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**AN INTERNATIONAL REVIEW OF CURRENTLY APPLICABLE STANDARDS  
FOR MEASURING AIRBORNE RADIOACTIVITY**

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# AN INTERNATIONAL REVIEW OF CURRENTLY APPLICABLE STANDARDS FOR MEASURING AIRBORNE RADIOACTIVITY

## Abstract

This report reviews currently applicable standards governing the design specification, performance, testing, calibration, and application of radiation protection instrumentation for monitoring and measuring radioactive aerosols. Standards can be categorized in several ways, including:

1. committee of origin at the international, regional, or national level;
2. nature of the standard as either procedural or technical;
3. type or form of radioactive aerosol;
4. relevance to a particular instrument design or hardware; and
5. applicability for monitoring in workplaces, effluent stacks, or the environment.

In general, the International Organization for Standardization (ISO) provides procedural guidance and the International Electrotechnical Commission (IEC) provides technical specifications. The national committees that are members of ISO and IEC work together to produce industry-wide, voluntary consensus standards that take global views into account. Regional bodies such as the Comité Européen de Normalisation (CEN) and the Comité Européen de Normalisation Electrotechnique (CENELEC) adopt ISO and IEC standards for their member countries. Many nations exclusively follow international standards or standards of their regional organizations. The national committees in other nations, such as the American National Standards Institute (ANSI) in the United States, prepare standards or accredit qualified organizations to prepare standards within their own country. ANSI accredits the Institute for Electrical and Electronic Engineers (IEEE) and the Health Physics Society (HPS) to develop air monitoring standards and maintain them in contemporary form. The development and maintenance of credible technical standards is a living process and the content, status, and applicability of the dozens of standards described in this report comprise a snapshot in time.

## INTRODUCTION

NUMEROUS STANDARDS at the international, regional, national, and local levels pertain to monitoring and measuring radioactive aerosols. As shown in Fig. 1, there are also a myriad of regulations, recommendations, requirements, and scientific resources. Recognizing their origins, content, and applicability can be daunting. The following sections present the findings of our recent *International Review of Currently Applicable Standards for Measuring Airborne Radioactivity*. The purpose of the review was to describe the standards organizations for airborne radioactivity and provide a snapshot of standards in common usage or development. This report can be found electronically at: <http://www.iec.ch/support/tcnews/>.

## INTERNATIONAL STANDARDS

The overarching bodies for global standardization are the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). The national committees of the member nations who participate in the development of international standards work together to produce what are termed *industry-wide, voluntary consensus* standards. Taking into account the views of interests worldwide, they represent the negotiated agreements of the participants, but not necessarily the specific wishes of all participants. Depending on the needs of the regulator, manufacturer or user, standards can be categorized in several ways, including:

1. committee of origin at the international, regional, or national level;
2. nature of the standard as either procedural or technical;
3. type or form of radioactive aerosol;
4. relevance to a particular instrument design or hardware; and
5. applicability for monitoring workplaces, effluent stacks, or the environment.

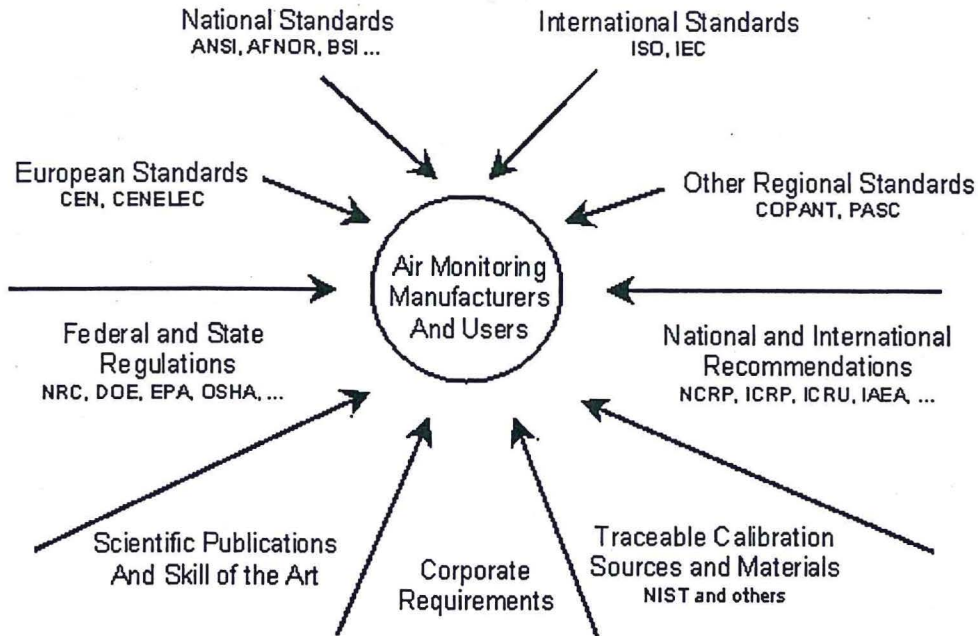


Fig. 1. Illustration of the relationships among standards, regulations, recommendations, requirements, and scientific resources for air monitoring equipment manufacturers and users.

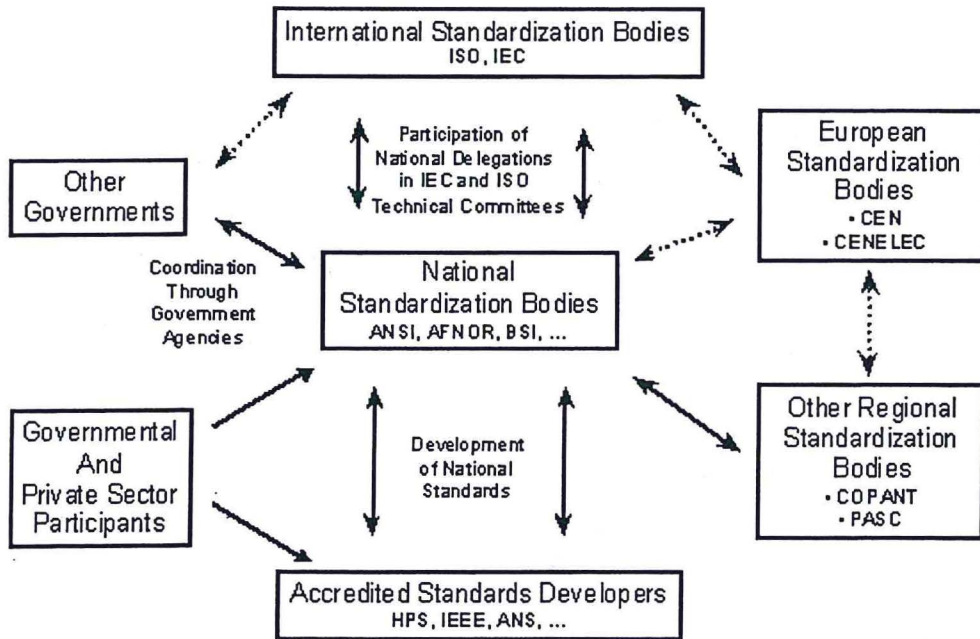


Fig 2. Interrelationships and interactions of private sector, national, and international interests in the development of industry-wide, voluntary consensus standards.

**The International Electrotechnical Commission (IEC)** ([www.iec.ch](http://www.iec.ch)) is the global organization that prepares and publishes international standards for electrical, electronic, and related technologies. It was founded in 1906 following passage of a resolution at the 1904 meeting of the International Electrical Congress in St. Louis, Missouri, USA. The IEC currently has 61 participating countries, including all the world's major trading nations and a growing number of industrializing countries.

As noted on the IEC website, the IEC charter embraces all electrotechnologies including electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication, and energy production and distribution, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, and safety and the environment. IEC Technical Committee TC45 was formed around 1960 to develop international standards covering nuclear-related instrumentation. TC45 evolved to comprise two subcommittees: SC45A (Nuclear Reactor Instrumentation) and SC45B (Radiation Protection Instrumentation). Working Group 13 of SC45B has the primary responsibilities for Measurements of Airborne Radioactivity.

IEC air monitoring standards include IEC 60579 (1977-01) on *Radioactive aerosol contamination meters and monitors*; IEC 60710 (1981-01) on *Radiation protection equipment for the measuring and monitoring of airborne tritium*; IEC 60761 (2002-01) on *Equipment for continuously monitoring radioactivity in gaseous effluents*, comprising Part 1: General requirements, Part 2: Specific requirements for radioactive aerosol monitors including transuranics, Part 3: Specific requirements for radioactive noble gas monitors, Part 4: Specific requirements for radioactive iodine monitors, and Part 5: Specific requirements for tritium monitors; IEC 60951 (1988-08) on *Radiation monitoring equipment for accident and post-accident conditions in nuclear power plants* comprising Part 1: General requirements, Part 2: Equipment for continuously monitoring radioactive noble gases in gaseous effluents, Part 3: High range area gamma radiation dose rate monitoring equipment, Part 4: Process stream in light water nuclear power plants, and Part 5: Radioactivity of air in light water nuclear power plants; IEC 61171 (1992-09) on *Atmospheric radioactive iodines in the environment*; IEC 61172 (1992-09) on *Radioactive aerosols in the environment*; and IEC 61578 (1997-08) on *Test methods for the calibration and verification of the effectiveness of radon compensation for alpha and/or beta aerosol measuring instruments*. IEC 62302 (in preparation) will cover *Equipment for noble gas monitoring in the workplace, effluents, and the environment*, and IEC 62303 (in preparation) will cover *Equipment for monitoring airborne tritium in the workplace, effluents, and the environment*.

Appendix A contains an annotated list of the relevant IEC standards for monitoring and measuring airborne radioactivity, including the scope for each standard as listed on the IEC website.

The International Organization for Standardization (ISO) ([www.iso.org](http://www.iso.org)) was formed in 1947 to fill the need for an international organization for standards outside of the electrical and electronic disciplines. ISO characterizes itself as “a network of national standards institutes from 140 countries working in partnership with international organizations, governments, industry, business and consumer representatives; a bridge between public and private sectors.” As is the case with the IEC, the ISO has numerous Technical Committees covering many disciplines. ISO air monitoring standards for radioactive materials are developed by ISO Technical Committee 85 (Nuclear Energy), Scientific Committee 2 (Radiation Protection), Working Group 14 (Air Control and Monitoring). There are common interests and collaborations between the IEC TC45/SC45B/WG13 and the ISO TC85/SC2/WG14 in terms of leadership and personnel volunteering to develop and maintain related standards.

ISO 2889 (1975) covers *General principles for sampling airborne radioactive materials*. As noted in Appendix B, the standard may be revised to address Part 1 (general requirements), Part 2 (stacks and ducts), Part 3 (workplace), and Part 4 (outdoors or in the environment).

## REGIONAL STANDARDS

The Comité Européen de Normalisation (CEN) ([www.cenorm.be](http://www.cenorm.be)) was established in 1961 and is responsible for harmonization of national standards issued from the various countries of the European Union. Standards in the electrotechnical sector are developed by the Comité Européen de Normalisation Electrotechnique (CENELEC) ([www.cenelec.org](http://www.cenelec.org)), which was established in 1973 and comprises the electrotechnical committees of some 19 European countries. CENELEC works closely with the CEN, IEC, and other similar organizations. More than eighty percent of the European standards adopted by CEN and CENELEC are identical to or based upon corresponding international standards. Appendix C is an annotated list of relevant European air monitoring and measuring standards. EN 481 (1993) covers *Workplace atmospheres – Size fraction definitions for measurement of airborne particles*.

There are other regional organizations such as the Pacific Area Standards Congress (PASC) ([www.pascnet.org](http://www.pascnet.org)), that are not engaged in development of air monitoring standards.

## NATIONAL STANDARDS

Most nations are represented in the international standards process by a national organization. These national organizations can (1) adopt and follow international standards, (2) adopt and follow standards provided by their regional standards bodies, and/or (3) prepare standards (or accredit qualified organizations to prepare them) as needed within their own country. Some organizations, such as the British Standards Institution (BSI) ([www.bsi-global.com](http://www.bsi-global.com)), have chosen not to develop their own set of standards for air monitoring and measuring, but instead contribute to and use the international standards of the ISO and IEC. In the member nations of the European Union, the various national standards are gradually being replaced by European standards. For example, standards developed by CEN and CENELEC are automatically adopted as national standards by the member countries. Other nations, including the United States, develop their own national standards, in addition to participating in the development of international standards.

The government of the United States is committed to using and participating in the development of voluntary consensus standards. This policy was affirmed on 20 October 1993 when the Office of Management and Budget (OMB) ([www.omb.gov](http://www.omb.gov)) issued OMB Circular No. A-119 on *Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment*. The commitment was codified in the *National Technology Transfer and Advancement Act of 1995* (Public Law 104-113). OMB issued a revision of Circular No. A-119 on 10 February 1998 "in order to make the terminology of the Circular consistent with the National Technology Transfer and Advancement Act of 1995, to issue guidance to the agencies on making their reports to OMB, to direct the Secretary of Commerce to issue policy guidance for conformity assessment, and to make changes for clarity." The revised circular states the purpose of federal agency participation in voluntary consensus standards bodies as follows: "Many voluntary consensus standards are appropriate or adaptable for the Government's purposes. The use of such standards, whenever practicable and appropriate, is intended to achieve the following goals: (a) Eliminate the cost to the Government of developing its own standards and decrease the cost of goods procured and the burden of complying with agency regulation. (b) Provide incentives and opportunities to establish standards that serve national needs. (c) Encourage long-term growth for U.S. enterprises and promote efficiency and economic competition through harmonization of standards. [and] (d) Further the policy of reliance upon the private sector to supply Government needs for goods and services."

The American National Standards Institute (ANSI) ([www.ansi.org](http://www.ansi.org)) is the national standardizing body in the United States. Its staff serve as the Secretariat for the US National Committee (USNC) for ISO and the USNC for the IEC. The USNCs appoint the US delegates and working group experts, all volunteers, who represent the USA in meetings of the IEC and ISO and participate as working group experts in the development of standards.

ANSI has accredited more than 250 professional societies or industrial firms to serve as the Secretariats for the committees that develop standards in specific topical areas and maintain them in contemporary form. ANSI then processes, adopts, and publishes national standards. In the areas of nuclear and health physics instrumentation and radiation safety, ANSI has accredited the Institute for Electrical and Electronic Engineers (IEEE) and the Health Physics Society (HPS).

The Institute of Electrical and Electronic Engineers (IEEE) ([www.ieee.org](http://www.ieee.org)) was formed in the late 1950s by a merger of the Institute of Electrical Engineers and the Institute of Radio Engineers. It is an international organization with most of its membership in the US and a continually growing number of members from outside the US. The IEEE is accredited by ANSI to serve as the sponsor and Secretariat of ANSI Committee N42, which is responsible for developing American National Standards in nuclear and health physics instrumentation including radiological safety instrumentation such as dosimeters, portable survey meters and contamination monitors. Although the IEEE is an international organization, its standards in this area are generated to a great extent nationally and are processed as American National

Standards through ANSI.

As noted in [Appendix D](#), ANSI/IEEE ANSI air monitoring standards include ANSI N42.17B (1989) on *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*; ANSI N42.18 (1980, Reaffirmed 1991) on *Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents*; ANSI N42.30 (2002) on *Performance Specification for Tritium Monitors*; ANSI N317 (1980) on *Performance Criteria for Instrumentation Used for In-Plant Plutonium Monitoring*; and ANSI N320 (1979, Reaffirmed 1985) on *Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation*. ANSI N323C (in preparation) will cover *Radiation Protection Instrumentation Test and Calibration – Air Monitoring Instruments*.

**The Health Physics Society (HPS)** ([www.hps.org](http://www.hps.org)) was founded in 1956 and is a society of occupational and environmental radiation safety professionals. ANSI has accredited HPS to serve as the sponsor and secretariat for ANSI Committee N13. ANSI N13 is responsible for the development of standards concerned with radiation safety and health physics activities, such as air sampling, whole body counting, external and internal dosimetry, and bioassay. Because the radiological safety instrumentation standards developed by the IEEE-sponsored ANSI Committee N42 are of considerable utility to the HPS, close communication is maintained between N42 and the HPS-sponsored ANSI Committee N13. Many members of N42 are health physicists who are also members of the HPS.

As noted in [Appendix E](#), ANSI/HPS standards include ANSI N13.1 (1969, Revised 1999) on *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities* and ANSI N13.2 (1969, Reaffirmed 1982) on *Administrative Practices in Radiation Monitoring*. ANSI N13.9 (in preparation) will be a *Guide to Environmental Surveillance around Nuclear Facilities*. [Table 1](#) illustrates how the various national and international standards can be grouped according to type of radionuclide and location of measurement.

**Table 1.** Matrix showing various air monitoring standards according to the location of application and the type of airborne radioactivity..

	General	Particles	Noble Gases	Iodine	Tritium
<b>General</b>	ANSI N42.17B ANSI N323 ANSI N13.2	IEC 61578			ANSI N42.30
<b>Effluent</b>	IEC 60761-1 ISO 2889 ANSI N13.1	IEC 60761-2	IEC 60761-3	IEC 60761-4	IEC 60761-5
<b>Workplace</b>	ANSI N42.18 ANSI N317	IEC 60579 EN 481			IEC 60710
<b>Environment</b>	ANSI N13.9	IEC 61172		IEC 61171	
<b>Emergency</b>	IEC 60951-1 ANSI N320	IEC 60951-5	IEC 60951-2		

**Standards of Interest from Other ANSI-Accredited Organizations.** The [American Nuclear Society \(ANS\)](#) ([www.ans.org](http://www.ans.org)) is responsible for the development and maintenance of standards that address the design, analysis, and operation of components, systems, and facilities involved in or utilizing nuclear technology. These standards reference the ANSI/IEEE and ANSI/HPS standards for radiological safety instrumentation. The [American Industrial Hygiene Association \(AIHA\)](#) ([www.aiha.org](http://www.aiha.org)) covers the non-radioisotope aspects of topics of interest to the users of ANSI/IEEE and ANSI/HPS standards. For example, the *American National Standard for Laboratory Ventilation* (ANSI/AIHA Z9.5-1992) provides guidance for controlling, monitoring, and measuring air contamination for laboratories or hoods other than those used for radioisotopes and the *American National Standard Practices for Respiratory Protection* (ANSI/AIHA Z88.2-1980) provide guidance for the selection and use of respirators. Similarly, the [American Society of Heating, Refrigerating, and Air-Conditioning Engineers \(ASHRAE\)](#) ([www.ashrae.org](http://www.ashrae.org))

has a *Method for Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter* (ANSI/ASHRAE 52-1968). The American Society for Testing and Materials (ASTM) ([www.astm.org](http://www.astm.org)) develops standards on the characteristics and performance of materials, products, systems, and services. Examples include *Standard Test Methods for Determining Air Change in a Single Zone by means of a Tracer Gas Dilution* (ANSI/ASTM E 741-93), a *Standard Guide for Qualification of Measurement Methods by a Laboratory within the Nuclear Industry* (ANSI/ASTM C 1086-95), and a standard for *Selection and Use of Portable Radiological Survey Instruments for Performing In Situ Radiological Assessments in Support of Decommissioning* (ANSI/ASTM E 1893-97). ASTM also has *Standard Terminology Relating to Sampling and Analysis of Atmospheres* (ANSI/ASTM D 1356-00), a *Standard Test Method for Respirable Dust in Workplace Atmospheres* (ANSI/ASTM D 4532-97), a *Standard Practice for Evaluating the Performance of Respirable Aerosol Samplers* (ANSI/ASTM D 6061-96), a *Standard Guide for Personal Samplers of Health-Related Aerosol Fractions* (ANSI/ASTM D 6062M-96), and a *Standard Guide for Air Sampling Strategies for Worker and Workplace Protection* (ANSI/ASTM E 1370-96).

The National Institute of Standards and Technology ([www.nist.gov](http://www.nist.gov)) is a key technical contributor to the U.S. standards infrastructure. The Standards Engineering Society ([www.ses-standards.org](http://www.ses-standards.org)) provides links to a number of standards organizations and information on the standards process. NSSN ([www.nssn.org](http://www.nssn.org)) serves as "a national resource for global standards" and provides information from more than 600 national, foreign, regional, and international bodies.

**The national standards organizations in France** provide another example of a strong national standards effort that contributes significantly to international standards developments in both the procedural and electrotechnical arenas. (See [Table 2](#) for a list of other national organizations who participate in the standards process.)

Association Française de Normalisation (AFNOR) ([www.afnor.fr](http://www.afnor.fr)) is the French member of ISO and CEN, and appoints experts to working groups of both. AFNOR was organized in 1926 and is controlled by the Ministry for Industry. It has a three-tier structure:

- *Experts* who comprise some 30,000 people from all walks of life, including companies, government, professional organizations, and trade unions. Some of these experts also work at the European (CEN) and international (ISO) levels.
- *Bureaux de Normalisation-BN*, which prepare the AFNOR standards. AFNOR has 31 BN. One of them is the Bureau de Normalisation des Equipements Nucléaires (BNEN), which was established in 1990 to develop relevant nuclear standards. One of the three commissions in BNEN is M60.1, which is responsible for monitoring the work of ISO/TC85/SC2 on "Nuclear Energy-Health Physics."
- *AFNOR*, which manages and coordinates the entire system.

As noted in [Appendix F](#), France has generic standards in the *Air Quality* category with requirements comparable to the US Clean Air Act of 1990, including NF X 43-021 (December 1984) on *Filter sampling of particulate material suspended in ambient air - Automatic sequential equipment*; NF X 43-022 (May 1985) on *Ambient air - Concepts relating to the sampling of particulate matter*; and NF X 43-257 (August 1988) on *Air in workplaces - Individual sampling of inspirable fraction of particulate pollution*. Other generic standards include NF X 44-051 (July 1978) on *Sampling of dust in a stream of gas (general case)* and NF X 44-052 (May 2002) on *Stationary Source Emissions - Determination of high range mass concentration of dust - Manual gravimetric method*. There are also specific air monitoring standards in the category of *Nuclear Energy - Measurement of radioactivity in the environment*, including NF M 60-312 (October 1999) on *Determination by liquid scintillation of the activity concentration of atmospheric tritium sampled by the sparging technique (air through water)*; NF M 60-760 (October 2001) on *Sampling of aerosols for measurement of radioactivity in the environment*; NF M 60-763 (March 1998) on *Radon and its short-lived decay products in the atmospheric environment: Origins and measuring methods*; NF M 60-764 (December 1997) on *Radon 222: Integrated methods for measurement of alpha potential energy of short life decay products in the atmospheric environment*; NF M 60-765 (December 1997) on *Radon 222: Methods for spot measurement of alpha potential energy of radon daughters in the atmospheric environment*; NF M 60-766 (December 1999) on *Radon 222: Integrated methods for measurement of the*

average volumic activity of radon in the atmospheric environment, with passive collection and a deferred analysis; NF M 60-767 (August 1999) on *Radon 222: Continuous measurement methods of the volumic activity of radon in the atmospheric environment*; NF M 60-768 (October 2002) on *Radon 222: Methods for the estimation of the surface activity of exhalation by accumulation methods*; NF M 60-769 (November 2000) on *Radon 222: Methods for spot measurement of the volumic activity of radon in the atmospheric environment*; NF M 60-770 (October 2000) on *Determination of the activity concentration for atmospheric deposits on the soil*; and NF M 60-771 (July 2001) on *Radon 222 in buildings – Methodologies for screening and complementary investigations*.

## OTHER SOURCES OF INFORMATION

There are a number of government regulations and guidance documents. The U.S. Nuclear Regulatory Commission Regulatory (NRC) ([www.nrc.gov](http://www.nrc.gov)) provided updated *Standards for Protection against Radiation* (10CFR20) in 1991, issued regulatory guidance on *Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled* (Regulatory Guide 8.25) in 1992, and published an associated document on *Air Sampling in the Workplace* (NUREG-1400) in 1993.

The U.S. Department of Energy (DOE) ([www.energy.gov](http://www.energy.gov)) published an *Operational Health Physics Training Manual* (ANL-88-26) in 1988; promulgated *Standards for Protection against Radiation* (10CFR835) in 1993; summarized the characteristics of aerosols from a wide range of activities such as powder handling, spills, and fires in a 1994 handbook on *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE-HDBK-3010-94, Vol. 1 and 2); and provided an updated *Implementation Guide for Air Monitoring for use with Title 10 Code of Federal Regulations Part 835 Occupational Radiation Protection* (DOE G 441.1-8) in 1999.

The U.S. Environmental Protection Agency (EPA) ([www.epa.gov](http://www.epa.gov)) issued *National Emission Standards for Hazardous Air Pollutants* (40CFR61) in 1991. The Occupational Safety and Health Administration (OSHA) ([www.osha.gov](http://www.osha.gov)) has promulgated an *Occupational Safety and Health Standard for Ionizing Radiation* (29CFR1910.1096).

The recommendations of the International Commission on Radiological Protection (ICRP) ([www.icrp.org](http://www.icrp.org)) are internationally accepted as a coherent and consistent approach to radiation protection. Of particular interest are *Principles of Environmental Monitoring related to the Handling of Radioactive Materials* (ICRP Publication 7) issued in 1965; *General Principles of Monitoring for Radiation Protection of Workers* (ICRP Publications 12 and 35) issued in 1968 and 1982; *Implications of Commission Recommendations that Doses be kept as Low As Reasonably Achievable* (ICRP Publication 22) issued in 1973; *Reference Man: Anatomical, Physiological and Metabolic Characteristics* (ICRP Publication 23) issued in 1975; *Limits on Intakes of Radionuclides by Workers* (ICRP Publication 30 and addendums) issued beginning in 1979; *Principles of Monitoring for the Radiation Protection of the Population* (ICRP Publication 43) issued in 1985; and several reports issued in 1994 on *Recommendations of the International Commission on Radiation Protection* (Publication 60), *Human Respiratory Tract Model for Radiological Protection* (ICRP Publication 66), and *Dose Coefficients for Intakes of Radionuclides by Workers* (ICRP Publication 68).

Dorrian and Bailey (1995) summarized the particle size distribution of radioactive aerosols measured in a wide range of industrial operations. The typical particle size distribution had an activity median aerodynamic diameter (AMAD) of 5  $\mu\text{m}$  with a geometric standard deviation of 2, although smaller size distributions were observed in operations involving high temperatures or fumes, and larger particle size distributions were observed in operations such as coarse powder handling. The typical size distribution values reported by Dorrian and Bailey are the accepted default values for use in ICRP Report 66 on the new Human Respiratory Tract Model for Radiological Protection. The previous default assumption in ICRP Report 30 for aerosol particle size in the work place had been an AMAD of 1  $\mu\text{m}$ , which remains the default value for the particle size of radioactive aerosols in the environment.

The National Council on Radiation Protection and Measurements (NCRP) ([www.ncrp.com](http://www.ncrp.com)) focused on fundamental considerations of human respiratory tract structure and function in deriving an alternate mathematical model on *Deposition, retention and dosimetry of inhaled radioactive substances* (NCRP Report 125) in 1997. The NCRP also has a 1978 report on *Instrumentation and Monitoring Methods for Radiation Protection* (NCRP Report 57) and a 1978 *Handbook of Radiation Protection Measurements*

Procedures (NCRP Report 58).

The International Commission on Radiation Units and Measurements (ICRU) ([www.icru.org](http://www.icru.org)) issued a document on *Radiation protection instrumentation and its application* (ICRU Report 20) in 1971. The International Atomic Energy Agency (IAEA) ([www.iaea.org](http://www.iaea.org)) has a 1978 report on *Particle Size Analysis in Estimating the Significance of Airborne Contamination* (IAEA Technical Report Series No. 179). The American Conference of Governmental Industrial Hygienists (ACGIH) ([www.acgih.org](http://www.acgih.org)) periodically updates its book series on *Air Sampling Instruments for Evaluation of Atmospheric Contaminants* that includes information on sampling radioactive aerosols (see, for example, Cohen 1995).

Measurement of radioactive aerosols involves most of the standard tools of aerosol science and technology, as well as a number of specialized techniques that take advantage of the unique physical properties of radioactive materials. In addition to the guidance and standards noted above, instruments and techniques for characterizing radioactive aerosols have been described extensively in numerous manuscripts, books, and reports (see, for example, Price, 1965; Raabe 1972; Turner 1996; Cember 1996; Schleien *et al.* 1998; or Hoover and Newton 2001). Published software and computational programs, such as Anand *et al.* (1996) and Riehl *et al.* (1996), are available for calculating aerosol losses in transport lines. Detailed review and application of this information, as well as the development of new techniques and applications, continue to occupy the careers of many aerosol scientists and health protection professionals.

## CONCLUSION

Manufacturers and users work together and in concert with regulatory bodies and corporate entities to identify, interpret, and comply with the appropriate standards. In some cases, new standards must be developed or existing standards must be revised to accommodate new industries, technologies, or expectations.

The development and maintenance of credible technical standards is a living process and the content, status, and applicability of the dozens of standards described in the current review comprise a snapshot in time. A similar review would be useful for industrial hygiene instrumentation and procedures.

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## Appendix A: IEC Standards

### IEC 60579 (1977-01)

#### *Radioactive aerosol contamination meters and monitors*

This standard is of historical interest in the area of effluent monitoring, but has been superseded by the comprehensive IEC 60761 series. It was applicable only to assemblies equipped with filters. It was not applicable to meters or monitors designed for selective monitoring.

### IEC 60710 (1981-01)

#### *Radiation protection equipment for the measuring and monitoring of airborne tritium*

This IEC standard has served the nuclear industry well and is currently under revision by IEC SC45B. The standard provides requirements and gives examples of acceptable methods for measuring and monitoring equipment to enable the determination of the average value of the concentration of atmospheric tritium in working areas and its variation as a function of time, and to actuate an alarm system if necessary.

### IEC 60761 (2002-01)

#### *Equipment for continuously monitoring radioactivity in gaseous effluents*

This comprehensive set of standards covers five areas:

#### IEC 60761-1 (2002-01)

##### Part 1: General requirements

#### IEC 60761-2 (2002-01) Part 2: Specific requirements for radioactive aerosol monitors including transuranics

#### IEC 60761-3 (2002-01) Part 3: Specific requirements for radioactive noble gas monitors

#### IEC 60761-4 (2002-01) Part 4: Specific requirements for radioactive iodine monitors

#### IEC 60761-5 (2002-01) Part 5: Specific requirements for tritium monitors

### IEC 60951 (1988-08)

#### *Radiation monitoring equipment for accident and post-accident conditions in nuclear power plants*

This five-part set of standards was written in the aftermath of the Three Mile Island and Chernobyl nuclear reactor accidents. The scope and content are not intended to provide detailed direction or guidance for air monitoring under normal workplace conditions or in the environment.

#### IEC 60951-1 (1988-08)

##### *Part 1: General requirements*

Part 1 provides guidance on the design principles and performance criteria for equipment to measure radiation and fluid (gases or liquids) radioactivity levels in reactor plants during and after an accident. Specifies general design and operating characteristics, general test procedures, radiation characteristics, electrical quantities, safety and environmental characteristics, as well as the documentation required.

#### IEC 60951-2 (1988-08)

##### *Part 2: Equipment for continuously monitoring radioactive noble gases in gaseous effluents*

Part 2 lays down specific requirements for monitoring equipment for noble gases and gaseous effluents, measuring in accident and post-accident conditions the volumetric activity of radioactive noble gases in effluents and the total discharge of noble gas activity over a given period. Does not deal with sampling procedures and laboratory analysis methods.

#### IEC 60951-3 (1989-12)

##### *Part 3: High range area gamma radiation dose rate monitoring equipment*

Part 3 lays down specific requirements, including technical characteristics and test conditions for area gamma radiation dose rate monitoring equipment for use in accident conditions. This may be used, for example, for detection of leaks in a system containing radioactivity and to give useful information for interpreting the accident conditions that are present, making, in some cases, an assessment of potential releases to the environment, and implementation of emergency procedures

#### IEC 60951-4 (1991-12)

##### *Part 4: Process stream in light water nuclear power plants*

Part 4 applies to equipment for the monitoring of radioactive substances within plant-process streams of stationary nuclear power plants using light water reactors during and after accident conditions. Provides criteria for the design, selection, functional location, testing and calibration of stationary radiation monitoring equipment to be used for continuous monitoring of plant process streams in operation during and after accident conditions.

IEC 60951-5 (1994-02)

*Part 5: Radioactivity of air in light water nuclear power plants*

Part 5 provides criteria for the design, selection, functional location, testing and calibration of installed equipment for monitoring airborne radioactivity within nuclear power plants with light water reactors during and after accident conditions.

IEC 61171 (1992-09)

*Radiation protection instrumentation – Monitoring equipment - Atmospheric radioactive iodines in the environment*

This international standard is applicable to transportable or installed equipment used for monitoring, as a function of time, airborne radioactive iodines in the environments near nuclear facilities during normal operations, during anticipated operational occurrences, or during accident conditions.

IEC 61172 (1992-09)

*Radiation protection instrumentation – Monitoring equipment - Radioactive aerosols in the environment*

This international standard is applicable to transportable or installed equipment for continuous monitoring of radioactive aerosol in the environment for both normal and accident conditions. For purposes of this standard, monitoring includes continuous sample collection with, if desired, the capability to automatically initiate sampling.

IEC 61578 (1997-08)

*Test methods for the calibration and verification of the effectiveness of radon compensation for alpha and/or beta aerosol measuring instruments*

This standard applies to realtime air monitoring instruments that use compensation algorithms to remove interference from the alpha emissions of naturally occurring radon progeny.

IEC DRAFT 62302 (in preparation)

*Equipment for noble gas monitoring in the workplace, effluents, and the environment*

IEC DRAFT 62303 (in preparation)

*Equipment for monitoring airborne tritium in the workplace, effluents, and the environment*



**Appendix B:  
ISO Standards**

ISO 2889 (1975)

*General principles for sampling airborne radioactive materials*

This standard was issued in 1972 and revised in 1975. It is under revision to incorporate technological advances and lessons learned since the 1970s. Its scope is similar to that of ANSI N13.1. Revisions are expected to cover optimal sampling methodology, including sampling and monitoring techniques, and combining sampling, monitoring and control procedures. The revised 2889 is being expanded as follows: Part 1 (general requirements), Part 2 (stacks and ducts), Part 3 (workplace), and Part 4 (outdoors or in the environment).



**Appendix C:  
European Standards**

EN 481 (1993)

*Workplace atmospheres – Size fraction definitions for measurement of airborne particles.*

This standard defines sampling conventions for particle size fractions which are used to assess the possible health effects from inhaling airborne particles in the workplace.



## Appendix D: ANSI N42 Standards (IEEE)

### ANSI N42.17B (1989)

#### *Performance Specification for Health Physics Instrumentation - Occupational Airborne Radioactivity Monitoring Instrumentation*

The scope of this standard includes performance criteria and testing procedures for instruments and instrument systems designed to continuously sample and quantify concentrations of radioactivity in ambient air in the workplace. This standard does not specify which instruments or systems are required, nor does it address the specific locations or applications of such instruments.

### ANSI N42.18 (1980, Reaffirmed 1991)

#### *Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents*

This standard provides recommendations for selecting instruments used to continuously monitor and measure radioactivity in effluents released to the environment. The scope includes all physical forms of radioactive materials such as gases, liquids, particulates, or dissolved solids singly or in combination, in effluent paths including liquid effluents. The standard does not provide specific requirements for instrument capabilities, emergency situations, or sample extractions and laboratory analyses. This standard is currently being reviewed and revised mainly in light of lessons learned and new technologies since 1980.

### ANSI N42.30 (2002)

#### *Performance Specification for Tritium Monitors*

This standard provides the performance requirements and test procedures for tritium monitors used for monitoring airborne tritium radioactivity. The standard applies to tritium monitors used to measure tritium in the work place. It does not specify which systems or instruments are required, nor does it address the specific locations or applications of such instruments.

### ANSI N317 (1980)

#### *Performance Criteria for Instrumentation Used for In-Plant Plutonium Monitoring*

The scope of this standard is limited to instruments used to monitor and measure airborne plutonium in handling and storage facilities. Reactors and irradiated fuel reprocessing facilities are specifically excluded. The standard includes requirements similar to those found in ANSI N42.17B, such as temperature response and alarm capabilities. Unlike N42.17B or N42.18, ANSI N317 includes a specific requirement for the sensitivity of instruments used to monitor for or measure airborne radioactive materials. This standard needs to be updated in light of current technology.

### ANSI N320 (1979, Reaffirmed 1985)

#### *Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation*

This standard addresses performance parameters and general placement for monitors used to measure radionuclides released during an accident at a reactor facility. Included in the standard are general discussions of monitoring systems and specific requirements for lower and upper detection limits for emergency monitoring instruments. This standard is being revised.

### ANSI N323C (in preparation)

#### *Radiation Protection Instrumentation Test and Calibration – Air Monitoring Instruments*

The general requirements of ANSI Standard N323 (1983) are being developed in the new ANSI 323C to provide detailed guidance for calibration of air sampling and monitoring instruments used to meet the requirements and recommendations of governmental regulations and other ANSI standards that specify when, where, and how air monitoring instruments shall, should, or may be used to sample or monitor airborne radioactive substances. It applies to fixed, portable, and personal air samplers and monitors used for regulatory compliance, including continuous air monitors for stack, work place, and environmental applications. Calibration of specialized air monitoring instruments such as working level monitors or process-monitoring instruments may involve issues that extend beyond the fundamental considerations presented in this standard. In such cases, designers and users should exercise professional judgment in the application of these requirements and should explicitly document the sampling objectives and the reasons for any exceptions to the requirements of this standard.



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**Appendix E:**  
**ANSI N13 Standards (HPS)**

**ANSI N13.1 (1969, Revised 1999)**

*Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*

This standard was originally issued in 1969 and was substantially revised in 1999 to account for improved understandings of the physics and practice of extractive air sampling. ANSI N13.1 (1999) is a performance-based document rather than one based on prescriptive rules and specifications. It includes discussions of air moving methods and air flow and air flowrate measurement devices. It does not address instrumentation used to quantify or measure the radioactivity in air samples. The revision of this significant standard will undoubtedly assist in preparing a revision of ISO 2889-1975.

**ANSI N13.2 (1969, Reaffirmed 1982)**

*Administrative Practices in Radiation Monitoring*

This standard is directed toward nuclear facility management, providing an administrative basis for programs to monitor and measure airborne radioactivity in the workplace and environment. This standard does not provide technical guidance for measuring or monitoring airborne radioactive materials.

**ANSI N13.9 (In preparation)**

*Guide to Environmental Surveillance around Nuclear Facilities*

This standard is under development to address specific issues of sampling in the outdoor environment.



## Appendix F: Applicable French National Standards

The first four French standards are generic and comparable to requirements of the US Clean Air Act of 1990.

NF X 43-021 (December 1984)

*Air Quality – Filter sampling of particulate material suspended in ambient air - Automatic sequential equipment*

This standard describes an automatic sequential apparatus for sampling with filters for particulate matter in environmental air. The concentration of various organic or minerals such as heavy metals, including lead, can thus be estimated.

NF X 43-022 (May 1985)

*Air Quality – Ambient air - Concepts relating to the sampling of particulate matter*

NF X 43-257 (August 1988)

*Air Quality – Air in workplaces - Individual sampling of inspirable fraction of particulate pollution*

NF X 44-051 (July 1978)

*Sampling of dust in a stream of gas (general case)*

NF X 44-052 (May 2002)

*Stationary Source Emissions – Determination of high range mass concentration of dust - Manual gravimetric method*

The following French standards are for specific applications for monitoring and measuring radioactive aerosols.

NF M 60-312 (October 1999)

*Nuclear energy – Measurement of environmental radioactivity - Air - Determination by liquid scintillation of the activity concentration of atmospheric tritium sampled by the sparging technique (air through water)*

This document describes a bubbler sampling method for determining the atmospheric concentration of tritium (vapor and gas). The detection limit of this method is about 1 Bq·m<sup>-3</sup>. It does not allow the measurement of the natural background. There are a number of passive or active sampling methods for determining the concentration of tritium in air. Most of them concern only tritium in water vapor form. These methods avoid the dilution of the atmospheric water vapor in the water of the bubblers and have a limit of detection of about 10 mBq·m<sup>-3</sup>.

NF M 60-760 (October 2001)

*Nuclear Energy – Measurement of radioactivity in the environment - Air - Sampling of aerosols for measurement of radioactivity in the environment*

This standard is concerned with sampling aerosols in the environment using filters to measure the specific activity (Bq·m<sup>-3</sup>) in the sampled air.

NF M 60-763 (March 1998)

*Nuclear Energy – Measurement of radioactivity in the environment - Air- Radon and its short-lived decay products in the atmospheric environment: Origins and measuring methods*

This document summarizes the available general knowledge regarding the origin and behavior of radon 222 in various atmospheric environments. The air sampling can be classified as occasional, continuous and/or integrated measurements.

NF M 60-764 (December 1997)

*Nuclear energy – Measurement of radioactivity in the environment - Air- Radon 222: Integrated methods for measurement of alpha potential energy of short life decay products in the atmospheric environment*

This document describes a method for determining the alpha potential volumetric energy (EAPV) of short (half) life progeny of radon 222 in the atmosphere over a period of one month. This measurement allows

for the evaluation of radiological exposure to man.

NF M 60-765 (December 1997)

*Nuclear Energy – Measurement of radioactivity in the environment - Air - Radon 222: Methods for spot measurement of alpha potential energy of radon daughters in the atmospheric environment*

This document describes a method for occasionally and quickly (in a few minutes) determining the alpha potential energy of the short-life daughter products of radon 222 in the atmosphere.

NF M 60-766 (December 1999)

*Nuclear energy – Measurement of radioactivity in the environment - Air - Radon 222: Integrated methods for measurement of the average volumic activity of radon in the atmospheric environment, with passive collection and a deferred analysis*

This document gives some requirements concerning the measurement of the average volumic activity of radon 222 by passive sampling in the atmosphere and delayed analysis. Among the different existing methods, only the integrated methods of measurement of the average volumic activity from several weeks up to one year are covered by this document, which describes the mode of sampling, the mode of detection, and the conditions for use. This document is used jointly with NF M 60-763.

NF M 60-767 (August 1999)

*Nuclear energy – Measurement of environmental radioactivity - Air - Radon 222: Continuous measurement methods of the volumic activity of radon in the atmospheric environment*

This document gives some requirements to measure the volumic activity of radon 222 in the atmosphere. Among the different methods used, only the methods of continuous measurement are covered in this document. This document describes the mode of sampling, the mode of detection, and the conditions for use. This document is used jointly with NF M 60-763.

NF M 60-768 (October 2002)

*Nuclear energy – Measurement of environmental radioactivity- Air - Radon 222: Methods for the estimation of the surface activity of exhalation by accumulation methods*

This document gives some requirements for the estimation of the surface exhalation rate of radon at a given point and time at an interface with the atmosphere, from the measurement of the volumic activity of radon 222 inside a storage volume. It is used jointly with NF M 60-763 M 60-767 and M 60-769.

NF M 60-769 (November 2000)

*Nuclear energy – Measurement of environmental radioactivity- Air - Radon 222: Methods for spot measurement of the volumic activity of radon in the atmospheric environment*

This document gives some requirements to measure the volumic activity of radon 222 in the atmosphere. Among the different existing methods, only the methods of spot measurement are covered by this document, which describes the mode of sampling, the mode of detection and the conditions for use. It is used jointly with NF M 60-763.

NF M 60-770 (October 2000)

*Nuclear energy –Measurement of environmental radioactivity- Air - Determination of the activity concentration for atmospheric deposits on the soil*

This document describes a passive device for collecting deposits of atmospheric radionuclides on soil in order to determine their identity and concentration. The sampling conditions and the periodicity are also given. The collection of the dried fallout is given specifically in NF X 43-007 (1973).

NF M 60-771 (July 2001)

*Nuclear energy – Measurement of environmental radioactivity- Air - Radon 222 in buildings – Methodologies for screening and complementary investigations*

This document provides some requirements to screen for radon and to conduct complementary measurements necessary to identify the source and transfer of radon in buildings. It was prepared for use with standards NF M 60-763, M 60-764, M 60-765, M 60-766, M 60-767, and M 60-769.



**Table 2. Selected List of National Standards Organizations.**

<b>Country</b>	<b>Symbol</b>	<b>Organization</b>
Austria <sup>a,c</sup>	ON	Österreichisches Normungsinstitut
Belgium <sup>a,c</sup>	IBN	Institut Belge de Normalisation
Bulgaria <sup>b</sup>	BDS	State Agency for Standardization and Metrology
Canada <sup>a,d</sup>	SCC	Standards Council of Canada
China <sup>a,d</sup>	CSBTS	China State Bureau of Quality and Technical Supervision
Czech Republic <sup>a</sup>	CSNI	Czech Standards Institute
Denmark <sup>b,c</sup>	DS	Dansk Standardiseringsraad
Egypt <sup>a</sup>	EOS	Egyptian Organization for Standardization and Quality Control
Finland <sup>a,c</sup>	SFS	Suomen Standardisoimislitto
France <sup>a,c</sup>	AFNOR	Association Française de Normalisation;
	UTE	Union Technique de l'Electricité
Germany <sup>a,c</sup>	DIN	Deutsches Institut für Normung
Greece <sup>c</sup>	ELOT	Hellenic Organization for Standardization
Iceland <sup>c</sup>	STRI	Technological Institute of Iceland
India <sup>b</sup>	BIS	Bureau of Indian Standards
Ireland <sup>b,c</sup>	NSAI	National Standards Authority of Ireland
Israel <sup>a</sup>	SII	Standards Institution of Israel
Italy <sup>a,c</sup>	UNI	Ente Nazionale Italiano Unificazione
Japan <sup>a,d</sup>	JISC	Japanese Industrial Standards Committee
Korea (Republic of) <sup>b,d</sup>	KATS	Korean Agency for Technology and Standards
Luxembourg <sup>c</sup>	SEE	Service de l'Energie de l'Etat
Netherlands <sup>b,c</sup>	NNI	Nederlands Normalisatie-Instituut
New Zealand <sup>b,d</sup>	SNZ	Standards New Zealand
Norway <sup>b,c</sup>	NSF	Norges Standardiseringsforbund
Poland <sup>b</sup>	PKN	Ogłoszenie Polskiego Komitetu Normalizacyjnego
Romania <sup>a</sup>	ASRO	Asociația de Standardizare din România
Portugal <sup>c</sup>	IPQ	Instituto Português de Qualidade
Russian Federation <sup>a,d</sup>	GOST R	Gosstandart of Russia
Slovakia <sup>b</sup>	SUTN	Slovenský Ústav Technickej Normalizácie
South Africa <sup>b,d</sup>	SABS	South African Bureau of Standards
Spain <sup>b,c</sup>	AENOR	Asociación Española de Normalización y Certificación
Sweden <sup>a,c</sup>	SIS	Standardiseringskommissionen i Sverige
Switzerland <sup>a,c</sup>	SNV	Schweizerische Normen-Vereinigung
Ukraine <sup>a</sup>	DSTU	State Committee of Ukraine for Standardization, Metrology & Certification
United Kingdom <sup>a,c</sup>	BSI	British Standards Institution
United States of America <sup>a,d</sup>	ANSI	American National Standards Institute
Yugoslavia <sup>b</sup>	SZS	Savezni zavod za standardizaciju

- <sup>a</sup> Indicates participating members of IEC SC45B
- <sup>b</sup> Indicates observer status for IEC SC45B
- <sup>c</sup> Indicates members of the Comité Européen de Normalisation (CEN) and the Comité Européen de Normalisation Electrotechnique (CENELEC).
- <sup>d</sup> Indicates members of the Pacific Area Standards Congress (PASC)

