



American National Standard

ANSI/HPS N43.16-2021

**Radiation Safety for Cargo and Vehicle Security
Screening Systems Using X-ray or Gamma Radiation,
Energies Up to 10 MeV**

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American National Standards Institute, Inc.



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Foreword (This foreword is not part of American National Standard N43.16)

The use of ionizing radiation to screen vehicles and cargo containers has increased rapidly over past decades. This technology makes it possible to rapidly screen vehicles and cargo containers for the presence of threat items and contraband. It also minimizes the need for security personnel to open or enter the vehicles or containers. When this technology became commercially available, little guidance had been published for this type of radiation use. In March 2003 the HPS/ANSI Accredited Committee N43 appointed working group N43.16 to draft a consensus standard addressing the radiation safety aspects of the technology.

This standard applies to security screening systems used for non-intrusive inspection of vehicles and cargo containers in which people are not expected to be present. The standard provides guidelines specific to the radiation safety aspects of the design, maintenance, and operation of these systems. It does not include electrical safety guidelines or any other safety, performance or use considerations outside of the realm of radiation safety. The standard is intended for manufacturers, distributors, installers, and users of the systems.

In setting dose limits the standard takes into consideration the minimization of the dose as balanced against the security benefit to society. This precludes the frivolous use of the security screening systems where no benefit is to be derived. The standard contains three informative annexes. Annex A (informative) provides descriptions of typical systems and operational modes. Annex B (informative) provides information on radiation measurement quantities, terminology, equipment and techniques. Annex C (normative) provides the background and examples for obtaining dose limits around systems based on actual operational conditions. Annex D (normative) provides techniques for performing radiation surveys.

It is important to reiterate that this standard includes requirements for both the manufacturers and users of screening systems. Sections 4 and 6 of this Standard contain requirements for both manufacturers and users. Section 5 contains only manufacturer requirements. Section 7 contains user requirements. Full compliance with this standard requires systems to be both manufactured and operated according to the standard. Simply procuring equipment that meets all the manufacturing performance requirements does not guarantee compliance. When there is no requirement for U.S. Nuclear Regulatory Commission licensing or state registration, the authors of this standard recommend equivalent oversight be performed by a qualified independent authority.

This standard does not address dose limits for intentional exposure of humans to the primary beam. Users of systems intended to expose humans to primary beam x-rays, gamma-radiation, or both (e.g., pedestrians, occupied vehicles) as well as vehicles and cargo containers shall also comply with the requirements of ANSI/HPS N43.17-2009 (Renewed as of 2018) *Radiation Safety for Personnel Security Screening Systems Using X-ray or Gamma Radiation*.

Key words: cargo and vehicle screening, gamma rays, health physics, linear accelerator (LINAC), national standard, radiation generating device (RGD), radiation safety, sealed radioactive sources

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Radiation Safety for Cargo and Vehicle Security Screening Systems Using X-Ray and Gamma Radiation, Energies Up To 10 MeV

1. Purpose and Scope

This standard sets forth guidelines and performance criteria for radiation safety aspects of the design, operation, and maintenance of non-intrusive inspection (NII) systems using x-ray or gamma radiation for security screening of cargo containers and vehicles.

This standard does not apply to the following:

- a) Cabinet x-ray system (as defined in Title 21, Code of Federal Regulations, Section 1020.40).
- b) X-ray systems used for medical diagnosis or treatment, medical research, or non-destructive testing.

For security screening operations where human occupants of a vehicle are intentionally exposed to the primary radiation beam, this standard addresses only those aspects of the operation related to cargo or vehicle screening. Users conducting such operations shall also comply with the requirements of ANSI/HPS N43.17-2009 [R2019], *Radiation Safety for Personnel Security Screening Systems Using X-ray or Gamma Radiation*.

This standard does not address electrical or other safety requirements, detection performance, or other use considerations unrelated to radiation safety. It also does not address the potential effects of ionizing radiation on radiosensitive cargo; however, it does require system manufacturers to disclose the dose to an inadvertently exposed individual, which provide an estimate of the dose to cargo.

2. Normative References

ANSI/HPS N43.17 – 2009 [Renewed 2019], *Radiation Safety for Personnel Security Screening Systems Using X-Ray or Gamma Radiation*, Health Physics Society, Herndon, VA.

3. Definitions

3.1 Shall and Should

The word “shall” is used to denote a requirement, compliance with which is necessary to meet current radiation protection standards; the word “should” denotes a recommendation that is intended to be followed when practicable.

3.2 Specific Terms

Absorbed dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose, in the Système Internationale (SI), is the joule per kilogram, given the special name gray (Gy). ($1 \text{ Gy} = 1 \text{ J kg}^{-1} = 100 \text{ rad}$.)

Access: Entry or insertion of the body or a part of the body into a particular area.

Access panel: Any barrier or panel that is designed to be removed or opened for maintenance or service purposes that, when removed or opened, affects radiation shielding.

Access point: Any location through which access to radiation areas or radioactive materials is possible. This includes entry or exit ports of sufficient size to permit human entry, irrespective of their intended use.

Accessible area: Any area where the body or a part of the body may be exposed to radiation without necessitating a shutdown of the radiation source.

Activity (A): The rate of transformation of radioactive material (defined as the quotient of dN by dt , where dN is the number of spontaneous nuclear transmutations or disintegrations that occur in a quantity of a radionuclide in the time interval dt). The SI unit of activity is becquerel (Bq). ($1 \text{ Bq} = 1 \text{ disintegration per second (s}^{-1}\text{)}$, and $3.7 \times 10^{10} \text{ Bq} = 1 \text{ curie (Ci)}$)

ALARA (as low as is reasonably achievable): Making every reasonable effort to maintain exposures to radiation as far below the dose limits as practical, taking into account the state of

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technology, the economics of improvements in relation to benefits to health and safety, and other societal and socioeconomic considerations.

Ambient dose equivalent: In this document ambient dose equivalent refers to $H^*(10)$ which is the dose equivalent at a point in a radiation field produced by the corresponding expanded and aligned field in the ICRU sphere (ICRU 1998) at a depth of 10 mm on the radius opposing the direction of the aligned field. The unit of ambient dose equivalent, $H^*(10)$ is joule per kilogram (J kg^{-1}), with the special name sievert (Sv). (1 Sv = 100 rem).

Backscatter imaging: An imaging technology in which an image of the vehicle or cargo container is created from measurements of radiation scattered or deflected from the object in the backward direction.

Backscatter system: A security screening system that employs backscatter imaging technology.

Bystander: A person near the system, who is not directly associated with the operation of the system. Bystanders may include members of the public in the vicinity of the unit, drivers of vehicles being scanned who have exited the vehicle, and traffic controllers.

Cabinet x-ray system: A cabinet x-ray system is any system that meets the applicability criteria of the federal radiation safety performance standard for cabinet x-ray (Title 21 CFR § 1020.40 Cabinet x-ray systems (a) *Applicability* and (b) *Definitions*).

Collimator: A device or devices used to limit the size, shape, and direction of the primary beam.

Contraband: Unlawful or unauthorized items which may include explosives, weapons, drugs, other threat agents, or stowaways.

Dose equivalent: It is the product of the absorbed dose D at a point in tissue and the quality factor Q at that point. The unit of dose equivalent, H , is the joule per kilogram (J kg^{-1}), with the special name sievert (Sv, 1 Sv = 100 rem).

Effective dose: A summation of the *equivalent doses* in tissues or organs each multiplied by the appropriate tissue weighting factor as defined by the ICRU (ICRU, 1998). The tissue weighting factors were modified by the International Commission on Radiological Protection in its Publication 103 (ICRP 2007). The unit of effective dose is joule per kilogram, and its special name is sievert (Sv). (1 Sv = 100 rem).

Equivalent dose: The absorbed dose in an organ or tissue multiplied by the appropriate radiation weighting factor (ICRU 1998). The unit of equivalent dose is joule per kilogram, and its special name is sievert (Sv, 1 Sv = 100 rem).

High radiation area: An area, accessible to individuals, in which radiation levels from radiation sources could result in an individual's receiving an equivalent deep dose (H_d) in excess of 1 mSv (100 mrem) in 1 h at 30 cm (1 foot) from the radiation source or 30 cm (1 foot) from any surface that the radiation penetrates.

IDC(20): The isodose contour around the volume outside of which the ambient dose equivalent rate averaged over any 1 minute of continuous operation does not exceed 20 microsieverts (2 millirems) per hour above background.

IDC(0.5): The isodose contour around the volume outside of which the ambient dose equivalent rate averaged over any 1 minute of continuous operation does not exceed 0.50 microsievert (50 microrems) per hour above background.

Inadvertent exposure: Unintentional exposure of an individual to the primary beam. Inadvertent exposures include ground guides or passers-by who enter the radiation control area or unauthorized individuals in cargo compartments of the vehicle or container (e.g., stowaways).

Kerma: The quotient of dE_{tr} by dm , where dE_{tr} is the sum of the initial kinetic energies of all of the charged particles liberated by uncharged radiation (e.g., photons and neutrons) in a volume element of mass dm :

$$K = \frac{dE_{tr}}{dm}$$

The unit of kerma is joule per kilogram (J kg^{-1}) and its special name is the gray (Gy). If the interacting

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medium is air, this quantity is often referred to as air kerma.

Leak test: A test to determine the integrity of the encapsulation of a sealed radioactive source.

Mobile system: A security screening system designed to operate in a moving source mode.

Moving source mode: An operational mode where the radiation source moves relative to the ground while the vehicle or cargo container being inspected remains stationary. Systems operating in this mode are commonly referred to as mobile systems.

Non-intrusive inspection (NII): Detection of concealed contraband items which does not involve the opening of, or the entry of personnel into, the vehicle and cargo container.

Occupancy factor: The fraction of the time during which the source is “on” that the maximally exposed individual is present in the area in question. For purposes of radiation protection, the accumulated radiation dose in an area may be multiplied by the occupancy factor to provide a better estimate of potential radiation doses that may be received by individuals. The maximally exposed individual is almost always an employee at the facility rather than a member of the public. Recommended occupancy factors for various types of areas are provided in several publications, such as National Council of Radiation Protection and Measurements (NCRP) Report No. 147, and range from 1 for offices, laboratories, and reception area to 1/40 for outdoor areas with transient traffic.

Operational mode: The operational mode refers to the motion of the source relative to the ground, see moving source mode and stationary source mode.

Portal system: A security screening system designed to operate in a stationary source mode where a vehicle moves through the *primary beam* under the driver's control. Note: ANSI N43.17-2009 also applies when the vehicle occupants move through the primary beam.

Primary beam: The radiation coming directly from the radiation source through an aperture in

the source housing into the volume defined by the collimator.

Qualified expert: A person having the knowledge and training to assess both the hazards presented by the specific radiation source(s) under consideration and the effectiveness of engineered and administrative controls used to mitigate those hazards. Examples of qualified experts would include, but are not limited to, professionals certified by the American Board of Health Physics, the American Board of Radiology, or the American Board of Medical Physics. Regardless of certification status, the qualified expert must have knowledge of: (1) the radiation physics associated with the specific systems to be evaluated, (2) the operating characteristics of the systems, (3) the facility-specific operational practices that will be used, (4) the operating history (problems) of similar systems, and (5) applicable regulations and national standards.

Quality factor (Q): An energy dependent dimensionless factor by which absorbed dose is to be multiplied to obtain the operational quantity called dose equivalent. The quality factor for x-rays and gamma rays is 1.0.

Radiation weighting factor (w_R): An energy dependent dimensionless factor by which absorbed dose is to be multiplied to obtain the radiation protection quantity called equivalent dose. The radiation weighting factor for x-rays and gamma rays is 1.0.

Radiation area: Any area accessible to individuals in which radiation levels could result in an individual's receiving deep-dose equivalent in excess of 0.05 mSv (5 mrem) in 1 h at 30 cm (1 foot) from the source or 30 cm (1 foot) from any surface that the radiation penetrates.

Radiation control area: The physical area required to safely operate the system and perform non-intrusive inspection, including the area needed for radiation protection, physical safety, operational concerns, and other hazards.

Radiation generating device: For purposed of this standard, an apparatus or a device emitting or capable of emitting ionizing radiation produced by electrical means. For example, an x-ray system or linear accelerator (LINAC).

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Radiation safety survey: An evaluation of the radiation hazards in and around an installation. It customarily includes a physical assessment of the arrangement and use of the equipment along with an assessment of the potential doses to individuals under the full range of expected operating conditions. This is typically accomplished by a combination of on-site measurements and calculations.

Roentgen (R): The special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air.

Safety interlock: A device or group of devices with the associated control system that is designed to sense a limit, an off-limit condition, or an improper sequence of events and automatically prevent or terminate radiation exposure. This is typically accomplished by preventing access to the hazardous area or by terminating or preventing radiation emission.

Scattered radiation: Radiation whose path or direction of propagation has deviated as a result of interaction with matter.

Sealed source: Any radioactive material or byproduct encased in a capsule designed to prevent leakage or escape of the material.

Shutter: A device that, when closed, prevents the beam from emerging from the source housing. When the shutter is open, the beam emerges from the source housing.

Skyshine: Radiation scattered by the air above a radiation source to points at ground level beyond a protective shield.

Source housing: An enclosure for a source that provides attenuation of the radiation emitted by the source.

Stationary source mode: An operational mode where the radiation source does not move relative to the ground. Systems operating in this mode are commonly referred to as portal systems.

System operator: A person having the necessary training and experience to safely operate the inspection system, and who is authorized by the facility to perform the process.

Safe operation of the system includes initiating or stopping the scan, verifying the system is operating correctly, and/or controlling access to the inspection area. This does not include individuals who may be remotely viewing the image results, but are not directly responsible for the other functions.

Use factor (U): The fraction of time that the primary beam is enabled.

Very high radiation area: Any area accessible to individuals in which radiation levels from radiation sources external to the body could result in an individual's receiving a deep-dose equivalent in excess of 5 Gy (500 rad) in 1 h at 1 m (3.3 feet) from the source or 1 m (3.3 feet) from any surface that the radiation penetrates.

4. Federal, State, and Local Regulations

Manufacturers, distributors and users of security screening systems under this standard shall comply with all applicable requirements in the U.S. Code of Federal Regulations (CFR), which include Title 21, Parts 1000 through 1004 and 1005.25, (U.S. Food and Drug Administration), Title 10, Parts 19 & 20 and 30-33 (U.S. Nuclear Regulatory Commission), and Title 29, 1910.1096 regarding occupational safety (U.S. Occupational Safety and Health Administration). In addition, the installation, operation, and maintenance of these systems may be subject to state and local regulations. Users shall comply with applicable state and local regulations, which may involve registration, licensing, and compliance with specific requirements.

5. Dose Limitation

This standard does not address dose limits for human occupants of a vehicle that are intentionally exposed to the primary radiation beam. Users conducting such operations shall also comply with the requirements of ANSI/HPS N43.17-2009 [R2019], *Radiation Safety for Personnel Security Screening Systems Using X-ray or Gamma Radiation*.

5.1 Dose to System Operating Crew

The annual effective dose to any member of the system operating crew shall be less than 50 mSv