A.1  TECMIPT Test Operations Procedures (TTOP)

For Radiation Detection Systems – Specific Methods

Radiation and Nuclear Detection
Capability Area Process Action Team (RN CAPAT)

Leticia Pibida, NIST  Peter Chiaro, ORNL

CAPAT Review & Concurrence: July 2012

Test and Evaluation Capabilities and Methodologies
Integrated Process Team (TECMIPT) Participants:

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REFERENCES:
(a) Chemical and Biological Defense Program (CBDP) Test and Evaluation (T&E) Standards Development Plan, dated 19 July 2010.
# Radiation Detection Systems – Specific Methods

**TTOP No. XXXX**
Version 1.25

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**ABSTRACT**
This TECMIPT test operations procedure (TTOP) provides test methods for testing of Personal Radiation Detectors (PRDs), Hand-held Radionuclide Identification Devices (RIDs), Backpack based Radiation Detection Systems (BRDs), Vehicle Mounted Radiation Detection Systems (VMDS), Airborne Radiological Detection, Identification, and Measurement System (ARDIMS) and Maritime-Based Radiation Detection System (MBRDS).

**SUBJECT TERMS**
Radiation detection systems, rad/nuc detectors, PRD, RID, BRD, VMDS, ARDIMS, MBRDS

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Approved for public release; distribution limited to U.S. Government Agencies and their contractors in accordance with DoD 5230.25 May 2011.
Radiological/Nuclear CAPAT recommends approval of the TTOP. If an organization non-concurs, a dissenting position paper will be attached.

### CONCURRENCE SHEET (1 of 2): DoD Agencies

<table>
<thead>
<tr>
<th>National Institute of Standards and Technology (NIST)</th>
<th>U.S. Army Test &amp; Evaluation Command (ATEC)/U.S. Army Evaluation Center (AEC)</th>
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<tr>
<td>Signature 5/23/12</td>
<td>Signature 1 June 2012</td>
</tr>
<tr>
<td>JAMES K. ECK, Colonel, USAF Vice Commander AFOTEC</td>
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<tr>
<td>Signature 24 Jun 12</td>
<td>Signature 25 Jun 2012</td>
</tr>
<tr>
<td>Commander Operational Test and Evaluation Force (COMOPTEVFOR)</td>
<td>Marine Corps Operational Test &amp; Evaluation Activity (MCOTEA)</td>
</tr>
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<td>Signature 21 May 12</td>
<td>Signature 21 May 2012</td>
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<tr>
<td>Joint Program Executive Office for Chemical Biological Defense (JPEO-CBD)</td>
<td>Deputy Under Secretary of the Army – Test &amp; Evaluation (DUSA-TE)</td>
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<tr>
<td>Signature Jan 12</td>
<td>Signature 7/17/12</td>
</tr>
<tr>
<td>Joint Requirements Office (JRO) for Chemical, Biological, Radiological, and Nuclear Defense</td>
<td>Chief, Nuclear Detection Technology Division (RD-NTD) Defense Threat Reduction Agency (DTRA)</td>
</tr>
<tr>
<td>Signature 24 July 12</td>
<td>Signature 7/12</td>
</tr>
</tbody>
</table>

Note: CAPAT member’s signature represents an O6 level concurrence from their organization. If the CAPAT representative is not empowered at this level, he must coordinate the signature process within his organization in a timeframe that meets the TECMIPT master schedule. (Reference: Test and Evaluation Capabilities and Methodologies Integrated Process Team (TECMIPT) Standard Operating Procedure (SOP), December 2010)
Radiological/Nuclear CAPAT recommends approval of the TTOP. If an organization non-concurs, a dissenting position paper will be attached.

Signature of interagency partners represents concurrence of methodology for DoD standards.

### CONCURRENCE SHEET (2 of 2): INTER-AGENCY PARTNER(S)

| Department of Homeland Security (DHS)  
| Domestic Nuclear Detection Office (DNDO) |
| Signature | Date |
| ![Signature Image] | 31 MAY 12 |

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1.0 Scope/Application
This document provides test methods and minimum baseline performance requirements for radiation detection systems (i.e., Personal Radiation Detectors, Hand-held Radionuclide Identification devices, Backpack based Radiation Detection Systems, Vehicle Mounted Radiation Detection Systems, Airborne Radiological Detection, Identification, and Measurement System, Maritime-Based Radiation Detection System). It provides the basic test methodologies for developmental testing of acquisition program systems, for a standardized Rad/Nuc Commercial off the Shelf (COTS) test program, and for the sharing of test data across agencies. The inclusion of baseline requirements listed in this document are necessary for wide applicability of the test data for interagency use. However, different documented user performance requirements for acquisition programs will supersede the baseline performance requirements in the Test and Evaluation Capabilities and Methodologies Integrated Process Team (TEMIPT) Test Operations Procedure (TTOP). Other existing Test Operations Procedures (TOPs) (see References 44 to 53) may be added or new ones developed for additional required tests.

The radiation detection systems covered in this document were identified as having high priority for the different services. Dosimeters, both passive and active, are covered in a separate TTOP.

The test procedures outlined within this TTOP will cover radiation detection instruments used for gamma-ray and neutron detection as well as radionuclide identification. For some applications neutron detection and radionuclide identification capabilities may be optional.

This document is based on several Technical Testing and Evaluation Plans (TT&E) developed by the Defense Threat Reduction Agency (DTRA). These TT&E documents are based on American National Standard Institute/ Institute of Electrical and Electronics Engineers (ANSI/IEEE), Internal Electrotechnical Commission (IEC) and Military standards.

2.0 Word Usage
The following word usage applies:

- The word “shall” signifies a mandatory requirement (where appropriate, a qualifying statement is included to indicate that there may be an allowable exception).
- The word “may” signifies an acceptable method or an example of good practice.
- The word “should” signifies a recommended specification or method.

3.0 Limitations
This TTOP does not include the specific test procedures used by a specific testing laboratory.

The performance requirements and test methods described in this TTOP are focused on controlled tests. It includes radiological, environmental, electromagnetic and mechanical tests. This document does not cover field and operational testing.

Based on the priority list developed by the RN CAPAT, this document provides performance requirements and associated test methods for the following types of radiation detection systems:

- Personal Radiation Detectors (PRDs)
4.0 Intended Instrument Functionality

4.1 Personal radiation detectors (PRDs)
These instruments are pocket-sized and worn on the body for the purpose of rapid detection of radioactive materials. These instruments are used for detection of photon-emitting, and optionally neutron-emitting, radioactive substances for the purposes of detection, interdiction, and prevention.

These instruments are used to detect and alert the user of changes in the measured radiation background that are above a selectable alarm threshold setting. These instruments that are not intended to provide accurate measurements of dose equivalent, or dose equivalent rate. However, if available, these devices can provide an approximate value of exposure rate.

4.2 Hand-held radionuclide identification devices (RIDs)
RIDs are used to detect, localize, and identify radioactive/nuclear materials, as well as provide gamma exposure rate measurement to ensure radiation safety during the localization and radionuclide identification process. RIDs may also provide an indication of the presence of neutron radiation.

In accordance with their intended use, the main desired characteristics of RIDs are: sensitivity to gamma radiation, reliability of radionuclide identification and approximate exposure rate indication.

4.3 Backpack based radiation detection systems (BRDs)
BRDs are primarily worn by the user during operation. They may also be used temporarily as area monitors. BRDs shall detect gamma radiation and may include neutron detection and the identification of gamma-ray emitting radionuclides.

BRDs are mainly designed for covert detection of radioactive/nuclear materials. In addition to covert detection, these instruments are useful for measurements at locations where the standard approach for deployment of fixed installed and hand-held instruments is not feasible. The BRDs may be equipped with a global positioning system (GPS).

4.4 Vehicle Mounted Radiation Detection Systems (VMDS)
Vehicle mounted systems are mobile systems that are mounted to or inside a vehicle such as a trailer or a sport utility vehicle. Mobile systems are typically in operation on a platform that is in motion but they can also be used while stationary.
This type of systems shall detect gamma radiation and may include neutron detection and the identification of gamma-ray emitting radionuclides. They may be equipped with a GPS and provide a means to indicate the direction of the source relative to the instrument.

4.5 Airborne Radiological Detection, Identification, and Measurement System (ARDIMS)

Airborne radiation detection systems (ARDIMS) can be used in different platforms (e.g. helicopter, fixed-wing) and can be mounted inside or outside planes and/or helicopters during operation. ARDIMS shall measure and store radiation levels (e.g. count rate, exposure rate) to enable detection and localization of radioactive materials, including discrete radioactive sources as well as extended sources. Data obtained by these systems are typically used to map the radioactivity measured in an area.

Real time detection (i.e. alarm) and directionality (i.e. indicate the direction of the source relative to the instrument) are optional. Neutron detection and the identification of gamma-ray emitting radionuclides are also optional.

4.6 Maritime-Based Radiation Detection System (MBRDS)

Maritime based systems are mobile systems that are mounted to or inside a boat or a ship. Maritime systems are typically in operation on a platform that is in motion but they can also be used while stationary. Maritime based systems have additional environmental requirements compared to mobile systems mounted on vehicles.

This instrument type shall detect gamma radiation and may include neutron detection and the identification of gamma-ray emitting radionuclides. They may be equipped with a GPS and provide a means to indicate the direction of the source relative to the instrument.

5.0 Test Facilities

It is recommended that test facilities will be accredited to ISO 17025 or equivalent standards.

Test facilities should develop their own test procedures based on their capabilities and radioactive sources available to perform the required tests. Test procedures shall be based on the test methods described in this document.

All sources used for testing shall be traceable to national standards (i.e., NIST or equivalent).

5.1 List of Test Equipment Required for Testing of Radiation Detection Systems

To perform the tests listed in this document a test facility should have as a minimum the following test equipment:

- Radioactive sources
- Calibrated gamma-measurement instrument, such as a microrem meter or ionization chamber
- High Purity Germanium (HPGe) gamma-ray spectrometer
- Shielding material
- Phantoms
• Environmental chambers (temperature/humidity)
• Dust chamber
• Different spray nozzles for moisture testing
• Salt fog chamber
• Vibration tables (size will depend on radiation instrument tested)
• Spring hammer or equivalent device for impact test
• RF chamber (size will depend on radiation instrument tested)
• Antenna for radiated emission tests
• Magnetic field generator (e.g., Helmholtz coils)
• Electrostatic discharge (ESD) generator

Note that this test equipment may require additional instrumentation to calibrate and operate.

5.2 List of Test Facilities and Associated Capabilities
Several testing facilities have the infrastructure to perform all or part of the test methods listed in this document. See Annex D for more details.

5.3 Laboratory Accreditation Program
At present there is no laboratory accreditation program for the test requirements and methods described in this document.

There is a laboratory accreditation program (accreditation to ISO 17025) available for testing radiation detection systems against the ANSI/IEEE and IEC standards for homeland security application as well as detection of illicit trafficking of radioactive materials. This existing accreditation program is run by the National Voluntary Laboratory Accreditation Program (NVLAP). Some tests described in this document go beyond the ANSI/IEEE and IEC standards requirements and test methods.

6.0 Health & Safety
Health & Safety is covered by the regulations of each individual testing laboratory. This should be covered in the quality manual of the testing laboratory.

7.0 Default Performance Requirements
7.1 Documentation Requirements
Sections 7.1.1, 7.1.2, and 7.1.3 specify the requirements for documentation.

7.1.1 Manufacturer provided test report
The manufacturer shall provide a report covering the tests performed in accordance with the requirements of this document.

7.1.2 Certificate
The manufacturer shall provide a certificate or other documentation containing at least the following information:

— Contacts for the manufacturer including, but not limited to, name, address, telephone number, fax number, e-mail address, etc.
— Type of instrument, detector, and types of radiation the instrument is designed to measure
— Range of exposure rates the instrument is designed to measure
— Range of photon energies the instrument is designed to measure
— Reference points and reference orientation for radiation source used for testing
— Location and dimensions of the sensitive volumes of the detectors
— Response of the instrument to different appropriate radiation energies
— Results of tests for accuracy, linearity, and lower limit of detection
— Weight and dimensions of the instrument
— Power supply (battery) requirements
— Radionuclide library (if the instrument has radionuclide identification capability)
— Explanation of confidence index (if the instrument has radionuclide identification capability)
— Results of tests under environmental conditions
— Results of electrical and mechanical tests

7.1.3 **Operation and maintenance manuals**
The manufacturer shall supply an operational and maintenance manual containing at least the following information for the user:

— Operating instructions and restrictions
— Schematic electrical diagrams plus spare parts list and specifications
— Troubleshooting guide

7.2 **General Requirements**
These requirements are listed based on the instrument size and type of usage.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>PRD</th>
<th>RID</th>
<th>Backpacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>not exceed 400 g</td>
<td>No specific requirement</td>
<td>less than 20 lbs including the battery but without wireless communication and spectrometry capabilities</td>
</tr>
<tr>
<td>Size</td>
<td>20 cm in length, 10 cm in width, and 5 cm in thickness, excluding any clip, retaining device, or external alarm unless it is incorporated into another device</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Operating modes</td>
<td>No specific requirement</td>
<td>The instrument shall have at least two different operating modes as follows: <em>Routine mode</em>: an operating mode that includes detection and identification of</td>
<td>The manufacturer shall state the response (or integration) time for gross count measurements. This time is the interval over which the instrument checks for an alarm condition based on the measured</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>radionuclides, indication of neutron radiation, and exposure rate measurement. Restricted mode: a password controlled operating mode that when accessed, allows the user to control the parameters that can affect the result of a measurement (e.g., radionuclide library, routine function control, calibration parameters, alarm thresholds).</td>
<td></td>
<td>background.</td>
<td></td>
</tr>
<tr>
<td>Data communication</td>
<td>No specific requirement</td>
<td>It shall store data. It shall store at least 50 complete (unprocessed) spectra data sets. Be capable of writing data to external applications (e.g., GADRAS) Transfer full data sets in near real-time (within 5 minutes) to remote locations (e.g., through a USB port and/or SD Card). Ability to switch off or on wireless operation when a wireless, &quot;tethered&quot; controller is available. Ability to switch off or on GPS, when provided</td>
<td>BRDs shall have the ability to internally store at least 1000 complete data sets as initiated by the user. A data set shall contain the elements listed in Section 8.8 for gross counts and radionuclide identification. The instrument shall be able to provide near real time data (data packets) locally and to a remote location through wireless link. The real time data shall include: integrated dose, dose rate, count rate, and may have the ability to determine stay-time values (stay time will need to be defined based on permitted exposure level). Data packets containing real-time data shall be stored for remote viewing (not greater than 5 min delay) and for later transfer and review on a periphery device or remote location either through manual interface (e.g., USB or SD card) or through wireless interface. The monitor shall provide controlled access to real-time response data. Be capable of writing data to external applications (e.g., GADRAS) Transfer full data sets in near real-time (within 1 minutes) to remote locations. Have the capability to transmit data packets continuously. Be compatible with the MFK-R wireless platform. Notify operator of sustained loss of wireless connectivity within 5 minutes of loss of connectivity to the MFK-R and within 5 seconds to the user (local to the monitor). During loss of connectivity, be capable of storing data locally and to automatically transmit data once connectivity is reestablished. Ability for user to switch off or on wireless operation. Ability for user to switch off or on GPS.</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>Data format</td>
<td>If available, meet ANSI N42.42 requirements. See Section 8.8 for minimum information to be included in the file.</td>
<td>Stored data shall meet ANSI N42.42 requirements. See Section 8.8 for minimum information to be included in the file.</td>
<td>Type 1 encryption for wireless operations (Army solution); Navy does not want any classified equipment to accompany boarding parties.</td>
</tr>
<tr>
<td>Energy range</td>
<td>60 keV to 1.3 MeV</td>
<td>50 keV to 3 MeV</td>
<td>50 keV to 3000 keV</td>
</tr>
<tr>
<td>Exposure rate range (or dose rate range or count rate)</td>
<td>from 5 µR/h to not less than 2 mR/h</td>
<td>No specific requirement, as stated by the manufacturer</td>
<td>No specific requirement, as stated by the manufacturer</td>
</tr>
<tr>
<td>Exposure (or dose) range</td>
<td>No specific requirement</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detector type</td>
<td>Provided by manufacturer</td>
<td>Provided by manufacturer</td>
<td>Provided by manufacturer</td>
</tr>
<tr>
<td>Reference point marking</td>
<td>on the front or back and on the side indicating the effective center of the detector and orientation with respect to wearer</td>
<td>The reference point for the detector shall be marked. Location of the effective center(s) or area(s) of detection (reference point) shall be marked.</td>
<td>The reference point for the detector shall be marked. Location of the effective center(s) or area(s) of detection (reference point) shall be marked.</td>
</tr>
<tr>
<td>Mounting or fitting requirements (e.g. clips, lanyards, straps)</td>
<td>The instrument shall have clips or lanyards to securely fix the instrument to the user</td>
<td>Not applicable</td>
<td>Backpacks shall be designed to: Distribute weight, as much as practical, front to back for good balance, Be easy to remove, Be easy to repair, Look like a normal backpack to the maximum extent practical, Have generous openings around arms, and Have some means to affix ID across the back. Backpacks shall have: Light padding when worn without ballistic protection, A strap on the back to grab for emergency access, Sturdy shoulder pads, and Molly straps on back</td>
</tr>
<tr>
<td>Explosives atmospheres</td>
<td>If claimed, based on UL-913</td>
<td>If claimed, based on UL-913</td>
<td>If claimed, based on UL-913</td>
</tr>
<tr>
<td>Alarms</td>
<td>It shall not be possible to disable all alarms at the same time</td>
<td>Shall have user selectable exposure rate alarm thresholds</td>
<td>Shall have user selectable exposure rate alarm thresholds</td>
</tr>
<tr>
<td>Visual alarm</td>
<td>It shall be activated when exposed to a radiation field above the alarm threshold</td>
<td>It shall be activated when exposed to a radiation field above the alarm threshold.</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Audible alarm</td>
<td>The frequency range within 1000 Hz to 4000 Hz. If an intermittent alarm is provided, the signal interval shall not exceed 2 s. The A-weighted alarm volume at a distance of 30 cm from the alarm source shall be at least 85 dB(A) and shall not exceed 100 dB(A).</td>
<td>A mutable audible indication proportional to the exposure rate shall be available. For the test of the gamma alarm threshold shall be set to 1 mR/h and the instrument shall be exposed to 125Cs to an exposure rate of 2 mR/h.</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Vibration alarm</td>
<td>The use of soft-sided</td>
<td>Not applicable</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>carrying pouches is discouraged. If a holder is used, there should be no loss of vibration intensity to the user. The intensity of the vibration at the surface of the instrument shall be greater than 0.8 g.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel protection alarm</td>
<td>Not applicable</td>
<td>An alarm shall be provided to alert the user that indicated exposure rates are above a user-selected threshold level. The alarm shall be both audible and visual, and shall be adjustable through the restricted mode. The alarm shall have an “acknowledge” or other similar control to silence the audible function. It shall not be possible to switch off all alarm indicators at the same time</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Controls</td>
<td>user-friendly for routine operation and capable of operation if the user is wearing thermal gloves</td>
<td>Controls should be user-friendly for routine operation and should have a menu structure that is simple and easy to be followed intuitively. Controls and switches should be designed in a way to minimize accidental operation when the user is wearing gloves (thermal type). Ability to instantly go silent (mute radio emissions, acoustical emissions, and perceptible vibrations).</td>
<td>Controls should be user-friendly for routine operation and should have a menu structure that is simple and easy to be followed intuitively. Controls and switches should be designed in a way to minimize accidental operation when the user is wearing gloves (thermal type). Ability to instantly go silent (mute radio emissions, acoustical emissions, and perceptible vibrations).</td>
</tr>
<tr>
<td>Display</td>
<td>Radiation levels should be displayed using one or more of the following methods: - Digital display: exposure or dose rate (µR/h, cGy/h, mrem/h, µSv/h). - Unit-less display - Non-numerical display The display shall be readable in low (&lt;150 lux) and high light levels (&gt;10 000 lux) and at all operational temperatures</td>
<td>A display that is easily readable over the required temperature range of -40 °C to 60 °C and under different lighting conditions (low (&lt;150 lux) and high light levels (&gt;10 000 lux)) A display/controller (e.g., PDA) that may be removed from the instrument for un-tethered operation Ability to display GPS and detector response data on same display Ability to retain previous background levels (e.g., archive background by GPS coordinates) Significant changes in the measured exposure rate shall be indicated visually and shall be proportional to the exposure rate.</td>
<td>A display that is easily readable over the required temperature range of -40 °C to 60 °C and under different lighting conditions (low (&lt;150 lux) and high light levels (&gt;10 000 lux)) A display/controller (e.g., PDA) that may be removed from the instrument for un-tethered operation Ability to display GPS and detector response data on same display Ability to retain previous background levels (e.g., archive background by GPS coordinates) Significant changes in the measured exposure rate shall be indicated visually and shall be proportional to the exposure rate.</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
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<tr>
<td>measured exposure rate shall be indicated visually and shall be proportional to the exposure rate.</td>
<td>All external instrument controls, displays, and adjustments shall be identified as to function. Internal controls shall be identified through markings and identification in technical manuals. External markings shall be easily readable and permanently fixed under normal conditions of use including the use of standard chemical agent decontaminates. The following markings shall appear on the exterior of the instrument or each major subassembly as appropriate: - Manufacturer and model number - Unique serial number</td>
<td></td>
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</tr>
<tr>
<td>Instrument Marking</td>
<td>manufacturer’s name, model, serial and firmware numbers</td>
<td>All external instrument controls, displays, and adjustments shall be identified as to function. Internal controls shall be identified through markings and identification in technical manuals. External markings shall be easily readable and permanently fixed under normal conditions of use including the use of standard chemical agent decontaminates. The following markings shall appear on the exterior of the instrument or each major subassembly as appropriate: - Manufacturer and model number - Unique serial number - Function designation for controls, switches, and adjustments that are not menu or software driven.</td>
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</tr>
<tr>
<td>Batteries and Battery lifetime</td>
<td>Batteries used shall be widely available, shall not be unique to the instrument, and shall be replaceable in the field without the use of special tools. The batteries shall be capable of powering the instrument in a non-alarm state for 16 h in a 50 µR/h field. The batteries shall be capable of powering the instrument alarm continuously for 30 min. The instrument shall have a low battery indicator.</td>
<td>The instrument shall have the ability to support a continuous mission time of 8 hours on battery power using a combination of internal and external batteries. The low-battery indication shall be no lower than the minimum voltage required for proper operation. Instruments shall be equipped with a test circuit or other visible direct indicator of battery condition for each battery circuit. The battery test shall duplicate the load appropriate for the device to ensure battery functionality. The manufacturer shall state the expected continuous operating time using the recommended batteries and the conditions (functional and environmental) used to determine this time. The instrument shall be capable of operating from an external DC source with a voltage from 11 – 28 VDC. Adequate protection from reverse polarity, over-voltage, and electrical noise must be provided. Rechargeable-type batteries shall be recharged within 4 hours.</td>
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<tr>
<td></td>
<td>The instrument shall have the ability to support a continuous mission time of 8 hours on battery power using “hot swappable battery(s). Access to the battery compartment shall be capable without special tools. The low-battery indication shall be no lower than the minimum voltage required for proper operation. BRDs shall be equipped with a test circuit or other visible direct indicator of battery condition for each battery circuit. The battery test shall duplicate the load appropriate for the device to ensure battery functionality. The manufacturer shall state the expected continuous operating time using the recommended batteries and the conditions (functional and environmental) used to determine this time. The instrument shall be capable of operating from an external DC source with a voltage from 11 – 28 VDC. Adequate protection from reverse polarity, over-voltage, and electrical noise must be provided. Rechargeable-type batteries shall be recharged within 4 hours.</td>
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<td>Requirement</td>
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<td>RID</td>
<td>Backpacks</td>
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<tr>
<td>Power supply</td>
<td>Not applicable</td>
<td>Battery chargers shall meet US electrical standards. The instrument shall be capable of operating from single phase AC power with voltage between 110V – 240V and frequency from 47Hz – 63Hz.</td>
<td>A lamp or similar device shall be available to indicate when the batteries are fully charged.</td>
</tr>
<tr>
<td>Stabilization or warm-up time</td>
<td>Stated by manufacturer or less than 1 minute</td>
<td>The manufacturer shall state the time required for the instrument to become fully functional from either a dead start or when in a standby mode. The maximum time shall be less than 2 minutes. NOTE – For cooled HPGe detector systems, it is assumed that the detector is already cooled.</td>
<td>The manufacturer shall state the time required for the instrument to become fully functional. The maximum time shall be less than 10 minutes.</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>It shall have the ability to self-calibrate, monitor functionality, and diagnose malfunctions without user interaction.</td>
<td>The instrument shall have the ability to self-calibrate, monitor functionality, and diagnose malfunctions without user interaction.</td>
<td>The instrument shall have the ability to self-calibrate, monitor functionality, and diagnose malfunctions without user interaction. BRDs shall be capable of operating independently of any peripheral device or remote station and shall be unaffected by any malfunction of a peripheral device.</td>
</tr>
<tr>
<td>Radionuclide library</td>
<td>Not applicable</td>
<td>It shall have a user-definable radionuclide library with access via the restricted mode</td>
<td>It shall have a user-definable radionuclide library with access via the restricted mode. Radionuclide identification capability is optional.</td>
</tr>
<tr>
<td>Time to perform a radionuclide identification</td>
<td>Not applicable</td>
<td>Within the manufacturer stated identification time or 2 minutes whichever is the shorter</td>
<td>Within the manufacturer stated identification time or 1 minute whichever is the shorter</td>
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</table>

Table 2: Vehicle mounted mobile systems – General Requirements

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<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
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<tbody>
<tr>
<td>Weight</td>
<td>No specific requirement.</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
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<tr>
<td>Size</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
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<tr>
<td>Operating modes</td>
<td>The instrument shall be designed to continuously measure ambient radiation levels and provide an indication when the radiation level increases to a level that is above a set point when the instrument is working either a stationary (i.e. instrument and vehicle not moving), or mobile mode (i.e. instrument and vehicle moving). For testing purposes, the stationary mode the sources are moved past the instrument. And for mobile</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
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<tr>
<td><strong>Data communication</strong></td>
<td>The instrument shall be capable of operating independently of any peripheral device or remote station that is not an essential component of the instrument and shall be unaffected by any malfunction of a peripheral device (e.g., MFK-R).</td>
<td>Data flow from each detection module to the user interface shall be through an EMI resistant cable.</td>
<td>The instrument shall have the ability to internally store at least 1000 complete data sets as initiated by the user.</td>
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<td></td>
<td>The VMDS shall have the ability to store at least 1000 complete data sets or not less than 3 hours of data.</td>
<td>The ARDIMS shall have the ability to store data for at least one mission or 3 h.</td>
<td>For the communication interface, the monitor must meet the following requirements:</td>
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<td></td>
<td>Data flow from the detection module to the user interface shall be through an EMI resistant cable.</td>
<td>The ARDIMS shall be able to provide data to an MFK-R. The ARDIMS data format shall be based on ANSI N42.42.</td>
<td>- Meet the data format requirements as defined in ANSI N42.42</td>
</tr>
<tr>
<td></td>
<td>The VMDS shall be able to provide data through a USB or Ethernet connection to an MFK-R.</td>
<td>The ARDIMS shall notify the operator of sustained loss of connectivity within 5 s if there is a loss of connectivity between the detection module and the controller.</td>
<td>- Have the capability to transfer full data sets in near real-time (within 1 minute) to remote locations through wireless communication link, and either USB port or SD Card.</td>
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<td></td>
<td>The VMDS shall notify the operator of sustained loss of connectivity within 5 minutes of loss of connectivity to the MFK-R and within 5 seconds if there is a loss of connectivity between the trailer components and the controller (user display).</td>
<td>The user should have the ability to switch on or off the GPS.</td>
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<td></td>
<td>The user shall also have the ability to switch on or off the GPS.</td>
<td>The following is a list of requirements for the VMDS interface to the MFK-R:</td>
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<td></td>
<td>The following is a list of requirements for the VMDS interface to the MFK-R:</td>
<td>When the VMDS is not towed by the HMMWV, or the VMDS is being used as an unattended “stand alone” detector, it is desired that an NS node on the wireless MFK-R STIRS network be used to monitor VMDS output. Displayed information shall include:</td>
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<td>- Time and date in GMT format and should include local offset.</td>
<td>- Time and date in GMT format and should include local offset.</td>
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<tr>
<td></td>
<td>- VMDS identification.</td>
<td>- VMDS identification.</td>
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<td></td>
<td>- Location and movement speed (GPS).</td>
<td>- Location and movement speed (GPS).</td>
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<td></td>
<td>- Alarm type (gamma-ray and/or neutron) and level (count rate).</td>
<td>- Alarm type (gamma-ray and/or neutron) and level (count rate).</td>
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<tr>
<td></td>
<td>- Background (gamma and neutron) count rate,</td>
<td>- Background (gamma and neutron) count rate,</td>
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<td></td>
<td>- Radionuclide identification results (when applicable).</td>
<td>- Radionuclide identification results (when applicable).</td>
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<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
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<tr>
<td>Data format</td>
<td>Stored data shall meet ANSI N42.42 requirements. See Section 8.8 for minimum information to be included in the file.</td>
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</tr>
<tr>
<td>Energy range</td>
<td>50 keV to 3000 keV</td>
<td>50 keV to 3000 keV</td>
<td>No specific requirement, the manufacturer shall state the range</td>
</tr>
<tr>
<td>Exposure rate range (or dose rate range or count rate)</td>
<td>No specific requirement, the manufacturer shall state the range for gamma-ray count rate measurement and for neutron count rate indication.</td>
<td>No specific requirement, the manufacturer shall state the range for gamma-ray count rate measurement and for neutron count rate indication.</td>
<td>No specific requirement, the manufacturer shall state the range for gamma-ray count rate measurement and for neutron count rate indication.</td>
</tr>
<tr>
<td>Exposure (or dose) range</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detector type</td>
<td>Provided by manufacturer</td>
<td>Provided by manufacturer</td>
<td>Provided by manufacturer</td>
</tr>
<tr>
<td>Reference point marking</td>
<td>The reference point for the detector shall be marked.</td>
<td>The reference point for the detector shall be marked. Location of the effective center(s) or area(s) of detection (reference point) shall be marked.</td>
<td>No specific requirement</td>
</tr>
<tr>
<td>Mounting or fitting requirements (e.g. clips, lanyards, straps)</td>
<td>The manufacturer shall provide a description of the method used to attach, remove, and transport the detection module. Examine the module to verify that it is designed to be removable with limited (commercial off-the-shelf) tools and that shock absorption material is used to reduce shock and vibration transients to the sensitive components such as the radiation detectors or computer assemblies. Document any defects or other damage that may be observed. The VMDS (trailer component) shall be designed to meet the military requirements for that specific trailer platform. When mounted in the trailer, the detection module shall be designed to distribute weight evenly across the axle for highway stability. The tongue weight shall also be defined and provided by the manufacturer, and be acceptable for the tow vehicle hitch assembly. The VMDS shall be modular in design to permit assembly and disassembly. The VDS should consist of a detection module, power generator, batteries, and controller. The controller shall be provided by manufacturer, and be designed to meet the military requirements for items mounted to a helicopter platform. Helicopters include Bell 412 (~UH-1H), UH-60, and AV-8B, or MQ-8B. Mounting instructions shall be provided by manufacturers. The internal components of the detection module shall be positioned such that the weight is distributed evenly throughout the module. The ARDIMS should consist of a detection module and controller that will typically be powered by the helicopter. The controller shall be tethered to the unit and will typically be placed in the crew area of the helicopter. Data flow from each detection module to the user interface shall be through an EMI resistant cable.</td>
<td>The ARDIMS shall be designed to meet the military requirements for items mounted to a helicopter platform. Helicopters include Bell 412 (~UH-1H), UH-60, and AV-8B, or MQ-8B. Mounting instructions shall be provided by manufacturers. The internal components of the detection module shall be positioned such that the weight is distributed evenly throughout the module. The ARDIMS should consist of a detection module and controller that will typically be powered by the helicopter. The controller shall be tethered to the unit and will typically be placed in the crew area of the helicopter. Data flow from each detection module to the user interface shall be through an EMI resistant cable.</td>
<td>No specific requirement</td>
</tr>
</tbody>
</table>

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<table>
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<tr>
<th>Requirement</th>
<th>Ground</th>
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<th>Maritime</th>
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<tr>
<td></td>
<td>shall be tethered to the unit and will typically be placed in the passenger area of the tow vehicle.</td>
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<td>If claimed, based on UL-913</td>
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<td>Explosives atmospheres</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
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<td></td>
<td>Shall have a user-selectable radiation indication alarm type</td>
<td>Shall have a user-selectable exposure rate alarm threshold</td>
<td>Ability to instantly go silent (mute radio emissions, acoustical emissions, and perceptual vibrations)</td>
</tr>
<tr>
<td>Alarms</td>
<td>The user shall have the ability to control and mute the volume of audible alarms</td>
<td>The user shall have the ability to control and mute the volume of audible alarms</td>
<td>The user shall have the ability to mute audible alarms</td>
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<tr>
<td>Visual alarm</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
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<td>Audible alarm</td>
<td>The user shall have the ability to control and mute the volume of audible alarms</td>
<td>The user shall have the ability to control and mute the volume of audible alarms</td>
<td>The user shall have the ability to mute audible alarms</td>
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<tr>
<td>Vibration alarm</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
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<tr>
<td>Personnel protection alarm</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
<td>No specific requirement</td>
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<tr>
<td>Controls and user interface</td>
<td>Controls and switches that are designed in a way to minimize accidental operation when the user is wearing gloves (thermal type). Controls should be user-friendly for routine operation and a menu structure that is simple and easy to be followed intuitively. The user shall have the ability to perform a background update and initiate a radionuclide identification (if applicable)</td>
<td>Controls and switches that are designed in a way to minimize accidental operation when the user is wearing gloves (thermal type). Controls should be user-friendly for routine operation and a menu structure that is simple and easy to be followed intuitively. The user shall have the ability to perform a background update and initiate a radionuclide identification (if applicable)</td>
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</tr>
<tr>
<td>Display and indications</td>
<td>A display/controller (e.g., PDA, laptop) that can be removed from the vehicle for tethered operation to the module. A display that is easily readable over the required temperature range of -40 ºC to 60 ºC, under different lighting conditions (low (&lt;150 lux) and high light levels (&gt;10 000 lux)) Shall have the ability to display radionuclide identification results and spectrum The ability to change readout (exposure rate and/or identification results) display font sizes, The ability to display GPS and detector response data on same display, The ability to retain previous background levels (e.g.,</td>
<td>A display/controller (e.g., PDA, laptop) that can be removed from the helicopter for tethered operation to the module, A display that is easily readable over the required temperature range of -40 ºC to 60 ºC and under different lighting conditions (low (&lt;150 lux) and high light levels (&gt;10 000 lux)) Shall have the ability to display radionuclide identification results Shall provide an indication that the radiation background has changed to the extent that it could impact instrument sensitivity. Shall have a detector status indicators, including: - high/low detector rate counts, - detector failure, and - energy stabilization.</td>
<td>A display that is easily readable over the required temperature range of -40 ºC to 60 ºC and under different lighting conditions (low (&lt;150 lux) and high light levels (&gt;10 000 lux)) Shall have the ability to display radionuclide identification results Shall provide an indication that the radiation background has changed to the extent that it could impact instrument sensitivity. Shall have a detector status indicators, including: - high/low detector rate counts, - detector failure, and - energy stabilization.</td>
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<tbody>
<tr>
<td>archive background by GPS</td>
<td>Shall have a radiation overload indication</td>
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<td>coordinates),</td>
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<td>An indication that the</td>
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<td>radiation background has</td>
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<td>changed to the extent that</td>
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<td>it could impact instrument</td>
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<td>sensitivity</td>
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<td>Detector status indicators,</td>
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<td>including:</td>
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<td>- high/low detector rate</td>
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<td>counts,</td>
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<td>- detector failure, and</td>
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<td>- energy stabilization.</td>
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<td>Battery status indicators,</td>
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<td>including low power or power</td>
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<td>loss</td>
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<td>Excessive speed</td>
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<td>Radiation overload</td>
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<td>Instrument Marking</td>
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<td>All external instrument</td>
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<td>controls, displays, and</td>
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<td>adjustments shall be</td>
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<td>identified as to function.</td>
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<td>Internal controls shall be</td>
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<td>identified through markings</td>
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<td>and identification in</td>
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<td>technical manuals.</td>
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<td>External markings shall be</td>
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<td>easily readable and</td>
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<td>permanently fixed under</td>
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<td>normal conditions of use</td>
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<td>including the use of standard</td>
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<td>chemical agent decontaminates</td>
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<td>The following markings shall</td>
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<td>appear on the exterior of</td>
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<td>the instrument or each major</td>
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<td>subassembly as appropriate:</td>
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<tr>
<td>- Manufacturer and model</td>
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<td>number</td>
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<tr>
<td>- Unique serial number</td>
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<tr>
<td>Batteries and Battery</td>
<td>The VMDS shall have the ability to support a continuous mission time of</td>
<td>No specific requirement</td>
<td>The instrument shall have the ability</td>
</tr>
<tr>
<td>lifetime</td>
<td>8 hours on trailer-mounted battery power. It is desirable that the VMDS</td>
<td></td>
<td>to support a continuous mission time of 8 hours on battery power using</td>
</tr>
<tr>
<td></td>
<td>have the ability to operate for 24 hours</td>
<td></td>
<td>“hot swappable” battery(s).</td>
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<td></td>
<td>Access to the battery compartment shall be capable without special</td>
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<td>tools.</td>
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<td></td>
<td>The low-battery indication shall be no lower than the minimum</td>
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<td></td>
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<td></td>
<td>voltage required for proper operation.</td>
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<td>The battery compartment shall be accessible using COTS tools.</td>
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<td>The VMDS shall be operational while the batteries are being charged.</td>
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<td>The manufacturer shall state the expected continuous operating time</td>
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<td>using the recommended batteries and the conditions (functional and</td>
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<td>environmental) used to determine</td>
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</tbody>
</table>

**Table:**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>archive background by GPS</td>
<td>Shall have a radiation overload indication</td>
<td></td>
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<tr>
<td>coordinates),</td>
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<td>An indication that the</td>
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<td>radiation background has</td>
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<td>changed to the extent that</td>
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<td>it could impact instrument</td>
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<tr>
<td>sensitivity</td>
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<td>Detector status indicators,</td>
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<td>including:</td>
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<td>- high/low detector rate</td>
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<td>counts,</td>
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<tr>
<td>- detector failure, and</td>
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<td>- energy stabilization.</td>
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<tr>
<td>Battery status indicators,</td>
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<td>including low power or power</td>
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<td>loss</td>
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<tr>
<td>Excessive speed</td>
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<td>Radiation overload</td>
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<tr>
<td>Instrument Marking</td>
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<tr>
<td>All external instrument</td>
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<tr>
<td>controls, displays, and</td>
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<tr>
<td>adjustments shall be</td>
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<tr>
<td>identified as to function.</td>
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<tr>
<td>Internal controls shall be</td>
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<td>identified through markings</td>
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<td>and identification in</td>
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<td>technical manuals.</td>
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<tr>
<td>External markings shall be</td>
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<td>easily readable and</td>
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<td>permanently fixed under</td>
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<td>normal conditions of use</td>
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<td>including the use of standard</td>
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<td>chemical agent decontaminates</td>
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<td>The following markings shall</td>
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<td>appear on the exterior of</td>
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<td>the instrument or each major</td>
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<td>subassembly as appropriate:</td>
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<tr>
<td>- Manufacturer and model</td>
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<td>number</td>
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<td>environmental) used to determine</td>
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</tbody>
</table>

**Unclassified**
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<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td>The generator shall meet US electrical standards.</td>
<td>The ARDIMS shall have the ability to operate from onboard power.</td>
<td>Rechargeable-type batteries shall be recharged within 4 hours.</td>
</tr>
<tr>
<td></td>
<td>If the instrument is capable of operating from single phase AC power, then it shall operate with voltage between 100V – 240V and frequency from 47Hz – 63Hz.</td>
<td>It is desirable that the ARDIMS have the ability to accept AC or DC power. If provided, switching between power sources should be automatic and require minimal user actions.</td>
<td>The instrument shall be capable of operating from single phase AC power with voltage between 100V – 240V and frequency from 47Hz – 63Hz.</td>
</tr>
<tr>
<td></td>
<td>It is desirable that the VMDS have the ability to accept AC or DC power. If provided, switching between power sources should be automatic and require minimal user actions.</td>
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<tr>
<td></td>
<td>The generator shall meet US electrical standards.</td>
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<td></td>
<td>The generator shall have the ability to run from JP-8.</td>
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<tr>
<td>Stabilization or warm-up time</td>
<td>The manufacturer shall state the time required for the instrument to become fully functional. The maximum time shall be less than 10 minutes.</td>
<td>The manufacturer shall state the time required for the instrument to become fully functional. The maximum time shall be less than 10 minutes.</td>
<td>The manufacturer shall state the time required for the instrument to become fully functional. The maximum time shall be less than 10 minutes.</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>The instrument shall have the ability to self-calibrate, monitor functionality, and diagnose malfunctions without user interaction.</td>
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<td>The instrument shall have the ability to self-calibrate, monitor functionality, and diagnose malfunctions without user interaction.</td>
</tr>
<tr>
<td></td>
<td>The instrument shall be capable of operating independently of any peripheral device or remote station that is not an essential component of the instrument and shall be unaffected by any malfunction of a peripheral device (e.g., MFK-R).</td>
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</tr>
<tr>
<td>Radionuclide library</td>
<td>It shall have a user-definable radionuclide library with access via the restricted mode. Radionuclide identification capability is optional.</td>
<td>Shall have a user-definable radionuclide library Radionuclide identification capability is optional.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Time to perform a radionuclide identification</td>
<td>Within the manufacturer stated identification time or 1 minute whichever is the shorter</td>
<td>Within the manufacturer stated identification time or 30 s whichever is the shorter</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

### 7.3 Radiological Requirements

These requirements are listed based on the instrument size and type of usage.
Table 3: Handheld and body-worn instruments – Radiological Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>PRD</th>
<th>RID</th>
<th>Backpacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>False alarm rate</td>
<td>1 alarm in 10 h when operated in a stable background environment</td>
<td>Not applicable</td>
<td>1 alarm over the time required to perform 1000 measurements when operated in a stable background environment. The measurement time will depend on the instrument integration or response time provided by the manufacturer or setup for the measurement. For example, if the instrument integration or response time is 5 s, the requirement is 1 alarm in 5000 s.</td>
</tr>
<tr>
<td>Response time</td>
<td>Not applicable</td>
<td>The instrument shall indicate an increase in exposure rate within 2 s, when exposed to an increase in the ambient exposure rate to 50 µR/h (using 137Cs) above the ambient background level, over a time period that is ≤ 0.5 sec. The displayed exposure rate indication shall be within ±50% of the new exposure rate within 5 s of the change. When the exposure rate is returned to its original level; the instrument shall indicate a decrease in the exposure rate within 2 s. The displayed exposure rate indication shall be within ±50% of the changed exposure rate within 5 s of the change.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Time-to-alarm photons</td>
<td>≤2 s after exposure to an increase in exposure rate of 50 µR/h using 137Cs, 241Am and 60Co</td>
<td>The alarm shall activate within 3 s of to an increased in exposure to 137Cs. For the test, the gamma alarm threshold shall be set to 1 mR/h and the instrument shall be exposed to a 137Cs source producing an exposure rate of 2 mR/h.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Time-to-alarm neutrons</td>
<td>≤2 s after exposure to 252Cf 2×10^3 neutrons/s ± 20% encapsulated in 1 cm steel plus 1 cm lead placed at 25 cm with PRD mounted on a 30 cm × 30 cm × 15 cm PMMA phantom</td>
<td>The neutron alarm shall activate within 2 s when the instrument is exposed to an unmoderated 252Cf neutron source with a flux of 2×10^4 n/s ± 20% (~0.01 µg) placed at 25 cm from the instrument.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detector response to gamma radiation – mobile mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>An alarm shall be triggered when the 241Am, 232Th, 137Cs, 133Ba, 60Co and 57Co sources move past the BRD at 1.2 m/s and a distance of 3 m. Source activities for this test are given in Table 15.</td>
</tr>
<tr>
<td>Detector response to gamma radiation – stationary mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>An alarm shall be triggered when the unmoderated and moderated 252Cf source move past the BRD at 1.2 m/s and a distance of 2 m. Source activities for this test are given in Table 15.</td>
</tr>
<tr>
<td>Detector response to neutron radiation – mobile mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
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<tr>
<td>----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Detector response to neutron radiation – stationary mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detection of gradually increasing radiation levels - Stopped</td>
<td>The PRD shall alarm in ≤2 s when a $^{137}$Cs source approaches at 0.5 m/s and stops at the position where the exposure rate is 50 µR/h above background</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>The PRD shall alarm in ≤2 s when the $2 \times 10^5$ neutrons/s ± 20% encapsulated in 1 cm steel plus 1 cm lead $^{252}$Cf source approaches at 0.5 m/s and stops at 10 cm from the PRD, with PRD mounted on a 30 cm × 30 cm × 15 cm PMMA phantom</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detection of gradually increasing radiation levels – Pass-by</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>The BRD’s alarm threshold shall not be affected by slowly increasing radiation levels that may be caused when a wearer is slowly approaching or is being approached by a radioactive source. An alarm shall be activated or the user shall be alerted that the background has changed within 2 s when the $^{137}$Cs reaches the parallel distance of 3 m and the unmoderated $^{252}$Cf reaches the parallel distance of 2 m, when the sources is moving through the centerline at a speed of 0.5 m/s. The background change alert shall be visual and/or audible (the type of alarm shall be user selectable), and shall be different than monitoring alarms.</td>
</tr>
<tr>
<td>Accuracy test for photons – Ambient dose equivalent rate or exposure rate</td>
<td>Displayed exposure rates shall be within ±30% of the conventionally true value of the applied exposure rate using $^{137}$Cs, for expose rates that are equivalent to 20%, 50%, and 80% of the response range of the instrument.</td>
<td>Displayed exposure rates shall be within ±30% of the conventionally true value of the applied exposure rate using $^{137}$Cs, for expose rates of 0.1 mR/h, 5 mR/h, and 80% of the manufacturer-stated maximum response.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Over-range response</td>
<td>The PRD indication shall remain at the maximum and an over-range indication shall be displayed when exposed to 2 times the maximum exposure rate specified by the manufacturer, using $^{137}$Cs. The instrument shall recover within 1 min when the radiation field is reduced.</td>
<td>The RID indication shall remain at the maximum and an over-range indication shall be displayed when exposed to 2 times the maximum exposure rate specified by the manufacturer, using $^{137}$Cs.</td>
<td>The BRD indication shall remain at the maximum and an over-range indication shall be displayed (e.g. an alarm indicating “high background” or “high counts”) when exposed to a radiation field that is greater than the manufacturer-stated maximum or a minimum of 10 mR/h when using $^{137}$Cs. The time required to return to non-alarm condition after the exposure rate is returned to background levels shall not be greater than 1 min.</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
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<td>-------------------------------------------------</td>
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</tr>
<tr>
<td>Neutron indication in the presence of photons</td>
<td>The PRD shall not indicate the presence of neutrons when exposed to a $^{137}$Cs radiation field of 10 mR/h. The neutron time-to-alarm shall not be affected by the $^{137}$Cs radiation field of 10 mR/h.</td>
<td>The RID shall not indicate the presence of neutrons when exposed to a $^{137}$Cs radiation field of as specified by the manufacture (if no value is specified a 10 mR/h field should be used). The neuron time-to-alarm shall not be affected by the gamma radiation field.</td>
<td>The BRD shall not indicate the presence of neutrons when exposed to a $^{60}$Co radiation field of as specified by the manufacture (if no value is specified a 10 mR/h field should be used). The neutron detection response to unmoderated $^{252}$Cf shall not be affected by the gamma radiation field.</td>
</tr>
<tr>
<td>Angular response to gamma radiation – mobile mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>An alarm shall be triggered when the $^{241}$Am, $^{228}$Th, $^{137}$Cs, $^{133}$Ba, $^{60}$Co and $^{51}$Co sources move through the centerline and around the BRD in the 2 orthogonal planes in 45° increments (360° of coverage in 2 orthogonal planes), at 1.2 m/s and a distance of 3 m. Source activities for this test are given in Table 15. NOTE – the rotation is around the centerline of the BRD when mounted on the phantom.</td>
</tr>
<tr>
<td>Angular response to gamma radiation – stationary mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>The BRD readings shall be within ±20% when compared to the reference reading (normal direction, 90° in Figure 8) for the $^{241}$Am, $^{137}$Cs, and $^{60}$Co sources when placed at the centerline and around the BRD in the horizontal plane in 45° increments (360° of coverage), at a distance of 3 m. Source activities for this test are given in Table 15. NOTE – the rotation is around the centerline of the BRD when mounted on the phantom.</td>
</tr>
<tr>
<td>Angular response to neutron radiation – mobile mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>An alarm shall be triggered when the unmoderated and moderated $^{252}$Cf source move through the centerline and around the BRD in the 2 orthogonal planes in 45° increments (360° of coverage in 2 orthogonal planes), at 1.2 m/s and a distance of 2 m. Source activities for this test are given in Table 15. NOTE – the rotation is around the centerline of the BRD when mounted on the phantom.</td>
</tr>
<tr>
<td>Angular response to neutron radiation – stationary mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>The BRD readings shall be within ±20% when compared to the reference reading (normal direction, 90° in Figure 8) for the moderated $^{252}$Cf source when placed at the centerline and around the BRD in the horizontal plane in 45° increments (360° of coverage), at a distance of 2 m. Source activities for this test are given in Table 15. NOTE – the rotation is around the centerline of the BRD when mounted on the phantom.</td>
</tr>
<tr>
<td>Determination of absolute counting efficiency</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Radionuclide identification general tests</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>An indication shall be displayed or otherwise provided (i.e., “not identified” Identification capabilities are optional. An indication shall be displayed or</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
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<tr>
<td>or “unknown”) if a radionuclide cannot be identified. The manufacturer shall describe the meaning of reliability or confidence indications. The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification. Manufacturers shall specify which analysis modes are available for instrument operation. Some examples are: - Region summing, - Peak fitting, - Least squares analysis of library spectra (both manufacturers and user supplied), - Automatic switching, - Operation of user supplied spectral analysis software, and/or - Other manufacturer spectral analysis techniques. These requirements shall be applied to each available mode, unless the instrument selects the analysis mode automatically.</td>
<td>otherwise provided (i.e., “not identified” or “unknown”) if a radionuclide cannot be identified. The manufacturer shall describe the meaning of reliability or confidence indications. The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification.</td>
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</tr>
</tbody>
</table>

<p>| Radionuclide library | Not applicable | The manufacturer shall state the radionuclides that the instrument can identify and their category. As a minimum the list shall contain the radionuclides listed in Table 15. The gamma-ray exposure rate at the reference point of the detector from each source shall be 50 µR/h. |
| Single radionuclide identification bare sources | Not applicable | The instrument shall be able to identify the following radionuclides within the time specified by the manufacturer with a maximum of 2 minutes. 57Co, 60Co, 67Ga, 99mTc, 131I, 133Ba, 137Cs, 192Ir, 201Tl, 226Ra, 232Th, U (HEU), U, 233Pu, 241Am. The gamma-ray exposure rate at the reference point of the detector from each source shall be 5 µR/h above background. |
| Single radionuclide identification shielded sources | Not applicable | The instrument shall be able to correctly identify the following radionuclides within the time specified by the manufacturer with a maximum of 2 minutes. Surrounded by a 5 mm steel shielding: 57Co, 60Co, 67Ga, 99mTc, 131I, 133Ba, 137Cs, 192Ir, 201Tl, 226Ra, 232Th, U (HEU), U, 233Pu, 241Am. The instrument shall be able to correctly identify the following radionuclides within the time specified by the manufacturer with a maximum of 1 minute: 133Ba, 137Cs and 60Co surrounded by 3 cm of steel. 67Ga, 99mTc and 131I surrounded by 8 cm of PMMA. |</p>
<table>
<thead>
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<th>Requirement</th>
<th>PRD</th>
<th>RID</th>
<th>Backpacks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simultaneous radionuclide</strong></td>
<td>Not applicable</td>
<td>The instrument shall be able to simultaneously identify $^{133}$Ba and RG PU when the exposure rate from each radionuclide is approximately 50 µR/h at the reference point of the instrument.</td>
<td>The gamma-ray exposure rate at the reference point of the detector from each source shall be 5 µR/h above background.</td>
</tr>
<tr>
<td><strong>Identification</strong></td>
<td>Not applicable</td>
<td>The instrument shall be able to simultaneously identify $^{133}$Ba and RG PU when the exposure rate from each radionuclide is approximately 50 µR/h at the reference point of the instrument.</td>
<td>The instrument shall be able to simultaneously identify the following source combinations: $^{99m}$Tc + DU, and $^{131}$I + WGP U when the exposure rate from each radionuclide is approximately 5 µR/h above background at the reference point of the instrument.</td>
</tr>
<tr>
<td><strong>Masking</strong></td>
<td>Not applicable</td>
<td>The instrument shall be able to identify the radionuclide of interest ($^{241}$Am and $^{60}$Co) in the presence of an increased gamma-ray background from natural thorium ($^{232}$Th) when the exposure rate from each radionuclide is approximately 50 µR/h at the reference point of the instrument.</td>
<td>The instrument shall be able to identify the radionuclide of interest (WGP U and DU) in the presence of an increased gamma-ray background for the following source combinations: $^{226}$Ra + $^{232}$Th + WGP U when the exposure rate from each radionuclide is approximately 5 µR/h above background at the reference point of the instrument.</td>
</tr>
<tr>
<td><strong>Interfering ionizing radiation</strong></td>
<td>Not applicable</td>
<td>The instrument shall identify $^{137}$Cs producing an exposure rate of 50 µR/h at the reference point of the instrument when exposed to the photons emitted from a shielded pure beta-emitting radionuclide such as $^{32}$P or $^{90}$Sr/$^{90}$Y producing a radiation field of 50 µR/h at the reference point of the instrument.</td>
<td>Not applicable</td>
</tr>
<tr>
<td><strong>Over-range characteristics</strong></td>
<td>Not applicable</td>
<td>The manufacturer shall state the maximum gamma-ray exposure rate (relative to $^{137}$Cs) for identification.</td>
<td>The manufacturer shall state the maximum gamma-ray exposure rate (relative to $^{137}$Cs) for identification.</td>
</tr>
<tr>
<td><strong>Identification with angle of</strong></td>
<td>Not applicable</td>
<td>It is also required for the instrument to identify $^{60}$Co while exposed to maximum exposure rate of $^{137}$Cs.</td>
<td>It is also required for the instrument to identify $^{60}$Co while exposed to maximum exposure rate of $^{137}$Cs.</td>
</tr>
<tr>
<td><strong>Variation of identification</strong></td>
<td>Not applicable</td>
<td>The identification of $^{241}$Am, $^{60}$Co and $^{137}$Cs radionuclides shall be acceptable over incident angles from 0° to ±45° from the vertical direction (i.e. for exposure rate of 50 µR/h of the</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Requirement</td>
<td>RID</td>
<td>Backpacks</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>False identification</td>
<td>Not applicable</td>
<td>The instrument shall not identify a radionuclide that is not present when operated in a stable and low ambient radiation background. An indication shall also be provided stating that the field is too low to perform an identification.</td>
<td></td>
</tr>
<tr>
<td>Shielded SNM identification</td>
<td>Not applicable</td>
<td>The instrument shall have the ability to detect and identify a significant quantity of SNM behind a 2.54 cm of Pb shield and in the presence of masking and/or naturally occurring radioisotopes using a count time of 1,000 seconds or less.</td>
<td></td>
</tr>
<tr>
<td>Interference from surrounding material</td>
<td>Not applicable</td>
<td>The instrument shall identify $^{137}$Cs producing an exposure rate of 500 µR/h at the reference point of the instrument when a $^{137}$Cs source is surrounded by steel 1 cm thick with an air gap around the source of approximately 5 cm.</td>
<td></td>
</tr>
<tr>
<td>Real time identification capabilities</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>This is optional. If available, the instrument shall be able to identify the following radionuclides within 5 seconds of exposure: $^{57}$Fe, $^{60}$Co, $^{65}$Zn, $^{66}$Zn, $^{67}$Zn, $^{68}$Zn, $^{90}$Mo, $^{131}$I, $^{133}$Ba, $^{137}$Cs, $^{192}$Ir, $^{226}$Ra, $^{232}$Th, $^{233}$U, $^{235}$U (HEU), $^{238}$U, $^{239}$Pu, $^{241}$Am. The gamma-ray exposure rate at the reference point of the detector from each source shall be 50 µR/h.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: Vehicle mounted mobile systems – Radiological requirements**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>False alarm rate</td>
<td>1 alarm in a 2 h period when operated in a stable background environment.</td>
<td>1 alarm in a 2 h period when operated in a stable background environment.</td>
<td>1 alarm in a 1 h period when operated in a stable background environment.</td>
</tr>
<tr>
<td>Response time</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Time-to-alarm photons</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Time-to-alarm neutrons</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detector response to gamma radiation – mobile mode</td>
<td>An alarm shall be triggered when the $^{252}$Th, $^{137}$Cs, $^{56}$Ba, $^{60}$Co and $^{65}$Co sources move past the VMDS at 2.22 m/s (5 mph) and a distance of 3 m. Source activities for this test are given in Table 15. For characterization purposes, the same measurements shall also be performed at 4.44 m/s (10 mph).</td>
<td>Systems are characterized using a $^{137}$Cs source with an activity between 4 to 5 mCi. The source shall be placed at 50 ft and 100 ft from the centerline of the detection assembly (zero displacement distance) and moved at a transient speed of 40 mph. Count rate and/or exposure rate values, alarms and radionuclides identified and spectra (if available) shall be recorded. Each module will be placed on an assembly that...</td>
<td>An alarm shall be triggered when $^{57}$Co, $^{137}$Cs, and $^{60}$Co sources produce an exposure rate of 50 µR/h and 5 µR/h at the detection assembly reference point and move at a speed of 2.6 m/s (~5 knots) at a minimum distance of 3 m from the reference point through the centerline of the instrument.</td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Detector response to gamma radiation – stationary mode</td>
<td>For characterization purposes, the detection efficiency for the $^{232}$Th, $^{137}$Cs, $^{241}$Am, $^{60}$Co and $^{57}$Co sources shall be measured when the sources placed at 10 m and 100 m from the VMDS, the measurement time shall be at least 2 min. Source activities for this test are given in Table 15.</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detector response to neutron radiation – mobile mode</td>
<td>An alarm shall be triggered when the unmoderated and moderated $^{252}$Cf source from Table 15 move pass the BRD at 2.22 m/s (5 mph) and a distance of 3 m. Source activities for this test are given in Table 15. For characterization purposes, the same measurements shall also be performed at 4.44 m/s (10 mph).</td>
<td>These are supposed to be characterization parameter not performance requirements, therefore count rate values, and alarms shall be recorded for the following test parameters: Each module will be placed on an assembly that represents a typical mounting assembly for a mission. The centerline of the mounting assembly (i.e. centered between each module) is going to be used as the reference point to measure distance. The moderated $^{252}$Cf source from Table 15 shall pass at a distance (or height) of 3 m, 5 m and 10 m from the centerline. For each of these distances the source will be moved at 5, 10, 20 and 40 mph. For 5 parallel positions or spacing relative to the centerline of the assembly (centerline, 3, 5, 10 and 15 cm).</td>
<td>An alarm shall be triggered when the unmoderated and moderated $^{252}$Cf source from Table 15 move at a speed of 2.6 m/s (~5 knots) at a minimum distance of 3 m from the reference point through the centerline of the instrument.</td>
</tr>
<tr>
<td>Detector response to neutron radiation – stationary mode</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detection of gradually increasing radiation levels - Stopped</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Detection of gradually increasing radiation levels – Pass-by</td>
<td>The alarm threshold shall not be affected by slowly increasing radiation levels that may be caused when VMDS is slowly approaching or is being approached by a radiation source. This requirement shall be met for the $^{137}$Cs listed in Table 15 moving at 0.44 m/s (1 mph) at a parallel distance of 3 m. The alarm shall be activated within 2 s of reaching the distance of closest approach.</td>
<td>Not applicable</td>
<td>The alarm threshold shall not be affected by slowly increasing radiation levels that may be caused when MBRDS is slowly approaching or is being approached by a radiation source. This requirement shall be met for the $^{137}$Cs listed in Table 15 moving at 0.5 m/s at a parallel distance of 3 m. The alarm shall be activated within 2 s of reaching the distance of closest approach.</td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Accuracy test for photons – Ambient dose equivalent rate or exposure rate</td>
<td>Displayed exposure rates shall be within ±30% of the conventionally true value of the applied exposure rate using 137Cs for 3 exposure rates in the range of 0.5 mR/h to 10 mR/h.</td>
<td>Displayed exposure rates shall be within ±30% of the conventionally true value of the applied exposure rate using 137Cs for 3 exposure rates in the range of 0.5 mR/h to 10 mR/h (testing shall take place at 0.5 mR/h, 5 mR/h, and 10 mR/h).</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Over-range response</td>
<td>If a VMDS is exposed to a radiation field produced by 137Cs that is greater than the manufacturer-stated maximum, it is desirable that an alarm indicating for example “over-range”, “high background” or “high counts” be activated and remains activated until the radiation field is reduced or the alarm is reset/acknowledged by the user. If the alarm can be reset/acknowledged by the user without the radiation field being reduced, a visual indication shall be provided indicating that the radiation field is still present. The time required to return to non-alarm condition after the exposure rate is returned to background levels shall not be greater than 1 min. If maximum exposure rate value is not provided by the manufacturer, testing shall be performed with a field of 20 mR/h above background.</td>
<td>If a ARDIMS is exposed to a radiation field produced by 60Co that is greater than the manufacturer-stated maximum, it is desirable that an alarm indicating for example “over-range”, “high background” or “high counts” be activated and remains activated until the radiation field is reduced or the alarm is reset/acknowledged by the user. If the alarm can be reset/acknowledged by the user without the radiation field being reduced, a visual indication shall be provided indicating that the radiation field is still present. The time required to return to non-alarm condition after the exposure rate is returned to background levels shall not be greater than 1 min. If maximum exposure rate value is not provided by the manufacturer, testing shall be performed with a field of 10 mR/h above background.</td>
<td>If a MBRDS is exposed to a radiation field produced by 60Co that is greater than the manufacturer-stated maximum, it is desirable that an alarm indicating for example “over-range”, “high background” or “high counts” be activated and remains activated until the radiation field is reduced or the alarm is reset/acknowledged by the user. If the alarm can be reset/acknowledged by the user without the radiation field being reduced, a visual indication shall be provided indicating that the radiation field is still present. The time required to return to non-alarm condition after the exposure rate is returned to background levels shall not be greater than 1 min. If maximum exposure rate value is not provided by the manufacturer, testing shall be performed with a field of 10 mR/h above background.</td>
</tr>
<tr>
<td>Neutron indication in the presence of photons</td>
<td>Gamma radiation produced by 137Cs at exposure rates up to 20 mR/h (or 10 mR/h using 60Co) shall not trigger the neutron alarm. In addition, the VMDS shall be able to detect an increase in neutron radiation while being exposed to gamma radiation.</td>
<td>Gamma radiation produced by 60Co at exposure rates up to 10 mR/h shall not trigger the neutron alarm. In addition, the ARDIMS shall be able to detect an increase in neutron radiation while being exposed to gamma radiation.</td>
<td>Gamma radiation produced by 60Co at exposure rates up to 10 mR/h shall not trigger the neutron alarm. In addition, the MBRDS shall be able to detect an increase in neutron radiation while being exposed to gamma radiation.</td>
</tr>
<tr>
<td>Angular response to gamma radiation – mobile mode</td>
<td>The VMDS shall provide an indication as to which side of the vehicle the source is detected. The minimum requirement is that the instrument indicates on which side of the vehicle the source is located. This requirement shall be met for the 57Co, 137Cs, and 60Co sources moving at 2.22 m/s and 3 m away from</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Angular response to gamma radiation – stationary mode</td>
<td>The VMDS shall provide an indication as to which side of the vehicle the source is detected. The minimum requirement is for the direction to be indicated with an angular resolution of ±90° about the position vector. This requirement shall be met for the 57Co, 137Cs, and 60Co sources placed at 3 m away from the centerline of the VMDS, for at least 1 min, with 30° increments to cover 360°. See Figure 3 for source locations.</td>
<td>Not applicable</td>
<td>The MBRDS may provide the ability to indicate the source direction relative to the direction of the detection assembly. When provided, the direction indicated by the instrument shall be within ±15° of the actual angle. This requirement shall be met for 57Co, 137Cs, and 60Co (from Table 15) placed at 3 m from the centerline of the detection assembly and the height of the source is at the centerline of the instrument for every 15° increments to cover 360°. The reference position (90°) shall be perpendicular to the transit direction of the boat.</td>
</tr>
<tr>
<td>Angular response to neutron radiation – mobile mode</td>
<td>The VMDS shall provide an indication as to which side of the vehicle the source is detected. The minimum requirement is that the instrument indicates on which side of the vehicle the source is located. This requirement shall be met for the unmoderated 252Cf source moving at 2.22 m/s and 3 m away from the centerline at vertical heights of 1m, 2 m and 3 m from the ground.</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Angular response to neutron radiation – stationary mode</td>
<td>The VMDS shall provide an indication as to which side of the vehicle the source is detected. The minimum requirement is for the direction to be indicated with an angular resolution of ±90° about the position vector. This requirement shall be met for the moderated 252Cf source placed at 3 m away from the centerline of the VMDS, for at least 1 min, with 15° increments to cover 360°. The horizontal centerline of the source shall be the same as the horizontal centerline of the module. The reference position (0°) shall be perpendicular to the transit direction of the towed</td>
<td>When the detection alarm is activated, an ARDIMS shall provide a directional response (360° of coverage over a single horizontal plane) of the source emissions relative to the direction of the detection assembly. This requirement shall be met for moderated 252Cf from Table 15 placed at 1 m from the centerline of the detection assembly (this is the distance or height) and at a radial distance of 2 m and 5 m in 45° increments, see Figure 2.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>Determination of absolute counting efficiency</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
| Radionuclide identification general tests        | Identification capabilities are optional.  
An indication shall be displayed or otherwise provided (i.e., “not identified” or “unknown”) if a radionuclide cannot be identified.  
The manufacturer shall describe the meaning of reliability or confidence indications.  
The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification. | Identification capabilities are optional.  
An indication shall be displayed or otherwise provided (i.e., “not identified” or “unknown”) if a radionuclide cannot be identified.  
The manufacturer shall describe the meaning of reliability or confidence indications.  
The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification. | Identification capabilities are optional.  
An indication shall be displayed or otherwise provided (i.e., “not identified” or “unknown”) if a radionuclide cannot be identified.  
The manufacturer shall describe the meaning of reliability or confidence indications.  
The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification. |
| Radionuclide library                             | The manufacturer shall state the radionuclides that the instrument can identify and their category. As a minimum the list shall contain the radionuclides listed in Table 15. | The manufacturer shall state the radionuclides that the instrument can identify and their category. As a minimum the list shall contain the radionuclides listed in Table 15. | The manufacturer shall state the radionuclides that the instrument can identify and their category. As a minimum the list shall contain the radionuclides listed in Table 15. |
| Single radionuclide identification bare sources  | The instrument shall be able to identify the radionuclides listed in Table 15 (except for 252Cf) within the time specified by the manufacturer with a maximum of 1 minute. The gamma-ray exposure rate at the reference point of the detector from each source shall be 5 µR/h.  
This requirement shall be met for sources moving at 2.22 m/s (5 mph).  
The instrument shall be characterized for sources moving at 4.44 m/s (10 mph). | The instrument shall be able to identify the radionuclides listed in Table 15 (except for 252Cf) within the time specified by the manufacturer with a maximum of 1 minute. The gamma-ray exposure rate at the reference point of the detector from each source shall be 10 µR/h. | The instrument shall be able to identify the radionuclides listed in Table 15 (except for 252Cf) within the time specified by the manufacturer with a maximum of 1 minute. The gamma-ray exposure rate at the reference point of the detector from each source shall be 10 µR/h. |
| Single radionuclide identification shielded sources | The instrument shall be able to correctly identify the following radionuclides within the time specified by the manufacturer with a maximum of 1 minute:  
133Ba,  
90Cs and  
60Co surrounded by 3 cm of steel.  
99mTc and  
131I surrounded by 8 cm of PMMA.  
The gamma-ray exposure rate at the reference point of the detector from each source shall be 5 µR/h. | Not applicable | Not applicable |
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>This requirement shall be met for sources moving at 2.22 m/s (5 mph). The instrument shall be characterized for sources moving at 4.44 m/s (10 mph).</td>
<td>The instrument shall be able to simultaneously identify the following source combinations: $^{99m}$Tc+ DU, and $^{131}$I+ WGPu when the exposure rate from each radionuclide is approximately 5 µR/h at the reference point of the instrument. This requirement shall be met for sources moving at 2.22 m/s (5 mph). The instrument shall be characterized for sources moving at 4.44 m/s (10 mph).</td>
<td>The instrument shall be able to simultaneously identify the following source combinations: $^{99m}$Tc+ DU, and $^{131}$I+ WGPu when the exposure rate from each radionuclide is approximately 10 µR/h at the reference point of the instrument.</td>
<td></td>
</tr>
<tr>
<td>Simultaneous radionuclide identification</td>
<td>The instrument shall be able to identify the radionuclide of interest (WGPu and DU) in the presence of an increased gamma-ray background for the following source combinations: $^{226}$Ra + $^{232}$Th + WGPu, $^{226}$Ra + $^{232}$Th + DU when the exposure rate from each radionuclide is approximately 5 µR/h at the reference point of the instrument. This requirement shall be met for sources moving at 2.22 m/s (5 mph). The instrument shall be characterized for sources moving at 4.44 m/s (10 mph).</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>Masking</td>
<td>The instrument shall be able to identify the radionuclide of interest (HEU and DU) in the presence of an increased gamma-ray background for the following source combinations: $^{226}$Ra + $^{232}$Th + HEU, $^{226}$Ra + $^{232}$Th + DU when the exposure rate from each radionuclide is approximately 10 µR/h at the reference point of the instrument. This requirement shall be met for sources moving at 2.22 m/s (5 mph). The instrument shall be characterized for sources moving at 4.44 m/s (10 mph).</td>
<td>The instrument shall be able to simultaneously identify the following source combinations: $^{99m}$Tc+ DU, and $^{131}$I+ WGPu when the exposure rate from each radionuclide is approximately 10 µR/h at the reference point of the instrument.</td>
<td></td>
</tr>
<tr>
<td>Interfering ionizing radiation (beta)</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Over-range characteristics for identification</td>
<td>The manufacturer shall state the maximum gamma-ray exposure rate (relative to $^{137}$Cs) for identification. If not provided it shall be 0.1 mR/h. It is also required for the instrument to identify $^{60}$Co producing a field of 5 µR/h while exposed to maximum exposure rate of $^{137}$Cs.</td>
<td>The manufacturer shall state the maximum gamma-ray exposure rate (relative to $^{137}$Cs) for identification. If not provided it shall be 0.1 mR/h. It is also required for the instrument to identify $^{60}$Co producing a field of 10 µR/h while exposed to maximum exposure rate of $^{137}$Cs.</td>
<td>The manufacturer shall state the maximum gamma-ray exposure rate (relative to $^{137}$Cs) for identification. If not provided it shall be 0.1 mR/h. It is also required for the instrument to identify $^{60}$Co producing a field of 10 µR/h while exposed to maximum exposure rate of $^{137}$Cs.</td>
</tr>
<tr>
<td>Variation of identification with angle of incidence</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>False identification</td>
<td>The instrument shall not be able to identify $^{60}$Co producing a field of 10 µR/h while exposed to maximum exposure rate of $^{137}$Cs.</td>
<td>The instrument shall not be able to identify $^{60}$Co producing a field of 10 µR/h while exposed to maximum exposure rate of $^{137}$Cs.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Requirement</td>
<td>Ground</td>
<td>Aerial</td>
<td>Maritime</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>identify a radionuclide that is not present when operated in a stable and low ambient radiation background, not more than 10 µR/h. An indication shall also be provided stating that the field is too low to perform an identification.</td>
<td>identify a radionuclide that is not present when operated in a stable and low ambient radiation background, not more than 10 µR/h. An indication shall also be provided stating that the field is too low to perform an identification.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shielded SNM identification</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Interference from surrounding material</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Real time identification capabilities</td>
<td>This is optional. If available, the instrument shall be able to identify the following radionuclides within 5 seconds of exposure. 67, Co, 60, Co, 67, Ga, 99m, Tc, I, 131, Ba, 133, Cs, 212, Ra, 232, Th, 235, U (HEU), 235, U, 239, Pu, 241, Am. The gamma-ray exposure rate at the reference point of the detector from each source shall be 50 µR/h.</td>
<td>This is optional. If available, the instrument shall be able to identify the following radionuclides within 5 seconds of exposure. 67, Co, 60, Co, 67, Ga, 99m, Tc, I, 131, Ba, 133, Cs, 212, Ra, 232, Th, 235, U (HEU), 235, U, 239, Pu, 241, Am. The gamma-ray exposure rate at the reference point of the detector from each source shall be 50 µR/h.</td>
<td>This is optional. If available, the instrument shall be able to identify the following radionuclides within 5 seconds of exposure. 67, Co, 60, Co, 67, Ga, 99m, Tc, I, 131, Ba, 133, Cs, 212, Th, 235, U (HEU), 235, U, 239, Pu, 241, Am. The gamma-ray exposure rate at the reference point of the detector from each source shall be 50 µR/h.</td>
</tr>
</tbody>
</table>

**Figure 1:** Diagram of parallel positions or spacing and distances for testing of aerial systems.
7.4 Environmental Requirements

These requirements are listed based on the instrument size and type of usage.

Table 5: Handheld and body-worn instruments – Environmental Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>PRD</th>
<th>RID</th>
<th>Backpacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature - operation</td>
<td>-40 °C to +60 °C</td>
<td>-40 °C to +60 °C</td>
<td>-40 °C to +60 °C</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Temperature - storage</td>
<td>-40 °C to +71 °C</td>
<td>-40 °C to +71 °C</td>
<td>-40 °C to +71 °C</td>
</tr>
<tr>
<td>Temperature shock</td>
<td>22 °C to -40 °C, -40 °C to</td>
<td>22 °C to -40 °C, -40 °C to</td>
<td>22 °C to -40 °C, -40 °C to 22 °C</td>
</tr>
<tr>
<td></td>
<td>22 °C, 22 °C to 60 °C,</td>
<td>22 °C, 22 °C to 60 °C,</td>
<td>22 °C to 60 °C, and 60 °C to 22 °C</td>
</tr>
<tr>
<td></td>
<td>and 60 °C to 22 °C</td>
<td>and 60 °C to 22 °C</td>
<td></td>
</tr>
<tr>
<td>Cyclic humidity</td>
<td>from 22 °C ± 2 °C and</td>
<td>from 22 °C ± 2 °C and</td>
<td>from 22 °C ± 2 °C and 40% RH cycle to:</td>
</tr>
<tr>
<td></td>
<td>40% RH cycle to:</td>
<td>40% RH cycle to:</td>
<td>- 60 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 60 °C and 93 ± 3 % RH</td>
<td>- 60 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 20 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 20 °C and 93 ± 3 % RH</td>
<td>- 20 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 60 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>and back to</td>
<td>and back to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 22 °C ± 2 °C and 40% RH</td>
<td>- 22 °C ± 2 °C and 40% RH</td>
<td></td>
</tr>
<tr>
<td>Condensing moisture</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Moisture and dust</td>
<td>Meet IP57 (IEC 60529)</td>
<td>Meet IP53 (IEC 60529)</td>
<td>Meet IP57 (IEC 60529) requirements</td>
</tr>
<tr>
<td>Low and high temperature start-up</td>
<td>Operational when switched</td>
<td>Operational when switched</td>
<td>Operational when switched on at -40 °C and 60 °C</td>
</tr>
<tr>
<td></td>
<td>on at -40 °C and 60 °C</td>
<td>on at -40 °C and 60 °C</td>
<td></td>
</tr>
<tr>
<td>Maritime environment</td>
<td>Salt fog as defined in MIL</td>
<td>Salt fog as defined in MIL</td>
<td>Salt fog as defined in MIL Standard 810.</td>
</tr>
<tr>
<td></td>
<td>Standard 810.</td>
<td>Standard 810.</td>
<td></td>
</tr>
<tr>
<td>Chemical protection</td>
<td>Operate following exposure</td>
<td>Operate following exposure</td>
<td>Operate following exposure to petroleum products</td>
</tr>
<tr>
<td></td>
<td>to petroleum products such</td>
<td>to petroleum products such</td>
<td>such as jet fuel (i.e., JP-5/8) and diesel fuel</td>
</tr>
<tr>
<td></td>
<td>as jet fuel (i.e., JP-5/8)</td>
<td>as jet fuel (i.e., JP-5/8)</td>
<td>(ground vehicles and marine).</td>
</tr>
<tr>
<td></td>
<td>and diesel fuel (ground</td>
<td>and diesel fuel (ground</td>
<td></td>
</tr>
<tr>
<td>Decontamination procedure survivability</td>
<td>Operate following standard</td>
<td>Operate following standard</td>
<td>Operate following standard chemical agent</td>
</tr>
<tr>
<td></td>
<td>chemical agent decontamination to include TICs and TIMS and radiological decontamination.</td>
<td>chemical agent decontamination to include TICs and TIMS and radiological decontamination.</td>
<td>decontamination to include TICs and TIMS and radiological decontamination.</td>
</tr>
</tbody>
</table>

Table 6: Vehicle mounted mobile systems – Environmental requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature - operation</td>
<td>-40 °C to +60 °C</td>
<td>-40 °C to +60 °C</td>
<td>-40 °C to +60 °C</td>
</tr>
<tr>
<td>Temperature - storage</td>
<td>-40 °C to +71 °C</td>
<td>-40 °C to +71 °C</td>
<td>-40 °C to +71 °C</td>
</tr>
<tr>
<td>Temperature shock</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Cyclic humidity</td>
<td>from 22 °C ± 2 °C and 40% RH</td>
<td>from 22 °C ± 2 °C and 40% RH</td>
<td>from 22 °C ± 2 °C and 40% RH cycle to:</td>
</tr>
<tr>
<td></td>
<td>cycle to:</td>
<td>cycle to:</td>
<td>- 60 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 60 °C and 93 ± 3 % RH</td>
<td>- 60 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 20 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 20 °C and 93 ± 3 % RH</td>
<td>- 20 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 30 °C and 93 ± 3 % RH</td>
<td>- 60 °C and 93 ± 3 % RH</td>
</tr>
<tr>
<td></td>
<td>and back to</td>
<td>and back to</td>
<td>- 22 °C ± 2 °C and 40% RH</td>
</tr>
<tr>
<td></td>
<td>- 22 °C ± 2 °C and 40% RH</td>
<td>- 22 °C ± 2 °C and 40% RH</td>
<td></td>
</tr>
<tr>
<td>Condensing moisture</td>
<td>Not applicable</td>
<td>The instrument shall be able</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to withstand exposure to a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>cyclic humidity and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>temperature environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>which causes condensing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>moisture, the cycle should</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>be from 22 °C and 40% RH,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to 22 °C and not less than 95%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>RH, to 55°C and not less</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>than 95% RH, to 25°C and not</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>less than 95% RH, repeat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the cycle by increasing to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>55°C and not less than</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>95% RH, to 25°C and not less</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>than 95% RH, to 25°C and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>not less than 95% RH, to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25°C and 75% RH, to 25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and 40% RH.</td>
<td></td>
</tr>
</tbody>
</table>
### 7.5 Electromagnetic and Power Requirements

These requirements are listed based on the instrument size and type of usage.

#### Table 7: Handheld and body-worn instruments – Electromagnetic and Power Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture and dust</td>
<td>The instrument is intended to operate with a cover installed on the M1102 trailer or inside a vehicle to conceal and protect detection system and other equipment attached to the trailer bed. Water ingress shall be minimal, the instrument without the trailer or vehicle shall meet IPx3 (IEC 60529) requirements.</td>
<td>Meet IP55 (IEC 60529) requirements</td>
<td>Meet IP55 (IEC 60529) requirements</td>
</tr>
<tr>
<td>Low and high temperature start-up</td>
<td>Operational when switched on at -40 °C and 60 °C</td>
<td>Operational when switched on at -40 °C and 60 °C</td>
<td>Operational when switched on at -40 °C and 60 °C</td>
</tr>
<tr>
<td>Maritime environment</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Salt fog as defined in MIL Standard 810.</td>
</tr>
<tr>
<td>Chemical protection</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Decontamination procedure survivability</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

#### Table 8: Vehicle mounted mobile systems – Electromagnetic and Power Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Frequency</td>
<td>Not affected by RF over a frequency range of 30 MHz to 18 GHz at an intensity of 50 V/m. (IEC 61000-4-3)</td>
<td>Not affected by RF over a frequency range of 30 MHz to 18 GHz at an intensity of 50 V/m. (IEC 61000-4-3)</td>
<td>Not affected by RF over a frequency range of 30 MHz to 18 GHz at an intensity of 50 V/m. (IEC 61000-4-3)</td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>Not affected by 10 Gauss (1 mT) direct current (DC) magnetic fields in all three mutually orthogonal orientations</td>
<td>Not affected by 10 Gauss (1 mT) direct current (DC) magnetic fields in all three mutually orthogonal orientations</td>
<td>Not affected by 10 Gauss (1 mT) direct current (DC) magnetic fields in all three mutually orthogonal orientations</td>
</tr>
<tr>
<td>Radiated emissions</td>
<td>The RF emission from the PRD shall not exceed values in Table 9</td>
<td>The RF emission from the RID shall not exceed values in Table 9</td>
<td>The RF emission from the BRD shall not exceed values in Table 9</td>
</tr>
<tr>
<td>Electrostatic discharge</td>
<td>Not affected by 8 kV contact discharge (IEC 61000-4-2)</td>
<td>Not affected by 8 kV contact discharge (IEC 61000-4-2)</td>
<td>Not affected by 8 kV contact discharge (IEC 61000-4-2)</td>
</tr>
<tr>
<td>Conducted disturbances induced by bursts and radio frequencies</td>
<td>Not Applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
### Requirement Orientations

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground Orientations</th>
<th>Aerial Orientations</th>
<th>Maritime Orientations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiated emissions</td>
<td>The RF emission from the instrument shall not exceed values in Table 9</td>
<td>The RF emission from the instrument shall not exceed values in Table 9</td>
<td>The RF emission from the instrument shall not exceed values in Table 9</td>
</tr>
<tr>
<td>Electrostatic discharge</td>
<td>Not affected by 6 kV contact discharge (IEC 61000-4-2)</td>
<td>Not affected by 6 kV contact discharge (IEC 61000-4-2)</td>
<td>Not affected by 6 kV contact discharge (IEC 61000-4-2)</td>
</tr>
<tr>
<td>Conducted disturbances induced by bursts and radio frequencies</td>
<td>The instrument shall not be affected by a RF field over the frequency range of 150 kHz to 80 MHz at an intensity of 140 dB(μV) 80% amplitude modulated with a 1 kHz sine wave that can be conducted onto the instrument through the cabling.</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

### Table 9 - Radiated RF emission limits

<table>
<thead>
<tr>
<th>Emission frequency range (MHz)</th>
<th>Field strength (micro-volts/meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–88</td>
<td>100</td>
</tr>
<tr>
<td>88–216</td>
<td>150</td>
</tr>
<tr>
<td>216–960</td>
<td>200</td>
</tr>
<tr>
<td>Above 960</td>
<td>500</td>
</tr>
</tbody>
</table>

### 7.6 Mechanical Requirements

These requirements are listed based on the instrument size and type of usage.

#### Table 10: Handheld and body-worn instruments – Mechanical Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>PRD</th>
<th>RID</th>
<th>Backpacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td>The PRD shall withstand random vibration at 0.01 g²/Hz (spectral density) using 5 Hz and 500 Hz for the frequency endpoints for a period of 1 h in each of three orthogonal orientations. No alarms shall occur during the test.</td>
<td>The RID shall withstand random vibration at 0.01 g²/Hz (spectral density) using 5 Hz and 500 Hz for the frequency endpoints for a period of 1 h in each of three orthogonal orientations. No alarms shall occur during the test.</td>
<td>The BRD shall withstand random vibration at 0.01 g²/Hz (spectral density) using 5 Hz and 500 Hz for the frequency endpoints for a period of 1 h in each of three orthogonal orientations. No alarms shall occur during the test.</td>
</tr>
<tr>
<td>Impact</td>
<td>The PRD response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
<td>The RID response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
<td>The BRD response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
</tr>
<tr>
<td>Drop</td>
<td>The PRD shall withstand drops on each of its six surfaces from a height of 1.5 m onto a concrete surface</td>
<td>The PRD shall withstand being dropped while in its transport case from a height of 122 cm on each of three axes onto a concrete surface</td>
<td>The PRD shall withstand being dropped from a height of 122 cm on each of three axes onto a concrete surface in the operational configuration</td>
</tr>
<tr>
<td>Mechanical shock</td>
<td>Not applicable</td>
<td>The instrument shall withstand exposure to shock pulses of 50</td>
<td>The instrument shall withstand exposure to shock pulses of 50</td>
</tr>
<tr>
<td>Requirement</td>
<td>PRD</td>
<td>RID</td>
<td>Backpacks</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----------</td>
</tr>
<tr>
<td>g peak acceleration, each applied for a nominal 18 ms in each of three mutually orthogonal axes.</td>
<td></td>
<td></td>
<td>peak acceleration, each applied for a nominal 18 ms in each of three mutually orthogonal axes.</td>
</tr>
</tbody>
</table>

Table 11: Vehicle mounted mobile systems – Mechanical Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ground</th>
<th>Aerial</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td>The instrument shall withstand exposure to random vibrations associated with the operation of vehicle mounted equipment for 1 hour. The random vibration shall be based on the break point frequencies located in Table 12. The physical condition and functionality of the instrument shall not be affected by exposure (e.g., solder joints shall hold, nuts and bolts shall not come loose).</td>
<td>The mounted detection module shall withstand exposure to vibrations associated with the operation of helicopter equipment for 4 hours. The random vibration shall be based on the break point frequencies shown in Table 13 (see Figure 4). All values are based on Category 18 (MIL-810 standard) for helicopter mounted external stores. The physical condition and functionality of the instrument shall not be affected by exposure (e.g., solder joints shall hold, nuts and bolts shall not come loose).</td>
<td>The instrument shall withstand exposure to vibration associated with the operation of equipment onboard a 7 m rigid hull inflatable boat (RHIB) at speeds of not more than 15 knots for 2 hours. This corresponds to a random vibration at 0.01 g²/Hz (spectral density) using 1 and 100 Hz for the frequency endpoints (note that the lower frequency can be changed due to the capabilities of the vibration system). The physical condition and functionality of the mounted assembly shall not be affected by exposure to the vibration environment (e.g., solder joints shall hold, nuts and bolts shall not come loose).</td>
</tr>
<tr>
<td>Impact</td>
<td>The instrument response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
<td>The instrument response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
<td>The instrument response shall be unaffected by impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (IEC 60068-2-75)</td>
</tr>
<tr>
<td>Drop</td>
<td>The instrument should withstand being dropped from a height of 61 cm onto a concrete surface in the vertical orientation. This requirement is based on the ability of the system to survive a drop from the bed of a trailer onto the ground and the use of personnel to carry the item. The manufacturer shall provide a description of the method used to attach, remove, and transport the detection module.</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Mechanical shock</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>The instrument shall withstand exposure to shock pulses of 12 g peak acceleration, each applied for a nominal 18 ms in each of three mutually orthogonal axes.</td>
</tr>
</tbody>
</table>

Table 12: Random Vibration Break Points - vehicle

<table>
<thead>
<tr>
<th>Break Point</th>
<th>Frequency, Hz</th>
<th>g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>0.5</td>
</tr>
</tbody>
</table>
### Table 13: Random Vibration Break Points - aerial

<table>
<thead>
<tr>
<th>Break Point</th>
<th>Frequency, Hz</th>
<th>g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0.0020</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>0.020</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>0.020</td>
</tr>
<tr>
<td>4 (f₁)</td>
<td>500</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

### Table 13: Random Vibration Break Points - aerial

<table>
<thead>
<tr>
<th>Break Point</th>
<th>Frequency, Hz</th>
<th>g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0.0020</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>0.020</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>0.020</td>
</tr>
<tr>
<td>4 (f₁)</td>
<td>500</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

#### Figure 4: Helicopter vibration exposure. Figure from Military Standard 810.

#### 8.0 General Test Procedures

Unless otherwise specified, all tests enumerated in this document are to be considered as type tests (see definition). Type testing should be performed using at least three units except for large instruments that a minimum of two units should be used. Certain tests may be considered as acceptance tests (see definition) by agreement between the customer and manufacturer. These test methods do not cover sustainability or operational testing.

#### 8.1 Standard Test Conditions

Testing of the radiation detection systems shall be carried out under standard test conditions for environmental quantities, such as temperature and pressure, that may influence the instrument.
performance. The system shall be tested under the conditions specified in Table 14, except where the effect of the condition or quantity itself is being tested.

<table>
<thead>
<tr>
<th>Influence quantity</th>
<th>Standard test conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>15 °C to 25 °C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>50% to 75%</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>86 kPa to 106,6 kPa (at 0 °C)</td>
</tr>
<tr>
<td>Gamma Background</td>
<td>≤10 μR/h</td>
</tr>
<tr>
<td>Neutron background</td>
<td>≤200 neutrons per second per square meter</td>
</tr>
<tr>
<td>Electromagnetic field</td>
<td>Controlled, natural conditions</td>
</tr>
<tr>
<td>Magnetic induction</td>
<td>Controlled, natural conditions</td>
</tr>
<tr>
<td>Reference photon radiation</td>
<td>(^{137})Cs, (^{241})Am, (^{57})Co and (^{60})Co</td>
</tr>
<tr>
<td>Reference neutron radiation</td>
<td>unmoderated and moderated (^{252})Cf (moderated by 4 cm high density polyethylene), 20 000 s(^{-1}) (±20 %) encapsulated in 1 cm steel plus 0.5 cm lead</td>
</tr>
</tbody>
</table>

**8.2 Statistical fluctuations**

For tests involving the use of radioactive sources to verify susceptibility to an environmental, electromagnetic, or mechanical condition, it is necessary to verify the magnitude of the statistical fluctuations of the dosimeter indication arising from the random nature of radiation. If the statistical fluctuations are a significant fraction of the variation of the indication permitted in the test, then the radiation ambient dose equivalent rate should be increased to ensure that the mean value of such readings may be estimated with sufficient precision to demonstrate compliance with the test in question. It is recommended that the coefficient of variation (COV) for each nominal mean reading be less than or equal to 12%. For neutron or background measurements, attaining a COV to meet this requirement may not be possible.

NOTE: 12% is from statistical analysis techniques for dosimeter testing and has proven to be a simple way of determining when a group of readings are acceptable for compliance testing.

The interval between such readings should be sufficient to ensure that the readings are statistically independent.

**8.3 Statistical considerations**

The number of trials used in the different test methods are based on Binomial or Poisson statistics as required by the specific instrument response under test, see Annex C.

**8.4 Uncertainties in the measurements**

Unless otherwise stated for a specific quantity, the uncertainties for any measurable quantity (e.g. radiation field, temperature, humidity, electromagnetic field) should not exceed 30% with a coverage factor, \(k\), of 2 (95% confidence interval).

**8.5 Background radiation during testing**

Testing shall be performed in an area with a nominal natural radiation background that has only natural variation as defined in Table 14. The gamma-ray background intensity shall be
measured using a pressurized ion chamber or similar environmental radiation measurement device that is calibrated to provide gamma-ray ambient dose equivalent rate. If the radiation detection system is equipped with neutron response capability, the neutron background should be the natural background and should not be artificially modified during testing.

8.6 Units of measure

For the purposes of this document the radiological units of exposure rate (R/h) shall be used for x-ray and gamma-ray radiation, unless otherwise stated. Additional information is provided in Annex A.

For neutron radiation measurements, the neutron source emission expressed in neutrons per second is used, unless otherwise stated.

8.7 Gamma exposure rate measurements and source activity

When radiation exposure rates above background levels are required for testing, the positioning of the instrument under testing shall be based on the exposure rate measurements from a calibrated gamma-measurement instrument, such as a microrad meter or ionization chamber.

When radiation exposure rates at background levels are required for testing, the positioning of the instrument under testing shall be based on the exposure rate calculations. A calculation for estimating exposure rates for point source is given in Annex A.

Sources used for testing shall be traceable to NIST or equivalent primary standard laboratory and shall have appropriate documentation to demonstrate the traceability chain (see ANSI N42.22 standard and 15USC271).

For testing purposes, the following radioactive sources are recommended, unless otherwise specified in a particular test method.

Table 15: Recommended test sources
<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Activity (µCi) Unshielded (3)</th>
<th>Activity (µCi) 3 cm Steel Shielded (3)</th>
<th>Activity (µCi) 8 cm PMMA Shielded (3)(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{241}$Am</td>
<td>47 (1.74 MBq)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{133}$Ba</td>
<td>9 (333 kBq)</td>
<td>148 (5.48 MBq)</td>
<td>--</td>
</tr>
<tr>
<td>$^{90}$Co</td>
<td>15 (555 kBq)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{90}$Co</td>
<td>7 (259 kBq)</td>
<td>25 (925 kBq)</td>
<td>--</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>16 (592 kBq)</td>
<td>85 (3.15 MBq)</td>
<td>--</td>
</tr>
<tr>
<td>DU (5)(6)</td>
<td>4.5 kg (3 mm minimum thickness)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{67}$Ga</td>
<td>16 (592 kBq)</td>
<td>--</td>
<td>94 (3.48 MBq)</td>
</tr>
<tr>
<td>HEU (5)(6)</td>
<td>237 g (1 mm minimum thickness)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{131}$I</td>
<td>10 (370 kBq)</td>
<td>--</td>
<td>23 (851 kBq)</td>
</tr>
<tr>
<td>$^{192}$Ir</td>
<td>6 (222 kBq)</td>
<td>61 (2.26 MBq)</td>
<td>--</td>
</tr>
<tr>
<td>$^{40}$K</td>
<td>128 (4.74 MBq)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{239}$Np</td>
<td>90 mg with 1 cm Fe shielding</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{55}$Mn</td>
<td>16 (592 kBq)</td>
<td>--</td>
<td>127 (4.7 MBq)</td>
</tr>
<tr>
<td>$^{201}$Tl</td>
<td>10 (370 kBq)</td>
<td>--</td>
<td>88 (3.26 MBq)</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>8 (296 kBq)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{232}$Th</td>
<td>14 (518 kBq)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>WGPu (5)</td>
<td>3 - 5 g with 1 cm Fe shielding (5 mm minimum thickness)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$^{252}$Cf (2)</td>
<td>$2 \times 10^7$ n/s ± 20% encapsulated in 1 cm steel plus 0.5 cm lead unmoderated and moderated by 4 cm high density polyethylene</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

(1) – Values stated are based on calculations performed using published information available at the time of drafting, and are based on photon emission rates using those photons with energies greater than 25 keV with the radioactive material contained in a 0.25 mm stainless steel encapsulation. An emission rate of 500,000 gamma-rays per second was used as a basis. This was determined using the approximate emission rate of $^{137}$Cs for an exposure rate of 5 µR/h at 1 meter.

(2) - The neutron source is encapsulated in 1 cm steel and 0.5 cm lead.

(3) – Unless otherwise stated, the shown mass values are based on a total gamma-ray emission rates of 500,000 gamma-rays/s at energies greater than 40 keV.

(4) – “PMMA” = polymethyl methacrylate.

(5) – The amounts of HEU and DU are stated in terms of cross-sectional area as well as the mass of solid spheres. This is because these sources are surface emitters and the cross-sectional area determines the flux. WGPu, RGPu, and $^{237}$Np are shielded with 1 cm Fe for handling purposes due to ES&H issues and for particularly Pu, they emit quite a few low-energy gamma rays that don’t contribute to the ability to identify the isotopes. 20 years age is used as a basis for the transport calculations.

(6) – For this protocol, HEU has an enrichment that is at least 90% $^{235}$U and DU at 0.2% $^{235}$U. RGPu contains more than 10% $^{240}$Pu and WGPu less than 7% $^{240}$Pu.

### 8.8 Data format

The output data provided by the different radiation detection systems shall be formatted as XML based on the requirements stated in ANSI N42.42, unless otherwise specified. The minimum set of data elements is specified for the different types of radiation detection systems.

It is recommended that the minimum set of elements is required.

For gamma-only systems as a minimum they shall have:
- Manufacturer name
- Instrument model
• Serial number
• Software version
• Instrument class (e.g., Backpack, Personal Radiation Detector, Radionuclide Identifier)
• Gamma detector kind (e.g., NaI, GMT, PVT)
• Date and time of measurement
• Measured background radiation levels (i.e., count rate or exposure rate or dose rate, or total counts or exposure or dose with associated measurement time duration as applicable)
• Measured gamma-ray radiation levels (i.e., count rate or exposure rate or dose rate, or total counts or exposure or dose with associated measurement time duration as applicable)
• Gamma-ray alarm indication

In addition if it has energy window capabilities:
• Energy window start energy-value
• Energy window end energy-value
• Measured gamma-ray radiation levels in each energy window (i.e., count rate and/or counts with associated measurement time duration)
• Energy window alarm indication

In addition if it has neutron detection capabilities:
• Neutron detector kind (e.g., He-3, LiGlass)
• Background neutron level (i.e, count rate and/or counts with associated measurement time duration, level indication)
• Measured neutron radiation levels (i.e., count rate and/or counts with associated measurement time duration)
• Neutron alarm indication

In addition if it has radionuclide identification capabilities:
• Background spectrum
• Live time and real time for background spectrum
• Unprocessed measured spectrum
• Live time and real time for measured spectrum
• Energy calibration for each background and measured spectrum
• Radionuclide identification results
• Confidence indication

In addition if it has occupancy and speed sensors:
• Occupancy sensor status
• Item speed
• Indication that the item stopped within the detection zone
• Sensor failure

In addition if it has GPS:
• Instrument location (latitude/longitude)

In addition if it has localization and directionality capabilities:
• Relative distance between instrument and measured item
• Item location relative to instrument
In addition it should also have some the following information depending on the instrument’s requirements:

- Over-range indication for detection
- Indication of background changes that can affect the overall sensitivity of the instrument
- System failures
- Indicate changes in operational status (e.g., occupied, alarm, monitoring background, fault, blocked, dwell, search)
- “Low-exposure rate for identification”
- “High-exposure rate for identification”
- Over-range indication for identification
- Operating modes (e.g., “search” mode and “monitor” mode)
- Operational parameters
- Diagnostic capabilities
- Indication of battery status

8.9 Neutron testing

Neutron tests should be performed in a low scatter irradiation facility (see ISO 8529-1:2001) or with the instrument placed in an area where there is open space on all sides of at least 1 m.

8.10 General testing information

During testing, the instrument shall be oriented with respect to the radiation source as indicated by the manufacturer.

If the instrument requires a background radiation measurement, it will be allowed to acquire the data in a manner specified by the manufacturer before testing is initiated.

8.11 Pre- and post-test measurements

Most environmental, electromagnetic and mechanical tests verify the instrument response before and after being exposed to different test conditions. The instrument response verification is carried out by performing pre- and post-test measurements. These measurements will depend on the instrument capabilities (e.g. gamma detection, neutron detection, radionuclide identification) and they should be carried out as follows:

- Pre-test measurement:

  Switch on the instrument and allow it to warm up normally.

  Gamma detection: expose the instrument to a $^{137}\text{Cs}$ source radiation field that produces a stable reading on the instrument; take 10 independent readings (i.e., exposure rate, dose rate, count rate). Calculate the mean, standard deviation and the coefficient of variation (COV); check that the COV $\leq 12\%$.

  Neutron detection: expose the instrument to an unmoderated $^{252}\text{Cf}$ neutron source that produces a stable reading on the instrument; take 10 independent readings (i.e. count rate). Calculate the mean, standard deviation and the coefficient of variation (COV); for neutrons it might not be possible to obtain a COV $\leq 12\%$.  

Radionuclide identification: expose the instrument to $^{57}$Co and $^{60}$Co, take 10 spectra. Record the radionuclides identified as well as the mean and standard deviation of the peak centroids and the FWHM for the 60 keV line for $^{241}$Am and 1332 keV line for $^{60}$Co. The time to perform a radionuclide identification is provided by the manufacturer or set by the requirements.

- Post-test measurement:

The post-test measurements are the same as the pre-test plus the following:

Gamma detection: calculate the percent difference between the pre- and post-test mean readings.

Neutron detection: calculate the percent difference between the pre- and post-test mean readings.

Radionuclide identification: calculate the percent difference between the pre- and post-test mean peak centroid and FWHM. Record the identification results.

8.12 Evaluation of radionuclide identification response

For radiation detection systems with spectrometric capabilities, the radionuclide identification response shall be analyzed using the technique described in Annex B. Therefore, throughout this document the performance for this type of systems is acceptable when the identification results are complete and correct.

If naturally occurring radionuclides such as $^{40}$K, $^{226}$Ra, and/or $^{232}$Th are identified, actions should be taken to reduce or eliminate the source prior to performing the test. If the radionuclide is expected and cannot be removed, the test result shall be acceptable when the expected naturally occurring radionuclide is identified.

A spectrum of all the sources used for testing shall be acquired to verify if there are detectable impurities that can affect the response of the instrument under test. The spectrum should be acquired using a HPGe detector based spectrometer.

8.13 Detection zones and setup requirements

Detection zones are defined for testing purposes. These zones define the region over which the instruments are expected to detect a radioactive source. Detection zones are defined for those instruments that require testing at different heights and distances.

**Backpack based radiation detection systems (BRDs)**

During testing the centerline of the backpack shall be mounted at 1.5 m from the floor. The stand that holds the backpack shall be made of low z materials, such as aluminum, to minimize scattering. The height detection zone goes from the ground up to 3 m above ground. As it is not practical to move source placed on the ground, the lowest height is going to be 10 cm above ground. Therefore, the bottom of the detection is at 10 cm from the ground, the middle is at 1.5 m and the top is at 3 m above ground.

For testing, the distance is measured between the centerline of the backpack and center of the source. The evaluation distance is part of the requirements.
Vehicle Mounted Radiation Detection Systems (VMDS)
The VMDS shall be set up based on the manufacturer’s specifications on a M1102 trailer with the cover or top on. Once set up for testing, no changes shall be made that could affect the overall response of the instrument.

Typical dimensions of the M1102 trailer specifications are as follows:
Length = 2.33 m
Width (full width inside) = 2.04 m
Width (inner space between tires) = 1.41 m
Height (from floor to top edge) = 1.33 m
Height (from floor to bottom of trailer) ~ 75 cm

Typical dimensions of the M1102 trailer top (hard cover) specifications are as follows:
Top dimensions:
Length = 2.33 m
Width = 2.2 m
Height = 1.25 m
Weight = 166.5 kg
Inside clearance over cargo bed = 1.68 cm

Crated dimensions:
Length = 2.54 m
Width = 2.41 m
Height = 1.37 m
Weight = 234 kg

For testing, the distance is measured between the centerline of the VDS and center of the source. The evaluation distance is part of the requirements.

The detection zone is defined as in the ANSI N42.43 standard. The manufacturer shall state the height of the detection zone over which the monitor meets the radiological requirements stated in this standard. As a minimum, the detection zone shall be 2 m high. For testing purposes, the height of the detection zone shall be from 1 m to 3 m above the ground or road surface with the detection assembly mounted at the same height as it is mounted when on the mobile platform.

Airborne Radiological Detection, Identification, and Measurement System (ARDIMS)
The orientation of the ARDIMS shall be same as that used when attached to a helicopter. The diagram in Figure 5 shows the type of mounting to be used.
Maritime-Based Radiation Detection System (MBRDS)
The orientation of the MBRDS shall be the same as that used when attached to the maritime platform of use.

For testing purposes, the centerline of the MBRDS shall be placed at 1.5 m from the floor. The stand that holds the instrument shall be made of low z materials, such as aluminum, to minimize scattering.

8.14 Use of phantoms

When testing body-worn type instruments such as the PRDs and the backpacks, the instruments shall be mounted on a phantom to simulate the presence of the human body. For these types of instruments, all radiological tests shall be performed with the instruments mounted on a phantom.

The PRDs and dosimeters shall be mounted centered on a 30 cm × 30 cm × 15 cm polymethyl methacrylate (PMMA) phantom.

The backpack type instruments shall be mounted of a PMMA phantom similar to that shown in Figure 6.
8.15 Parameter setting
The parameter settings of the instrument under test should be setup prior to the start of the tests. Parameter setting values should be those provided by the manufacturer or those required for an intended use. Parameter settings should not be changed during testing unless specifically required in a test method. If issues arise during testing that require changes in the parameter setting, testing needs to be repeated for the new set of parameters.

Parameter settings used during testing shall be recorded.
8.16 Maintaining performance

Maintaining a level of performance that meets the specifications as stated in this document depends upon establishing appropriate operating parameters, maintaining calibration, implementing a suitable response-testing and maintenance program, auditing compliance with quality requirements, and providing proper training for operating personnel.

9.0 Test Operations Procedures

9.1 General test

9.1.1 Controls and user interface

Controls shall be verified to be clearly identified, easily operable under conditions of expected use, and adequately protected from accidental operation.

The instrument shall be placed on a flat, hard surface. The instrument may be supported or braced to maintain this orientation. A 1 kg weight shall be placed on the opposite side. The instrument shall not turn off or change mode. The test shall be repeated for each side of the instrument.

A minimum of three potential users of this type of instrument shall review the operating instructions provided by the manufacturer. If required, each user should verify that the instrument can be operated as required in the Service CONOPS. Following the review, each potential user shall operate the instrument.

Specifically, the potential users shall:

— Turn on the instrument and verify that it is working properly (e.g. the battery is charged; the detector is present and working; self-check passed, if available).

— Wear the instrument as recommended in the manual.

— Using an available source, cause the unit to alarm and note the indication method (audible, visual, and vibratory).

— While measuring radiation, increase the exposure rate and observe the display. Note the method used to indicate the increase in the radiation level.

— Turn off the instrument.

This procedure shall also be performed with the potential users wearing protective gloves. Gloves worn shall be typical of those used for thermal protection. If required, this procedure shall be performed while the potential users are wearing full Mission Oriented Protective Posture (MOPP) gear in addition to thermal gear.

A survey form (see Annex C) shall be completed by each potential user to assess the usability of the instrument’s controls, interface, and operation. A report shall be generated based on the survey results.

The instrument and technical manual shall be inspected and reviewed to verify that all the control and user interface requirements are met.
9.1.2 **Documentation check**
The manufacturer-provided documentation shall be reviewed to ensure compliance with the requirement listed in section 7.1.

9.1.3 **Instrument marking**
The following shall be verified to be available and recorded: manufacturer’s name along with the model, serial number, and firmware number of the instrument and detector, if separate.

9.1.4 **Detector type**
The following shall be identified and recorded: type of radiation that can be measured with the instrument (gamma only or gamma/neutron) and the radiation detector types used (e.g., NaI, CsI, GM).

9.1.5 **Stabilization time**
The manual shall be reviewed and the stated stabilization time shall be recorded. If not provided by the manufacturer the stabilization time shall be as required. Switch on the instrument and verify that it is fully operational in the time specified for the instrument under test (e.g. PRDs 1 minute or less) by performing a pre-test measurement.

9.1.6 **Diagnostics**
The ability to perform self-diagnostics is verified through the test process. Any malfunctions shall be recorded throughout the testing process. The record shall include information as to whether the instrument provided information to the user.

9.1.7 **Displays and indications**
The instrument shall be inspected and the type of display noted. Note whether the display is backlit. It shall be verified that the display is readable at low light (<150 lux) and high light levels (>10 000 lux).

The instrument and technical manual shall be inspected and reviewed to verify that all the display and indications requirements are met.

9.1.8 **Operating modes**
The instrument manual shall be reviewed and the operating modes shall be recorded. Verify that the operating modes meet the requirements.

9.1.9 **Energy range**
The instrument manual shall be reviewed and the stated range shall be recorded. The range is confirmed during the accuracy test.

9.1.10 **Exposure rate (or dose rate) range**
The instrument manual shall be reviewed and the stated range shall be recorded. The range is confirmed during the accuracy test.

9.1.11 **Exposure (or dose) range**
The instrument manual shall be reviewed and the stated range shall be recorded.

9.1.12 **Alarms**
If required, verify by following the manual’s instructions that exposure rate alarm threshold are user selectable.
If required, it shall be verified that it is not possible to deactivate all alarms at the same time.

9.1.13 Visual alarms
Verify that the visual alarm of the instrument activates when an appropriate radiation source is placed as close to the instrument as practical.

Expose the instrument to a radiation field that is above the alarm threshold and verify that the visual alarm can be disabled.

9.1.14 Audible alarms
The audible alarm of the instrument shall be activated with an appropriate radiation source that may be placed as close to the instrument as practical. The A-weighted sound level at a distance of 30 cm shall be measured and compared to the performance requirements.

Expose the instrument to a radiation field that is above the alarm threshold and verify that the alarm can be muted.

9.1.15 Vibration alarms
The instrument manual shall be reviewed and the vibratory motor-rotation frequency as stated by the manufacturer shall be recorded.

New batteries shall be installed before testing. The instrument shall be attached to a flat, hard surface using non-cushioning double-sided tape, if possible. A single axis accelerometer shall be attached to the side of the instrument that, when worn, is closest to the wearer.

After allowing the vibration measurement system to settle, the alarm shall be activated and once the measurement is stable, the results shall be recorded. The measured intensity shall be recorded and the value compared with the requirement (e.g. greater than 0.8 g for PRDs). After a period of 10 s, the radiation field shall be reduced and the instrument shall be permitted to return to normal. The test shall be repeated nine additional times. Each measured reading shall be equal or greater than the acceptable value.

Expose the instrument to a radiation field that is above the alarm threshold and verify that the vibration alarm can be disabled.

9.1.16 Personnel protection alarm
Following instructions provided in the instrument manual, set the personal protection exposure rate alarm to activate at the required level. Cause the instrument to alarm using a gamma-ray emitting radiation source of sufficient strength (i.e. above alarm threshold). Silence the alarm and verify that the visual and/or vibration alarm remains active. If the system has a vibratory alarm, verify that the alarm operates as stated by the manufacturer.

9.1.17 Size
The physical dimensions of the instrument shall be measured. The instrument shall be measured outside of its holster or carrying case and the measurement shall exclude the clip and/or lanyard.
9.1.18 Mass
The instrument, including the battery, shall be weighed. For body-worn instruments, the holster and clip and/or lanyard shall be included in the measurement of the mass.

9.1.19 Reference point marking
The instrument shall be inspected to verify that reference points are present on the front or back and on the side indicating the effective center of the detector.

For body-worn instruments, verify that the instrument orientation with respect to the wearer is specified. The presence of a clip may be used as the reference point to indicate proper orientation.

9.1.20 Mounting or fitting requirements
For body-worn instruments, the instrument shall be inspected to verify that the required means are provided to securely fix the instrument to the user (e.g. straps, clip, ring, or lanyard). Three potential users shall observe and use the instrument to verify requirements.

9.1.21 Explosive atmospheres
The documentation provided by the manufacturer shall be inspected. The documentation shall state whether or not the instrument is suitable for use in explosive atmospheres. A certificate of compliance shall be provided if the manufacturer states that the instrument may be used in explosive atmospheres. Compliance shall be based on testing done in accordance with UL-913 or equivalent standard.

9.1.22 Batteries and battery lifetime
Record the battery type used by the instrument. If required, record if the batteries are replaceable without the use of special tools. If required, record if the batteries are hot-swappable.

Different types of instruments have different requirements for battery life-time during a non-alarm state and a continuous alarm state.

For the non-alarm battery life-time test, recharge the battery or install a fresh set of batteries. Under standard test conditions, the instrument shall be switched on, allowed to stabilize, and a pre-test measurement shall be performed as described in Section 8.11. The alarm threshold shall be adjusted to prevent instrument alarming during test. The instrument shall then be exposed to an exposure rate of 50 µR/h using $^{137}$Cs for the required time period. If the alarm threshold cannot be adjusted, the test can be performed without the presence of a $^{137}$Cs source. The low battery indicator shall not come on during the required time period. At the end of this time period, verify that the instrument is operational by performing a post-test measurement as described in Section 8.11.

For the alarm battery life-time test, recharge the battery or install a fresh set of batteries. Under standard test conditions, the instrument shall be switched on, allowed to stabilize, and a pre-test measurement shall be performed as described in Section 8.11. The radiation field shall be increased as needed to activate the alarm. It shall be verified that the alarm sounds continuously for the required time period. At the end of this time period, verify that the instrument is operational by performing a post-test measurement as described in Section 8.11.
To verify the low battery indication, the batteries shall be replaced with a DC power supply. Under standard test conditions, the instrument shall be switched on, allowed to stabilize, and a pre-test measurement shall be performed as described in Section 8.11. The applied voltage shall be reduced until the low battery indication is activated. Verify that the instrument is operational by performing a post-test measurement as described in Section 8.11.

If the instrument is capable of operating from an external DC source with a voltage from 11 – 28 VDC, the instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement. Perform a pre-test measurement. Reduce the applied voltage to 11 VDC. Verify that the instrument operates by performing a post-test measurement. Record the results of the test. Increase the voltage to 28 VDC and repeat the test.

**9.1.23 Power supply**

Verify and record if the instrument accepts AC or DC power. Verify by review and inspection that it meets power requirements.

To verify if battery chargers or instruments meet US electrical standards, review the manual and perform a physical inspection of the charger or instrument marking.

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement. Perform a pre-test measurement. Reduce the applied voltage to 110 VAC. Verify that the instrument operates by performing a post-test measurement. Record the results of the test. Increase the voltage to 240 VAC and repeat the test. Repeat the test with the voltage at 120 VAC but this time by reducing the frequency to 47 Hz then increasing the frequency to 63 Hz.

**9.1.24 Data communication**

If the instrument transmits data record the type of data transmission technique used and verify that it meets requirements.

Verify that the transfer protocol is fully described in the technical manual and that is freely distributable.

The instrument shall be allowed to operate for the required period of time. During that time, cause the unit to alarm and to store data as defined by the manufacturer. Following the manufacturer’s instructions, verify that data can be transmitted to a remote device such as a PC. Verify that all the requirements are met.

When using wireless data transfer techniques verify data security considerations and encryption capabilities and verify that the following:

a. Shut down the receiver and observe the instrument. Record the time required for the instrument to indicate that there is a loss of connectivity. The time shall be within 5 s for acceptability. Make the connection operational and then turn off the instrument. Record the time required for the receiver to indicate loss of connectivity. The time shall be within 5 minutes of the loss.

b. Make the connection operational then turn off the remote receiver. During the loss of connectivity, make exposure rate measurements and perform an identification. Re-establish the connection and verify that the instrument stored
the data and that the stored data was transferred automatically once the connection was re-established.

c. With the instrument operational, switch off the wireless interface and verify that the instrument remains fully operational by performing an exposure rate measurement, neutron response, and identification.

For GPS requirements, switch off the GPS and verify that the instrument remains functional by performing exposure rate and radionuclide identification measurements (i.e. a pre-test measurement).

**9.1.25 Data format**

If the instrument transmits (wireless, infrared, etc.) or stores data, verify that the data format is in XML. The data format requirements are defined by the ANSI N42.42 standard and by Section 8.8 in this document.

Verify that the data format is fully described in the technical manual and that it is freely distributable.

The instrument shall be allowed to operate for the required period of time. During that time, cause the unit to alarm and to store data as defined by the manufacturer. Following the manufacturer’s instructions, transmit any stored data to a remote device such as a PC. Verify that the required data elements are provided in the output data file. Note that the minimum required content of the output data file depends on the instrument type.

**9.2 Radiological tests**

If additional instrument performance requirements are needed for a particular type of radiation detection instrument, other applicable existing TOPs listed below may be used for testing.

- Test Operations Procedure, TOP 1-2-618 (2008), Initial Nuclear Radiation Hardness Validation Test
- Test Operations Procedure, TOP 1-2-612 (2008), Nuclear Environment Survivability

**9.2.1 False alarm rate**

The instrument shall be placed in an area where the ambient background is stable. The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement. The instrument shall be monitored for a time period or a number of occupancies depending on the false alarm requirement and number of alarms recorded. The monitoring time and the number of occupancies shall be based on Table 21 and Table 23 in Annex C.

For example, if the requirement is 1 alarm in 10 h (equal to 0.1 alarms/h), then from Table 21, the instrument shall be observed for 30 hours and no alarms are allowed.
For example, if the requirement is 1 alarm in 1000 occupancies, then from Table 23, the instrument shall be exposed to 4500 occupancies and 1 alarm is allowed.

9.2.2 Response time
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

The instrument shall be placed at the point of measurement and the radiation field shall be increased to the required value (e.g. by 50 µR/h above background for RIDs) using ¹³⁷Cs in a period of not more than 0.5 s.

It shall be verified that the instrument indication (i.e. exposure rate) increased within 2 s, when exposed to a ¹³⁷Cs source, and that the displayed exposure rate indication is within the required value (e.g. ±50 % of the ¹³⁷Cs exposure rate for RIDs) within 5 s of the change in the radiation field.

The exposure rate shall then be returned to its original background level by removing the ¹³⁷Cs source in a period of not more than 0.5 s. The instrument shall indicate the decrease in the exposure rate within 2s. The displayed exposure rate indication shall be within the required value (e.g. ±50 % for background level for RIDs) within 5 s of the change in the radiation field.

This test shall consist of total of 10 trials.

9.2.3 Time-to-alarm; photons
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

The instrument shall be placed at the point of measurement and the radiation field shall be increased based on the requirement (e.g. by 50 µR/h for PRDs) above background using ¹³⁷Cs in a period of not more than 0.5 s.

It shall be verified that the instrument alarms in the required time (e.g. ≤2 s for PRDs) and that all requirements are met. The field shall be reduced and the test repeated.

This test shall consist of a total of 60 trials.

If required, the entire process shall be repeated using ²⁴¹Am and ⁶⁰Co.

9.2.4 Time-to-alarm; neutrons
This test shall be performed only if the instrument has neutron detection capabilities. The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

The instrument shall be placed at the point of measurement and the exposed to the required neutron field.

The neutron field shall be increased to the required level within a period of not more than 2 s. The instrument shall indicate the presence of neutrons within the required time period (e.g. a
period of ≤2 s for PRDs) after the field increase. The field shall be reduced and the test repeated.

This test shall consist of a total of 60 trials.

9.2.5 Detection of gradually increasing radiation levels – Pass-by
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

From the normal background position, slowly approach a $^{137}$Cs source at the required speed (e.g. 0.12 m/s for BRDs) at a parallel distance of 1 m to 3 m between the source and the reference point (or centerline). The exposure rate produced by the $^{137}$Cs source shall be 50 µR/h ± 20% at the distance of closest approach, see Figure 7. The alarm shall activate within the required time (e.g. 2 s for BRDs) after the source reaches the position of closest approach. Return the source to the original position, allow the instrument to stabilize, and repeat the process.

This test shall consist of a total of 10 trials.

If the instrument has neutron detection capabilities, repeat the test using the unmoderated and moderated $^{252}$Cf source listed in Table 14. The speed and distance of closest approach (parallel distance) for neutrons will depend on the requirements, for example BRDs the speed in 0.12 m/s at a distance of 1 m.

Note that the response is acceptable if the alarm is activated before the distance of closest approach is reached.

Figure 7: Example of source movement for BRD system
9.2.6 Detection of gradually increasing radiation levels – Stopped

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

From the normal background position, slowly approach a $^{137}$Cs source at the required speed (e.g. 0.5 m/s for PRDs) and stop at the position where the radiation level produced by a $^{137}$Cs source is approximately 50 µR/h above background at the reference position of the instrument. The alarm shall activate within the required time (e.g. 2 s for PRDs) after the source reaches the position of closest approach. Return the source to the original position, allow the instrument to stabilize, and repeat the process.

This test shall consist of a total of 10 trials.

If the instrument has neutron detection capabilities, repeat the test using the unmoderated and moderated $^{252}$Cf source listed in Table 14. The approaching speed and distance at which the neutron source is stopped will depend on the requirements, for example PRDs the speed in 0.5 m/s at a distance of 10 cm.

Note that the response is acceptable if the alarm is activated before the distance of closest approach is reached.

9.2.7 Accuracy test for photons – exposure rate

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Expose the instrument to the required fields produce by $^{137}$Cs (e.g. 20%, 50%, and 80% of the maximum response range of the instrument for PRDs). Ten readings shall be recorded for each required field.

The mean exposure rate shall be within the required conventionally true value of the applied exposure rate (e.g. ±30% for the PRDs) when using $^{137}$Cs.

For instruments with unit-less displays, this test can be performed if the manufacturer provides a conversion table to convert the displayed value to an exposure rate.

9.2.8 Over-range response

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Expose the instrument to a $^{137}$Cs field that meets the requirements (e.g. twice the maximum range specified by the manufacturer for PRDs and RIDs). The instrument shall display that an over-range condition exists until the radiation field is reduced. Verify that the instrument recovers within the required time (e.g. 1 min for PRDs and BRDs, 30 min RIDs) after the radiation field is reduced.

This test shall consist of a total of 3 trials.

NOTE - An over-range indication can be for example the display of a message such as “over-range”, “high background” or “high counts”.

Unclassified
NOTE – the exposure time is instrument dependent (e.g. at least 5 min for RIDs)

9.2.9 Neutron indication in the presence of photons
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

The instrument shall be exposed to a $^{60}$Co or $^{137}$Cs radiation field of 10 mR/h or 20 mR/h as required. The instrument shall not indicate the presence of neutron radiation. Remove the $^{60}$Co or $^{137}$Cs source and allow the monitor to return to normal operation and repeat the test for a total of 3 trials. Record the gamma and neutron alarms.

Repeat the gamma exposure, but this time expose the instrument to the unmoderated neutron source and verify that the neutron alarm activates. Remove the $^{60}$Co or $^{137}$Cs source and allow the monitor to return to normal operation and repeat the test for a total of 3 trials. Record the gamma and neutron alarms.

The performance is acceptable if the neutron detector is insensitive to photon radiation. In addition, the instrument shall be able to detect an increase in neutron radiation while being exposed to gamma radiation.

9.2.10 Detector response to gamma radiation – mobile mode
Using the $^{241}$Am, $^{232}$Th, $^{133}$Ba, $^{60}$Co, and $^{57}$Co (see Table 15) sources, pass each source horizontally through the detection zone at the required test speed and distance through the bottom, middle, and top of the detection zone.

This test shall consist of a total of 60 trials for each source and each height.

If the instrument has energy windowing, verify that the correct energy window alarm is activated. The energy windowing parameters shall be provided by the manufacturer.

9.2.11 Detector response to gamma radiation – stationary mode
Using the $^{241}$Am, $^{232}$Th, $^{133}$Ba, $^{60}$Co, and $^{57}$Co (see Table 15) sources, place each source horizontally in the detection zone for the required time and distance at the bottom, middle, and top of the detection zone.

This test shall consist of a total of 60 trials for each source and each height.

If the instrument has energy windowing, verify that the correct energy window alarm is activated. The energy windowing parameters shall be provided by the manufacturer.

9.2.12 Detector response to neutron radiation – mobile mode
Using the $^{252}$Cf neutron (see Table 15) source unmoderated and moderated, pass each source horizontally through the detection zone at the required test speed and distance through the bottom, middle, and top of the detection zone.

This test shall consist of a total of 60 trials for each source and each height.
9.2.13 Detector response to neutron radiation – stationary mode
Using the $^{252}$Cf neutron (see Table 15) source unmoderated and moderated, place each source horizontally in the detection zone for the required time and distance at the bottom, middle, and top of the detection zone.

This test shall consist of a total of 60 trials for each source and each height.

9.2.14 Angular response to gamma radiation – mobile mode
Using the required sources (e.g., source activities listed in Table 15), turn each source around the instrument (or the instrument around the source) at the required distance from the centerline of the instrument and at the required speed (e.g., for VMDS the distance is 3 m and the speed is 2.22 m/s see Figure 10). The instrument response is acceptable is it can correctly indicate the source location with the resolution as specified in the requirement.

This test shall consist of a total of 10 trials per test position.

NOTE – the source direction of motion shall be perpendicular to the radial direction for each angle. Half of the trials should be performed with the source moving in one direction and the other half in the opposite direction.

If the instrument has energy windowing, verify that the correct energy window alarm is activated. The energy windowing parameters shall be provided by the manufacturer.

If the instrument has radionuclide identification capabilities, record the radionuclides identified during the 10 trials.

If the instrument has directionality indication capabilities, the direction indicated by the instrument shall be recorded for each angle increment.

For body-worm instruments, these measurements shall be performed with the instrument mounted on the phantom and by rotating the instrument together with the phantom around the reference point or centerline of the instrument (see Figure 8).

If required, this test shall be performed around the two orthogonal planes (see Figure 9).
Figure 8: Example of angular testing points for BRD system (horizontal plane)

Figure 9: Example of orthogonal testing planes for BRD system
9.2.15 Angular response to gamma radiation – stationary mode

Using the required sources (source activities listed in Table 15) sources, place each source at the required angular increments at the centerline of the instrument for the required test time and distance (e.g. 3 m for the VMDS).

This test shall consist of a total of 10 trials per test position.

Determine the mean detection efficiency by calculating the total net number of counts (gross counts with background subtracted) from the 10 trials divided by the time the source is within the instrument detection zone (or the mean count rate is provided by the instrument) divided by the source activity (expressed in Becquerel). The mean relative efficiency to the reference angle (e.g. for VMDS is 0° in Figure 10) shall also be computed from these 10 trials.

If the instrument has radionuclide identification capabilities, record the radionuclides identified during the 10 trials.

If the instrument has directionality indication capabilities, the direction indicated by the instrument shall be recorded for each angle increment.

For body-worm instruments, these measurements shall be performed with the instrument mounted on the phantom and by rotating the instrument together with the phantom around the reference point or centerline of the instrument.

If required, this test shall be performed around the two orthogonal planes (see Figure 9).

9.2.16 Angular response to neutron radiation – mobile mode

Using the $^{252}$Cf neutron (see Table 15) source unmoderated and moderated, turn each source around the instrument (or the instrument around the source) at the required distance from the centerline of the instrument and at the required speed (e.g. for VMDS the distance is 3 m and the speed is 2.22 m/s see Figure 10).

This test shall consist of a total of 10 trials per test position.
NOTE – the source direction of motion shall be perpendicular to the radial direction for each angle. Half of the trials should be performed with the source in one direction and the other half moving in the opposite direction.

If the instrument has directionality indication capabilities, the direction indicated by the instrument shall be recorded for each angle increment.

For body-worn instruments, these measurements shall be performed with the instrument mounted on the phantom and by rotating the instrument together with the phantom around the reference point or centerline of the instrument.

If required, this test shall be performed around the two orthogonal planes (see Figure 9).

9.2.17 Angular response to neutron radiation – stationary mode
Using the $^{252}\text{Cf}$ neutron (see Table 15) source unmoderated and moderated, place each source at the required angular increments at the centerline of the instrument for the required test time and distance (e.g. 3 m for the VMDS).

This test shall consist of a total of 10 trials per test position.

Determine the mean detection efficiency by calculating the total net number of counts (gross counts with background subtracted) from the 10 trials divided by the time the source is within the instrument detection zone (or the mean count rate is provided by the instrument) divided by the source flux. The mean relative efficiency to the reference angle (e.g. for VMDS is $0^\circ$ in Figure 10) shall also be computed from these 10 trials.

If the instrument has directionality indication capabilities, the direction indicated by the instrument shall be recorded for each angle increment.

For body-worn instruments, these measurements shall be performed with the instrument mounted on the phantom and by rotating the instrument together with the phantom around the reference point or centerline of the instrument.

If required, this test shall be performed around the two orthogonal planes (see Figure 9).

9.2.18 Determination of absolute counting efficiency
The absolute counting efficiency in static mode is determined by placing each of the required sources at the centerline of the instrument at the distances and measurement times as specified in the requirement.

The absolute counting efficiency in transient mode is determined by passing each of the required sources by the centerline of the instrument at the distances and speeds as specified in the requirement. The speed and distance at which these measurements are performed need to be reported.

Ten independent readings per test position shall be obtained.

Ten independent background count rate readings shall be acquired without any source present.
Determine the mean gamma detection efficiency by calculating the total net number of counts (gross counts with background subtracted) from the 10 readings divided by the time the source is within the instrument detection zone (or the mean count rate is provided by the instrument) divided by the source activity (expressed in Becquerel).

Determine the mean neutron detection efficiency by calculating the total net number of counts (gross counts with background subtracted) from the 10 readings divided by the time the source is within the instrument detection zone (or the mean count rate is provided by the instrument) divided by the source flux (neutrons/s).

Determine the efficiency using the following equation:

\[ \varepsilon = \frac{R_n}{A} \]

Where:

- \( \varepsilon \) is the efficiency
- \( R_n \) is the net count rate (gross count rate minus background count rate)
- \( A \) is the source activity

If the sources used for these tests are encapsulated, details on the source encapsulation shall be reported. If this information is not available the actual source emission rate shall be measured and reported.

### 9.2.19 Radionuclide identification general tests

Review the instrument manual and verify that an indication such as “not identified” or “unknown” is provided if a radionuclide cannot be identified.

Review the instrument manual and verify that the reliability or confidence indications are described.

Review the instrument manual and verify that the instrument provides an indication if the exposure rate is too high or too low for radionuclide identification. These indications are verified through the “Over-range characteristics for identification” and “False identification” tests.

If required, review the instrument manual and record the analysis modes available for instrument radionuclide identification operation.

### 9.2.20 Radionuclide library and categorization

Review the manual and note the radionuclides listed in the instrument library. The radionuclide categorization shall also be noted.

The radionuclides of greatest interest and those most likely to be encountered can be listed in four different categories. For example:

- Special Nuclear Materials: Uranium (used to indicate \( ^{235}\text{U}, \ 235\text{U} \)), \( ^{237}\text{Np} \), \( ^{239}\text{Pu} \).
- Industrial radionuclides: \( ^{57}\text{Co}, \ 60\text{Co}, \ ^{133}\text{Ba}, \ ^{137}\text{Cs}, \ ^{192}\text{Ir}, \ ^{204}\text{Tl}, \ ^{226}\text{Ra}, \ ^{241}\text{Am} \), and DU (\( ^{238}\text{U} \)).
- Medical radionuclides: \( ^{67}\text{Ga}, \ ^{99m}\text{Tc}, \ ^{131}\text{I}, \ ^{201}\text{Tl} \).
- Naturally Occurring Radioactive Materials (NORM): \( ^{40}\text{K}, \ ^{226}\text{Ra} \) and daughters, \( ^{232}\text{Th} \) and daughters
Verify that the list shall contain as a minimum, the radionuclides listed in Table 15.

9.2.21 Single radionuclide identification bare and shielded sources

One at a time, position the required sources from those listed in Table 15 (except for $^{252}\text{Cf}$) at the centerline of the instrument and at the required distance (or exposure rate) and for a time as required for the instrument under test (e.g. for RIDs place the source to produce an exposure rate of approximately 50 µR/h and the measurement shall last 2 minutes).

The test shall consist of 10 consecutive trials for each radionuclide.

If identification of moving sources is required, repeat the test but now the sources will move pass the instrument at the required speed and heights.

NOTE - It is not necessary to validate the identification of non-listed radionuclides.

NOTE - When testing the identification capabilities of spectroscopy-based radiation instruments, the instrument shall identify the radionuclide(s) of interest or that radionuclide(s) and expected daughter(s), and no others. If naturally occurring radionuclides such as $^{40}\text{K}$ are identified during a controlled test, actions should be taken to reduce or eliminate the source of radiation prior to continuing the test.

NOTE – Manufacturers may use $^{40}\text{K}$ to ensure that their system is functioning properly. This response is typically addressed by background subtraction when a measurement is performed.

9.2.22 Simultaneous radionuclide identification and masking

Expose the instrument to each of the required sources combinations. One at a time, position each of the source combinations at a distance (or exposure rate) and for a time as required for the instrument under test (e.g. for RIDs each radionuclide shall produce an exposure rate of approximately 50 µR/h and the measurement shall last 2 minutes).

The test shall consist of 10 consecutive trials for each radionuclide combination.

If identification of moving sources is required, repeat the test but now the sources will move pass the instrument at the required speed and heights.

9.2.23 False identification

Perform a radionuclide identification with the instrument in a stable background of not more than 10 µR/h with no radiation sources present. A shielded box or enclosure may be required to perform the test. No unexpected radionuclides shall be identified. In addition, the instrument shall indicate that the field is too low to perform an identification. The indication may consist of a statement such as “move closer to the source.”

The test shall consist of 10 consecutive trials.

If naturally occurring radionuclides such as $^{40}\text{K}$ are identified, actions should be taken to reduce or eliminate the source prior to performing the test. If the radionuclide is expected and cannot be removed, the test result shall be acceptable when the expected naturally occurring radionuclide is identified.
9.2.24 Overload characteristics for identification
Increase the ambient exposure rate using $^{137}$Cs to 90% the maximum exposure rate for radionuclide identification as stated by the manufacturer at the face of the instrument (or at least by 0.1 mR/h if there is no manufacturer stated value available) and perform a radionuclide identification using $^{137}$Cs at the required level. The instrument shall correctly identify $^{137}$Cs.

The test shall consist of 10 consecutive trials.

If required, increase the ambient exposure rate using $^{137}$Cs to the maximum exposure rate for radionuclide identification as stated by the manufacturer at the face of the instrument (or at least by 0.1 mR/h if there is no manufacturer stated value available) and perform a radionuclide identification using $^{60}$Co at the required level. The instrument shall correctly identify $^{60}$Co.

The test shall consist of 10 consecutive trials.

NOTE – when testing with $^{60}$Co the instrument can also display $^{137}$Cs as part of the correct identification.

9.2.25 Variation of identification with angle of incidence
Expose the front face (this corresponds to a 90° angle in Figure 8) of the instrument to a $^{241}$Am source at a distance (or exposure rate) and for a time as required for the instrument under test (e.g. for RIDs place the source to produce an exposure rate of approximately 50 µR/h and the measurement shall last 2 minutes). Repeat the process with the incident angle at +45° and –45° in each of two orthogonal planes (this corresponds to 45° and 135° angles in Figure 8). Repeat the test using $^{60}$Co and $^{137}$Cs. The test shall consist of 10 trials for each orientation.

9.2.26 Shielded SNM identification
Expose the instrument to a SNM source of significant activity (activity to be determined) placed behind a 2.54 cm of lead shield and in the presence of masking and/or naturally occurring radioisotopes using the required count time (e.g. 1,000 seconds or less for RIDs). The test shall consist of 10 trials. The instrument shall be reset between each trial, if appropriate.

9.2.27 Interfering ionizing radiation (beta)
Expose the instrument to a shielded beta emitter ($^{32}$P or $^{90}$Sr/$^{90}$Y). The photon (e.g., x-rays, Bremsstrahlung) radiation field shall be 50 µR/h at the reference point of the instrument. In addition, expose the instrument to a $^{137}$Cs source producing a gamma-ray exposure rate 50 µR/h at the reference point of the instrument.

The test shall consist of 10 trials.

Remove the $^{137}$Cs source and with the instrument exposed only to the shielded beta emitter, perform an identification. The identification results shall not include any unexpected radionuclides and should indicate the presence of a "not identified" radionuclide or "suspected beta emitter or Bremsstrahlung radiation" repeat for 10 consecutive trials.

9.2.28 Interference from surrounding material
Expose the instrument to a $^{137}$Cs source that produces a 500 µR/h exposure rate at the reference point of the instrument. The source shall be surrounded by steel 1 cm thick; the air gap between the source and the steel shall be approximately 5 cm. The distance between the instrument and the steel shall be at least 10 cm.
The test shall consist of 10 trials.

**9.2.29 Full Width-Half Maximum (FWHM)**
Expose the instrument to a $^{137}$Cs source that provides an exposure rate of 50 µR/h at the reference point of the instrument. Collect a minimum of 20 000 net counts for the main gamma-ray line (662 keV), determine the FWHM and its associated uncertainty from the acquired spectrum. Specify the software used to determine the FWHM.

Repeat this measurement using $^{241}$Am (60 keV gamma-ray line) and $^{60}$Co (1173 keV and 1332 keV gamma-ray lines).

**9.2.30 Full-energy-peak Efficiency**
Prior to performing the test, collect a ten-minute background spectrum and record the total counts obtained.

Full-energy-peak efficiency measurements shall be carried out for $^{57}$Co (122 keV, Emission probability = 0.8551, $T_{1/2}$ = 271.8 days), $^{133}$Ba (356 keV, Emission probability = 0.6205, $T_{1/2}$ = 10.52 years), $^{137}$Cs (662 keV, Emission probability = 0.851, $T_{1/2}$ = 30.04 years), and $^{60}$Co (1173 and 1332 keV, Emission probability = 0.99857 and 0.99983 respectively, $T_{1/2}$ = 5.271 years).

NOTE – data from ENSDF and BNM-LNHB/CEA

Record the source activity and reference time. Sources used for these measurements should have the same encapsulation. Record the material and thickness of the source encapsulation.

One at a time, position each source at 50 cm from the reference position of the instrument. Collect a spectrum until a minimum of 20 000 net counts for the main gamma-ray line are obtained. Specify the software used to determine the net peak area of the gamma-ray lines.

Determine the full-energy peak efficiency for each source by dividing the net peak area of the gamma-ray line by the live time of the measurement, by the emission probability of the given gamma-ray line and by the source activity (expressed in Bq).

NOTE – for heavily encapsulated sources attenuation correction shall be made for comparison with measurements when using point source with minimum attenuation.

**9.2.31 Real time identification capabilities**

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

The instrument shall be placed at the point of measurement and the radiation field shall be increased based on the requirement (e.g. by 50 µR/h for BRDs) above background using $^{137}$Cs in a period of not more than 0.5 s.

It shall be verified that the instrument identifies the correct radionuclide in the required time (e.g. ≤5 s for BRDs) and that all requirements are met. The field shall be reduced and the test repeated.

This test shall consist of a total of 10 trials.
If required, the entire process shall be repeated using $^{57}\text{Co}$, $^{60}\text{Co}$, $^{67}\text{Ga}$, $^{99m}\text{Tc}$, $^{131}\text{I}$, $^{133}\text{Ba}$, $^{192}\text{Ir}$, $^{201}\text{Tl}$, $^{226}\text{Ra}$, $^{232}\text{Th}$, HEU, DU, WGPu, $^{241}\text{Am}$.

9.3 Environmental tests

If additional instrument performance requirements are needed for a particular type of radiation detection instrument, other applicable existing TOPs and standards listed below may be used for testing.

Military Standard 810, Environmental Engineering Considerations and Laboratory tests

Test Operations Procedure, TOP 8-4-007(1985), U.S. Army Test and Evaluation Command Test Operations Procedures, Cold Regions Environmental Test of Nuclear, Biological, and Chemical Decontamination Equipment

Test Operations Procedure, TOP 8-4-005(1986), U.S. Army Test and Evaluation Command Test Operations Procedures, Cold Regions Environmental Test of Nuclear, Biological, and Chemical Equipment (Alarms and Detectors)


Test Operations Procedure, TOP 1-2-621 (2009), Outdoor Sand and Dust Testing

U.S. Army Test and Evaluation Command Development Test II – Common Test Operations Final Procedures, TOP 2-2-815 (1975), Rain and Freezing Rain

Test Operations Procedure, TOP 8-2-111 (1998), Nuclear, Biological and Chemical (NBC) Contamination Survivability, Small Items of Equipment

Test Operations Procedure, TOP 08-2-510A (2011), Chemical and Biological Contamination Survivability (CBCS), Large Item Exteriors

9.3.1 Temperature - operational

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in an environmental chamber at a temperature of 22 °C ±2 °C. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 h. During the last 15 min of the stabilization period perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

NOTE – If additional supporting equipment, such as battery chargers, is required to operate in the same environment as the instrument under test, then this equipment shall also undergo this test.
The RH level within the chamber should be kept low enough (typically <65%) to prevent condensation.

Increase the temperature in the chamber at a rate of 10 °C/h to maximum required temperature (e.g. +60 °C for operational temperature range for PRDs and BRDs). At each 10 °C increment, stabilize the temperature for a period of 45 min. During the last 15 min of each stabilization period, perform a post-test measurement as describe in Sections 8.11. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The instrument shall be kept at the high temperature limit for a period of 8 h with post-test readings recorded and the alarm tested during the last 15 min of the 8 h period.

This same process shall be performed for temperatures that are less than the reference temperature of 22 °C. The temperature shall be reduced from 22 °C at a rate of 10 °C/h to minimum required temperature (e.g. −40 °C for operational temperature range for PRDs and BRDs). The test at low temperature shall be the same as that performed at high temperature.

The instrument response is acceptable if the post-test requirements listed in Sections 8.11 are met.

Record all alarms that occur during the test when no radioactive sources are present.

9.3.2 Temperature - storage

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in the environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 hours. During the last 30 minutes of the stabilization period, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The RH level within the chamber should be kept low enough (typically <65%) to prevent condensation.

Switch the instrument off and reduce the temperature at a rate of 10 °C/h to minimum required temperature (e.g. −40 °C for PRDs). Maintain the temperature for a soak period of 24 hours then increase the temperature to 22 °C at a rate of 10 °C/h. After a period of 4 hours, perform a post-test measurement as described in Sections 8.11 to verify instrument functionality. Repeat the test for the high temperature storage condition (e.g. +71 °C for PRDs) but with a soak period of 4 hours.

The instrument response is acceptable if the post-test requirements listed in Sections 8.11 are met.

9.3.3 Temperature shock

The instrument shall be fully functional within the required recovery time period (e.g. 30 min for PRDs) when exposure to rapid temperature changes from 22°C to the minimum operational
temperature required (e.g. –40 °C for PRDs), from the minimum operational temperature required to 22 °C, from 22 °C to the maximum operational temperature required (e.g. 60 °C for PRDs), and from the maximum operational temperature required to 22 °C with each change being made in less than 1 min.

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in the environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for a period of 1 hour. During the last 15 minutes of the stabilization period, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The RH level within the chamber should be kept low enough (typically <65%) to prevent condensation.

The instrument shall then be exposed to the maximum operational temperature required (e.g. 60 °C for PRDs) with the temperature change being made in less than 1 min.

The instrument shall be observed continuously. Every 15 min, post-test measurement as described in Sections 8.11 shall be recorded. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

After the required recovery time period (e.g. 30 min for PRDs), the instrument response shall meet the post-test requirements listed in Sections 8.11.

Record all alarms that occur during the test when no radioactive sources are present.

If the instrument is unable to perform properly or does not pass the post-test measurements after the required recovery time period, observe the instrument until it recovers or until temperature stabilization is reached (whichever occurs first), with the time required for recovery noted.

Following the stabilization period at the high temperature value, expose the instrument to a temperature of 22 °C ± 2 °C. This change shall be performed in less than 1 min and the analysis process stated above repeated.

The entire process shall be repeated for 22 °C to the minimum operational temperature required (e.g. –40 °C for PRDs) and from the minimum operational temperature required to 22 °C.

9.3.4 Cyclic humidity

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in an environmental chamber at a temperature of 22 °C ± 2 °C and 40% RH. Allow the chamber and instrument to stabilize at 22 °C for a period of 1 h. During the last 15 min of the stabilization period, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm,
neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Increase the humidity at a rate not exceeding 10 % RH/h until attaining 93 ± 3 % RH. With the chamber at this RH setting, increase the temperature to 60 °C at a rate not exceeding 10 °C/h (4 h). Observe the gamma and neutron response throughout the test by performing post-test measurements and verifying that the requirements are met as described in Sections 8.11. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The humidity and temperature shall be maintained at these values for 12 h. Reduce the temperature to 30 °C at a rate not exceeding 10 °C/h while maintaining the RH level (3 h). Maintain the temperature and humidity level for a period of 4 hours then reduce the temperature to 20 °C at a rate not exceeding 10 °C/h and maintain those conditions for 4 h while continuing to observe the response. Following the 20 °C exposure, increase the temperature to 30 °C at a rate not exceeding 10 °C/h (1 h) and maintain those conditions for 4 h then increase the temperature to 60 °C at a rate not exceeding 10 °C/h (3 h) and hold those conditions for 12 h. Following exposure, reduce the temperature to 22 °C and 40% RH at a rate not exceeding 10 °C/h and 10% RH/h respectively.

At each test point, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Record all alarms that occur during the test when no radioactive sources are present.

### 9.3.5 Condensing moisture

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in an environmental chamber at a temperature of 22 °C ± 2 °C and 40% RH. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 h. During the last 30 min of the stabilization period, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Increase the relative humidity to no less than 95% over a 1 hour time period. With the chamber at the RH setting, begin the temperature cycle by increasing the temperature to 55°C over a 3 hour time period. Maintain these conditions for 9 hours. While maintaining the RH level, ramp the temperature down to 25°C over a time period of 4.5 hours. Maintain these conditions for 7 hours.

Repeat the temperature cycle by increasing the temperature to 55°C over a 3 hour time period. Maintain these conditions for 9 hours. While maintaining the RH level, ramp the temperature down to 25°C over 4.5 hours time period. Maintain these conditions for 7 hours.

At the end of the second temperature cycle, reduce the RH to 75% over a 0.5 hour time period. Maintain the RH level and reduce the temperature to 22°C over a 0.5 hour time period.
Maintain these conditions for 1 hour. Reduce the RH to 40% over the next 0.5 hour time period.

Once the final conditions are obtained, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

### 9.3.6 Dust test

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the dust test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Expose the instrument to the dust environment with no radioactive sources present. The dust test shall be performed depending on the ingress protection rating (IP) requirement for the instrument under test as described in the IEC 60529 or MIL-STD-810.

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

An inspection shall be performed to determine the extent of dust ingress. Particular attention shall be made to the battery compartment and any other easily accessed portions of the instrument. The protection is satisfactory if, on inspection, powder has not accumulated in a quantity or location such that, as with any other kind of dust, it could interfere with the correct operation of the instrument.

Record all alarms that occur during the test when no radioactive sources are present.

### 9.3.7 Moisture test

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the moisture test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Expose the instrument to the moisture environment with no radioactive sources present. The moisture test shall be performed depending on the ingress protection rating (IP) requirement for the instrument under test as described in the IEC 60529.

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).
The instrument, including the battery compartment, shall be inspected to ensure that moisture did not penetrate into the instrument.

Record all alarms that occur during the test when no radioactive sources are present.

9.3.8 Low and high temperature start-up
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Place the instrument in the environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 hours. During the last 15 minutes of the stabilization period, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radioactive sources, switch the instrument off, and decrease the temperature to the minimum operational temperature required at a rate of 10 °C/h (e.g. −40 °C for PRDs). Allow the temperature to stabilize for a period of 2 h.

Switch on the instrument, and after the manufacturer’s stated warm-up time, perform post-test measurements as described in Sections 8.11. After the post-test readings are obtained, verify that requirements are met and that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the sources, switch off the instrument and return the temperature to 22 °C at a rate of 10 °C/h.

Record all alarms that occur during the test when no radioactive sources are present.

For the high temperature start-up test perform the same test but starting at 22 °C and going to the maximum operational temperature required for the instrument under test.

9.3.9 Maritime environment
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The instrument shall then be placed in a salt fog environment for two 24-hour periods. The temperature of the chamber shall be maintained at 35°C. The salt fog fallout shall be such that a receptacle collects from 1 to 3 mL of solution per hour for each 80 cm$^2$ of horizontal collecting area. After each salt fog exposure period, there is a 24 hour drying period.
The instrument shall respond to the presence of radiation throughout the test and after the test. After each of the two 24-hour salt fog exposure periods, perform post-test measurements as described in Sections 8.11. After the post-test readings are obtained, verify that requirements are met and that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Record all alarms that occur during the salt fog exposure or drying periods when no radioactive sources are present.

Following the last drying period, an inspection shall be performed to determine the extent of salt fog ingress. Particular attention shall be made to the battery compartment and any other easily accessed portions of the instrument. The protection is satisfactory if, on inspection, salt residue has not accumulated in a quantity or location such that it could interfere with the correct operation of the instrument. The instrument should not show any visual signs of corrosion, internal or external. In addition, perform post-test measurements as described in Sections 8.11. After the post-test readings are obtained, verify that requirements are met and that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

### 9.3.10 Decontamination procedure survivability

When required, the instrument shall be able to operate following standard chemical agent decontamination to include TICs and TIMS per U.S. Army “NBC Contamination Survivability Criteria for Army Materiel”.

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to exposure to decontamination agents, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

The decontamination procedure is performed by cleaning the instrument with mild soap and damp towel. If additional decontamination procedures are required, the decontamination procedure is performed by cleaning the unit as directed in the applicable document.

Following the decontamination procedure, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

### 9.3.11 Protection from Petroleum, Oil and Lubricants

When required the instrument shall be able to operate following exposure to petroleum products such as jet fuel, jet fuel, oil, brake fluid, antifreeze, universal cleaners, and/or diesel fuel.

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to exposure to petroleum products, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e.
gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Expose the instrument to the petroleum products following the requirements for the instrument under test.

Following the exposure, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

9.4 Electromagnetic tests

If additional instrument performance requirements are needed for a particular type of radiation detection instrument, other applicable existing TOPs and standards listed below may be used for testing.

Military Standard 461, Requirements for the Control of Electromagnetic Interferences Characteristics of Subsystems and Equipment

Military Standard 464, Electromagnetic Environmental Effects Requirements for Systems


Test Operations Procedure, TOP 6-2-559 (1978), Electromagnetic radiation analysis

9.4.1 Electrostatic discharge

The “contact discharge” technique (see IEC 61000-4-2) for conductive surfaces and coupling planes shall be used. Discharge points shall be selected based on user accessibility.

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the ESD test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radiation field and expose the instrument to ESD. There shall be ten discharges per discharge point with a 1 s recovery time between each discharge. It is recommended that tests first be performed at 2 kV, then if acceptable, 4 kV, followed by 6 kV.
Following each test point (i.e. 2 kV, 4 kV and 6 kV), perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Record all alarms that occur as a result of the electrostatic discharge alone when no radioactive sources are present.

9.4.2 Radio frequency
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the RF test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Place the instrument and the radioactive sources in a RF controlled environment and expose it to the required RF field (e.g. 80 MHz to 1 GHz and 1.4 GHz to 2.5 GHz at 50 V/m 80% amplitude modulated with a 1 kHz sine wave for PRDs). The test should be performed using an automated sweep at a frequency change rate not greater than 1% of the fundamental (previous) frequency (see IEC 61000-4-3). Dwell time should be chosen based on the instrument's response time, but should not be less than 3 s.

During the test, verify that there are no substantial changes in response (deviations not exceeding ±15 % of the initial mean gamma-ray or neutron readings).

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radiation source and repeat the test. Record all alarms that occur as a result of the RF radiation alone when no radioactive sources are present.

NOTE—The COV requirement is not applicable when testing without radiation sources.

The test shall be repeated in a total of three orthogonal orientations.

9.4.3 Conducted disturbances induced by burst and radio frequencies
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the magnetic field test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Expose the instrument to a conducted RF field over the frequency range of 150 kHz to 80 MHz at an intensity of 140 dB (μV) 80 % amplitude modulated with a 1 kHz sine wave.
The test should be performed using an automated sweep at a frequency change rate not greater than 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor’s response time, but should not be less than 3 seconds.

During the test, verify that there are no substantial changes in response (deviations not exceeding ±15% of the initial mean gamma-ray or neutron readings).

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radiation source and repeat the test. Record all alarms that occur as a result of the conducted disturbances alone when no radioactive sources are present.

NOTE—The COV requirement is not applicable when testing without radiation sources.

### 9.4.4 Magnetic fields

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the magnetic field test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Expose the instrument together with the radioactive sources to the required magnetic field (e.g. 10 gauss (1 mT) for all types of instruments).

During the test, verify that there are no substantial changes in response (deviations not exceeding ±15% of the initial mean gamma-ray or neutron readings).

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radiation source and repeat the test. Record all alarms that occur as a result of the magnetic field radiation alone when no radioactive sources are present.

NOTE—The COV requirement is not applicable when testing without radiation sources.

The test shall be repeated for all three mutually orthogonal orientations of the instrument with respect to the magnetic field.

### 9.4.5 Radiated emissions

Place the instrument in a shielded room or chamber, as appropriate. Place an antenna three meters from the assembly. With the instrument off, collect a background spectrum using a bandwidth of 50 kHz.
Switch the instrument on and allow it to stabilize. If required, the instrument shall be allowed to acquire a background measurement. Perform an RF scan. RF emissions shall be less than those required throughout the test.

9.5 Mechanical tests

If additional instrument performance requirements are needed for a particular type of radiation detection instrument, other applicable existing TOPs and standards listed below may be used for testing.

- Military Standard 810, Environmental Engineering Considerations and Laboratory tests

9.5.1 Vibration

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radioactive sources.

For body-worn and hand-held instrument, expose the instrument to the required vibration field. The time that the instrument is exposed to the vibration varies according to the requirement. The test shall be performed in each of the three orthogonal orientation of the instrument.

For large mobile instrument, expose the instrument to the required vibration field. The time that the instrument is exposed to the vibration varies according to the requirement. The instrument orientation used for testing shall be the same as that used when mounted in the field.

Record all alarms that occur as a result of the vibration alone when no radioactive sources are present.

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source). Inspect the instrument for mechanical damage and loose components.
9.5.2 **Drop test**

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radioactive sources.

The instrument shall then be dropped according to the requirements (e.g. drops on each of its six surfaces from a height of 1.5 m onto a concrete floor for PRDs).

Record all alarms that occur as a result of the drops alone when no radioactive sources are present.

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

9.5.3 **Mechanical shock test**

The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Subject the instrument to 10 pulses of the required peak acceleration, each applied for the required nominal time interval in three orthogonal directions.

Record all alarms that occur as a result of the impacts alone when no radioactive sources are present.

After each set of 10 shocks, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

After the test, inspect the instrument for mechanical damage and loose components. If internal inspection is not possible, check for loose components by gently shaking the instrument.
9.5.4 Impact (microphonics) test
The instrument shall be switched on and allowed to stabilize. If required, the instrument shall be allowed to acquire a background measurement.

Prior to the test, perform a pre-test measurement as described in Sections 8.11. After the pre-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

Remove the radioactive sources.

Using an appropriate test device (i.e., spring hammer), expose the instrument case to impact requirements (e.g. three impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m) (see IEC 60068-2-75). The test shall be performed on each side of the instrument case while observing the response.

Record all alarms that occur as a result of the impacts alone when no radioactive sources are present.

Following the test, perform post-test measurements and verify that requirements in Sections 8.11 are met. After the post-test readings are obtained, verify that all functional alarms (i.e. gamma alarm, neutron alarm) are activated when the exposure rate is above the alarm threshold (this might require the use of an additional source).

10.0 Data Management
Data management should follow ISO 17025 or equivalent requirements.

11.0 Quality Control/Quality Assurance
Quality control measures shall ensure accurate data collection, transcription, and manipulation.

Quality assurance includes a check or audit of the procedures, including validation protocols (with test conditions, number of trials, etc.) and validation criteria. This audit and its results should undergo a peer or panel review process following ISO 17025 or equivalent requirements.

A Validation Protocol should be finalized as a result of validating the test method.

12.0 Non-conformance/Corrective Action
Any non-conformance or corrective actions will be documented in the experimental report or after action report for the specific experiment, clearly stating where any issues arose and the impact this has had on the results.

13.0 Forms/Data Sheets
Forms and data sheets for data collection should be based on the specific test methods and test parameters shall be recorded.
14.0 References

The following referenced documents apply to the radiation detection systems covered in this document. The references that apply to the environmental, electromagnetic and mechanical requirements are also listed below.


[2] ANSI N42.22, American National Standard—Traceability of Radioactive Sources to the National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control.


[8] ANSI N42.49A, American National Standard for Performance Criteria for Alarming Electronic Personal Emergency Radiation Detectors (PERDs) for Exposure Control


[10] Military Standard 461, Requirements for the Control of Electromagnetic Interferences Characteristics of Subsystems and Equipment


[18] IEC 60529, Degrees of Protection Provided by Enclosures (IP Code)


[22] IEC 60721-3-1, Classification of environmental conditions - Part 3 Classification of groups of environmental parameters and their severities - Section 1: Storage

[23] IEC 60721-3-2, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 2: Transportation

[24] IEC 60721-3-3, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 3: Stationary use at weather protected locations

[25] IEC 60721-3-4, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 4: Stationary use at non-weather protected locations

[26] IEC 60721-3-5, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations

[27] IEC 60721-3-6, Classification of environmental conditions. Part 3: Classification of groups of environmental parameters and their severities. Ship environment

[28] IEC 60721-3-7, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 7: Portable and non-stationary use


[31] Technical Testing and Evaluation Plan (TT&E), Defense Threat Reduction Agency (DTRA), Radionuclide Identifiers


[34] Technical Testing and Evaluation Plan (TT&E), Defense Threat Reduction Agency (DTRA), Airborne Radiological Detection, Identification, and Measurement System (ARDIMS)


[40] Test Operations Procedure, TOP 8-4-005(1986), U.S. Army Test and Evaluation Command Test Operations Procedures, Cold Regions Environmental Test of Nuclear, Biological, and Chemical Equipment (Alarms and Detectors)


[52] Test Operations Procedure, TOP 08-2-510A (2011), Chemical and Biological Contamination Survivability (CBCS), Large Item Exteriors


15.0 Definitions and abbreviations

15.1 Definitions

**acceptance test:** Evaluation or measurement of performance characteristics to verify that certain stated specifications and contractual requirements are met.

**accuracy:** The degree of agreement between the observed value and the conventionally accepted true value of the quantity being measured.

**air kerma:** letter symbol, $K$, quotient of $dE_v$ by $dm$, where $dE_v$ is the sum of the initial kinetic energies of all the charged particles in a mass $dm$ of air, thus $K = \frac{dE_{tr}}{dm}$. Unit: J kg$^{-1}$. The special name for the unit of air kerma is gray (Gy) (ICRU 60)

**alarm:** An audible, visual, or other signal activated when the instrument reading or response exceeds a preset value or falls outside of a preset range.

**area monitor:** A radiation measurement system that is designed to detect increases in the ambient radiation level within an area surrounding or adjacent to the detector.

**body-worn:** Radiation instruments that are worn on the body while being used, e.g., personal radiation detectors and backpacks.

**calibrate:** To adjust and/or determine the response or reading of a device relative to a series of conventionally true values.

**calibration:** A set of operations under specified conditions that establishes the relationship between values indicated by a measuring instrument or measuring system and the conventionally true values of the quantity or variable being measured.

**check source:** A not-necessarily calibrated source that is used to confirm the continuing functionality of an instrument.

**coefficient of variation (COV):** Ratio of the standard deviation, $s$, to the arithmetic mean, $x$, of a set of $n$ measurements, $x_i$, given by the following formula:
\[ V = \frac{s}{\bar{x}} = \frac{1}{\bar{x}} \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \]

**conventionally true value (CTV):** The commonly accepted best estimate of the value of that quantity.

**NOTE—** This and the associated uncertainty will preferably be determined by a national or transfer standard, or by a reference instrument that has been calibrated against a national or transfer standard, or by a measurement quality assurance (MQA) interaction with the National Institute of Standards and Technology (NIST) or an accredited calibration laboratory.

**detection limits:** The extremes of detection or quantification for the radiation of interest.

**NOTE—** The lower detection limit is the minimum statistically quantifiable instrument response or reading. The upper detection limit is the maximum level at which the instrument meets the required accuracy.

**detector:** A device or component designed to produce a quantifiable response to ionizing radiation normally measured electronically.

**effective range of measurement:** Range of measurements within which the requirements of this standard are met.

**exposure:** The measure of ionization produced in air by x-ray or gamma-ray radiation.

**NOTE—** The special unit of exposure rate is the Roentgen per hour, abbreviated in this standard as R/h.

**false alarm:** Alarm NOT caused by a radioactive source under the specified background conditions.

**hand-carried:** Radiation instruments that are used while being carried.

**indication:** Displayed signal from the instrument to the user conveying information such as scale or decade, status, malfunction or other critical information.

**influence quantity:** Quantity that may have a bearing on the result of a measurement without being the subject of the measurement.

**installed:** Radiation instruments that are permanently mounted at a location for use.

**instrument:** A complete system consisting of one or more assemblies designed to quantify one or more characteristics of ionizing radiation or radioactive material.

**mobile:** Radiation instruments that are mounted to moving platforms and that operate while in motion.

**monitoring:** To continuously indicate the state or condition of a system or assembly.

**NOTE—** May also be used for the real-time measurement of radioactivity or radiation levels.
**portable:** Radiation instruments that are easily moved from location to location for use and that don’t operate while in transit.

**over-range response:** The response of an instrument when exposed to radiation intensities greater than the upper measurement limit.

**radioactive material:** In this standard, radioactive material includes both special nuclear and radioactive material, unless otherwise specifically noted.

**range:** All values lying between the lower and upper detection limits.

**reading:** The indicated or displayed value of the readout.

**response time:** The time interval required for the instrument reading to change from 10% to 90% of the final reading or vice versa, following a step change in the radiation level at the detector.

**restricted mode:** An advanced operating mode that can be accessed by an expert user (e.g., via password) to control the parameters that can affect the result of a measurement (e.g., radionuclide library, routine function control, calibration parameters, alarm thresholds).

NOTE—May also be called the “advanced” or “expert” mode.

**routine test:** Test that applies to each independent instrument to ascertain compliance with specified criteria.

**sensitive volume (of a detector):** Part of the detector which is sensitive to a radiation and is used for detection.

**standard deviation:** The positive square root of the variance.

**standard test conditions:** The range of values of a set of influence quantities under which a calibration or a measurement of response is carried out.

**test:** A procedure whereby the instrument, circuit, or component is evaluated.

**transportable:** Radiation instruments that may require mechanical lifting equipment when moved to different locations and that don’t operate while in transit.

**type test:** Initial test of two or more production instruments made to a specific design to show that the design meets defined specifications.

**uncertainty:** The estimated bounds of the deviation from the conventionally true value, generally expressed as a percent of the mean, ordinarily taken as the square root of the sum of the squares of two components: 1) Random errors that are evaluated by statistical means; and 2) systematic errors that are evaluated by other means.

**variance (σ²):** A measure of dispersion, which is the sum of the squared deviation of observations from their mean divided by one less than the number of observations.
\[ \sigma^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2. \]

### 15.2 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANSI</td>
<td>American National Standard Institute</td>
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<tr>
<td>ARDIMS</td>
<td>Airborne Radiological Detection, Identification, and Measurement System</td>
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<td>BRD</td>
<td>Backpack based radiation detection system</td>
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<tr>
<td>BNM-LNHB/CEA</td>
<td>Bureau National de Métrologie-Laboratoire National Henri Becquerel/Commissariat à l’énergie atomique</td>
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<tr>
<td>CONOPS</td>
<td>Concept of Operations</td>
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<tr>
<td>COV</td>
<td>Coefficient of Variation</td>
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<td>DC</td>
<td>Direct current</td>
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<td>DTRA</td>
<td>Defense Threat Reduction Agency</td>
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<td>DU</td>
<td>Depleted Uranium</td>
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<tr>
<td>ENSDF</td>
<td>Evaluated Nuclear Structure Data File</td>
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<tr>
<td>EPD</td>
<td>Electronic Personal Dosimeter</td>
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<tr>
<td>ESD</td>
<td>Electrostatic discharge</td>
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<tr>
<td>FWHM</td>
<td>Full Width Half Maximum</td>
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<tr>
<td>ID</td>
<td>Identification</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>GADRAS</td>
<td>Gamma Detector Response and Analysis Software</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>HEU</td>
<td>Highly Enriched Uranium</td>
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<tr>
<td>IP</td>
<td>Ingress Protection Rating</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>MBRDS</td>
<td>Maritime-Based Radiation Detection System</td>
</tr>
<tr>
<td>MKF-R</td>
<td>Mobile Field Kit – Radiological</td>
</tr>
<tr>
<td>NBC</td>
<td>Nuclear, biological, and chemical</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>NORM</td>
<td>Naturally Occurring Radioactive Materials</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PMMA</td>
<td>Polymethyl methacrylate</td>
</tr>
<tr>
<td>PRD</td>
<td>Personal radiation detector</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RH</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>RG-Pu</td>
<td>Reactor Grade Plutonium</td>
</tr>
<tr>
<td>RND</td>
<td>Radionuclide identification device</td>
</tr>
<tr>
<td>SD</td>
<td>Secure Digital</td>
</tr>
<tr>
<td>SNM</td>
<td>Special Nuclear Material</td>
</tr>
<tr>
<td>TECMIPT</td>
<td>Test and Evaluation Capabilities and Methodologies Integrated Process Team</td>
</tr>
<tr>
<td>TICs</td>
<td>Toxic Industrial Chemicals</td>
</tr>
<tr>
<td>TIMS</td>
<td>Toxic industrial Materials</td>
</tr>
<tr>
<td>TOP</td>
<td>Test Operations Procedure</td>
</tr>
<tr>
<td>TT&amp;OP</td>
<td>TECMIPT Test Operations Procedure</td>
</tr>
<tr>
<td>TT&amp;E</td>
<td>Technical Testing and Evaluation Plans</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriters Laboratory</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>VMDS</td>
<td>Vehicle Mounted Radiation Detection Systems</td>
</tr>
</tbody>
</table>
WGPu  Weapons Grade Plutonium
XML  eXtendable Markup Language
Annex B – Exposure and dose rate considerations

B.1 Exposure rate and dose rate conversion

For the purposes of this document the radiological units of exposure rate (R/h) shall be used for x-ray and gamma-ray radiation, unless otherwise stated. Exposure rate is a measure of the charge liberated by ionization radiation (x- or gamma-rays) per unit mass of air per unit time. Exposure rate is expressed in this standard in units of milliroentgens per hour (mR/h), or in coulombs per kilogram per hour (C/kg/h), where 1 mR/h = 2.58×10⁻⁷ C/kg/h. Exposure rate can be converted to air-kerma rate by using the conversion equations for air listed in Table 16.

Table 16- Roentgen to Gy conversion equations for air

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Conversion equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons (&lt;300 keV)</td>
<td>1 R/h = 8.764 mGy/h</td>
</tr>
<tr>
<td>¹³⁷Cs</td>
<td>1 R/h = 8.778 mGy/h</td>
</tr>
<tr>
<td>⁶⁰Co</td>
<td>1 R/h = 8.792 mGy/h</td>
</tr>
</tbody>
</table>

For x-rays and gamma-rays the factor to convert from absorbed-dose (Gy) to dose equivalent (Sv) is equal to 1. Therefore in SI units 1 Gy = 1 Sv.

Conversion coefficients can be used to convert from air-kerma to dose equivalent quantities such as the deep and shallow ambient dose equivalent (H*(10) and H*(0.07)), and the deep and shallow personal dose equivalent (Hp(10) and Hp(0.07)). The conversion coefficients are tabulated as a function of photon energy for ISO beam qualities in ISO 4037-3 [R36].

A subset of conversion coefficients from air-kerma to deep ambient dose equivalent, H*(10), (International Commission on Radiation Units and Measurement (ICRU) Tissue Sphere Phantom at a depth of 10 mm) are given in Table 17.

Table 17 - Conversion coefficients from air-kerma to H*(10)

<table>
<thead>
<tr>
<th>Photon Source</th>
<th>C₅ (Sv/Gy) (a)</th>
<th>C₅ (rem/R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>²⁴¹Am</td>
<td>1.74</td>
<td>1.66</td>
</tr>
<tr>
<td>N80 (65 keV)</td>
<td>1.73</td>
<td>1.65</td>
</tr>
<tr>
<td>¹³⁷Cs</td>
<td>1.20</td>
<td>1.06</td>
</tr>
<tr>
<td>⁶⁰Co</td>
<td>1.16</td>
<td>1.03</td>
</tr>
</tbody>
</table>

(a) ISO 4037-3 [R36]

B.2 Exposure rate calculations

To determine the exposure rate produced by shielded point sources the following approximation can be used. Other software packages are available but care should be taken with the conversion factors and the mass attenuation coefficients and the mass energy-absorption coefficient used as there are many discrepancies in the literature.

The exposure rate constant expressed in units of R m² h⁻¹ Ci⁻¹ for an isotope that emits one photon of energy hν per disintegration can be approximated as [Ref. 2]:

\[ \Gamma = 194.5 \ h\nu \ (\mu_{ab}/p)_{air} \]
Where $h\nu$ is the energy of the photon emitted expressed in MeV and $\left(\mu_{ab}/\rho\right)_{air}$ is the energy absorption coefficient for air expressed in $m^2/kg$.

The exposure rate constant for an isotope that emits photons $h\nu_1$, $h\nu_2$, $h\nu_3 \ldots h\nu_n$ and the number of these per disintegration is $N_1$, $N_2$, $N_3 \ldots N_n$ can be approximated as:

$$\Gamma = 194.5 \sum_{i=1}^{n} N_i h\nu_i \left(\mu_{ab}/\rho\right)_{air}$$

The exposure rate, $\dot{X}$, at any point P, distance $d$, from a source activity (point source) is expressed as:

$$\dot{X} = \frac{\Gamma A}{d^2}$$

Then the source activity can be estimated as:

$$A = \frac{\dot{X} d^2}{\Gamma}$$

For monoenergetic photons with an incident intensity $I_0$, penetrating a layer of material with thickness, $x$ (expressed in cm) and density $\rho$ (expressed in g/cm$^3$), emerges with intensity $I$ given by the exponential attenuation law:

$$\frac{I}{I_0} = \exp\left[-\left(\mu/\rho\right) x \rho\right]$$

Where $\mu/\rho$ is the mass attenuation coefficient expressed in units of cm$^2$/g.

Then for a shielded point source the source activity can be approximated as:

$$A = \frac{\dot{X} d^2}{194.5 \sum_{i=1}^{n} N_i h\nu_i \left(\mu_{ab}/\rho\right)_{air} \exp\left[-\left(\mu/\rho\right) x \rho\right]}$$

References:


B.3 Activity to Fluence Conversion

Radiation from an x-ray generator or a radioactive source consists of a beam of photons, usually with a variety of energies. If we consider that the beam is monoenergetic, then one way
to describe the beam would be to specify the number of photons, $dN$, that would cross an area, $da$, taken at right angles to the beam. The ratio of these would yield what the International Commission of Radiological Units and Measurements (ICRU) has called fluence or photon fluence represented by the capital Greek letter phi, $\Phi$.

$$\Phi = \frac{dN}{da}$$ (1)

At time we may be interested in the number of photons that pass through unit area per unit time. This is called the fluence rate and it is represented by the lower case Greek letter phi, $\phi$, thus:

$$\phi = \frac{d\Phi}{dt} = \frac{dN}{da \: dt}$$ (2)

When the emission of the source is isotropic and we integrate equation (2), we have that the fluence rate at a radius, $r$, from the source can be expressed as:

$$\phi = \frac{R}{4\pi r^2}$$ (3)

where $R$ is the number of photons per second emitted from the source.

$R$ can be expressed as a function of the source activity, $A$ (expressed in Becquerel), as:

$$R = A \ast p(E)$$ (4)

where $p(E)$ is the emission probability of a gamma ray at energy $E$. Then the fluence rate can be expressed as:

$$\phi = \frac{A \ast p(E)}{4\pi r^2}$$ (5)

If the source emits gamma rays at different energies, then the fluence rate can be expressed as:

$$\phi = \frac{A}{4\pi r^2} \sum_i p(E_i)$$ (6)

Note that the fluence rate value obtained using equation (6) will depend on the cut-off energy used in the calculation. Most radiation detection instruments have difficulties detecting gamma-rays with energies lower than 30 keV.

As an example of how make use of this, let us look at some of the sources listed in Table 15, and use source activity for $^{137}\text{Cs}$ as the reference. So for different radionuclides, distances and fluence rates we obtain the following activities for two different cut-off energies:

**Table 18: Activities for different fluence rates and distances for a cut-off energy of 30 keV**
In these tables, required activities in different ANSI/IEEE standards are listed together with the calculated activities for different fluence rates.

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Co-57</th>
<th>Ba-133</th>
<th>Cs-137</th>
<th>Co-60</th>
<th>Th-232</th>
<th>Am-241</th>
<th>Ra-226</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (m)</td>
<td>0.75</td>
<td>1</td>
<td>1.5</td>
<td>2.5</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Radionuclide</td>
<td>Co-57</td>
<td>Ba-133</td>
<td>Cs-137</td>
<td>Co-60</td>
<td>Th-232</td>
<td>Am-241</td>
<td>Ra-226</td>
</tr>
<tr>
<td>Fluence rate</td>
<td>0.695</td>
<td>3.4</td>
<td>4.34</td>
<td>N42.35</td>
<td>N42.38</td>
<td>N42.43</td>
<td>Activity (uCi)</td>
</tr>
<tr>
<td>(photons/s/cm²)</td>
<td>N42.35 values</td>
<td>N42.38 values</td>
<td>N42.43 values</td>
<td>0.695</td>
<td>3.4</td>
<td>4.34</td>
<td></td>
</tr>
<tr>
<td>(cut-off energy 30 keV)</td>
<td>1.18</td>
<td>0.51</td>
<td>1.44</td>
<td>0.67</td>
<td>0.38</td>
<td>3.60</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>2.45</td>
<td>0.92</td>
<td>2.56</td>
<td>1.18</td>
<td>0.68</td>
<td>6.55</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>5.52</td>
<td>2.06</td>
<td>5.77</td>
<td>2.66</td>
<td>1.54</td>
<td>14.74</td>
<td>3.02</td>
</tr>
<tr>
<td></td>
<td>15.3</td>
<td>7.2</td>
<td>16</td>
<td>7.4</td>
<td>4.3</td>
<td>41</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>61.33</td>
<td>22.88</td>
<td>64.06</td>
<td>29.56</td>
<td>17.09</td>
<td>160.8</td>
<td>33.52</td>
</tr>
<tr>
<td></td>
<td>88.29</td>
<td>32.95</td>
<td>92.24</td>
<td>42.56</td>
<td>24.61</td>
<td>235.89</td>
<td>48.27</td>
</tr>
<tr>
<td></td>
<td>119.8</td>
<td>4.48</td>
<td>12.54</td>
<td>5.78</td>
<td>3.34</td>
<td>32.07</td>
<td>6.56</td>
</tr>
<tr>
<td></td>
<td>750.07</td>
<td>28.05</td>
<td>78.37</td>
<td>36.14</td>
<td>20.89</td>
<td>200.46</td>
<td>41.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15.3</td>
<td>5.77</td>
<td>16</td>
<td>7.38</td>
<td>8.37</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>956.18</td>
<td>35.73</td>
<td>100.02</td>
<td>46.15</td>
<td>52.34</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>14</td>
<td>16</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Table 19: Activities for different fluence rates and distances for a cut-off energy of 50 keV

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Co-57</th>
<th>Ba-133</th>
<th>Cs-137</th>
<th>Co-60</th>
<th>Th-232</th>
<th>Am-241</th>
<th>Ra-226</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (m)</td>
<td>0.75</td>
<td>1</td>
<td>1.5</td>
<td>2.5</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Radionuclide</td>
<td>Co-57</td>
<td>Ba-133</td>
<td>Cs-137</td>
<td>Co-60</td>
<td>Th-232</td>
<td>Am-241</td>
<td>Ra-226</td>
</tr>
<tr>
<td>Fluence rate</td>
<td>0.642</td>
<td>3.4</td>
<td>4.01</td>
<td>N42.35</td>
<td>N42.38</td>
<td>N42.43</td>
<td>Activity (uCi)</td>
</tr>
<tr>
<td>(photons/s/cm²)</td>
<td>N42.35 values</td>
<td>N42.38 values</td>
<td>N42.43 values</td>
<td>0.642</td>
<td>3.4</td>
<td>4.01</td>
<td></td>
</tr>
<tr>
<td>(cut-off energy 50 keV)</td>
<td>1.27</td>
<td>0.9</td>
<td>1.44</td>
<td>0.62</td>
<td>0.38</td>
<td>3.42</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>2.26</td>
<td>1.6</td>
<td>2.56</td>
<td>1.09</td>
<td>0.63</td>
<td>6.07</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>5.09</td>
<td>3.6</td>
<td>5.76</td>
<td>2.46</td>
<td>1.43</td>
<td>13.66</td>
<td>2.42</td>
</tr>
<tr>
<td></td>
<td>14.13</td>
<td>9.99</td>
<td>16</td>
<td>6.84</td>
<td>3.96</td>
<td>37.95</td>
<td>6.73</td>
</tr>
<tr>
<td></td>
<td>56.51</td>
<td>39.95</td>
<td>64.03</td>
<td>27.35</td>
<td>15.84</td>
<td>151.8</td>
<td>26.91</td>
</tr>
<tr>
<td></td>
<td>81.37</td>
<td>57.53</td>
<td>92.21</td>
<td>39.38</td>
<td>22.81</td>
<td>218.59</td>
<td>38.76</td>
</tr>
<tr>
<td></td>
<td>119.8</td>
<td>8.47</td>
<td>12.57</td>
<td>5.78</td>
<td>3.35</td>
<td>32.15</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>750.07</td>
<td>52.92</td>
<td>84.8</td>
<td>36.14</td>
<td>20.95</td>
<td>200.9</td>
<td>35.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.98</td>
<td>100.08</td>
<td>6.82</td>
<td>3.95</td>
<td>37.91</td>
<td>6.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>62.37</td>
<td>42.64</td>
<td>46.15</td>
<td>24.71</td>
<td>236.93</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>7</td>
<td>14</td>
<td>7</td>
<td>47</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>14</td>
<td>16</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

In these tables, required activities in different ANSI/IEEE standards are listed together with the calculated activities for different fluence rates.
Annex C - Guidance Regarding Identification Performance

Below is a summary of the definitions used to characterize identification results for spectrometric systems. The described technique was developed as a means to analyze results obtained from spectral injection studies at the International Atomic Energy Agency.

1 Complete & Correct (C&C)
   - Source "X" identified as "X"
   - Sources "X+Y" identified as "X+Y"

   For example:
   - $^{235}$U $\rightarrow$ $^{235}$U
   - $^{235}$U $\rightarrow$ $^{235}$U + $^{40}$K
   - $^{235}$U $\rightarrow$ $^{235}$U + $^{40}$K + $^{232}$Th
   - $^{235}$U $\rightarrow$ $^{235}$U + $^{40}$K + $^{232}$Th + $^{226}$Ra
   - $^{238}$U + $^{67}$Ga $\rightarrow$ $^{235}$U + $^{67}$Ga + $^{40}$K + $^{232}$Th + $^{226}$Ra

   Complete and Correct may also include daughter(s) and impurities of the target radionuclide(s) and NORM ($^{40}$K, $^{226}$Ra, and/or $^{232}$Th). Table 20 provides a list of daughters and possible impurities.

2 Incomplete
   - Source "X+Y" identified as "X" or "Y"

   For example:
   - $^{235}$U + $^{226}$Ra $\rightarrow$ $^{226}$Ra

3 Incorrect
   - Source "X" identified as "X + Y".

   For example:
   - $^{235}$U $\rightarrow$ $^{235}$U + $^{237}$Np
   - $^{67}$Ga $\rightarrow$ $^{235}$U + $^{67}$Ga

4 Incomplete & Incorrect (I&I)
   - Source "A" being identified as "C"
   - Source "A+B" identified as "C+D"

   For example:
   - $^{235}$U $\rightarrow$ $^{67}$Ga
   - $^{235}$U + $^{137}$Cs $\rightarrow$ $^{99m}$Tc + $^{133}$Ba

Table 20: List of daughters and possible impurities

<table>
<thead>
<tr>
<th>Radionuclide(s)/Materials</th>
<th>Daughters and Possible Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{201}$Tl</td>
<td>$^{201}$Tl</td>
</tr>
<tr>
<td>DU</td>
<td>$^{208}$U, $^{208}$Ra</td>
</tr>
<tr>
<td>WGPu</td>
<td>$^{241}$Pu, $^{241}$Pu, $^{240}$Pu, $^{241}$Pu, $^{244}$Am, $^{237}$U, $^{244}$Pa, $^{245}$U</td>
</tr>
<tr>
<td>HEU</td>
<td>$^{238}$U, $^{244}$Pa</td>
</tr>
<tr>
<td>$^{233}$Tc</td>
<td>$^{99}$Mo</td>
</tr>
<tr>
<td>$^{232}$Th</td>
<td>$^{232}$Th, $^{232}$U</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>$^{212}$Bi, $^{212}$Pb</td>
</tr>
</tbody>
</table>
Annex D – Statistical considerations

D.1 Poisson Occurrence Rate Confidence Bounds

Poisson distribution
A random variable used to describe a number of occurrences of some phenomena over a fixed period of time or within a fixed region of space can often be modeled by the Poisson distribution (DeGroot, 1989). Examples include the number of telephone calls received by a switchboard operator during a fixed period of time; the number of radioactive particles that strike a certain target during a fixed period of time; and the number of bomb hits in a defined area. The Poisson distribution is given as (Casella & Berger, 2002):

\[ P(x | \lambda) = \frac{e^{-\lambda} \lambda^x}{x!} \quad x = 0, 1, 2, \ldots ; 0 \leq \lambda \]  

(1)

The single positive parameter \( \lambda \) is the expected number of occurrences per unit time, sometimes referred to as the mean occurrence rate. In addition to being the expected value of the Poisson distribution, \( \lambda \) is also the variance of the distribution. The occurrence rate can be estimated by

\[ \hat{\lambda} = \frac{x}{n} \]  

(2)

where \( x \) is the number of occurrences observed and \( n \) the number of units of time over which the observation was made.

Confidence Intervals
A two-sided \( 100(1 - \alpha)\% \) confidence interval for \( \lambda \), given \( x \) occurrences in \( n \) units of time can be found by (Hahn & Meeker, 1991):

\[ \left[ \hat{\lambda} - \frac{0.5 \chi^2_{(\alpha/2,2x)}}{n}, \hat{\lambda} + \frac{0.5 \chi^2_{(1-\alpha/2,2x+2)}}{n} \right] \]  

(3)

where \( \chi^2_{(r)} \) is the \( 100r \)th percentile of a chi-square distribution with \( r \) degrees of freedom. One-sided lower and upper \( 100(1 - \alpha)\% \) confidence bounds for \( \lambda \) are obtained by replacing \( \alpha/2 \) by \( \alpha \) in the first and second parts of Equation(3), respectively. Thus, a \( 100(1 - \alpha)\% \) one sided upper confidence bound for \( \lambda \) is:

\[ \bar{\lambda} = \frac{0.5 \chi^2_{(1-\alpha/2,2x+2)}}{n} \]  

(4)

False Alarm Testing
The number of false alarms produced by a radiation detection system over some fixed time period for which the false alarm rate is not expected to vary (e.g. stable background) can be reasonably modeled by a Poisson distribution. The false alarm occurrence rate can be estimated, as described by Equation (2) by the number of occurrences observed over a fixed period of time divided by the number of units of time this observation was made.

When reporting estimates that are a result of limited test observations, some measure of the sampling variability and hence the uncertainty of the estimate should be provided. One approach to including such information is in the form of a confidence interval or a confidence bound. As it is desired to maintain a false alarm rate as small as possible, a one-sided upper confidence bound is an appropriate measure to report as it provides information of how large the desirably small true false alarm rate may actually be. For example, if 0 false alarms were observed in a test period of 3 hours, the false alarm rate would be estimated to be $\hat{\lambda} = 0$ per hour with a 95% upper confidence bound of $\hat{\lambda} = 1$ per hour. Thus, one could state with 95% confidence that the false alarm rate for the radiation detection system is no greater than 1 per hour.

When developing a false alarm test, the desired precision and strength in a false alarm statement as well as the estimate uncertainty must be considered. In the noted example, stating that a false alarm rate does not exceed 1 per hour may be of limited use but given the limited test time, a stronger statement cannot be made. If one would like to state that the false alarm rate will not exceed 1 per 8 hour work shift ($\hat{\lambda} = 0.125$), a false alarm test must extend for 24 hours with 0 occurrences observed. Table 21 displays the 95% one-sided upper confidence bounds for the hourly false alarm rate for test durations ranging from 1 hour to 48 hours and number of observed false alarm occurrences ranging from 0 to 10.

| Test Duration (hours) | 0   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1                     | 3.00| 4.74| 6.30| 7.75| 9.15| 10.51| 11.84| 13.15| 14.43| 15.71| 16.96|
| 2                     | 1.50| 2.37| 3.15| 3.88| 4.58| 5.26 | 5.92 | 6.57 | 7.22 | 7.85 | 8.48 |
| 3                     | 1.00| 1.58| 2.10| 2.58| 3.05| 3.50 | 3.95 | 4.38 | 4.81 | 5.24 | 5.65 |
| 4                     | 0.75| 1.19| 1.57| 1.94| 2.29| 2.63 | 2.96 | 3.29 | 3.61 | 3.93 | 4.24 |
| 5                     | 0.60| 0.95| 1.26| 1.55| 1.83| 2.10 | 2.37 | 2.63 | 2.89 | 3.14 | 3.39 |
| 6                     | 0.50| 0.79| 1.05| 1.29| 1.53| 1.75 | 1.97 | 2.19 | 2.41 | 2.62 | 2.83 |
| 7                     | 0.43| 0.68| 0.90| 1.11| 1.31| 1.50 | 1.69 | 1.88 | 2.06 | 2.24 | 2.42 |
| 8                     | 0.37| 0.59| 0.79| 0.97| 1.14| 1.31 | 1.48 | 1.64 | 1.80 | 1.96 | 2.12 |
| 9                     | 0.33| 0.53| 0.70| 0.86| 1.02| 1.17 | 1.32 | 1.46 | 1.60 | 1.75 | 1.88 |
| 10                    | 0.30| 0.47| 0.63| 0.78| 0.92| 1.05 | 1.18 | 1.31 | 1.44 | 1.57 | 1.70 |
| 11                    | 0.27| 0.43| 0.57| 0.70| 0.83| 0.96 | 1.08 | 1.20 | 1.31 | 1.43 | 1.54 |
| 12                    | 0.25| 0.40| 0.52| 0.65| 0.76| 0.88 | 0.99 | 1.10 | 1.20 | 1.31 | 1.41 |
| 13                    | 0.23| 0.36| 0.48| 0.60| 0.70| 0.81 | 0.91 | 1.01 | 1.11 | 1.21 | 1.30 |
| 14                    | 0.21| 0.34| 0.45| 0.55| 0.65| 0.75 | 0.85 | 0.94 | 1.03 | 1.12 | 1.21 |
| 15                    | 0.20| 0.32| 0.42| 0.52| 0.61| 0.70 | 0.79 | 0.88 | 0.96 | 1.05 | 1.13 |
| 16                    | 0.19| 0.30| 0.39| 0.48| 0.57| 0.66 | 0.74 | 0.82 | 0.90 | 0.98 | 1.06 |
| 17                    | 0.18| 0.28| 0.37| 0.46| 0.54| 0.62 | 0.70 | 0.77 | 0.85 | 0.92 | 1.00 |
D.2 Binomial Distribution

Sample size calculation

When an observable is described by only two possible outcomes (e.g. alarm, no alarm) the number of occurrences is modelled by the Binomial distribution.

Let the observable \( X \) have \( \text{Bin}(n, p) \) distribution. For a given \( (1-\alpha)\% \) confidence level, the lower \( (1-\alpha)\% \) confidence bound, \( p = p(X, n, \alpha) \), for the binomial probability \( p \) is known (Bickel, Doksum, 1977, pp 180-182; Casella, Berger, 2002, pp 411-412) to have the form
\[ p = \max \{ p : \text{binocdf}(X-1, n, p) \geq 1 - \alpha \}. \]

where,
\[
\text{binocdf}(x, n, p) = \sum_{k=0}^{x} \binom{n}{k} p^k (1-p)^{n-k},
\]

for the binomial cumulative distribution function is employed. Our goal is for given \( X \) to determine the range of \( n \) such that, say, for prescribed \( \alpha \), one has \( p \geq p_0 \). This range is formed by all sufficiently large positive integers.

Notice that \( \text{binocdf}(n-1, n, p) = 1 - p^n \), so that when \( X = n \) (i.e. there are no failures in \( n \) trials), the smallest sample size \( n \) can be found from the formula,
\[ n = \frac{\log \alpha}{\log p_0}. \]

The following tables of more general \( n \)-values are constructed by using \( \text{binocdf}(x, n, p) \) function for several \( \alpha \) and for different values of the \((1-\alpha)\%\) guaranteed probability of success \( p_0 \), i.e. the prescribed or guaranteed values of \( p \).
Table 22: The necessary sample sizes for different levels $p_0 = 0.99; 0.98; 0.95; 0.90; 0.80$ and the number of failures $k$ for $\alpha = 0.05$

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<th>0.99</th>
<th>$n$</th>
<th>0.98</th>
<th>$n$</th>
<th>0.95</th>
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False Alarm Testing

To prove the requirement that the probability of a false alarm ($P_{FA}$) is no greater than 1 in 1,000; i.e. $P_{FA} \leq 0.001$, one must show the upper confidence bound for the estimate of $P_{FA}$ to be less than or equal to 0.001. The probability of a false alarm is estimated based on the Binomial distribution (see Casella & Berger (2002)). A 95% upper confidence bound for the estimate of $P_{FA}$ can be calculated based on the methods of Agresti and Coull (1998) as displayed in Equation (5).

$$P_{FA}^* = \frac{x + z_{0.95}^2}{2n} + z_{0.95} \sqrt{\frac{x}{n} \left(1 - \frac{x}{n}\right) + \frac{z_{0.95}^2}{4n^2}}$$

(5)

Where $x$ is the number of alarms observed, $n$ is the total number of occupancies, and $z_{0.95} = 1.645$ is the 95% quantile from the standard normal distribution.

Assuming no alarms will be observed ($x = 0$), Equation (5) can be solved for $n$ provided the upper confidence bound for false alarms, $P_{FA}^* = 0.001$. This value, $n = 2703$, is the minimum number of occupancies that must be observed without a false alarm to prove the requirement that the probability of a false alarm is no greater than 1 in 1,000.

Alternatively, assuming a single alarm will be observed ($x = 1$), Equation (5), with $P_{FA}^* = 0.001$ can again be solved for $n$. This value, $n = 4480$, is the minimum number of occupancies that must be observed with only a single false alarm to prove the requirement that the probability of a false alarm is no greater than 1 in 1,000.

Table 23 provides the upper confidence bound for the probability of a false alarm for various numbers of occupancies when 0, 1, ..., 10 false alarms are observed. It’s important to note that the number of occupancies to be observed must be determined prior to testing, that is, one should not begin testing and adjust the number of occupancies based on the results obtained at any point in time.

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</table>
References


Annex E – List of Test Facilities and Associated Capabilities

The following information was provided by the individual test facility.

E.1 Oak Ridge National Laboratory (ORNL)

The ORNL Technical Testing and Analysis Center performs radiological, temperature, humidity, air pressure (altitude), magnetic field, EMI/EMC, line noise, voltage variation, vibration, shock tests against ANSI and IEC standards for radiation detection instruments. Automated data collection and viewing when needed. Uses NIST traceable sources for testing of radiation detection instruments. NIST traceability is claimed for the calibration of all instrumentation used for testing. The following is a list of the testing capabilities:

Environmental Testing:
- Two Environmental Chambers
  - Temperature (-70 to 170 ºC each)
  - Large volume addition 6.5 ft (d) x 8.5 ft (w) x 9.5 ft (h)
- Maritime
- Moisture
- Dust

Radio Frequency Testing (emissions and susceptibility)
- EMCO model 5311 Gigahertz Transverse Electromagnetic (GTEM) wave cell
  - DC to 18 GHz with up to 1 kW input power.
- Three-meter Anechoic Chamber for large device analysis
  - 80MHz to 18GHz

Microphonics Specialized Testing
- Atmospheric conditions
- Magnetic fields
- Ionizing Radiation Gamma
  - Beta
  - Alpha
  - Neutron
  - X-Ray

Field Characterization
- RF, Mechanical Shock, Vibration and Radiation
- Power Line Test Systems
  - Sags, surges, voltage fluctuations, and transients
- Ionizing Radiation
  - Gamma, Beta, Alpha, Neutron, and X-Ray

Mechanical Testing
- Vibration and mechanical shock
- Random and sine vibration
- Large device up to 5000 lbs capacity system available
- Driven Linear System (DLS) for controlled linear movements (transient testing) up to 8K per hour
Magnetic Field
- 10 Gauss DC and 1.26 Gauss AC

E.2 Pacific Northwest National Laboratory (PNNL)/Northwest EMC

Radiological
Radiological testing is performed using a variety of irradiators and source materials. Irradiators include:

- Low-Scatter Neutron Facility that provides neutron (heavy water- $D_2O$- moderated and unmoderated $^{252}Cf$) and gamma ($^{60}Co$ and $^{137}Cs$) irradiations in a free-space geometry
- X-ray laboratory capable of National Institute of Technology (NIST) and International Standards Organization (ISO) specified bremsstrahlung and K-fluorescent x-ray spectra
- Gamma reference fields using an open (2π) $^{241}Am$ source and a collimated beam $^{137}Cs$ irradiator
- A high-exposure facility capable of delivering a large-volume, uniform gamma radiation field (0.08 R/h to ~5 x 10R/h) for standard calibrations or evaluating the effects of radiological dose on materials
- beta-particle laboratory that maintains $^{85}Kr$, $^{204}Tl$, $^{147}Pm$, and $^{90}Sr$/$^{90}Y$ as international secondary standard sources for instrument and dosimetry characterization

Source materials include:
- an extensive inventory of planchet and point sources
- Special nuclear materials required by the ANSI N42.XX series of instrument testing standards.
- Neutron sources including moderated and unmoderated $^{252}Cf$, AmBe, and PuBe sources
- Naturally Occurring Radioactive Materials (NORM) as needed for testing
- Contract mechanisms to easily acquire short-lived medical isotopes as needed.
- Isotopes available at PNNL include isotopes required by ANSI N42.34:
  - $^{40}K$, $^{57}Co$, $^{60}Co$, $^{67}Ga$, $^{99m}Tc$, $^{125}I$, $^{131}I$, $^{133Ba}$, $^{137}Cs$, $^{192Ir}$, $^{201Tl}$, $^{226Ra}$, $^{232Th}$, $^{233}U$, $^{235}U$, $^{238}U$, Pu [Reactor grade plutonium], $^{241}Am$

Environmental
Environmental chambers are available with temperature and relative humidity (RH) ranges of -70°C to 170°C and 5% to 95% RH. Condensing environments can be created in the chambers.

A pressure/vacuum chamber simulates atmospheric pressure from 26 kPa to 370 kPa.

Electromagnetic Compatibility
Electromagnetic compatibility testing is performed at a subcontracted facility managed by Northwest EMC. Northwest EMC is NVLAP accredited to perform the clause 8 electromagnetic compatibility tests in the DHS ANSI N42.XX series of standards.

Mechanical
Instrument performance after and during mechanical vibrations and shocks is determined using a variety of test equipment, including two vibration tables and a mechanical shock generator.

Small payloads (up to 45 kg [100 lb]) are tested on a table with a maximum acceleration of 10 G, over the frequency range of 10 to 60 Hz (Figure 2.19). A computer controller can be used for high-range, random, and fine vibrations with the smaller table. Up to 680 kg (1500 lb) are tested on a vibration table with a maximum acceleration of 3.2 G over the frequency range of 8 to 60 Hz. A maximum acceleration of 63 G over the frequency range of 5 Hz to 10 kHz is available with smaller test loads.

A mechanical shock generator produces mechanical shocks up to 100 G.

**AC Power and Line Noise Susceptibility**
Instruments are tested for immunity to variants in the AC power and for line noise susceptibility using an AC power line noise tester. Variations in power line voltage and frequency are generated over the voltage range of 0 to 125 V (or 0 to 250 V) and in the frequency range of 20 to 2,000 Hz. Voltage sags and surges of 0 to ±5% of the power supply frequency can be generated. To simulate large transients (e.g., lightning strikes), a transient generator capable of generating ring wave and bi-wave transients meeting specifications of ANSI/IEEE C62.41 (1991) is used.

**E.3 Global Testing Laboratory (GTL)/Savannah River Site/Savannah River National Laboratory (SRNL)**

**Savannah River Site/Savannah River National Laboratory**
- Automated technology for calibration and testing radiation detection devices
- NVLAP Accreditation for Calibration Services
- Comprehensive instrument testing, calibration and maintenance
- Capacity of 3000 radiation detection instrument calibrations per month
- 10 CFR 835 Compliant
- 10 irradiator systems throughout shielded facility with computerized instrument and source positioning, video capability and safety interlocks
  - X-ray irradiator (up to 250 keV)
  - Low Scatter Irradiator
  - Low Level Irradiator
  - Gamma Beam Irradiator (up to 10,000 R/h)
  - Panoramic Irradiator
  - Beta Beam Irradiator (up to 20 rad/h)
  - Three Gamma Well Irradiators
  - Neutron Well Irradiator
- NIST traceable sources in a variety of sizes
  - Co-60, Sr/Y-90
  - Cs-137
  - Pu-239
  - Cf-252 bare and moderated
- Numerous low-level, sealed sources for bench-top instrument testing and calibration
- Equipment and tritium gas for tritium detection equipment testing and calibration
- Two Environmental test chambers for variable temperature and humidity tests
- Loading dock with hydraulic lift for large equipment

**Global Testing Laboratories**

- Testing certifications include: ISTA, ANSI C63.4, ISO 17025, CE Marking, TUV America (CARAT), NEMKO (ELA certified), FCC/IC (Canada), NVLAP 200409-0, NMFTA
  - Equipment includes:
    - Two Environmental Test Chambers for variable temperature and humidity tests
    - Drop Tester
    - Two Vibration Testers capable of sine, random, and transit shock for equipment up to 5,000 lbs
    - Dust Chamber
    - Semi-Anechoic Chamber
  - RF Emissions Measurements
    - FCC Part 2, 15, 18, 76, and 95
    - EN 55011, 13, 14, 16, 20 & 22
    - EN 50081-1 & 82-1
    - EN 61000-3-2 & 3
    - ETS/CISPR/IEC
    - EN 60601-1-2
  - RF Immunity Measurements
    - EN 55020
    - IEC 1000-4-2, 3, 4, 5, 6, 8 & 11
    - EN 50082-1 & 82-2
    - EN 61000-4-2, 3, 4, 5, 6, 8 & 11
    - EN 60601-1-2
  - Safety Tests
    - UL/CSA/cUL/TUV/NEMKO
    - CE Low Voltage Directive
    - IEC/EN 61010
    - IEC/EN 60950
    - IEC/EN 60335
    - EN 60601
  - Environmental
    - NEMA/SAE
  - NEBS Testing
    - TA-NWT-00487
    - GR-63-CORE
    - GR-950-CORE
    - GR-1089-CORE
  - Transportation
    - ISTA Certified Test Laboratory
    - NMFTA (Item 180)
    - Vibration up to 5,000 lbs

**E.4 WDTC - Dugway**

Dugway processes the following sources:
- Co-60 (sealed source), 12,000 Curies, for use in a J.L. Shepherd & Associates Model 484C self-shielded irradiator
• Co-60 (sealed source), 24,000 Curies, for use in a J.L. MDS Nordion Model C-198 self-shielded irradiator

Dugway tests warfighter equipment that is used worldwide so it is expected to be operationally ready despite being subject to a multitude of physical and environmental stresses that each item may encounter during its life cycle. Stresses can include the affects of handling, transportation (e.g. road vibration/shock, in-flight vibration or low pressure), open or closed storage (temperature/humidity extremes), and deployment by soldiers and ground personnel in land vehicles, or aboard ships and aircraft. The U.S. military operates in all climates, including tropical, arctic, and arid locations, where materiel and equipment may be subject to extremes of heat, cold, precipitation, wind, salt water, fog, dust, and sand.

MIL-STD-810 is the standard for all U.S. Department of Defense (DoD) departments and agencies that requires, as part of the acquisition process, tailoring an item’s design and engineering criteria to environmental conditions that the materiel or equipment will experience throughout its service life. The test and evaluation community develops methods and conduct tests that replicate the effects of environmental stress to ensure each item will function as required. The Joint Test Facility Branch supports the West Desert Test Center’s (WDTC) chemical, biological, and special programs test projects by maintaining the joint chemical/biological test facilities and providing certified facility operators and technicians to conduct tests and evaluate materiel and equipment to meet MIL-STD-810 standards.

The WDTC utilizes 40 environmental conditioning chambers to subject materiel and equipment to extremes caused by physical forces (e.g. vibration, shock, drop) and the environment (e.g. temperature, humidity, altitude, marine areas) and in both cyclic and steady-state conditions. Five specialty chambers are available to test the effects of fungal growth, salt fog, altitude, vibration, and time and temperature reactions of munitions (slow cook-off).

Mobile and skid-mounted chambers which replicate the extremes of climatic environments may also be used to disseminate environmental or battlefield contaminants, such as fog oil or jet propulsion fuel (JP-8) for chamber and field test trials. Dynamic and environmental tests may be video recorded while photographs are taken to capture the results of each test. Scientists, test officers, and analysts perform data acquisition, measurement, control, and analysis with National Instruments Corporation’s LabVIEW software.

**Vibration/Shock/Loose Cargo** – Vibration testing determines how test items can both function in and withstand vibration exposures during its life cycle, including environmental effects, materiel duty cycle, and equipment maintenance. The physical test chamber and bounce table are housed within the Vibration Test Building located at the Carr Facility and are certified for testing high explosive munitions.

The 8x8x6.5-foot physical test chamber features a 5x5-foot vibration table for test items up to 6,000 pounds and utilizes a two-inch displacement generating up to 38,000 pound-force for high-intensity shock tests. The physical test chamber allows vibration testing under varying temperature (-100°F to 200°F) and humidity (5% to 98%) conditions. The 6x8-foot loose cargo transportation simulator (bounce table) provides a one-inch circular orbit (up to 300 rpm) to test an item’s ability to withstand transportation over rough terrain. Certified technicians analyze the dynamic deflections of or within the material which may cause or contribute to structural fatigue and mechanical wear of structures, assemblies, and parts.
Drop Tests – The WDTC utilizes a 12.1-m (40-ft.) drop tower to analyze the impact of single test items or multiple test items that have been packaged and palletized (up to five cubic feet) with weights up to 3,000 pounds (maximum 250 pounds for high explosives). The drop tower facility includes a control room bunker and observation bunker, with steel, concrete, and earth drop surfaces to perform tests to MIL-STD-331 standards. Test items are attached to a quick-release hook, raised by hoist to the designated height and released for a free-fall drop. Test items may be dropped at various orientations, including:
- Major axis horizontal
- Major axis vertical, base down
- Major axis vertical, nose down
- Major axis 45°, base down
- Major axis 45°, nose down

Technicians perform damage assessments to determine if the items are packaged properly, and for munitions and explosives, record whether the test item exploded, burned, lost propellant or is safe to handle.

Slow Cook-Off – This test determines the time and temperature at which a test cartridge (one round bare and one round in shipping overpack) or other energetic item will react when submitted to a gradually increasing thermal environment. Certified test personnel conduct slow cook-off tests inside an impenetrable conditioning chamber housed within a mobile, 10x10x10-foot custom-built trailer. The conditioning chamber has a heating capacity from 70°F to 700°F and each test item is subject to increasing temperatures at a rate of 3.3°C (5.9°F) per hour until a reaction occurs. Once the reaction occurs, the elapsed time of heating component parts (e.g. fin assembly, fuse, and burster) is recorded along with the time/temperature relationship, cratering, and fragment size to indicate degree of reaction.

Environmental Tests

Altitude (Low Pressure) – Altitude tests determine if materiel can withstand or operate in a low pressure environment, or withstand rapid temperature changes. The Altitude Chamber is located at the Carr Facility and can create atmospheric pressure ranging from sea level to 100,000 feet. The 4x4x4-foot chamber can be used to test explosives in a temperature-controlled environment ranging from -70°F to 200°F. Certified technicians examine the effects of altitude on test items that may include: leaks from gasket-sealed enclosures, deformation/rupture of sealed containers, evaporation of lubricants, and operational malfunctions of mechanical/electrical components.

High and Low Temperature – Testers evaluate the potential effects of high and low temperature conditions on materiel safety, integrity, and performance during storage, operation, and handling. The WDTC employs 13 fixed and 7 mobile chambers each able to achieve temperatures between -100°F and 200°F. Four fixed chambers (12x8x8-ft.) are located at the Carr Facility; the nine large (25x8x8-ft.) chambers are located at the White Sage Mortar Range and at German Village. Mobile temperature chambers (12x7x7-ft.) can be transported to any test location and all chambers are certified to test explosives. Tests determine whether
temperature extremes temporarily or permanently impair performance of materiel by changing physical properties or dimensions, such as:

- Materiel parts bind, harden, or become brittle
- Lubricant viscosity changes
- Failure of packing, gaskets, seals, bearings and shafts
- Changes in electronic components
- Changes in burning of explosives or propellants

Conditioning chambers are also used for temperature shock (sudden air temperature changes >10°C/18°F) testing and accelerated aging tests of stored materials.

**Humidity** – Testers determine the resistance of materiel items stored or deployed in warm, humid environments, environments in which high levels of humidity occur, or to provide an indication of potential problems associated with humidity. The WDTC provides 17 mobile conditioning chambers (12x7x7-ft.) to create relative humidity (RH) conditions ranging from 3% to 97%; six chambers generate temperatures between 15°F and 200°F and 11 chambers have temperature capabilities between -100°F and 200°F. Certified technicians analyze the effects of humidity on materiel including:

- Surface changes, such as:
  - Oxidation
  - Increased chemical reactions
  - Chemical or electrochemical breakdown of organic and inorganic surface coatings

- Material property changes, including:
  - Swelling
  - Loss of physical strength
  - Changes in elasticity or plasticity
  - Degradation of explosives and propellants by absorption

- Condensation and free water causing:
  - Electrical short circuits
  - Fogging on optical surfaces
  - Changes in thermal transfer characteristics
**Fungus** – Test operators conduct fungus tests to assess the extent to which materiel will support fungal growth and how any fungal growth will affect materiel performance or utilization. The fungus chamber (22x8x8-ft.) is located at the Carr Facility and generates RH up to 98% with temperatures ranging from 15°F to 200°F. Mobile conditioning chambers are also used for fungal growth tests and evaluation.

WDTC microbiologists analyze the detrimental effects of fungal growth that may include:

- Direct breakdown of nonresistant materials and how the fungi use them as nutrients, such as:
  - Natural materials – Cellulosic materials; animal/vegetable-based adhesives; grease, oils, hydrocarbons; leather
  - Synthetic materials – PVC formulations; certain polyurethanes; plastics that contain organic fillers of laminating materials; paints/varnishes containing susceptible constituents.

- Damage to fungus-resistant materials from an indirect attack when:
  - Fungal growth on surface deposits, such as dust, grease, perspiration, and other contaminants causing damage to underlying material.
  - Metabolic waste products excreted by fungus causing metal corrosion, etching of glass, or staining/degrading plastics and other materials
  - Fungal growth on adjacent materials that is susceptible to direct attack some in contact with resistant materials.

**Salt Fog** – Tests determine the effectiveness and quality of protective coatings and finishes on materiel and material coupons, and to locate potential problem areas, quality control deficiencies, and design flaws in a short period of time. The salt fog chamber (12x8x8-ft.) located at the Carr Facility delivers a 5% salt solution mist (pH 6.5-7.2) to test items over a four-day test trial. Test operators alternate 24-hour salt mist applications with 24-hour drying periods under temperature-controlled conditions (15°F - 200°F). Test officers and technicians analyze test items for:

- Corrosion effects – Electrochemical reactions, accelerated stress, and formation of acidic/alkaline solutions following salt ionization in water.

- Electrical effects – Impairment of electrical equipment, production of conductive coatings, and corrosion of insulating materials and metals.

- Physical effects – Clogging or binding of mechanical components and assemblies, and paint blistering resulting from electrolysis.

**E.5 NSWCCD - Carderock Division**

Provides full spectrum support necessary to equip Navy ships and shore operations with radiation detectors, dosimetry devices and monitoring systems to protect Fleet and shipyard personnel from potential exposure to ionizing radiation. Provides the body of knowledge and the
laboratory facilities for research, development, testing and evaluation of new detection scintillators, solid state detectors, neutron detectors and advanced dosimetry phosphors, and provides partnering with industry to assure technological sustainment and superiority for the fleet’s war fighting missions. Executes the radiation detection acquisition plan as delineated by the program objective memorandum, to include product testing and evaluation leading to contract award, product acceptance testing and assistance in equipment fielding. Participates in national standards formulation pertaining to radiation detection and calibration, and provides in-service engineering support for fielded radiation detection systems. Provides facilities to support R&D efforts related to the detection and identification of Special Nuclear Material, including a 3 MV tandem accelerator equipped with state-of-the-art detection and spectroscopy systems, with the capability of producing tunable and highly controllable sources of neutrons, gamma rays, heavy charged particles.

E.6 WSMR testing capabilities

Performs radiological, nuclear weapons effects, temperature, humidity, air pressure (altitude), magnetic field, EMI/EMC, line noise, voltage variation, vibration, shock tests against ANSI and IEC standards for radiation detection instruments. Automated data collection and viewing when needed. WSMR testing capabilities is dependent on two separate organizations at WSMR; Survivability, Vulnerability and Assessment Directorate (SVAD). The following is a list of the WSMR testing capabilities in each area:

SVAD / WSTC. The SVAD / WSTC conduct complete life-cycle Nuclear Weapon Effects (NWE), Radiological Effects (RE), Electromagnetic Environmental Effects (E3), Directed Energy Weapons (DEW) and Applied Environments testing, evaluation and assessment. The SVAD has a full spectrum of in-house capabilities and facilities that allows for turnkey testing of almost any system, equipment, component or device in any of the above-mentioned environments. In order to provide a complete list of SVAD / WSTC capabilities, the information is provided in each of the following categories:

Nuclear Weapons Effects and Radiological Capabilities. SVAD / WSTC possess the following NWE and RE capabilities that support a multitude of different tests and assessments. The capabilities are:

a. The Linear Electron Accelerator (LINAC) is designed to simulate the gamma spike associated with a nuclear weapon detonation by producing high-intensity, short-duration pulses of high-energy electron radiation for simulated threat level exposures.

Technical Data

- Energy particle: Up to 25 MeV
- Pulse Width (FWHM)
  - Short Pulse: 7 – 200 nanoseconds (ns)
  - Long Pulse: 200 ns – 10 microseconds
- Rise Time (10 – 90%) ≤ 3 nanoseconds (Short Pulse)
- Dose Rate: 1 x 10^5 to 2.5 x 10^12 RAD(Si)/s (pulse width dependent)
- Repetition Rate Single Pulse to 50 pps
- Reproducibility ≤ 1.5%
- Exposure Cell – 6m X 6m X 7m
c. **The Physics International 538 (PI-538)** Gamma Radiation Simulator is normally Reactor time-tied for a Combined Environment. It enables a combined gamma dose rate and neutron fluence environment. The PI-538 also provides for Synergistic Effects Experiments. It can also be utilized for only gamma dose rate testing.

**Technical Data**

- Energy: (Total) 100 kJ / (Particle) 4.2 MeV
- Dose Rate: 1E10 RADs(Si)/s @ 50 cm
- Dose 1200: RADs(Si) @ 50 cm
- Pulse Width: ~85 ns
- Rise time: ~20 ns
- Repetition Rate: 4 pulses / hr
- Exposure Cell – 10m X 4m X 4m

d. **The Eldorado Irradiator Facility** is used for gamma dose simulation testing. The facility is capable of providing dose rates between 20 and 0.01 RAD-Si/sec in the direct beam with no attenuation. The Eldorado can also operate in an extended operation mode to fulfill the unique requirements of Space Radiation Environment tests. Utilizing off axis irradiations or aluminum attenuators lower dose rates are achieved.

**Technical Data**

- One Cobalt-60 Source (10, 300 Curies)
  - Purchased September 1994
- Dose Rates From 20 to less than 0.01 RAD(Si)/sec
- ELDRS Rates:
  - 0.012 RAD(Si)/sec Free Field
  - 0.001 RADs (Si)/sec Attenuated
- Exposure Cell – 6m X 6m X 7m

e. **The Radiation Correlation Facility (RCL)** is used to provide radiation fallout field simulation. The fallout field is simulated using two small sources, a Cobalt-60 isotope (Co-60) source (which simulates the early fallout spectrum up to ≈4 hours and the late fallout spectrum ≈+5 days) and a Cesium 137 isotope (CS-137) source (which simulates the mid time fallout spectrum ≈4 hours to ≈5 days).

**Technical Data**

- 75 mCi Cs-137
- 40 mCi Co-60
- 9 X 27 meters test area
- Co-located with Gamma Radiation Facility (GRF)

f. **The Fast Burst Reactor (FBR)** is an unmoderated and unreflected cylindrical assembly of uranium and molybdenum alloy. The FBR produces high-yield pulses of microsecond (μs) width, as well as long-term, steady state radiation, to closely simulate the neutron radiation environment produced by a fission weapon.

**Technical Data**
• System / Piece-part Level
• Burst and Steady-State (Power) Modes
• Burst Mode: Up to $6.5 \times 10^{13}$ n/cm$^2$ of 45μs width
• Steady state Mode: Up to 8 kW
• Gamma enhanced environment uses Cd loaded poly to produce gamma dose rates up to 108 RAD(Si) during pulse
• Large (15 m x 15 m x 6 m) heavily shielded underground exposure cell
• Individual or Combined Environments- Neutron and Gamma
• Adjacent underground experimenters room
• Underground and above ground experiments
• Outdoor exposure site

g. The White Sands Solar Thermal Test Facility produces intense thermal radiation pulses to simulate the thermal radiation from detonation of a nuclear weapon.

Technical Data

• Simulates nuclear thermal radiation.
• Total power = 33 kW
• $Q=0$, $Q-dot= 90$ (100) cal/cm$^2$-sec, $t_s=0.1\text{-}0.7$ sec
• Pulse, steady-state or square
• At full power, the energy generated can penetrate a ½” stainless steel plate in 40 sec
• Spectrum fidelity
• 10 cm diameter spot size

h. The Semiconductor Test Laboratory is a research, characterization and test facility complex where all varieties of electronic/photonic devices can be completely characterized (>7,000 already have), exposed to the correct initial nuclear radiation environment, and post-characterized within two minutes of irradiation to accurately measure any parametric degradation due to that radiation. Use to validate all Army nuclear survivable systems and to continue validation of their hardened critical items throughout their production and deployment (life-cycle). The equipment includes mainframe semiconductor test systems, board development equipment and supporting benchtop electronics equipment.

Technical Data

• Parametric characterizations are performed on the following mainframe testers:

  • Teradyne A575
  • Teradyne A580
  • Teradyne A585
  • Teradyne J750
  • Teradyne FLEX
  • Teradyne MicroFLEX
  • Credence ASL3000
  • Credence ASL3000RF (RF/Mixed)
  • Credence KALOS2
  • Credence D10 (Microcontroller/Mixed)
• Large variety of benchtop equipment
i. Additionally, SVAD / WSTC possess many other additional NIST traceable sources in support of radiological testing and equipment performance verification.

- **Americium 241 (Am-241):**
  - Liquid: Up to 5 uCi
  - Solid: Up to 6.4 uCi
- **Barium 133 (Ba-133):** Up to 2.6 uCi
- **Carbon 14 (C-14):**
  - Liquid: Up to 99.8 nCi
  - Solid: Up to 150 nCi
- **Cadmium 109 (Cd-109):** Up to 340 nCi
- **Chlorine 36 (Cl-36):** Up to 620 nCi
- **Cobalt 57 (Co-57):** 170 nCi
- **Cobalt 60 (Co-60):** Up to 9,265 uCi
- **Cesium 137 (Cs-137):** Up to 6.6 uCi
- **Europium 152 (Eu-152):** Up to 2.7 uCi
- **Europium 154 (Eu-154):** Up to 610 nCi
- **Iron 55 (Fe-55):** 85 pCi
- **Hydrogen 3 (Tritium) (H-3):** Up to 110 nCi
- **Manganese 54 (Mn-54):** Up to 200 nCi
- **Sodium 22 (Na-22):** Up to 600 nCi
- **Nickel 63 (Ni-63):** 89 nCi
- **Radium 226 (Ra-226):** Up to 4.9 uCi
- **Antimony 125 (Sb-125):** 1.1 nCi
- **Tin 121 (Sn-121):** 6.5 pCi
- **Strontium 90 (Sr-90):** Up to 9.9 uCi
- **Thorium 230 (Th-232):** 40 pCi
- **Uranium 238 (U-238):** Up to 5.32 uCi
- **Neptunium 237 (Np-237):** Up to 71 uCi
- **Plutonium 239 (Pu-239):** Up to 66.3 mCi

**Electromagnetic Environmental Effects (E3) Capabilities.** SVAD / WSTC possess the following E3 capabilities that support a multitude of different tests and assessments. SVAD operates extensive Electromagnetic (EM) Environmental Effects (E^3) Test Facilities to support the requirements for test and evaluation of systems while being subjected to electromagnetic environments (EMEs). SVAD E^3 test and evaluation capabilities are:

- Electromagnetic Radiation (EMR) – Operational (External RF EME)
- Electromagnetic Compatibility (EMC)
- Electromagnetic Interference (EMI)
- Electrostatic Discharge (ESD)
- Electromagnetic Pulse (EMP)
- EM Radiation Hazards (Fuel, Ordnance and Personnel)
- Lightning Effects (LE)

a. External RF EME is fully compliant to all the standards specified above and can support sub-systems and systems up to a large system, such as a Patriot Missile System. To such, we have both the required average and peak power requirements.

**Technical Data**

- **Entire Body Uniform Illuminations @ Full Threat**
  - 10 kHz – 500 MHz for Patriot size system
  - 10 kHz – 45 GHz for HMMWV size system
  - Up to 50 kW Transmitters for the lower spectrum
  - > 200 V/m field strength on Large Systems
  - AM, FM, PM and CW Modulations
  - Vertical and Horizontal Polarizations

- **Localized Illumination @ Full Threat**
  - 500 MHz – 45 GHz
  - AM, FM, PM and CW Modulations
  - Vertical and Horizontal Polarizations

- **Three Separate 72-ton, 33’ Diameter Turntable Sites**
- **One 70-ton, hydraulic Positioning System at Peak Power Test Site**
- **Seven Simultaneous Test Capabilities**
- **Capability to Safari to other locations**
- **Very Large EM Shielded Test Cell**
  - Radiated Emissions / EMI
  - Shielding Effectiveness
  - Interior Dimensions of 60’ long by 40’ wide and 40’ high
  - Exhaust System for Diesel and Turbine Engines

- **Peak Power No. 1**
  - 40’ x 8’ ISO Transportable Container
  - L-K Band Pulsed System
  - Variable Frequency: 1 – 18 GHz
  - 15 Magnetrons, most 1 MW
  - Pulse Forming Network - 1-2 μs and optional 350 ns pulse width (FWHM)
  - Peak Power up to 3-5 kV/m @ 6m
  - Fully Automated
  - Each Magnetron has 50 Programmable Frequencies

- **Peak Power No. 2**
  - 40’ x 8’ ISO Transportable Container
  - L-K Band Pulsed System
  - Variable Frequency: 1 – 9 GHz
  - 8 Magnetrons, all>125 kW, most 1 MW
  - Capability to drive 3 MW Magnetrons
  - Pulse Forming Network – 1-2 μs and optional 350 ns pulse width (FWHM)
  - Peak Power up to 3-55 kV/m @ 1 m
  - Fully Automated
  - Each Magnetron has 50 Programmable Frequencies

- **Peak Power No. 3**
  - Pulsed UHF System
  - Variable Frequency: 140 MHz – 1 GHz
  - Average 150 kW
  - 2 - 250 μs pulse width

- **Peak Power No. 4**
b. EMC / EMI are fully compliant to all the standards specified above and can support sub-systems. To such, we have the capabilities to conduct the following tests.

**Technical Data**

- MIL-STD-461E/F Compliant
  - Anechoic Chamber
  - Radiated Susceptibility
    - 0.1 MHz – 45 GHz (200 V/m Intensity)
  - Radiated Emissions, 3 MHz - 40 GHz
  - Conducted Emissions (all MIL-STD)
  - Conducted Susceptibility (CS-114, CS-115 and CS-116)
  - Radiated Susceptibility RS-105
  - MIL-STD-188-125 Pulsed Current Injection

c. ESD and Hazards are fully compliant to all the standards specified above and can support sub-systems. To such, we have the capabilities to conduct the following tests.

**Technical Data**

- Helicopter ESD
  - Up to 300 kV DC/Positive and Negative
  - Up to 400 kV DC/Positive
- Personnel ESD
- HERO – Hazards of Electromagnetic Radiation to Ordnance
- HERF – Hazards of Electromagnetic Radiation to Fuel
- HERP – Hazards of Electromagnetic Radiation to Personnel

d. **The Horizontally Polarized Dipole II (HPDII)** High-Altitude Electromagnetic Pulse (EMP) simulator is a MIL-STD- 2169B Early-Time Waveform type free field HEMP simulator. The HPD-II is located at WSMR, but is a mobile EMP simulator and routinely requested to be transported to remote sites. The mobile HPD-II consists of a lowboy trailer used to transport the pulser, antenna and a 100-channel data acquisition trailer. Additionally, a new Horizontal and Vertical EMP is being developed and should be available NLT 1 Jan 12.

**Technical Data**

- MIL-STD-2169B, E1 System Tests
- 30 X 30 m Test Area
- Peak E-field – 70 kV/m
- Rise time - <2 nsec
- FWHM – 20 nsec
• Mobile
• Pulse Power Current Injection
• Multiple Methods for data collection
• 100 Channels of instrumentation

e. The Lightning Test facility (LTF) is capable of simulating both the direct and indirect lightning strike characteristic required in lightning effect testing. The LTF is also capable of simulating the characteristic of a direct strike. A high current bank is capable of producing components A and D. The “A” component is 200,000 Amps.

Technical Data

• MIL-STD-464A Compliant
• 50 X 50 m Test Area
• Peak E-Field – up to 200 kV/m
• Rise time – 2 µsec
• FWHM – 20 µsec
• Multiple Methods for data collection
• 100 Channels of instrumentation
• Separate Direct and Indirect Strike Capabilities

Directed Energy Weapons (DEW) Capabilities. SVAD / WSTC possess the following DEW capabilities that support a multitude of different tests and assessments. SVAD DEW test and evaluation capabilities are comprised of laser and Radio Frequency Weapons (RF):

a. Pulsed Laser Vulnerability Test Systems (PLVTS) Facility is a research and test facilities complex where components and systems can be tested for survivability to various lasers. Test requirements are specified in system’s System Threat Assessment Report (STAR). The fundamental mission of the PLVTS is to provide the facilities, expertise and methodologies to perform Test and Evaluations of Laser Systems, Laser Pointer Trackers, and susceptibility and vulnerability testing.

Technical Data

• 10.6 micron wavelength
  o 1000 Joules Pulse Energy
  o Peak Power – 35 MW
  o PRF – Single Pulse to 30 Hz
  o Transportable
• Tunable Frequency Agile Lasers
• 60 cm Transportable Advanced Pointer Tracker (APT)
• Eye-Safe lasers

b. RF Weapons is a research and test facilities complex are high power microwave test suites of Narrow and Wide Band Threat Systems (NBTS and WBTS), Ultra-Wide Band (UWB) and RELTRON, and also includes small suitcase wide band threat system (DIEHL Source), and data acquisition systems. The high powered, narrow and wide band emitters and antenna systems are a Joint asset in the Department of Defense (DoD) for use by the other Services. The mission is conducting High Power Microwave testing at narrow and wide bands in an open air test for major DoD systems.
Technical Data

- **Narrowband**
  - HPM Threat Simulator
  - DETEC NBTS A
  - **Narrowband – Future**
    - **DETEC NBTS A**
    - **DETEC NBTS A Prime**
    - **DETEC NBTS B**
    - **DETEC NBTS C**
- **Wideband**
  - DETEC SWBTS
  - DETEC WBTS
- **Ultra-Wideband**
- **Data Acquisition**
  - Sensor Suite
  - Threat Hazard Prediction
- **Wideband (WB)**
  - WBTS - 100 – 3000 MHz
- **Ultra-Wideband (UWB)**
  - 600 – 4000 MHz
  - 30,000 V/m @ 30 meters
- **Small-Wideband**
  - SWBTS
  - 150 – 280 MHz
- **Super Reltrons, High Energy**
  - 750 – 3000 MHz
  - 590 ns Pulsewidth
  - 5 pps
  - Up to 50,000 kV/m @ 15m, 3m x 4m
- **NBTS Suite A**
  - 20 Hz Rep Rate
  - 1000 – 1700 MHz
- **NBTS Suite A Prime**
- **NBTS Suite B**
- **High Power Microwave (HPM) – Small Systems**
  - 31 Magnetrons, 125 – 3000 MW
  - 350, 1000 and 2000 ns pulsewidth
  - 4 - 6 kV/m @ 6m
  - 1.25 – 40 GHz
  - Amplifier System, 140 – 1000 MHz, 150 kW
- **Containerized, Transportable**

**Applied Environments Capabilities.** SVAD / WSTC possess the following Applied Environments capabilities that support a multitude of different tests and assessments. SVAD Applied Environments test and evaluation capabilities are comprised of Climatics, Shock and Vibration, Radiography, Metallurgy, and Chemistry:
a. Climatics Facilities are research and test facilities where components, sub-systems and systems can be tested for performance for Hot Temperature, Low Temperature, Salt Fog, Humidity, Rain, Ice, Solar Radiation, Sand and Dust as shown below.

Technical Data

- Temperature Test Facility (TTF) - Hazardous
  - Large Chamber (105'L x 40'W x 50'H)
  - Small Chamber (35'L x 30'W x 20'H)
  - Salt Fog & Humidity Chamber (20'L x 15'W x 10'H)
- Multipurpose Chamber (70' x 24' x 21') - Non-Hazardous
  - Temperature (70 to 180o F)
  - Humidity and Salt Fog (5 to 100%)
  - Rain (0.5 to 27 in./hr)
  - Solar (360 Btu/hr/ft2)
- Environmental Test Area II (ETA-II)
  - Sand & Dust Chamber
  - Outdoor Blowing Sand Facility
  - Outdoor Rain Facility
- Portable (Remote) Test Facilities

b. Dynamic Facilities are research and test facilities where components, sub-systems and systems can be tested and contains several electrodynamic vibration exciters, a 108 inch diameter arm centrifuge, a rocket motor static fire thrust stand, and shock machines for hazardous or nonhazardous testing. Large reaction masses accommodate multiple exciters for tests involving large forces, massive test items, or multiple degrees-of-freedom excitation. Simultaneous temperature conditioning testing can be accomplished during vibration and shock testing. Computer based vibration control systems provide drive signal generation and closed loop control for stationary or transient test environments. Multi-axis vibration control systems are available for simultaneously controlling up to eight shakers.

Technical Data

- Vibration
  - Transportation
    - Truck, Trailer, & Track Vehicle
- Aircraft
- Loose Cargo
- Shock
  - Rough-Handling Drop
  - Classical & Compound Waveforms
  - Rail Impact
  - Pendulum Impact
  - Bench Handling
- Acceleration

c. Chemistry, Metallurgy and Microbiology Facilities are research and test facilities where components, sub-systems and systems. The Chemistry Laboratory is an all-purpose testing facility with a wide range of analytical activities. The laboratory is well equipped with modern instrumentation for the analysis of water, hazardous waste, wastewater, soils, and sludge.
Analytical services also include conformance testing, air quality measurements, explosives analysis, and unknown residue identification. The Metallurgy Laboratory is responsible for providing Non-destructive Testing Evaluation of Army materiel and equipment. Hazardous (explosives) tests are routinely performed at the facility. The laboratory provides a full complement of metallurgical capabilities devoted to material acceptance, failure analysis, corrosion analysis, heat treating, tensile testing, steel analysis and composition, and determination of physical and mechanical properties of ferrous and non-ferrous materials used in modern weapon systems. The Microbiology Laboratory conducts microbial testing in accordance with Mil-Std-810 to resolve problems presented by the biodeterioration of U.S. Army Materiel. The Microbiology Laboratory has three fungus test chambers that are available to determine the susceptibility of materiel to microbial attack. These chambers are employed to test components, subassemblies, small missiles, and materials.

**Technical Data: Chemistry Lab**

- Conformance Testing
- Project Support (Centralized and Field Work)
  - Missile Exhaust Gas Analysis
  - Explosives Analysis
  - Failure Analysis
  - Identification of Unknown Samples
  - Analytical Services Tailored to Customer's Request
- Environmental Analysis
  - Hazardous Waste Characterization
  - Identification of Unknowns
  - PCB Analysis
  - Air and Water Quality Measurements
  - Spill Characterizations
- ORLAB Certified

**Technical Data: Metallurgy Lab**

- Nondestructive Evaluation (NDE) of Material
- Failure and Material Analysis on Metallic, Nonmetallic, and Advanced Engineering Materials
  - Scanning Electron Microscope (SEM)
  - Energy Dispersive X-Ray (EDX) Analyzer
  - LECO Carbon Determinator
  - Lietz Optical Metallograph
  - Antonik Digital Hardness Tester
  - Antonik Microhardness Tester with Digital Interface
- Heat Treating Equipment and Furnaces
- 50,000 lb Servo-Hydraulic Tension, Compression, Fatigue, and Fracture
- Toughness Testing Machine Equipped with Crack Correlation
- 22” Diamond Wire Guillotine Saw

**Technical Data: Microbiology Lab**

- Expertise
  - MIL-STD 810 Tests
  - ASTM
• Federal Test Methods
• Resources
  ▪ Complete Laboratory Facility
  ▪ Large Test Chamber
• Project Support / Testing
  ▪ Research and Development
  ▪ Test and Evaluation
  ▪ Consulting and Monitoring

E.7 US Army Test Measurement and Diagnostic Equipment (TMDE) Activity

The U.S. Army Test, Measurement, and Diagnostic Equipment Activity (USATA) mission is to provide the Army with metrology, calibration, and repair support for test, measurement, and diagnostic equipment (TMDE) in all required parameters, and to ensure that the measurements made with calibrated TMDE are traceable to national, international, or intrinsic standards of measurement via the U.S. Army Primary Standards Laboratory (APSL).

U.S. Army Primary Standards Laboratory: The U.S. Army Primary Standards Laboratory (APSL), a major component of USATA, is the Army’s center of expertise in the field of metrology. It is the Army’s highest level measurement laboratory in all parameters requiring support by Army weapons systems. In this capacity, the APSL provides metrology and calibration services which are directly traceable to legal measurement standards maintained by the National Institute of Standards and Technology (NIST), the U.S. Naval Observatory, or to fundamental natural phenomena.

The APSL consists of U.S. Army Dosimetry Center, as well as five major metrology laboratories: the Physical Standards Laboratory, the Applied Physics Standards Laboratory, the Electrical Standards Laboratory, the Electromagnetic Standards Laboratory, and the Radiation Standards Laboratory. Each laboratory is accredited to ISO/IEC 17025 in all of the major measurement parameters by the American Association for Laboratory Accreditation (A2LA). The Army Dosimetry Center is fully accredited by the National Voluntary Laboratory Accreditation Program (NVLAP). Point of contact for details regarding APSL services is the Laboratory Director, telephone (256) 876-2666.

U.S. Army Radiation Standards Laboratory: The Radiation Standards Laboratory (RSL) consists of three measurement sections: Photonics, Nucleonics, and Nuclear Counting. The Photonics section provides calibrations and measurements for non-ionizing radiation parameters. The Nucleonics section provides calibrations and measurements for ionizing radiation parameters. The Nuclear Counting section analyzes submitted samples for the presence of radioactive material and potential radioactive contamination. Point of contact for details regarding available RSL services is the Laboratory Chief, telephone (256) 876-3340.

a. Nucleonic Section: The Nucleonics laboratory provides calibration of health physics radiation measurement instrumentation and ionizing radiation sources with direct traceability to the National Institute of Standards and Technology (NIST). In addition, it provides engineering support for the Army in the field of radiation metrology.

The laboratory maintains a measurement capability for planar alpha radiation sources that is been accredited to ISO / IEC 17025 by A2LA. Alpha sources are measured for emission rate using a NIST-designed and developed counting system, which is
periodically tested for proper operation using NIST-calibrated sources. Sources calibrated using this system, are in turn used to calibrate alpha measurement instrumentation used for health and safety purposes.

Two x-ray calibration systems in the laboratory are used to calibrate x-ray measurement instrumentation for Army hospitals, medical facilities, and non-destructive inspection (NDI) facilities. The Nucleonics laboratory is the only site within the Army that performs such calibrations. The Nucleonics laboratory is A2LA accredited to ISO / IEC 17025 for such calibrations. The calibration systems are fully automated for enhanced safety and productivity.

The laboratory maintains two calibration systems incorporating cesium-137 and cobalt-60 for use in calibrating a wide range of gamma radiation measurement instrumentation. These systems are also fully automated, and are controlled from rooms separate from the rooms containing the sources themselves. The source rooms are low-scatter environments, which increases calibration accuracy. The Nucleonics laboratory is A2LA accredited to ISO / IEC 17025 for gamma calibrations.

The laboratory maintains a beta irradiation system that uses NIST-calibrated \(^{90}\)SrY and \(^{85}\)Kr sources for use in instrument calibration and dosimeter irradiation. The system is also fully automated. The Nucleonics laboratory is A2LA accredited to ISO / IEC 17025 for beta irradiations.

Gamma-ray Calibrations and Irradiations

<table>
<thead>
<tr>
<th>Radiation Type</th>
<th>Energy (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{241})Am</td>
<td>60</td>
</tr>
<tr>
<td>(^{137})Cs</td>
<td>662</td>
</tr>
<tr>
<td>(^{60})Co</td>
<td>1250</td>
</tr>
</tbody>
</table>

X-ray Calibrations and Irradiations

All X-ray beam codes identified in ISO 4037-1, “X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods” (1996), as well as the following NIST x-ray beam codes: L40, L50, L80, L100, M30, M40, M50, M60, M100, M150, M200, M300, H50, H150, H250, S60, and S75.

Beta Calibrations and Irradiations:
\(^{90}\)SrY, \(^{85}\)Kr, depleted uranium slab

Alpha Source Emission (from planar anodized sources) for instrument calibration:
\(^{238}\)Pu, \(^{241}\)Am
Beta Source Emission (from planar anodized sources) for instrument calibration: $^{90}\text{Sr}Y$, $^{137}\text{Cs}$, $^{14}\text{C}$, $^{99}\text{Tc}$, $^{238}\text{U}$

b. **Nuclear Counting Section:** The Nuclear Counting laboratory is an ISO/IEC 17025 accredited laboratory providing sample analysis for gross alpha/beta, $^{60}\text{Co}$, $^{137}\text{Cs}$ by gas proportional counting and $^3\text{H}$, $^{55}\text{Fe}$, $^{63}\text{Ni}$ analysis by liquid scintillation counting. The laboratory also has gamma spectrometry capabilities.
# Annex F - Sample user interface evaluation technique

## Controls

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Was the on/off switch easy to find?</td>
<td>Y/N</td>
</tr>
<tr>
<td>2.</td>
<td>Were all the controls labeled?</td>
<td>Y/N</td>
</tr>
<tr>
<td>3.</td>
<td>Were all the labeled controls easy to read/interpret?</td>
<td>Y/N</td>
</tr>
<tr>
<td>4.</td>
<td>Were all the controls easy to operate without gloves?</td>
<td>Y/N</td>
</tr>
<tr>
<td>5.</td>
<td>Could all the controls be operated with gloves?</td>
<td>Y/N</td>
</tr>
</tbody>
</table>

## Interface

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Was everything readable in low light levels</td>
<td>Y/N</td>
</tr>
<tr>
<td>7.</td>
<td>Was everything readable in high light levels</td>
<td>Y/N</td>
</tr>
<tr>
<td>8.</td>
<td>Did the display contain abbreviations or icons? (If no, skip next question.)</td>
<td>Y/N</td>
</tr>
<tr>
<td>9.</td>
<td>Were the abbreviations or icons easy to interpret or understand?</td>
<td>Y/N</td>
</tr>
</tbody>
</table>

## Operation

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td>Did the instrument convey its state-of-health at start-up (e.g., battery life, detector present and working, memory available, mode of operation)?</td>
<td>Y/N</td>
</tr>
<tr>
<td>11.</td>
<td>Did you have to refer to the instruction manual more than once to complete the test?</td>
<td>Y/N</td>
</tr>
<tr>
<td>12.</td>
<td>Was the menu structure simple and intuitive?</td>
<td>Y/N</td>
</tr>
<tr>
<td>13.</td>
<td>At any time during the test did the instrument prompt you for action?</td>
<td>Y/N</td>
</tr>
<tr>
<td>14.</td>
<td>Did the instrument issue any cautions or warning? (If no, skip next question.)</td>
<td>Y/N</td>
</tr>
<tr>
<td>15.</td>
<td>Did the instrument provide information on the nature of the cautions or warning and a corresponding course of action?</td>
<td>Y/N</td>
</tr>
</tbody>
</table>