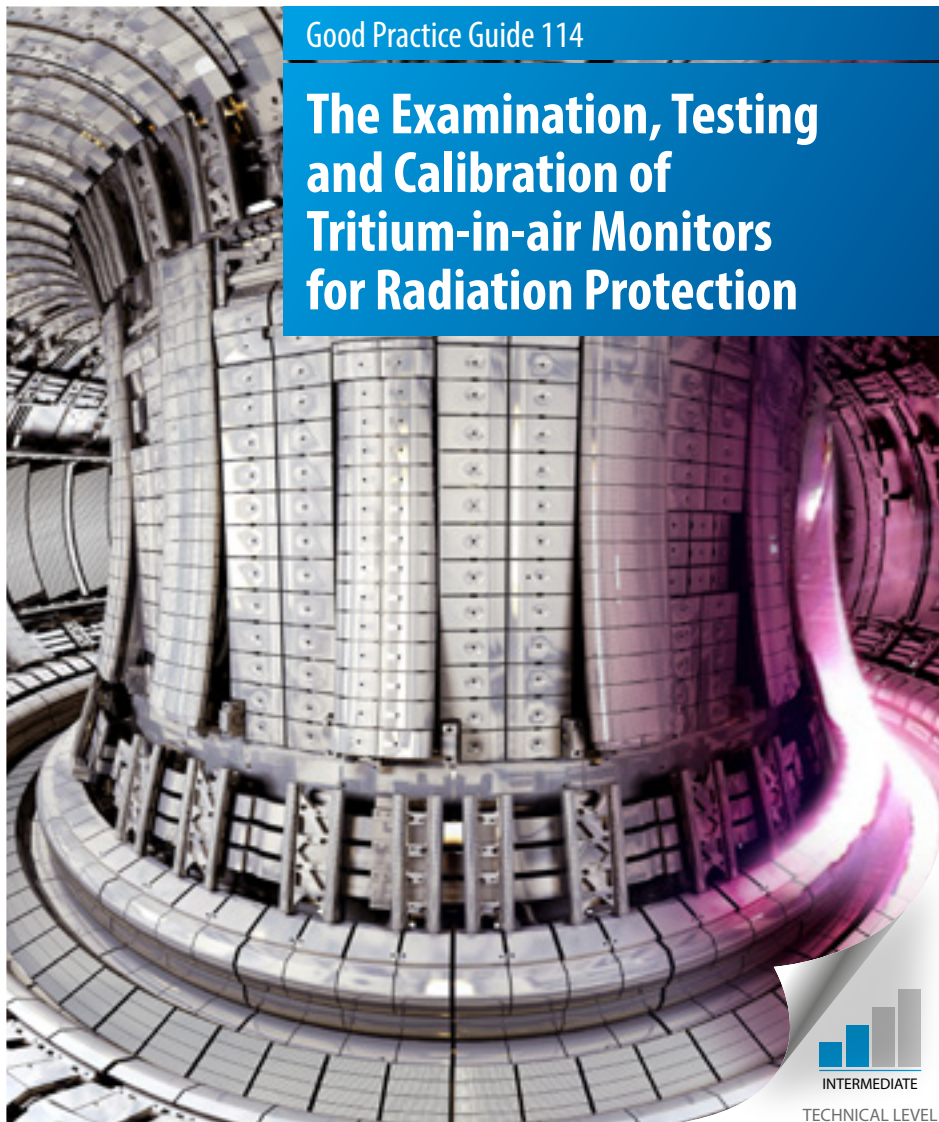




Good Practice Guide 114

The Examination, Testing and Calibration of Tritium-in-air Monitors for Radiation Protection



National
Measurement
System



Good Practice Guide 114

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Front Cover Image: *Joint European Torus (JET) vacuum vessel (Image courtesy: Culham Centre for Fusion Energy)*

Guide Information

What is it about?

This guide provides recommended procedures for examining, testing and calibrating tritium-in-air monitoring instruments for radiation protection. The procedures discussed in this guide involve the minimum level of testing recommended for instruments used in normal operating conditions.

Who is it for?

The guide's targeted readership mainly consists of nuclear industry operators; however, this guide may also be of interest to ionising radiation instrumentation suppliers in the healthcare sector.

What is its purpose?

The purpose of the guide is to provide technicians who use tritium-in-air monitoring systems with simple testing and calibration procedures to enable them to comply with the Ionising Radiations Regulations 1999 and ensure that the instruments remain fit for use.

What is the pre-required knowledge?

The guide assumes that the reader has little or no technical background knowledge of the instrumentation. However, a basic understanding of radioactivity and of ionising radiation instrumentation is assumed.

Key to icons:



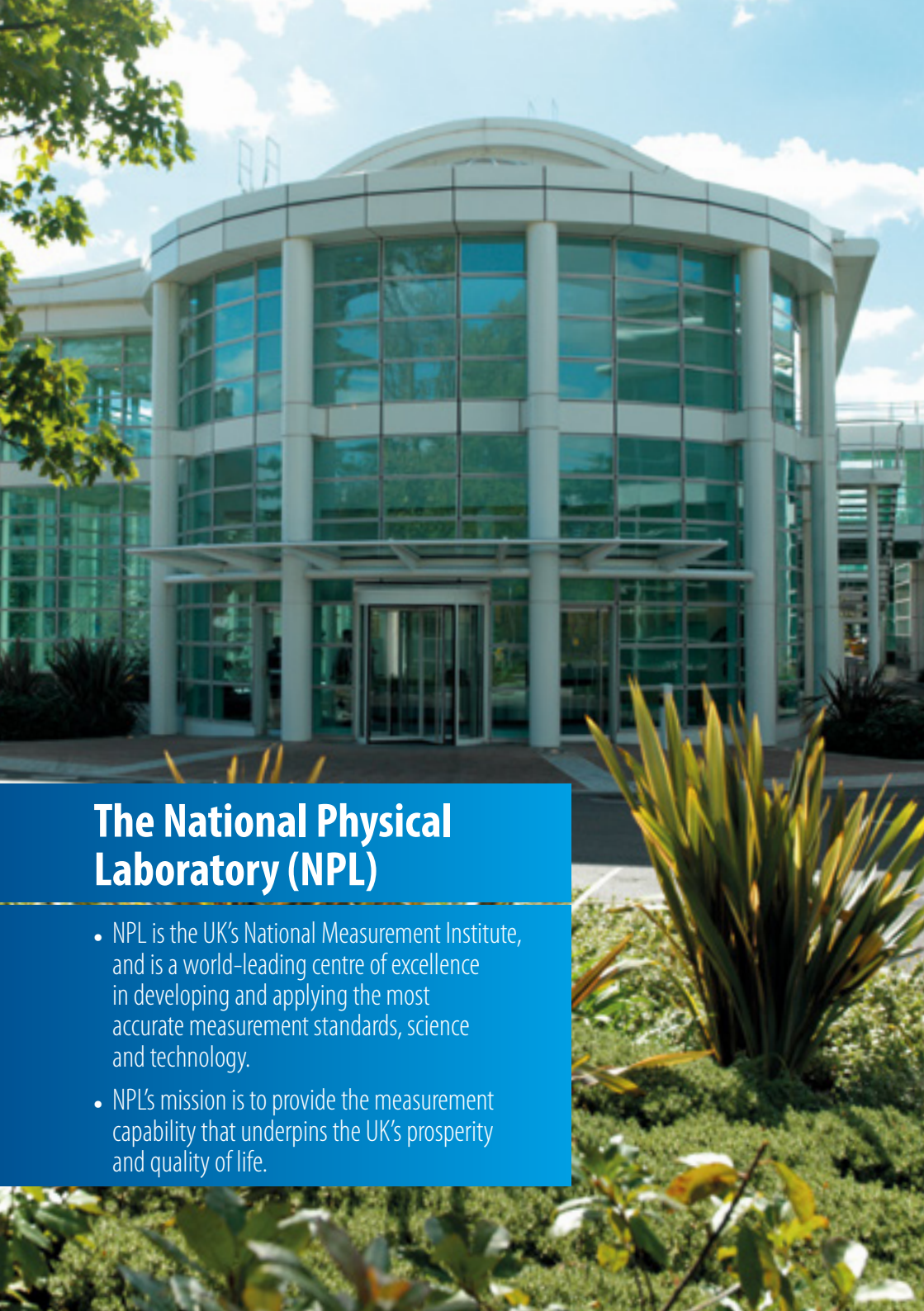
Need to know



Good to know



Checklist



The National Physical Laboratory (NPL)

- NPL is the UK's National Measurement Institute, and is a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology.
- NPL's mission is to provide the measurement capability that underpins the UK's prosperity and quality of life.

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Foreword

This Good Practice Guide has been written by members of the Airborne Radioactivity Monitoring Users Group in collaboration with the radiation user community. It describes recommended procedures for the examination, testing and calibration of tritium-in-air monitoring equipment. Test procedures recommended in this document are not legally binding; they are general methods based on current accepted good practice.

The current statutory requirement for air monitoring equipment tests is stated in the Ionising Radiations Regulations 1999¹. All employers who work with ionising radiation must ensure that levels are adequately monitored and that instruments are suitable for this purpose.

Although the testing regimes presented here are for general application, Qualified Persons responsible for the calibration of radiation protection instruments may, with the agreement of the Radiation Protection Adviser, modify regimes as necessary to suit their particular purpose, provided that the employer can demonstrate that the overall quality of the testing is not compromised.

The Airborne Radioactivity Monitoring Users Group *consists of representatives of UK establishments and organisations actively involved in air monitoring for tritium at environmental, workplace and process control levels. It is the aim of the group to facilitate the exchange of information regarding UK calibration facilities and their efficient use by those required to comply with the regulations on tritium use and measurements within the UK.*

Chapter I

Introduction

- Purpose of the guide

Purpose of the guide

The examination and testing of radiation protection instruments is a legal requirement for those carrying out work with ionising radiation^{1,2}. Sufficient equipment must be available to enable the user to comply with the regulations, and the instruments must be examined, tested and calibrated at appropriate intervals to ensure that they remain fit for use. Some types of 'tritium-in-air' monitoring equipment are either installed or not readily transportable. It is therefore often not possible to transport these instruments to a suitable calibration laboratory. Consequently, periodic examination and testing of such equipment may have to be carried out in the workplace. This approach will minimise the risk of damage caused by removal, transport and re-installation of equipment. It will also permit tests of auxiliary indicators, such as remote warning lights, audio-visual alarms or the removal of key components, e.g. electrometers for independent calibration, etc.

This Good Practice Guide (GPG) provides recommended procedures for the general examination, testing and calibration of tritium-in-air monitoring equipment used for the purpose of radiation protection. It is similar to GPG14³, GPG29⁴ and GPG82⁵ which provide advice for portable radiation protection instruments (dose rate and contamination), installed instruments and particulate-in-air monitors, respectively. Recommendations made in documents published by national and international organisations have been consulted during the preparation of this guide. To ensure calibration or type testing is conducted in accordance with these documents, current versions should be consulted.

The procedures detailed in this guidance provide the minimum level of testing that is recommended for instruments used in normal operating conditions. There may be special cases where testing requirements will go beyond these recommendations (for example, where instruments are used in conditions outside those envisaged in the standards above, such as in emergencies). In such circumstances, the employer may need to design alternative test procedures and the relevant national and international standards should be consulted.

The testing regimes contained herein have no legal standing, and employers may implement their own schemes, provided they ensure compliance with the relevant regulations.

The objective of testing is to demonstrate that the instrument is suitable and fit for use. This guide is intended to cover all equipment that is used to actively assess the airborne concentration of tritium in the workplace. These types of instruments are described in detail in 'Instruments' section. The guide does not cover the use of tritium bubblers.

Much of the periodic and function testing of these instruments will be done using gamma radiation. The justification for this approach is given in Appendix 1.

Chapter II

Testing Regime

- Brief introduction
- Type tests
- Tests before first use
- Periodic tests
- Routine function check
- Retest after repair/adjustment
- Analysis of test results

Brief introduction

For the purposes of this guidance, a **test** is defined as a procedure to evaluate an instrument's performance in order to establish its suitability, or its continued fitness, for a particular type or types of measurement in operational radiation protection.

A test may involve an element of **calibration**, which may be defined as the measurement of the response of the instrument to a known influence quantity, such as flow rate or activity concentration. It is important to recognise that the terms **test** and **calibration** are not synonymous: this is because a test will also involve a degree of **examination**, which may include, for example, an inspection of the mechanical and electrical state of the instrument.

Tritium-in-air monitoring equipment should undergo Tests Before First Use (TBFU) and subsequently Periodic Tests, which should be performed at suitable intervals in compliance with current national regulations and associated codes of practice. The findings of these tests must be compared with any previous test information and the appropriate Type Tests to confirm that the instrument is meeting its specification and is suitable for its intended use. The Type Tests are normally carried out by, or on behalf of, the instrument manufacturer. TBFU and Periodic Tests are carried out by, or on behalf of, the employer. Table 1 lists recommended TBFU and Periodic Tests.

It is recommended that additional function checks are carried out more frequently to ensure that the instrument remains fit for use and that there has been no unexpected change in performance.

A full record of test results, including details of any adjustments made to the instrument, should be kept for a period of at least 2 years or as determined by the employer.

Type Tests

Before purchasing an instrument, it is the responsibility of the employer to ensure that it is suitable for the intended use. Decisions about instrument selection should be made taking into account advice from the Radiation Protection Adviser (RPA), information from the manufacturer and other authoritative data that might be available.

The body of information regarding the characteristics and expected performance of instruments is called 'Type Test' data and is usually based on recommendations from international organisations such as International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). A number of IEC documents exist which detail the tests that are appropriate for the type testing of



Tests Before First Use and Periodic Tests

Instrument	Tests Before First Use (TBFU)	Periodic Tests
Portable tritium-in-air monitors	Parameter check	Parameter check
	Low flow alarm	Low flow alarm
	Leakage	Background
	Background	Linearity
	Response to Tritium Gas	Activity alarm test
	Response to other interfering radioactive gases	Gamma compensation
	Linearity	–
	Activity alarm test	–
	Gamma compensation	–
Installed tritium-in-air monitors	Parameter check	Parameter check
	Pump test	Pump test
	Flow rate accuracy	Flow rate accuracy
	Leakage	Low flow alarm
	Low flow alarm	Background
	Background	Activity alarm test
	Activity alarm test	Gamma compensation
	Gamma compensation	–

Table 1. *Summary of Tests Before First Use and Periodic Tests.*

particular types of instrument. Some of these IEC documents have been adopted as British and European standards (BS EN). A typical document for the testing of air monitoring equipment is BS EN 60761:2004⁶ ('Equipment for Continuous monitoring of radioactivity in gaseous effluents'). Other national or international standards may also be relevant. Type Tests are very comprehensive and may require specialised facilities. They should be performed by someone with appropriate expertise and insight into the use of the instruments and in a laboratory with secondary standard or similar status (for example, a laboratory accredited by UKAS) using measurement quantities specified by the International Commission on Radiological Units and Measurements (ICRU), and ISO-specified calibration sources.

The results of any tests carried out during the lifetime of an instrument should be compared with Type Test data to ensure that it continues to operate as expected; therefore, it is necessary to have access to the Type Test data for each instrument

tested. As a minimum requirement, the Type Test data should include results of tests that are equivalent to those defined in this guide as the TBFU (Table 1).

For most new instruments, the manufacturers, suppliers or other organisations may provide Type Test data that will enable the employer to decide the necessary scope of the TBFU. In the absence of Type Test data, the employer should perform their own Type Test to establish their own baseline data at the TBFU stage.

Tests Before First Use

The TBFU are intended to demonstrate that the instrument conforms to type and is suitable for its intended use.

These tests should identify any potential faults and identify any limitations of the instrument with respect to its intended use. The tests may be undertaken by the manufacturer, the employer or an independent laboratory.

Table 1 summarises the tests required for the TBFU for both installed and portable tritium-in-air monitors. The recommended procedures for each of the tests are provided in the sections 'Specific tests' (*page 25*) and 'Specific tests on the radiation detection assembly for portable tritium-in-air monitoring equipment' (*page 29*). Some of these tests may need to be repeated periodically as the performance of an instrument can vary with age, key components may deteriorate or fail, and damage may occur during use; these are some of the reasons for the subsequent Periodic Tests.

Periodic Tests

It is the responsibility of the employer to define the frequency of Periodic Tests based upon considerations such as the age of the equipment, the environment in which it is used, and the frequency of use. It is the recommendation of this guidance that examination, testing and calibration should be performed at least annually. However, the requirements of any regulations published in the future must be adhered to.

The purpose of Periodic Testing is to check that the instrument remains fit for use and to confirm that its performance has not changed significantly since the TBFU stage.

The tests required for the Periodic Tests are summarised in Table 1. They are broadly similar to those for the TBFU. Specific details of each test are provided in the sections 'Specific tests' (*page 25*) and 'Specific tests on the radiation detection assembly for portable tritium-in-air monitoring equipment' (*page 29*).

Because the instrument may have suffered from wear and tear or misuse, attention should be paid to the performance and the condition of its electrical and mechanical systems. For example, the pump within the air circuit is particularly vulnerable to wear and tear, and should be examined at least annually. The condition of any warning lights/audible alarms should also be checked, and any lights or indicators to which a user has to respond must be operating correctly. Other system components should be examined – e.g., filters for potential blockages, switch failure, earth current loops etc. If the instrument is normally connected to other components such as remote alarms and data logging systems, additional tests for the relevant input/output functions should be included.

Routine function check

A routine function check is carried out to ensure, with the minimum of interference, that the instrument is working correctly. The frequency of function checks must fit the application of the instrument and must be determined by the employer. Function checks may involve the following:

- response check
- background check
- flow rate check
- alarm check
- parameter check.

If the function check results fall outside prescribed limits, the instrument should be submitted for a Periodic Test. If the instrument requires repair or maintenance, the Qualified Person should consider whether another TBFU is required ('Retest after repair/adjustment').

Retest after repair/adjustment

After any repair, adjustment or modification that could affect the performance of the instrument, it may be necessary to repeat some of the TBFU or Type Tests. The degree of testing depends on the nature of the change. Certain changes may be so fundamental that some parts of the Type Test should be repeated – for example, replacement with a detector from an alternative manufacturer.

Analysis of test results

The results of the TBFU should be compared with the Type Test data and the Periodic Tests of an instrument should be compared with the TBFU to confirm that the instrument still conforms to type and remains fit for use.

A full record of test results, including details of any adjustments made to the instrument, should be kept. Current test results should be compared with previous results and any significant changes noted and investigated, even if all the results fall within specification. For example, the performance of an instrument should be regarded as suspect if a previously consistent response is now significantly different, even if it is still within acceptable limits.

Whenever an instrument is adjusted during the course of a Periodic Test or TBFU, a statement indicating the nature and magnitude of the adjustment should be made on the test report or calibration certificate.

An instrument will fail the TBFU or Periodic Tests if the results of any component of the appropriate tests are not within the acceptable limits defined in Tables 2 and 3, or if the instrument's performance is deemed unsatisfactory by the employer.



Tests required for tritium-in-air monitors

Test required	Comments	Pass/fail criteria	Test Before First Use	Periodic Test	Detailed reference
Parameter check (check that all accessible parameter settings are correct)	–	–	Yes	Yes	(page 26)
Low flow alarm	–	–	Yes	Yes	(page 26)
Flow rate accuracy (test the flow rate over the range encountered)	Not normally accessible in portable equipment. If variations are observed of more than 20 % from the true value, then investigations should be carried out	Failure if reading is more than 20 % is away from the true value	Yes	Yes	(page 26)
Fault alarm check	–	–	Yes	Yes	(page 27)

Table 2. Tests required for tritium-in-air monitors



Further tests required for tritium-in-air monitors

Test required	Comments	Pass/fail criteria	Test Before First Use	Periodic Test	Detailed reference
Background (Measure the background with no air flowing)	–	–	Yes	Yes	(page 30)
Response to tritium gas	–	Indicated activity concentration should be within $\pm 30\%$ of the reference concentration	Yes	Yes	(page 30)
Linearity	See detailed reference regarding positioning of detectors and source of gamma radiation	Agreement within $\pm 30\%$ of the Type Test data	Yes	Yes	(page 30)
Activity alarm	–	Alarm should sound where the indication is 20 % higher than the set alarm level	Yes	Yes	(page 32)
Gamma compensation	–	Response of the instrument to gamma radiation should be less than 10 % of its indication, with the compensation switched off.	Yes	Yes	(page 32)

Table 3. Further tests required for tritium-in-air monitors.

Instruments

- Brief introduction
- Pre-calibration checks

Brief introduction

The concentration of airborne tritium that an instrument may encounter, and the conditions under which it may be used, should be considered when selecting an instrument. The employer should seek advice from the RPA when an instrument selection is made.

Most portable and many installed tritium-in-air monitors use ionisation chambers as the detectors. Normally, ambient air is pumped through these, generally through a filter to prevent the ionisation chamber becoming dusty and in particular to prevent radioactive contamination. Most instruments incorporate a means of compensating for any gamma radiation present in the workplace. This is normally a sealed ionisation chamber of the same volume as the sample chamber. Where external gamma radiation is the only radiation present, then the output from the two chambers will be identical, provided the air density in the sample chamber is the same as that in the compensation chamber. Subtracting the two signals will lead to a background indication from the instrument. This is normally performed by arranging for the two chambers to collect charge of opposite signs and then connecting them to a common amplifier input. The test procedures given here are appropriate to such instruments. They do not apply to instruments that use scintillation detection or proportional counting.

Note that, for these instruments (unlike particulate in air monitors), flow rate is not critical as there is no collection process taking place. If the flow rate is lower than normal then the effect is to delay the response of the instrument.

Testing and calibrating tritium-in-air monitors using tritium itself is a relatively difficult process involving tritium-in-air activities typically of the order of $1\text{--}10\text{ MBq m}^{-3}$ and requires specialised facilities. This makes it extremely difficult to perform a linearity measurement over the complete instrument tritium range of activity concentrations. In operational use, a monitor may be expected to demonstrate essentially that there is no tritium present for much of the time, but it may also be expected to deal with the consequences of a major release. The alternative approach for testing is to use gamma radiation to generate a current in the detectors in such an instrument. The theoretical and experimental justifications for this approach are given in the Appendix at the end of the GPG.

Pre-calibration checks

Instruments may be damaged through use or in transit. Even in store, batteries can deteriorate and battery terminals may corrode. Thoroughly check the condition of any instrument before any tests or calibrations are carried out.

The list above is not exhaustive and the user (or QP or RPA) may consider additional checks that should be made prior to the test or calibration. Each instrument type has its own idiosyncrasies and modes of failure.

Some organisations will expect the instrument test laboratory to maintain instruments and perform repairs whereas others will see these purely as the responsibility of the customer. It is important that everyone involved in the testing and calibration process understands their own and others' responsibilities. The list above assumes the former.



Key steps in the pre-calibration check of the tritium-in-air monitoring instrument

- The instrument should be checked carefully for contamination. Any contamination should be noted and if above any limit should be reported in line with the organisation's procedures. If permissible, attempt to remove any loose contamination.
- If decontamination is not permitted, the contamination level should be assessed and the instrument owner informed. No further work should be performed on the instrument.
- Check for mechanical damage to the instrument case, meter, etc and perform any repairs required. Instruments that appear well maintained are generally much better looked after than poorly maintained examples.
- Check the state of the battery (or batteries), and check for corrosion around the battery terminals.
- Ensure all plugs and sockets are correctly tightened.
- Check any leads where appropriate, particularly where the cable goes into the plug.
- Where appropriate, check the pump is working correctly and there are no leaks in the pipe work. This can be done by visual inspection in many cases, or by gradually restricting the inlet and listening to the pump.
- Check any filters are intact and clean.
- Check and adjust any mechanical zero.
- Check and adjust any electronic zero.
- Check that any LCD or other panel display is working well and there are no missing segments, unacceptable contrast or colour variations across the screen.
- Check that any switches move freely and smoothly.
- If required, check ratemeter linearity using an appropriate pulse generator or current generator, following the manufacturer's recommendations. Note this is not generally required.
- Check any desiccators are in good condition and the desiccant is dry. The older type of desiccant is blue when dry and pink when wet, but more modern types can have a different colour code.
- Ensure the instrument is at ambient temperature.
- Allow the electronics to warm up.
- Check for contaminated detectors if the background is higher than expected.
- Gently shake the instrument and, if the indication fluctuates, recheck any leads.

If all these tests are passed, then the instrument can now be tested formally. Note that testing should follow soon after examination.

Specific tests

- Parameter check
- Low flow alarm
- Flow rate accuracy
- Fault alarm check

Parameter check

Confirm that any parameter settings stored within the instrument's electronic memory have been set to the appropriate values. If these parameters are controlled by a high level of security (e.g. via a supervisor password), this test may be conducted as part of the Periodic Test rather than the function check.

These parameters typically include:

- Derived Air Concentration (DAC in units of Bq m^{-3})
- Alarm setting
- Calibration factor, in units of $\text{A Bq}^{-1} \text{ m}^3$.

Low flow alarm

Check that any low flow alarm operates. The manufacturer's instructions should be followed.

Flow rate accuracy

This is generally applicable only to installed monitors.

Pump flow rate

- The pump is usually located downstream from the ionisation chamber.
- To measure the air flow rate of the pump, a suitable, accurate in-line flow meter should be installed between the pump and the ionisation chamber.
- The air flow rate of the pump should be set on this flow meter to within the manufacturer's specifications – ideally near the middle of the flow meter's range.
- The air flow rate of the pump is typically set at about $2 - 5 \text{ L min}^{-1}$.
- The airflow rate of the pump should be periodically checked by visually inspecting the flow meter.

An optical sensor alarm may be installed to ensure that the air flow rate through any rotameter falls within the correct range.

Sample flow rate

- A suitable, accurate in-line flow meter should be installed close to the sampling point, upstream from the monitor.
- Where a monitor serves several sampling points, a separate in-line flow meter should be installed for each sampling branch. A balanced air flow rate should be maintained through each branch.
- Sampling tubes should be kept as short as possible to ensure a reliable, constant air flow rate.
- The number of sampling points should be minimised.
- The air flow rate through the sampling tube is typically set at $1 - 2 \text{ L min}^{-1}$.
- The air flow rate through the sampling tubes should be periodically checked by visually inspecting the relevant flow meters.

Record the indication on the instrument's flow meter. Place a calibrated flow meter upstream of the inlet of the device and the collection filter. Measure the flow rate on the calibrated flow meter and compare with that recorded for the instrument flow meter. The instrument flow meter indication should not differ by more than 20 % from the calibrated flow meter indication. Where possible, the instrument should be adjusted so that its flow rate indication is within 10 % of that of the calibrated flow meter. If the discrepancies are greater than 10 %, this may indicate leakage and a separate leakage test should be undertaken.

Note that the instrument flow meter indication may change when the calibrated flow meter is used. A variable aperture flow meter can give incorrect results when operating at a pressure other than that at which it was calibrated. For example, errors can occur when introducing an obstruction upstream of a flow meter and consequently introducing a pressure drop.

Fault alarm check

Some types of instrument provide fault alarms. Where these can be triggered easily, this should be done. Manufacturer's instructions should be followed.

Specific tests on the radiation detection assembly for portable tritium-in-air monitors

- Background
- Response to tritium gas
- Linearity
- Activity alarm
- Gamma compensation

Background

Record the background indication. The purpose of the test is to identify whether the detector is contaminated or if there is electronic noise present.

Response to tritium gas

The majority of testing of tritium-in-air monitors uses gamma radiation. This is valid provided the instrument has been correctly assembled and the ambient air flows correctly through the ionisation chamber. However, where feasible, it is recommended that a single point test using tritium gas (generally HT or T₂) is performed as part of the TBFU. If other interfering radioactive gases (e.g., ⁴¹Ar or ¹⁴C species) are likely to be present during monitor operation consideration should be given to the response of the monitor to these interferences during TBFU.

Linearity

Cancelling gamma compensation

It is important to read the instrument manual before attempting to cancel or reverse the gamma compensation.

Tritium-in-air monitors almost always have some process for correction for ambient gamma radiation, generally using a pair (or pairs) of chambers, one through which ambient air is circulated and another sealed one for comparison. However, testing and calibration of these instruments makes use of their gamma sensitivity. There are two possibilities:

- The output from the compensation chamber can effectively be switched off by removing the collecting potential or by disconnecting the compensating chamber.
- The polarity of the signal from the compensating chamber can be reversed by reversing the collecting potential.

Where the compensating output can be switched off, there is one of the three options available:

- Unplugging the ion chamber from the amplifier
- Disconnecting the polarising supply at the ion chamber
- Removing the polarising battery.

If the ion chamber can be easily unplugged from the amplifier, this is generally the easiest option. The exposed socket on the amplifier should be covered by a cap, and the end of the lead should be insulated.

If the polarising supply can be disconnected from the chamber, it is necessary to ensure that the socket on the supply and the corresponding plug on the chamber are insulated. The lead should be removed and insulated if thought necessary. The plug should then be earthed down to the chamber body. If this is not done, significant ion collection can take place, particularly at low dose rates.

If the easiest option is to remove the polarising battery, this should be done and the battery replaced with a shorting link.

Where the polarity of the compensation chamber can be reversed:

Some instruments have a reed switch that allows the user to reverse the polarity on the compensation chamber. If polarity reversal is used the instrument will read double for a given dose rate and the conversion factor ('Gamma linearity') becomes $1.65 \mu\text{Sv h}^{-1} = 1 \text{ MBq m}^{-3}$.

Immediately after either shorting out or reversing the polarity, a significant current will flow. This will result in the wrong indication until this current has decayed.

Gamma linearity

The instrument should be mounted so that both the measurement and compensation chambers are equally exposed and the centre line of each is on the reference line for the exposure equipment. For co-axial chambers, this is easy to achieve, but for instruments with separate chambers then care will need to be taken.

Note that this may result in the need for a wide beam, which will limit the distance between the source and the chambers.

The instrument should be left to stabilise, any background corrections suggested by the manufacturer made and then switched to its lowest operating range or decade. The background on that range should be noted. The instrument should then be exposed to the gamma radiation. The dose rate should be such that the instrument indication is in the top half of the range or decade in question. For low dose rates, the indication may take a long time to reach equilibrium. The manufacturer's instructions should be consulted and at least three time constants should be allowed before the formal measurement begins. Where the indication is fluctuating significantly, the average should be determined over several time constants.

This process should be repeated over the instrument's entire range or over the range of tritium-in-air concentrations which could be reasonably expected.

The instrument performance should be determined in terms of $\mu\text{Sv h}^{-1} \text{MBq}^{-1} \text{m}^3$ and compared with type test or manufacturer's recommended values. Agreement should be within $\pm 30\%$ of the recommended value. In the absence of reference values, the expected performance for an instrument where the compensation can be switched off is $3.3 \mu\text{Sv h}^{-1} \text{MBq}^{-1} \text{m}^3$. Where the effect is to add the outputs from the detectors, the sensitivity is essentially doubled to $1.65 \mu\text{Sv h}^{-1} \text{MBq}^{-1} \text{m}^3$.

Activity alarm

Activate the alarm with a dose rate from a ^{137}Cs source sufficiently high to trigger the alarm. The dose rate should be selected so that the resulting indication is no more than 20 % above the set alarm level. Confirm correct operation of all alarm functions (e.g. local audible, visual and any remote indications).

Gamma compensation

Restore the compensation function to normal and allow the instrument to recover. Note that the compensation normally assumes that the air temperature and pressure are approximately 20 °C and 101.3 kPa respectively. Where this is not the case, then the compensation process will be excessive for high temperatures and low pressures and inadequate for the converse.

The instrument should then be exposed to one of the dose rates used in the linearity measurement. The performance is satisfactory if the indication is no more than 10 % of the value observed with the compensation removed (after correction for temperature and pressure, if required).

Facilities and traceability

- Brief introduction
- Certification of tests

Brief introduction

The majority of the tests on installed tritium-in-air monitoring equipment described in this document would be performed in a calibration laboratory. The facilities and traceability required in order to undertake tests on air monitoring equipment in a calibration laboratory are little different from those required for a portable instrument. The section in GPG14³ on the facilities required for the calibration of portable gamma dose rate monitors should be consulted for full information.

At least one exposure of the tritium-in-air monitor to tritium gas should be performed during TBFU at a UKAS accredited calibration laboratory to ensure accuracy of instrument response prior to its entering service. The gas used in this test should be traceable to national standards of radioactivity. The activity concentration used in the performance of the test should be sufficient to generate a response at the mid-point of the decade of measurement anticipated when the instrument is in service or at any other point as agreed between the manufacturer and the employer. Testing should be performed by the circulation of a tritium-in-air mixture through the monitor for a sufficient length of time to generate a constant instrument response. This should be within the limits specified in the relevant national or international standards.



Monitor response to radon

Note that some tritium-in-air monitors respond very effectively to radon (^{222}Rn) and thoron (^{220}Rn) in the atmosphere. Most are equipped with a particulate filter which will remove the fraction of the decay products attached to dust and some can electronically reject any alpha pulses observed in the ionisation chamber. However, it is important that the air in the test laboratory should not have significantly elevated radon or thoron concentrations.

Certification of tests

The results of tests performed under the current regulations should be communicated to the employer in a formal manner. The precise format (e.g. of a test certificate or report) is not specified in the regulations.

Pass certificate

The following basic information should be provided by the Test House:

- the name and address of customer
- a description of the instrument (including type and serial number)
- the type of test (i.e. Tests Before First Use, Periodic Test or retest after repair)

- any specific instrument settings used and any adjustments or repairs performed
- the results of any test using tritium, in terms of the background corrected observed activity concentration and the reference concentration, including a statement of uncertainty and the confidence level at which the uncertainty has been quoted
- the results of the gamma exposures performed, in terms of the indicated activity concentration per unit ambient dose equivalent rate, a statement of the uncertainty and the confidence level at which the uncertainty has been quoted
- a record of the background gamma dose rate and any relevant environmental conditions during the tests
- a statement that the test was carried out for the purposes of complying with the regulations
- the name and signature of the QP supervising the test
- the name, address and contact details (e.g. telephone number or Email address) of the Test House which performed the test
- the date of the test
- the test reference.

Test label

Instruments should be labelled with the following information after testing:

- a description of the instrument (including type and serial number)
- the date of the calibration or test
- the test reference.

Fail certificate

If an instrument fails to meet the pass/fail criteria of any component of a test, the Test House should prominently label the instrument as failed and make some indication of the nature of the failure on the certificate or test report. The certificate should clearly indicate that it is a failure certificate and there should be no possibility of confusion with a pass certificate.

Chapter VII

Quantities and units

- Typical units

Typical units

Typically, air monitors will display the measured response as the activity in air concentration with units of MBq m⁻³ or as the Derived Air Concentration (DAC).

The DAC for airborne activity is the average airborne activity concentration that will result in a radiation worker who is breathing at 20 L minute⁻¹ for the 2000 hour working year (i.e. 2400 m³) inhaling the Annual Limit of Intake (ALI).

Hence the DAC is:

$$DAC = \frac{ALI \left(\frac{Bq}{year} \right)}{2400 \left(\frac{m^3}{year} \right)}$$

The ALI is the annual intake by reference man that will result in a committed effective dose equivalent of 20 mSv. The ALI for tritium is 1 GBq, as stated in ICRP publication 68⁷. This leads to a DAC of 0.450 MBq m⁻³.

Use of gamma dose rates to calibrate tritium-in-air monitors

- General issues
- Derivation of the conversion factor between ambient gamma dose rate and expected indicated tritium in air concentration
- Experimental confirmation

General issues

There are very few facilities in the UK capable of delivering traceable quantities of tritium gas to tritium-in-air monitors and no facilities that can test the most common types across the full instrument range using tritium. Furthermore, tritium gas can plate out in the measurement chamber if the tritium levels are high, or after chronic exposure to low levels, thus leading to instruments with a high background. This effect can be irreversible, and, as most instruments are in place to monitor tritium levels close to background, is undesirable. It is very difficult to remove tritium or tritiated water bonded to the ionisation chamber. Methods such as heating the chamber to a high temperature can be attempted but in general it will not be possible to decontaminate them and they will have to be replaced. Consequently calibration with high concentrations of tritium is undesirable. Finally it should be remembered that tritium readily converts to tritiated water and in many cases it is assumed that the oxide form predominates in the environment. Tritium-in-air monitors are therefore frequently tested with known gamma dose rates rather than their normal measurand (i.e. tritium gas).

For flow-through tritium-in-air monitors, which use an ion chamber, gamma radiation is often the best way to establish the correct operation of the monitor. This note describes the derivation of the conversion factor.

Derivation of the conversion factor between ambient gamma dose rate and expected indicated tritium in air concentration

Presume a tritium-in-air concentration of 1 MBq m^{-3} .

The average decay energy of tritium is 5.7 keV^8 .

Hence, the energy deposition rate will be $10^6 \times 5.7 \text{ keV s}^{-1} \text{ m}^{-3}$. Converting from KeV to Joules gives a value of $9.13 \times 10^{-10} \text{ J s}^{-1} \text{ m}^{-3}$.

The density of air⁹ is 1.2041 kg m^{-3} .

Hence, the energy deposition rate = $7.58 \times 10^{-10} \text{ J s}^{-1} \text{ kg}^{-1}$ or $7.58 \times 10^{-10} \text{ Gy s}^{-1}$.

Converting this to Gy h^{-1} gives a value of $2.73 \times 10^{-6} \text{ Gy h}^{-1}$ or $2.73 \text{ } \mu\text{Gy h}^{-1}$.

The construction of the ion chambers (aluminium walls and volumes of the order of hundreds of cm³) means that they are close to air equivalent for ¹³⁷Cs gamma radiation. Hence exposing such ion chambers to ¹³⁷Cs gamma radiation at a level of 2.73 µGy h⁻¹ should generate a current corresponding to 1 MBq m⁻³ tritium.

Normally, radiation protection monitors are calibrated in terms of ambient dose equivalent rate expressed in Sieverts (Sv). For ¹³⁷Cs, the conversion factor is 1.20 Sv Gy⁻¹ air kerma. Folding this into the value above gives an expected 3.3 µSv h⁻¹ to generate an indication of 1 MBq m⁻³. This is the value appropriate to the situation where the output from the compensation chamber is disconnected or switched off. Where the polarity of the output has been reversed (so that it adds to the current from the flow-through chamber), the output is effectively doubled. In that case, 1.65 µSv h⁻¹ will generate an indication of 1 MBq m⁻³.

Experimental confirmation

Over a period of years, data have been collected for a large number of tritium-in-air monitors fitted with large volume ionisation chambers (about 1400 cm³) that have been calibrated using standardised tritium gas at NPL and traceable dose rates in a UKAS laboratory using a ¹³⁷Cs gamma source. These data are presented in Table 4 and in Figures 1,2 and 3.



Tritium-in-air monitors calibration data

Ratio of monitor indication to supplied activity concentration	Ratio of monitor response to 60 $\mu\text{Sv h}^{-1}$ to dose equivalent concentration (18.2 MBq m^{-3})	Ratio ^3H result/gamma result
0.929	0.77	1.21
0.903	0.91	0.99
0.899	0.94	0.96
1.208	0.94	1.29
0.903	0.99	0.91
1.213	1.16	1.05
1.493	1.43	1.04
0.982	1.16	0.85
0.798	0.88	0.91
1.158	1.38	0.84
0.842	1.10	0.77
1.136	1.27	0.90
1.339	1.54	0.87
0.882	1.05	0.84
1.078	0.99	1.09
0.809	0.94	0.86
0.882	1.05	0.84
0.882	1.05	0.84
0.943	1.10	0.86
0.882	0.91	0.97
1.146	1.43	0.80
0.936	0.94	1.00
0.732	0.96	0.76
0.847	0.98	0.87
0.809	0.88	0.92
0.791	0.84	0.94
0.773	0.99	0.78
1.263	1.27	1.00
0.761	0.94	0.81
0.832	1.05	0.80
0.761	1.05	0.73
1.603	1.43	1.12
1.047	1.05	1.00
1.047	0.94	1.12
0.890	0.88	1.01
0.770	0.99	0.78
0.807	0.93	0.87
0.798	1.02	0.78
0.592	1.05	0.57
0.846	1.05	0.81
0.862	1.02	0.85

0.934	0.99	0.94
1.005	0.99	1.02
0.917	0.88	1.04
0.902	1.02	0.89
1.009	0.94	1.08
0.902	0.96	0.94
0.677	0.85	0.79
0.752	0.83	0.91
0.902	0.99	0.91
0.752	0.88	0.85
0.827	0.66	1.25
0.902	0.99	0.91
Mean values and Standard deviations		
0.94	1.02	0.92
20.8 %	17.0 %	14.7 %

Table 4. Raw calibration data.

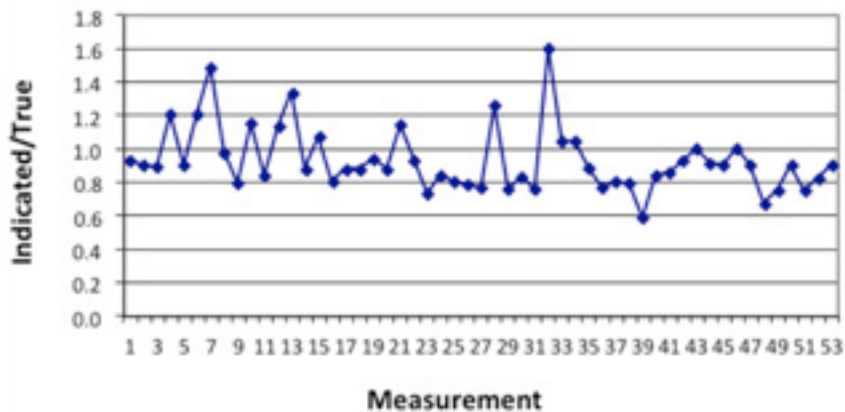


Figure 1. Tritium results indicate / true.

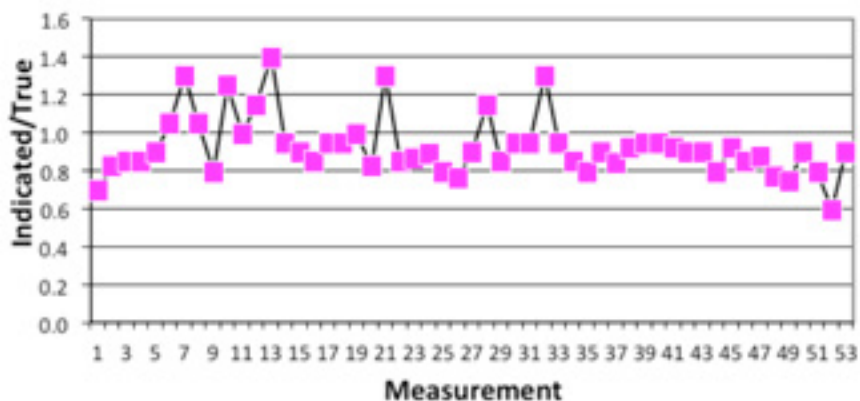


Figure 2. Calibration factors for 1400cc chambers using a gamma dose of $60 \mu\text{Sv h}^{-1}$.

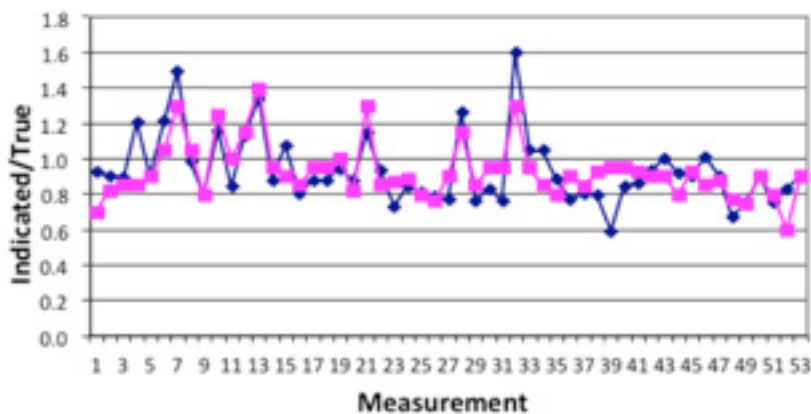


Figure 3. Comparison of gamma and tritium results for the same instrument.

Glossary

DAC:	Derived Air Concentration in units of Bq.m^{-3} . This is the concentration of radioactive particulate in air, which if inhaled for a working year (typically 2000 hours) would result in an inhalation committed dose of 20 mSv ¹ .
DAC.h:	The DAC integrated over the sampling time.
Employer:	The person or establishment who is legally responsible for the maintenance of the equipment.
Qualified Person (QP):	A person who possesses the necessary expertise in instrumentation, theory and practice appropriate to the instrumentation to be tested. This person may have responsibility as stated by the employer
Test Before First Use:	Test(s) performed on an instrument to demonstrate performance prior to its entering service.
Test House:	This is the organisation undertaking the testing of the instrument. This may be an independent calibration laboratory, a contract company who undertake the instrument testing in the workplace, or a department under direct management control of the employer that undertakes testing in the laboratory or in the workplace. Ideally, the Test House should hold UKAS accreditation for all the testing that it undertakes.

Further reading

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The Examination, Testing and Calibration of Tritium-in-air Monitors for Radiation Protection

Good Practice Guide 114

What is it about?

This guide provides recommended procedures for examining, testing and calibrating tritium-in-air monitoring instruments for radiation protection. The procedures discussed in this guide involve the minimum level of testing recommended for instruments used in normal operating conditions.

Who is it for?

The guide's targeted readership mainly consists of nuclear industry operators; however, this guide may also be of interest to ionising radiation instrumentation suppliers in the healthcare sector.

What is its purpose?

The purpose of the guide is to provide technicians who use tritium-in-air monitoring systems with simple testing and calibration procedures to enable them to comply with the Ionising Radiations Regulations 1999 and ensure that the instruments remain fit for use.

What is the pre-required knowledge?

The guide assumes that the reader has little or no technical background knowledge of the instrumentation. However, a basic understanding of radioactivity and of ionising radiation instrumentation is assumed.