

American National Standard Instrumentation and Systems for Monitoring Airborne Radioactivity

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

ANSI N42.54-2018

American National Standard Instrumentation and Systems for Monitoring Airborne Radioactivity

Sponsor

National Committee on Radiation Instrumentation, N42

Accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 11 January 2018

American National Standards Institute

Abstract: The complexity associated with quantitative assay and monitoring of aerosols and gasses can be substantial. This standard covers system design, manufacture, performance, testing, calibration, and maintenance requirements for noble gases, aerosols (including transuranics), tritium, and radioiodides.

Keywords: aerosol, air monitoring, ANSI 42.54, noble gas, radioiodine, transuranic, tritium

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2018 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 13 April 2018. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

Bladewerx and SpecIon are trademarks of Bladewerx, LLC.

Eichrom is a brand of Eichrom Technologies, LLC.

EMD Millipore and fluoropore are trademarks of Merck KGaA, Darmstadt, Germany.

Hollingsworth & Vose and hovoglas are trademarks Hollingsworth & Vose Company.

iCam is a trademark of Mirion Technologies, Inc., and/or its affiliates in the United States and/or other countries.

Monadnock is a trademark and brand of Monadnock Paper Mills, Inc.

Pall and Versapor are registered trademarks of Pall Corporation, registered in the U.S.A.

Staplex is a registered trademark of The Staplex Company, Inc.

Whatman is a trademark of General Electric Company or one of its subsidiaries.

PDF: ISBN 978-1-5044-4797-3 STD23065
Print: ISBN 978-1-5044-4798-0 STDPD23065

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Xplore at <http://ieeexplore.ieee.org/> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was approved, the National Committee on Radiation Instrumentation, N42, had the following membership:

Michael P. Unterweger, Chair
Morgan Cox, Vice Chair
Jennifer Santulli, Administrative Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Canberra.....	Robert Huckins
Commerce Dept., U.S. NIST	Leticia Pibida
Commerce Dept., U.S. NIST	Michael P. Unterweger
Consultant.....	Frank X. Masse
Department of Homeland Security	Peter Shebell
Harvard University	Joseph Ring
Health Physics Society	Wayne M. Glines
Lawrence Berkeley National Laboratory	Edward J. Lampo
Lawrence Livermore National Laboratory	David Trombino
NASA, GSFC	Sachidananda R. Babu
National Institute for Occupational Safety and Health.....	Mark D. Hoover
Oak Ridge National Laboratory	Peter J. Chiaro, Jr.
	Charles Britton (Alt.)
ORTEC, Ametek Inc.....	Frank Sergent
Pacific Northwest National Laboratory	Richard Kouzes
U.S. Army	Chad B. McKee
Members-At-Large	Morgan Cox
	Edward Groeber
	Ronald M. Keyser
	Greg Komp
	Mark L. Maiello
	Joseph C. McDonald
	Joseph Stencel
	Edward Walker

At the time this standard was approved, the ANSI N42.54 Working Group had the following membership:

Robert B. Hayes, Chair
Dennis Hadlock, Vice Chair
Murray E. Moore, Vice Chair

Brian Asamoto
David Baltz
Wesley Boyd
Martin Brennan
Morgan Cox
Frank Gavilla
Mark D. Hoover

Alan Justus
Phil Jenkins
Cynthia Jones
Andy Lasko
Tim Martinson
Roger Moroney

Tom O'Malley
Hillary Phillips
Jim Rolph
Jeff Sawyer
Roger Schanzenback
Lisa Spinelli
Edward Walker

Introduction

This introduction is not part of ANSI N42.54-2018, American National Standard—Instrumentation and Systems for Monitoring Airborne Radioactivity.

This standard encompasses monitoring all types of airborne radioactivity including aerosols, noble gases, iodines, and tritium in the workplace, in effluent, and in the environment. This standard includes initial design, manufacture, minimum performance, performance testing, calibration, and maintenance requirements. This standard covers both real-time monitors and air samplers. The standard is intended to provide guidance on industry best practices to obtain continual quality in the life cycle of relevant systems.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
2. Normative references	11
3. Definitions	13
4. General requirements	17
4.1 Software operability	17
4.2 Test criteria	18
4.3 System reliability	18
4.4 Human factors	18
4.5 Air circuit	18
4.6 Calibration standards	18
4.7 Minimum detectable activity	19
4.8 Decision limit	20
4.9 Display units and range	20
4.10 Intake and exhaust separation	20
4.11 Operational test requirement	20
4.12 Gamma ray shielding isotropism	20
4.13 Documentation requirements	20
4.14 General functional characteristic for airborne activity measurement instrumentation	21
4.15 Standard test conditions for electronic instrumentation	21
4.16 Tests to be performed under standard conditions	21
4.17 Tests to be performed with variation of influence quantities	21
4.18 Tests during system life cycle	21
4.19 Spare parts and consumables	25
4.20 Uncertainty quantification	25
4.21 Maintenance and calibration frequency	25
4.22 Consideration of design and performance factors not specified	27
4.23 Routine maintenance issues	27
5. Classifications of systems	27
5.1 Aerosols	28
5.2 Radioiodines	28
5.3 Noble gases	28
5.4 Tritium	29
5.5 Positron emitters	29
5.6 Other gaseous radionuclides	29
5.7 Air-sampling equipment	29
6. Specific requirements for radioactive aerosol monitors including transuranics	29
6.1 Design requirements	30
6.2 Performance requirements	30
6.3 Non-radiological calibration requirements	34
6.4 Radiological calibration	38
6.5 Radiation performance tests	40

7. Specific requirements for radioactive noble gas monitors.....	44
7.1 Design requirements.....	44
7.2 Performance test	45
8. Specific requirements for radioactive iodine monitors.....	49
8.1 Design requirements.....	49
8.2 Performance test	50
9. Specific requirements for tritium monitors and samplers.....	51
9.1 Scope	51
9.2 Design requirements.....	52
9.3 Performance test	54
10. Specific requirements for positron emitter monitors	56
10.1 Scope	57
10.2 Design requirements	57
10.3 Performance requirements	57
10.4 Calibration requirements	57
10.5 Radiological calibration.....	58
10.6 Sample flow rate indicator.....	58
Annex A (informative) Filter characteristics and parameters specifications.....	59
Annex B (informative) Guidelines for validating the manufacturer's stated design flow rate	65
Annex C (informative) Radioactive gas testing and calibration sources	68
Annex D (informative) Life-cycle issues and considerations.....	72
Annex E (informative) Bibliography.....	75

American National Standard Instrumentation and Systems for Monitoring Airborne Radioactivity

1. Overview

1.1 Scope

This standard encompasses monitoring all types of airborne radioactivity including aerosols, noble gases, iodines, and tritium in the workplace, in effluent, and in the environment. This standard includes initial design, manufacture, minimum performance, performance testing, calibration, and maintenance requirements. This standard covers both real-time monitors and air samplers.

1.2 Purpose

The purpose of this standard is to integrate the relevant materials from ANSI N42.17B, ANSI N42.18, ANSI N42.30, and ANSI N323C into a single standard.¹ The intended users would be government and commercial facilities having the potential for airborne radioactivity.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI N42.17B, Performance Specifications for Health Physics Instrumentation—Occupational Airborne Radioactivity Monitoring Instrumentation, American National Standard.²

ANSI N42.18, Specification and Performance of On-site Instrumentation for Continuous Monitoring Radioactivity in Effluents.

ANSI N42.22, American National Standard Traceability of Radioactive Sources to NIST and Associated Instrument Quality Control.

¹ Information on references can be found in Clause 2.

² ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

ANSI N42.23, American National Standard Measurement and Associated Instrument Assurance for Radioassay Laboratories.

ANSI N42.30, Performance Specifications for Tritium Monitors.

ANSI N320, American National Standard Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation.

ANSI N323AB, American National Standard for Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments.

ANSI N323C, American National Standard for Radiation Protection Instrumentation Test and Calibration—Air Monitoring Instruments.

ANSI/AARST MS-PC, Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air.

ANSI/HPS N13.1, Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities.

Code of Federal Regulations Title 10 Part 20 (10 CFR 20), Standards for Protection against Radiation.³

Code of Federal Regulations Title 10 Part 835 (10 CFR 835), Occupational Radiation Protection.

DOE/EH-0173T, Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.⁴

IAEA Safety Glossary, Terminology Used in Nuclear Safety and Radiation Protection.⁵

IEC 60761, Equipment for Continuous Monitoring of Radioactivity in Gaseous Effluents—Part 1: General requirements; Part 2: Specific requirements for radioactive aerosol monitors including transuranic aerosols; Part 3: Specific requirements for radioactive noble gas monitors; Part 4: Specific requirements for radioactive iodine monitors; Part 5: Specific requirements for tritium monitors.⁶

IEC 62302, Radiation protection instrumentation—Equipment for sampling and monitoring radioactive noble gases.

IEC 62303, Radiation protection instrumentation—Equipment for monitoring airborne tritium.

IEC 62706, Radiation protection instrumentation—Environmental, electromagnetic and mechanical performance requirements.

ILAC G24, Guidelines for the determination of calibration intervals of measuring instruments.⁷

ISO 2889, Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities.⁸

³ CFR publications are available from the U.S. Government Publishing Office (<http://www.ecfr.gov/>).

⁴ Available at <https://www.orau.org/ptp/pdf/eh0173t.pdf>.

⁵ IAEA publications are available from the International Atomic Energy Agency (<http://www.iaea.org/>).

⁶ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

⁷ ILAC publications are available from <http://ilac.org/publications-and-resources/>.

⁸ ISO publications are available from the International Organization for Standardization (<http://www.iso.org/>) and the American National Standards Institute (<http://www.ansi.org/>).

ISO 11929, Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation—Fundamentals and application.

NCSL RP-1, Establishment and Adjustment of Calibration Intervals.⁹

NIST SP 800-37, Guide for Applying the Risk Management Framework to Federal Information Systems: a Security Life Cycle Approach, Rev. 1, 2014.¹⁰

NIST SP 800-53, Recommended Security Controls and Assessment Procedures for Federal Information Systems and Organizations.

NIST SP 800-82, Guide to Industrial Control Systems (ICS) Security, Sept. 2008.

NIST Technical Note 1297, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, 1994.

USNRC Regulatory Guide 1.180, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interface in Safety-Related Instrumentation and Control Systems.¹¹

USNRC Regulatory Guide 5.71, Cyber Security Programs for Nuclear Facilities, Jan. 2010.¹²

3. Definitions

For the purposes of this document, the following terms and definitions apply. Terms not defined in this list shall be taken to agree with the IAEA Safety Glossary (IAEA 2007) or with 10 CFR 20.1003 definitions.

acceptance tests: A contractual test to prove to the purchaser that an instrument meets conditions of its specification.

accuracy: A lack of systematic bias in a measured value that is independent of the dispersion or precision from sequential measurements.

activity median aerodynamic diameter (AMAD): Fifty per cent of the activity in the aerosol is associated with particles of aerodynamic diameter greater than the AMAD. [Definition from International Commission on Radiological Protection (ICRP)]

aerosol: Airborne particulate matter that may be either solid or liquid as a colloidal suspension in air.

air: The mixture of gasses filling a local environment of interest.

alarm: Audible or visual indication of measurand that trips the set point.

NOTE—May be local and/or remote.¹³

analyte: The radionuclide being monitored; also known as the measurand.

assay: A quantitative measure of a physical quantity, typically material activity.

⁹ NCSL publications are available from the National Conference of Standard Laboratories (<http://www.ncsli.org/>).

¹⁰ NIST publications are available from the National Institute of Standards and Technology (<http://www.nist.gov/>).

¹¹ US Nuclear Regulatory Commission document available at [pbadupws.nrc.gov/docs/ML0037/ML003740218.pdf](http://www.nrc.gov/docs/ML0037/ML003740218.pdf).

¹² US Nuclear Regulatory Commission document available at <https://www.nrc.gov/docs/ML0903/ML090340159.pdf>.

¹³ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

atmosphere: The air or volume of gas in which measurement is made.

bulk stream: The air flow in a stack or duct, as opposed to the sample flow rate.

calibration: Comparison with possible adjustment of a measurement system to agree with the conventionally true value for select points in the range.

check source: A radiological source that is not calibrated like a reference source but only intended to give an indication that an instrument has a noticeable response to an appropriate radiation type.

coefficient of variation (CoV): The standard deviation σ expressed as a percentage of the mean $\bar{x}$ by the expression: $CoV = 100 \times \sigma / \bar{x}$.

confidence level (CL): As a function of the uncertainty, the prediction of the likelihood that a measured value will fall within a specified range.

conventionally true value: The value as determined through a National Metrology Institute (NMI) via quality comparison(s) with physical measurements.

cross talk: For detectors that respond to multiple radiation particle types with separate electronic channels that record that response, it is the level of response to one particle type in the response channel of the opposing particle type, normally expressed as a percent of the initial particle type source response.

NOTE—This phenomenon is most pronounced for simultaneous alpha and beta detector systems.

decision limit: The count or count rate at which the analyte can be statistically accepted as being detectable above background. *Syn:* **decision level; detection threshold.**

design frequency: The nominal frequency the instrument is intended to use for operations.

design voltage: The nominal voltage the instrument is intended to use for operations.

detection limit: The maximum value or level at which the instrument meets the required accuracy.

detection range (or simply range): All measured values between the decision limit and the detection limit.

dynamic radioactive source (DRS): A radiological source that is able to move in and out of the field of view of a detector for the purpose of real-time field testing.

effluent: The material discharged to the environment resulting from an anthropogenic process.

end user: The individual(s) who use the instrumentation, system, and components for operational purposes. *Syn:* **user.**

environment: Locations external to the facility.

flow: The time integrated value of flow rate.

flow rate: The measure of how much material passes through a defined area per unit time. *Syn:* **volumetric flow rate.**

human factors: Ergonomic and worker interaction considerations including space access, visual access, position of displays and controls, display colors/readability/fonts, indicating light illumination/colors, and audible sounds.

in-leakage: The amount of material mixing with a sampling system from outside the sampling pathway as a percentage of the flow rate.

latching alarms: Alarms that only reset with user interaction.

may: A safe harbor method by which compliance ensures adherence to that aspect of this standard (ANSI N42.54) but is not required.

mass flow rate: The volumetric flow rate corrected to a reference temperature and pressure [i.e., typical units are standard liters per minute (SLPM), where the “standard” temperature and pressure is definition-dependent].

maintainability: A focus on design features that tend to reduce maintenance time and maintenance errors with the goal to reduce maintenance labor and parts obsolescence.

monitoring: The real-time measurement of radioactivity or radiation levels.

National Metrology Institute (NMI): National Institute of Standards and Testing (NIST) or equivalent national metrology institute.

precision: A quantification of a measurements reproducibility typically defined by the standard deviation σ or coefficient of variation (CoV). Note that this metric (σ or CoV) refers only to the measurements for which the precision is ascribed. *See:* **coefficient of variation (CoV).**

performance test: Any test evaluating defined performance metrics of an instrument as a function of parametric influence quantities.

purchaser: The individual, group, or institution responsible for ensuring quality requirements are met in the procurement process for products or services intended to comply with this standard, ANSI N42.54.

qualification tests: Tests performed to verify that the requirements of a specification are fulfilled. These tests are subdivided into type tests and routine tests.

quality: A system property that describes the amount of agreement with written expectations in performance results in an auditable configuration.

NOTE—Written expectations for a technical measurement should be independently reviewed and management approved. Note that quality is generally a statistically quantitative property but may be subjective.

radionuclide: A radioactive isotope.

reference reading: The monitor’s response while operating under normal laboratory conditions.

reference response: The instrument response to a standard influence that can be used as a calibration check, trending parameter, and similar quality control purposes.

reference flow rate: The measured gas flow rate, proportional to the predefined temperature and pressure of a reference gas (e.g., this is comparable to the “standard flow rate” from a typical mass flow meter). *Syn:* **mass flow rate.**

NOTE—Various instrument manufacturers and technical societies define different values for their respective “standard” temperature and pressure.

reliability: A measure of the fractional portion of times a system will perform correctly when called upon to do so.

reproducibility: The degree of agreement between repeated measurements of the same property.

response: An indication of a material property such as a specified activity level.

response time: The time taken to indicate an instantaneous change from 10% to 90% of the conventionally true activity at the rated nominal flow rate.

representative sampling: An air sample that meets sufficient quality requirements to enable direct use of air volume to meet specifications on assays of radioactivity air concentrations.

retrospective evaluation: Laboratory analysis of a sample after removal from the sampling instrument.

routine tests: Tests that each individual instrument is subjected to, during or after manufacture, to ascertain whether it complies with certain criteria.

sampling: The process of collecting a sample from a volume of an atmosphere.

shall: A requirement essential to compliance with this standard, ANSI N42.54.

should: A recommended practice that if not implemented shall have documentation giving the reasons and justification for the same.

NOTE—This intentionally means that if *should* is not implemented when called out in this standard, ANSI N42.54, then there shall be a technical basis document containing an explanation as to why this is acceptable

standard temperature and pressure (STP) (not a universal definition): In order to use this, a reference temperature and pressure shall be specified and should be used consistently during testing, calibration, and use.

surface emission rate: The rate at which particles are ejected from a radiation source. Although this typically is used only for beta sources due to backscatter off the substrate, it can also apply to alpha sources.

technical basis document: A document demonstrating the physical principles justifying an operational approach, instrumentation configuration, or an analysis methodology.

NOTE—This should be a quality document that has been peer reviewed and management approved.

tritium: The hydrogen isotope with one proton and two neutrons in the nucleus (^3H or T).

NOTE—Unless otherwise stated, tritium, in this standard, covers tritium in gaseous or vapor forms, whether chemically combined or not.

tritium-in-air: Tritium of any chemical form in a gas form. For example: HTO-, T_2O -, DTO-, HT- DT-, and T_2 -in-air are all considered to be tritium-in-air.

tritium monitor: Equipment designed for the monitoring of airborne tritium in gaseous effluent discharged to the environment, in the environment, and in the atmosphere of a workplace.

tritium sampler: Equipment designed to collect a sample of tritium in any form for subsequent analysis.

type tests: Evaluation or measurement of all identified performance characteristics of at least two representative samples of production model instruments. (ANSI N42.17C-1989).

uncertainty: The degree to which a measured value could be wrong.

NOTE—This includes anticipated variations in all influencing parameters and should be quantified using standard error propagation methodologies (NIST 1994).

volumetric flow rate: The measured movement of a physical volume of gas, per unit time, defined by the temperature and pressure at the local sample location (this is comparable to some definitions of the “actual flow rate”).

warm-up time: The delay time after turning the instrument on until it will meet the performance requirements of this standard, ANSI N42.54.

workplace: The areas occupied by or accessible to workers.

4. General requirements

The contents of this clause apply to all monitors. Specific monitor types have additional requirements listed in Clause 6 through Clause 10. It is only in Clause 6 through Clause 10 that any of these requirements may be modified for specific technologies.

The monitoring of airborne radioactivity requires obtaining a sample of the air, evaluating the radioactive content of the sample, and returning the sample to the environment. The general requirements for equipment used to evaluate the sample are discussed in this clause.

This standard is applicable to equipment for collecting and measuring radioactivity in the workplace during normal operations and during anticipated abnormal operations, in effluent, and in the environment. This standard does not apply to equipment specifically for use in accident or post-accident conditions. Such equipment may require additional capabilities as described in ANSI N320.

This standard is restricted to equipment for collecting and/or measuring airborne radioactivity including gasses and aerosols. It does not deal with sample extraction (i.e., ANSI/HPS N13.1) or radiochemistry. The object of this standard is to establish mandatory general requirements and give examples of acceptable methods to collect and measure airborne radioactivity.

The general performance criteria, test procedures, calibration procedures, radiological, electrical, safety and environmental characteristics, the identification and certification for the airborne monitoring equipment are specified in this clause. If this equipment is part of a centralized system for continuous radiation monitoring in a nuclear facility, there may be additional requirements from other standards.

This standard addresses the requirements for commercial grade instrumentation. For safety-related monitors used in nuclear power plants, the applicable plant environmental and seismic qualification requirements established by the U.S. Nuclear Regulatory Commission (NRC), the Institute of Electrical and Electronics Engineers (IEEE), the American Society of Mechanical Engineers (ASME) and other industry standards shall be consulted.

4.1 Software operability

Where the instrumentation is controlled by software, the software and any underlying algorithms used shall be shown to operate correctly by the manufacturer under operational conditions. This should include reviewing all assumptions utilized in algorithms for dissemination in a technical basis document. This requirement equally applies to software after any changes have occurred to the software that could affect its performance.

4.2 Test criteria

All tests done in accordance with this standard must be fully reproducible and documented.

4.3 System reliability

Monitors and/or samplers shall be able to perform their intended function and be capable of providing reliable measurements in environments and process conditions to which the monitor may be subjected.

4.4 Human factors

The design should take into account human factors for the monitor users. This includes all of the following to provide reliable monitor performance:

- Functional testing
- Maintenance (including collection media replacement)
- Calibration
- Decontamination activities

4.5 Air circuit

Air path integrity shall be sufficient to allow quantitative measurement of radioactivity concentrations in air.

4.5.1 Out-leakage

Out-leakage is a facility issue that should be addressed when a monitoring system is being installed and before becoming operational. The testing should include the entire sampling line and the detector. This testing should be performed using sulfur hexafluoride (SF_6), an inert and harmless gas, at all system joints, valves, and any piping connections. The SF_6 can be detected at parts per billion levels and can pinpoint leaks. Any detected leak shall be sealed and the testing repeated to verify sealing.

4.5.2 In-leakage

In-leakage can dilute a sample whenever air can leak into the sample line anywhere along the transport system. This effect should be tested by demonstrating that the entire sampling line can sustain the vacuum after the vacuum pump had been turned off or sealed. The test should include all connectors to the source sampler and detector housing.

4.6 Calibration standards

Radioactive sources and measurement support instrumentation (for example thermometers, barometers, hygrometers and flow rate meters), shall be traceable to the National Institute of Standards and Technology (NIST) or equivalent National Metrology Institute (NMI).

4.7 Minimum detectable activity

Minimum detectable activity (MDA) for specific radionuclides or radiation types shall be stated by the manufacturer to indicate instrument sensitivity.

4.7.1 Radon progeny background

When the background of concern is the progeny of radon, the background shall, at a minimum, be equivalent to that when sampling a radon concentration of 48.1 Bq/m³ (1.3 pCi L⁻¹) at 50% equilibrium.

4.7.2 MDA formalism

When the MDA is used for specific radionuclides under typical local background conditions, it shall be determined using Equation (1) (Johnson and Birky [B3]):¹⁴

$$MDA = \left[3.29 \sqrt{B \times T_B \left(1 + \frac{T_G}{T_B} \right)} + 3 \right] / (K \times T_B) \quad (1)$$

where

B = background count rate

T_B = background count time

T_G = gross sample counting time

K = constant that is a combination of dimensional conversion factors, efficiencies, etc. (Strom and Stansbury [B4])

4.7.3 Prohibition of MDA use for detection decisions

The MDA shall not be used in the decision process for determining whether a detection has occurred by the end user (i.e., it shall not be used as a detection threshold or decision level).

An MDA should not be used to generate either a sample specific detection threshold or decision level.

4.7.3.1 MDA applicability

The end user shall only use an MDA prior to making a measurement and so shall not use it afterwards in any detection decision.

4.7.4 Radionuclides and background for testing

Radionuclides of interest and background conditions that are to be used in testing shall be agreed upon between the instrument manufacturer and the user.

¹⁴ The numbers in brackets correspond to those of the bibliography in Annex E.

4.8 Decision limit

This term is often also known as the *decision level* or *decision threshold* and shall be utilized by the end users as the number of counts measured or final instrument measurement of a quantity of analyte at or above which a decision is made that the analyte is definitely present.

The end user may establish this value as 1.645 times the standard deviation of the typical instrument dispersion above the average background reading if the instrument dispersion is normal at the background level.

4.9 Display units and range

Display units and range shall be stated in the operation manual.

4.10 Intake and exhaust separation

The manufacture shall design the sampling system to exhaust at a sufficient distance from the intake to prevent re-sampling of the sample stream.

4.11 Operational test requirement

The air-sampling system shall be designed to facilitate the testing of the configuration under operational conditions.

4.12 Gamma ray shielding isotropism

If gamma-ray shielding is used, it should result in nearly identical attenuation of radiation in all directions.

4.12.1 Sample accessibility via gamma shielding

Shield design should allow for easy access to sample media and detectors/electronics.

4.12.2 Ergonomics of gamma shielding

Shielding should consider ergonomic factors.

4.13 Documentation requirements

Documentation provided by the manufacturer for the sampling system should include, but not be limited to, the following items:

- Name of manufacturer, with address, phone, email, and website
- Type of instrument (s), detector (s), and serial number (s)

- Complete type test report including all test requirements and test results for radiological, electrical/electronic, mechanical, and environmental requirements
- Date of tests
- Conformance with applicable standards for test results
- Current operation and maintenance manuals, plus all system schematics, a comprehensive list of circuit boards and components
- Troubleshooting guide
- Detailed training manual for operators and service personnel as agreed upon between the manufacturer and the user

4.14 General functional characteristic for airborne activity measurement instrumentation

The functional general characteristics for airborne activity measuring instrumentation are provided in Table 1.

4.15 Standard test conditions for electronic instrumentation

The standard test conditions for electronic instrumentation are provided in Table 2.

4.16 Tests to be performed under standard conditions

The tests to be performed under the standard conditions are provided in Table 3.

4.17 Tests to be performed with variation of influence quantities

The tests to be performed with variation of the influence quantities are provided in Table 4.

4.18 Tests during system life cycle

The sample air circuit and filter media characteristics for installed airborne radiation monitoring instrumentation are provided in Table 5.

NOTE 1—Annex A contains reference information for the various types of commercially available filter media.

NOTE 2—Annex D provides life-cycle issues and considerations to incorporate all requirements of this standard.

Table 1—General functional characteristics

Characteristic	Requirement
Internal sampling lines	The materials and design used for internal sampling lines shall minimize condensation, corrosion, air flow restriction, electrostatic charge, particle loss, and inadvertent resuspension of any accumulated material.
Flow rate measurements	It shall be stated whether the instrument measures in volumetric (the actual temperature and pressure of the sampled gas) or mass (the reference temperature and pressure) flow rate units.
Sample flow (rate) measurement	The system design shall include a flow rate measurement, and, where applicable, flow rate control system. The vacuum pumping system shall be designed to meet the design flow rate.
Effluent flow (rate) measurement	The system design shall include an effluent flow rate measurement, and, where applicable, flow rate control system.
Total volume	Determination of total volume shall meet accuracy requirements in effluent monitors. Total air volume through a filter or cartridge may be required.
Pressure/vacuum measurement	When the monitoring system operates at other than the calibration pressure, the differential volume shall be compensated for in the measurement.
Operability check	A procedure or internal function that tests detectors, software, and electronics, shall be provided to periodically verify proper operation of the monitor.
Switches and controls	Switches or other controls shall be designed to prevent inadvertent activation or deactivation and shall be protected to prevent unauthorized changes.
Range	Multiple detectors may be used to cover the operating range. Overlap shall occur between individual detector ranges.
Over-range	When responding to an input signal in excess of the range of the instrument, the system shall indicate an over-range condition has occurred or is occurring.
Readouts	The readout shall clearly indicate the state of the measured values.
Alarm set points	Alarms shall be capable of being set to any value within the stated range.
Alarm acknowledgement	Monitors shall support latching alarms.
Visual alarms	Visual indicators shall communicate instrument status for alarms and failures.
Audible alarms	Audible alarms shall provide an output of greater than 75dB at 15 cm and operate in the frequency range of 500 Hz to 3000 Hz (ANSI N42.17B). ^a Where ear protection is required, the output should be increased accordingly. Audible alarm muting requires acknowledgement and shall not reset the visual alarm.

^aThis criteria is consistent with the former standard ANSI N42.17B.

Table 2—Standard test conditions

Influence quantity	Standard test condition
Ambient temperature	18 °C to 25 °C (64 °F to 77 °F)
Relative humidity	≤ 75%
Atmospheric pressure	70 kPa to 103.6 kPa
Stabilization time	<30 min
Background gamma radiation	≤0.25 μGy/h (≤25 μR/h)
Electrostatic field	Not to exceed 5000 V/m
Nonionizing electromagnetic field of external origin	Controlled natural conditions without the presence of man-made generators.
Magnetic induction of external origin	Less than twice the induction due to the Earth's magnetic field
Sample flow rate	Normal operation
Assembly controls	Set for Normal operation
Radioactive contamination	Indistinguishable from natural background
Radon 222/220 and progeny	< 37 Bq/m ³ (1 pCi L ⁻¹)
Chemical contamination	Negligible

**Table 3—Tests required to be performed under standard test conditions
(static tests for characterizing base performance)**

Characteristics on influence under test	Requirements
Reference response	See Table 4.
Precision	See Table 4.
Response time	See Table 4.
Over range	Remain at over range indication when exposed to an activity 2 times greater than the upper limit of the specified range
Stability of measurement value	Variation of measurement value less than 10% over 100 h. For intermittent use systems, the criterion is ±10% over the duration of intended operation. Measurement values chosen shall be >10 times background.
Alarm trip range	Shall cover the specified range of the instrument
Equipment fault alarms	As specified by the manufacturer as agreed to by the customer
Battery power supply	Battery life shall be tested and documented
AC power supply	As specified by the manufacturer as agreed to by the customer
Warm-up time	As specified by the manufacturer but < 30 min
Measurement range	Specified by the manufacturer
Sample flow rate alarms	High and low flow rate alarms
Stack flow rate accuracy	Flow rate within measurement system range