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Standard Guide for Gamma Radiation Shielding Performance Testing[1]

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1. Scope

1.1 This guide identifies appropriate test methods for determining the sufficiency of radiological shielding for hot cells and shielded enclosures.

1.2 After constructing or modifying radiological shielding, it is necessary to verify that shielding performance meets or exceeds the shielding performance requirements. This is typically accomplished using sealed test sources of much less activity than the design basis. This allows for modifications or correction of any discrepancies identified before the commissioning of the hot cell.

1.3 The guidance and practices recommended by this guide are applicable to both new and existing shielded facilities and enclosures for evaluating shielding suitability and locating the existence of shine paths or other shielding anomalies that result from design, manufacture, or construction.

1.4 Two types of testing may be performed.

1.4.1 Shielding performance verification testing provides evidence that the shielding configuration is sufficient for meeting established performance criteria and for identifying deficiencies in the shielding configuration or components that may not have been addressed during design. Test results are expected to demonstrate that shielding performance meets or exceeds design criteria, not match the dose rates predicted analytically.

1.4.2 Shielding performance verification testing identifies shielding deficiencies (hot spots) in the installed configuration relative to adjacent shielding but does not demonstrate compliance with any quantitative shielding performance requirement.

1.5 Performance testing should be specified and performed to assess shielding adequacy with sources in all critical locations.

1.6 Requirements for shielding performance testing should be clearly defined in design basis or procurement documentation.

1.7 This guide is not applicable to neutron radiation shielding performance evaluations.

1.8 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.8.1 Units for total activity should be given in Becquerel (Bq) or curies (Ci).

1.8.2 Units for dose rate as measured during testing should be given in Sieverts (Sv/h) or rad/h.

1.8.3 Distances and locations should be provided in centimetres or inches.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials

3. Terminology

3.1 For terms not defined in this guide, see Terminology C859.

3.2 *Definitions:*

3.2.1 *angular response sensitivity, n*—the ability of an instrument or detector to detect radiation based on the angle of incidence of the radiation on the instrument or detector.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.2 *Bremsstrahlung radiation, n*—electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron by an atomic nucleus.

3.2.2.1 *Discussion*—The moving particle loses kinetic energy, which is converted into a photon because energy is conserved.

3.2.3 *buildup factor, n*—for radiation passing through a medium, the buildup factor is the ratio of the total value of a specific radiation quantity (direct and scattered) measured as absorbed dose at any point within that medium to the contribution to that quantity from the incident uncollided radiation reaching that point.

3.2.3.1 *Discussion*—The buildup factor increases with increased shielding thickness and is higher for low atomic number materials.

3.2.4 *encapsulated source, n*—sealed source strong enough to maintain leak tightness under the conditions of use for which the source was designed and also under foreseeable mishaps.

3.2.4.1 *Discussion*—It is radioactive material that is permanently sealed in a capsule or closely bonded and in a solid form.

3.2.5 *Geiger-Müller counter, GM, n*—type of particle detector that measures ionizing radiation.

3.2.5.1 *Discussion*—The radiation-sensing element is an inert gas-filled Geiger-Müller tube (usually containing helium, neon, or argon with halogens added) at a low pressure that briefly conducts an electrical charge when a particle or photon of radiation makes the gas conductive by ionization. GMs display the number of ionization events, typically in "counts-per-second." The GM tube can detect the presence of radiation but not its energy, which determines the ionizing effect. Instruments that make use of an energy compensated GM tube are capable of displaying absorbed dose.

3.2.6 *ionization chamber, n*—beta-gamma radiation meter useful for direct measurement of exposure and dose rates, determining shielding effectiveness, checking source containers, monitoring radiation areas, and checking results following decontamination procedures.

3.2.6.1 *Discussion*—The unit contains an ion chamber that converts directly from ion chamber current to dose rate.

3.2.7 *manipulator through tube, n*—penetration provided specifically for installation of a master-slave manipulator.

3.2.7.1 *Discussion*—Typically, a hole with a diameter of a certain size depending on the manipulator being used that passes horizontally though the shield wall above the operators.

3.2.8 *penetration, n*—locations where utilities, instrumentation, or processes pass through the shield wall.

3.2.9 *sealed source, n*—radioactive source that has been enclosed within a sealed container that prevents loss of material, spread of contamination, and maintains the geometry of the radioactive material.

3.2.10 *shielding performance evaluation testing, n*—testing that assesses the uniformity in shielding performance.

3.2.10.1 *Discussion*—It is useful for locating void spaces that may reside in the shielding system.

3.2.11 *shielding performance verification testing, n*—testing used to demonstrate that shielding meets or exceeds the performance requirements established in the design basis or procurement documents.

3.2.12 *skyshine, n*—radiation that is scattered by the atmosphere or adjacent structures above a radiation source to points on the ground around the outsider perimeter.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *biological shielding, v*—for purposes of this guide, it is the radiation-absorbing shield used to protect personnel from the effects of nuclear particles or radiation.

3.3.2 *source location volume, n*—specifies the zone the source is expected to occupy within the shielded enclosure.

4. Summary of Guide

4.1 The test source(s) is positioned within the shielded enclosure and the dose rate is measured at established locations using a calibrated instrument.

4.2 It is important that test acceptance criteria reflect the test source and not the design basis source term.

5. Significance and Use

5.1 Shielding performance testing should be performed to verify analytical predictions of shielding effectiveness, compliance with design requirements, and determine the location(s) of shielding deficiencies that may require either supplemental shielding, design modification, or changes to operating methods and procedures to resolve.

5.2 Dose rates higher than adjacent shielding may be expected in the vicinity of master-slave manipulator penetrations as a result of cable or tape clearance requirements within the mechanisms where they pass through the shield walls. This is true even with supplemental shielding installed in the manipulator through tube.

5.3 Similar to manipulator penetrations, when sources are placed directly in front of penetrations and gaps resulting from access doors or panels, radiation levels directly on the other side of the gaps or penetrations may be higher than levels in adjacent shielding or analytical predictions. If these test configurations are representative of how the shielded enclosure will actually be operated (that is, the test configuration is representative of engineered source and normally occupied work locations) than the additional expense of designing or modifying the shielded enclosure should be considered if that location is normally occupied and will result in a significant increase of dose rates to personnel.

5.4 Frames around shield windows may have a higher potential for shielding deficiencies.

5.5 Shield walls constructed of concrete may be subject to the formation of void spaces that could result in diminished shielding performance.

5.6 Background radiation levels in the area where the dose measurement data are being gathered shall be monitored and their contribution to measured dose rates accounted for in the data analysis as part of the test report.

6. Apparatus

6.1 In HSE Ionizing Radiation Protection Series No. 7, Table 1, the recommended instrument for measuring gamma radiation dose rates is energy compensated GM counter, although an ionization chamber would be a viable alternative.[3]

6.2 Instrumentation used for dose rate measurements shall be calibrated in accordance with the requirements of NCRP 112.[4]

6.3 For shielding performance verification testing, traceable sealed calibration standards are preferred.

6.4 If encapsulated calibrated standards with the total activity or energy spectra desired are unavailable, then specially prepared sources may be used. Test sources of a known isotopic composition and activity are required.

6.5 The test source shall be selected specific to the facility and in conjunction with input from the radiation experts for the specific situation to be of sufficient activity to enable valid measurements (that is, result in measurements within the instruments span of calibration) and minimize exposure to test personnel making dose rate measurements.

6.6 For shielding performance verification testing, source holders or other means shall be pre-placed in the shielded enclosure to locate the source precisely and repeatedly when test results are to be compared against analytically predicted values to demonstrate the shielding meets a specific performance requirement. The precision required for source placement accuracy will be a function of source strength and wall construction. Shielding analysis will demonstrate the sensitivity of expected dose rate measurements as a function of test source location.

6.7 When a source location volume within the biological shield is specified rather than specific engineered locations, provision should be included in the test apparatus to ensure that the source remains within that volume during testing.

6.8 The use of multiple sources, different sources, or combinations thereof within the same shielded enclosure during testing is acceptable.

6.9 Test sources should be sealed and marked with a unique identification number that provides traceability to isotopic composition and a total activity value with an associated reference date that would allow an analyst to decay the source before performing analysis used to establish test acceptance criteria.

6.10 Sources should be selected such that measured values are within the calibrated range of the instrument used to measure dose rates.

7. Procedure

7.1 Detector orientation should be controlled to minimize the effects of angular response on test results.

7.2 All shielding performance testing should be performed using an approved test procedure developed for the specific application.

7.3 Background radiation levels that could affect the test results should be measured and recorded. When background levels are expected to vary, they should be measured and recorded throughout testing.

7.4 *Shielding Performance Verification Testing:*

7.4.1 The calibrated source is placed in repeatable test location(s) for each penetration to be tested.

7.4.2 Dose measurements are made at predetermined locations, typically in contact with the shielding and 30 cm [12 in.] away from the shielding being tested. Instrument readings and location shall be recorded.

7.4.3 Continue to reposition the source and take measurements until all data collection has been completed.

7.5 *Shielding Performance Evaluation Testing:*

7.5.1 A source is positioned within the shielded enclosure, opposite the area to be evaluated.

7.5.2 The instrument is used to measure dose rates in the region of the source. The size of the region that can be evaluated without moving the source may be determined analytically, as observed dose rates will be a function of source activity and geometry relative to the detector.

7.5.3 Regions in which an unexpected increase in measured dose occurs should be evaluated further to assess the reason for the change. Dose rate increases may indicate voids or deficiencies that shall be addressed before commissioning the shielded enclosure for use.

8. Hazards

8.1 Caution should be exercised around test sources to prevent unintended radiation exposures to personnel. Where practical, test sources should be placed remotely.

8.2 For evaluation of sources in multiple locations, typically sources are placed remotely using appropriate technology.

9. Report

9.1 The results of testing shall be documented in a written report that includes a description of the shielding performance requirement, test method, and findings.

9.2 The test procedure and raw data shall be included as attachments to the test report.

9.3 Test source and instrument calibration records for the instrument(s) used shall be attached to the test report.

9.4 *Additional Report Requirements for Shielding Performance Verification Testing:*

9.4.1 The test report should identify the test source(s) used, their relative significance with respect to the actual quantities and isotopes intended for use in the enclosure, and how the test results translate to desired shielding performance.

[3] HSE Ionizing Radiation Protection Series No 7, "Selection, use and maintenance of portable monitoring instruments," Health & Safety Executive, Sudbury, Suffolk, United Kingdom, 2011, http://www.hse.gov.uk/radiation/ionising/publications.htm.

[4] NCRP No 112, "Calibration of Survey Instruments Used in Radiation Protection for the Assessment of Ionizing Radiation Fields and Radioactive Surface Contamination," National Council on Radiation Protection and Measurements, 7910 Woodmont Ave., Suite 400, Bethesda, MD, 1991.