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Preventive Rad/Nuc Detection Equipment Categorization for Consequence Management

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Executive Summary

The overall objective of this project is to research, evaluate, and test first responder preventive radiological/nuclear detection equipment (PRND) to provide state and local agencies with guidance on how to best use this equipment for response after a radiological/nuclear release or detonation. While the equipment being tested in this effort has been specifically designed for detection and interdiction operations, the fleet of PRND equipment can help fill critical needs for radiological instrumentation should a consequence management response take place. This effort will provide scientific guidance on the best way to deploy and operate this class of equipment for consequence management missions.

With the support of the US Department of Homeland Security's (DHS) Domestic Nuclear Detection Office (DNDO), PRND equipment has been placed into service at federal, state, and local agencies throughout the nation. If the equipment capability and limitations are taken into account, this large inventory can be repurposed to support the emergency response in the aftermath of a radiological of nuclear event.

This report evaluates PRND equipment to define key categories of equipment and the types of missions they can be used for. This is important because there are over 100 different types of PRND equipment, often with significantly different capabilities with respect to the consequence management mission. The current DNDO draft NIMS PRND equipment types were used as a foundation and expanded, when necessary, to address key characteristics important for the consequence mission. Table 1 provides a summary of the PRND instrument categories developed for this effort. Also included on the table are some common response mission detection equipment categories that will be used for capability comparisons.

Table 1: Summary of Equipment Categorization

	Category	Defining Characteristics	Mission Applicability
Body worn	Personal Radiation Detector (PRD)	Highly sensitive, can detect small changes from background, alarming, body worn device capable of passing low exposure rate tests of ANSI N42.32, typically uses scintillation detectors.	PRND: Detection of low level radiation for contraband investigation. CM: Environmental and personnel contamination surveys in Cold Zone
	Spectroscopic Personal Radiation Detector (SPRD)	Highly sensitive, can detect and identify low levels of radiation, alarming, body worn device capable of passing low exposure rate tests of ANSI N42.48, typically uses scintillation detectors	PRND: Detection and identification of low level radiation for contraband investigation. CM: Environmental and personnel contamination surveys in Cold Zone, Radionuclide ID.
	Extended Range Personal Radiation Detector (ER-PRD)	Extended range, alarming, body worn device capable of passing low exposure rate tests of ANSI N42.32, but has an extended capability to measure up to 10 R/h or more.	PRND: Detection of low level radiation for contraband investigation. CM: Cold and Hot Zone Survey and responder exposure control.

	Personal Emergency Radiation Detectors (PERD) & Monitors	High range, alarming, body worn device capable of operating in harsh environments and capable of operating above 10 R/h, potentially up to 1,000 R/h (ANSI N42.49A)	CM: Detection and entry into Hot Zone, Exposure control and possibly dose monitoring tool.
	Electronic Personal Dosimeter (EPD)	High range, alarming, body worn device for occupational workers to measure personal dose equivalence for regulatory compliance. Performance requirements can be found in ANSI N42.20.	CM: Hot Zone detection, responder exposure control and dose monitoring tool if ruggedized
Human Carried	Radio-Isotope Identification Device (RIID)	Low range, hand-held radiation detector with gamma spectroscopic capabilities. The device should be capable of passing the radiological performance tests indicated in ANSI N42.34.	Identification of the type of radioactive material to support: PRND: LE investigation. CM: Public safety, Environmental and personnel contamination surveys in Cold Zone
	Hand-Held Survey Meter (Low Range)	Hand-held devices that detect low levels of radiation up to 10 mR/h or more. PRND mission related performance requirements in ANSI N42.33, additional requirements in N42.17A (normal conditions) and N42.17C (extreme conditions)	PRND: Detection of low level radiation for contraband investigation. CM: Workplace or public safety. Can be used to find contamination or hotline.
	Hand-Held Survey Meter (High Range)	Hand-held devices that measure high radiation levels to 10 R/h. Requirements can be found in N42.17A (normal conditions) and N42.17C (extreme conditions)	CM: Detection and entry into Hot Zone and responder exposure control
	Human-Portable Detector (Backpack)	Larger (backpack or suitcase sized) detectors capable of passing radiological performance tests indicated in ANSI N42.43	PRND: Detection of low level radiation for contraband investigation. CM: Environmental and personal contamination surveys in Cold Zone
Other	Vehicle Mounted Detection System	Large detector systems that can be mounted on a car, boat, or aircraft capable of passing radiological performance tests indicated in ANSI N42.43	PRND: Detection of low level radiation for contraband investigation. CM: Environmental and personal contamination surveys in Cold Zone
	Radiation Portal Monitors	Fixed or transportable detectors used as a non-intrusive means to screen people, vehicles, or other objects. Performance tests indicated in ANSI N42.35 (PRND) and FEMA-REP-21 (CM).	PRND: Detection of low level radiation on people or vehicles for contraband investigation. CM: Personal / object contamination monitoring.

The next step in the process of equipment categorization is to determine the specific capabilities that correspond to consequence management mission needs. An extensive effort has been undertaken to identify a wide range of instrument-specific data parameters about individual instruments currently in use for the PRND mission. This data has been compiled into an extended, cross referenced database.

Key Categorization References

DNDO NIMS TYPED RESOURCES

DNDO defines several basic categories of PRND equipment. The following definitions are from DNDO Document Number 400-INT-115300v2.1, Typed Resource Definitions Preventive Radiological/Nuclear Detection (PRND) Resources. This document defines 4 types of equipment:

- Personal Radiation Detector (PRD)
- Radio-Isotope Identification Device (RIID)
- Human-Portable Detector (Backpack)
- Vehicle-Mounted Detection System

PERSONAL RADIATION DETECTOR (PRD)

DESCRIPTION: An alarming personal radiation detector worn on the body to detect photons (and in some cases neutrons).

Type 1: Detects Gamma and Neutron radiation
Type 2: Detect Gamma radiation

COMMENTS

1. Additional optional features: isotope identification (spectroscopic), dose rate capable, count rates and other types of displays, low profile mode (Bluetooth or wireless), ruggedized, network capable, GPS.
2. Gamma Detector types would include sodium iodide (NaI), cesium iodide (CsI), CdZnTe (CZT) solid state detectors and other scintillator or solid state detectors. Less effective PRND detector types would include gas filled detectors such as GM or Ion Chamber detectors.

REFERENCES

1. ANSI/IEEE N42.32-2006 American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.
2. ANSI/IEEE N42.48-2008 American National Standard Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security.

RADIO-ISOTOPE IDENTIFICATION DEVICE (RIID)

DESCRIPTION: A portable radiation detector with gamma spectroscopic capabilities and neutron indication. Note: also known as a radionuclide identifier.

Type 1: High Resolution, < 1.0% Energy Resolution at 662 keV full width half maximum (FWHM)
Type 2: Medium/Low Resolution, 1.0% -9.0% FWHM

COMMENTS

1. Additional optional features: Gamma and neutron radiation detection, dose rate capable, low profile mode (Bluetooth or wireless), ruggedized, network capable, GPS.

REFERENCES

1. ANSI/IEEE N42.34-2006 American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides.

HUMAN-PORTABLE DETECTOR (BACKPACK)

DESCRIPTION: Instrument composed of several radiation detection components that are placed inside a backpack or other similar enclosure with an optional external control device (IEC 45B/754/CDV-referred to as backpack-type radiation detector).

Type 1: Detects Gamma and Neutron radiation, Isotope Identification
Type 2: Detects Gamma and Neutron radiation
Type 3: Detect Gamma radiation, Isotope Identification
Type 4: Detect Gamma radiation

COMMENTS

1. Additional optional features: Gamma and neutron radiation detection, dose rate capable, low profile mode (Bluetooth or wireless), ruggedized, network capable, GPS.

REFERENCES

1. ANSI/IEEE N42.43-2006 American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security.

VEHICLE MOUNTED DETECTION SYSTEM

DESCRIPTION: A Vehicle-Mounted Detection System is an instrument transported on a vehicular platform (truck, boat or aircraft) for detecting radiological and nuclear material.

Type 1: Detects Gamma and Neutron radiation, Isotope Identification
Type 2: Detects Gamma and Neutron radiation
Type 3: Detect Gamma radiation, Isotope Identification
Type 4: Detect Gamma radiation

COMMENTS

1. Additional optional features: Gamma and neutron radiation detection, dose rate capable, low profile mode (Bluetooth or wireless), ruggedized, network capable, GPS.

REFERENCES

1. ANSI/IEEE N42.43-2006 American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security.

Applicability DNDO NIMS Typing for Consequence Management Mission.

The equipment sub-types identifies variations that can detect neutron radiation and/or defines the spectroscopic capabilities. Although neutron radiation is important for the PRND mission, it is not needed for the consequence management mission. Once the radiation environment is characterized, spectroscopic information is not useful in the consequence management mission, and this type of device is less important. For this reason sub-typing will not be used in the equipment categorization for the consequence management mission.

There is additional PRND equipment that was not specifically addressed in the DNDO NIMS Typing. Portal monitors (both pedestrian and vehicle) are used for the PRND mission, as well as fixed detector systems. These equipment types will be addressed even if there is not a NIMS Typing for them as they can be valuable in consequence management.

American National Standard Institute (ANSI) PRND Equipment Standards

The Department of Homeland Security funded the development of a number of ANSI standards to define performance testing requirements for radiation detection equipment used in Homeland Security missions. [1] Except for ANSI N42.49A, the DHS funded standards do not include performance specifications required for consequence management. This is illustrated in Table 2, which shows how the standard operational range for PRND equipment compares to that for equipment designed for occupational and emergency response activities.

Occupational or Emergency Response Standards

- ANSI N323A (1997) "Radiation Protection Instrumentation: Test and Calibration, Portable Survey Instruments"
- ANSI N42.17A (2003) "Performance Specifications for Health Physics Instrumentation- Portable Instrumentation for Use in Normal Environmental Conditions"
- ANSI N42.17C (2005) "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Extreme Environmental Conditions"
- ANSI N42.20 (2003) "Radiation Protection Instrumentation: Performance Criteria for Active Personnel Radiation Monitors"
- ANSI N42.49A "American National Standard for Performance Criteria for Alarming Electronic Personal Emergency Radiation Detectors (PERDs) for Exposure Control"

PRND Equipment Standards

- ANSI N42.32 "American National Standard for Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security"
- ANSI N42.33 "American National Standard for Portable Radiation Detection Instrumentation for Homeland Security"

[1] Passive monitoring equipment can also be useful for Consequence Management, but is not used for PRND.

- ANSI N42.34 "American National Standard for Performance Criteria for Hand-held Instruments for the Detection and Identification for Radionuclides"
- ANSI N42.35 "American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors"
- ANSI N42.38 "American National Standard for Performance Criteria for Spectroscopy-Based Portal Monitors Used for Homeland Security"
- ANSI N42.43 "Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security"
- ANSI N42.48 "Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security"

Table 2—Summary of key ANSI standards.

ANSI Standard	Exposure Rate	
	Range for ^{137}Cs	Accuracy
N42.20 (ANSI, 2003c) **Active personnel radiation monitors (electronic dosimeters)**	1 – 100,000 mrem h^{-1}	± 20 % ±30 % low decade
N42.49A (ANSI, 2011) **Alarming Personal Emergency Radiation Detector (PERD)**	1 – 999,000 mR h^{-1}	± 15 % ±50%, < 10 mR h^{-1} ±30%, > 300 R h^{-1}
N42.32 (ANSI, 2006) & N42.48 (ANSI, 2008) **PRD & SPRD**	0.005 – 2 mR h^{-1}	±30 %
N42.34 (ANSI, 2006) **Radionuclide identifier**	0.025 – 2 mR h^{-1}	Refers to N42.17A ±10 %
N42.33 (ANSI, 2006) **Portable radiation detection instruments for Homeland Security**	0.005 – 10 mR h^{-1}	±30 %
ANSI N42.43 (ANSI, 2006) **Performance Criteria for Mobile and Transportable Radiation Monitors**	None Specified, though 0.1 mR h^{-1} used as max rate*.	None

*When testing spectroscopic analysis capability if manufacture does not specify a maximum exposure rate.

The specifications in Table 1 show that PRND standards focus on performance in low radiation fields, which would only useful for Cold Zone (< 10 mR/h) missions for consequence management operations. However, some of the PRND equipment currently in use have an extended range capability that could also support some emergency response activities.

The Intersection of DNDO NIMS Typed Equipment and ANSI Standards

The DNDO PRD category references the ANSI standard N42.32, but also implied that the category included equipment that would not pass the standard; "Less effective PRND detector types would include gas filled detectors such as Geiger Mueller(GM) or Ion Chamber detectors." Equipment depending on small GM or Ion chamber detectors have not successfully passed the low exposure rate tests of N42.32, however this equipment can be repurposed for the consequence management mission at higher exposure rates. It is therefore important to differentiate between the highly sensitive PRD detectors and equipment that is less sensitive, but has a higher range.

Both the Human Portable Detector (Backpack) and the Vehicle mounted detector system refer to ANSI Standard N42.43 as a reference, therefore cannot be differentiated using this standard.

Since ANSI standards for the PRND mission focus primarily on detecting low levels of radiation, they are not the optimum means to define equipment categories that will be used for the full range of consequence management missions, which may involve radiation exposure rates in excess of 10 mR/h.

Finally, some manufactures are creating enhanced PRND equipment that are relevant for the consequence management mission, but are not defined by a DNDO category or national standard. These devices represent an important capability that warrant a unique category of equipment.

Comparing the "Operational Range" of PRND equipment

One of the most important features of detection equipment for the PRND and CM missions is the operational exposure rate range. For example, the ability to measure higher exposure rates is important for exposure control and dose management in the CM mission, but detection of very low exposure rates is important for the PRND mission for the detection of contraband and in the CM mission for environmental measurements or detection of personal contamination. Unfortunately, an instrument's "operational range" has no common definition.

Appendix 1: Determining an Instrument's Operational Range, provides a discussion and example methodology for defining an instruments operational range. This was used to generate the operational ranges displayed in Figure 1, which demonstrate the variability of body worn devices that were purchased for the PRND mission. Many of these were purchased prior to the development of standards or without the benefit of testing to compare the equipment to the standards.

Using a logarithmic scale, the red and blue horizontal bars illustrate the instrument ranges, and the operational ranges required by the ANSI standards are shown with yellow bars. Equipment that might pass the PRD radiological tests have red bars, and equipment that does not have the sensitivity to pass the standard for a PRD are shown with blue bars.

Although most of the PRDs would only be useful in in fields less than 10 mR/h (cold zone), a significant number of PRDs (and the equipment with Blue bars) have the ability to support activities in the hot zone (> 10 mR/h) or even the dangerous-radiation Zone (> 10 R/h) through the use of a second, high range detector or specialized circuitry.

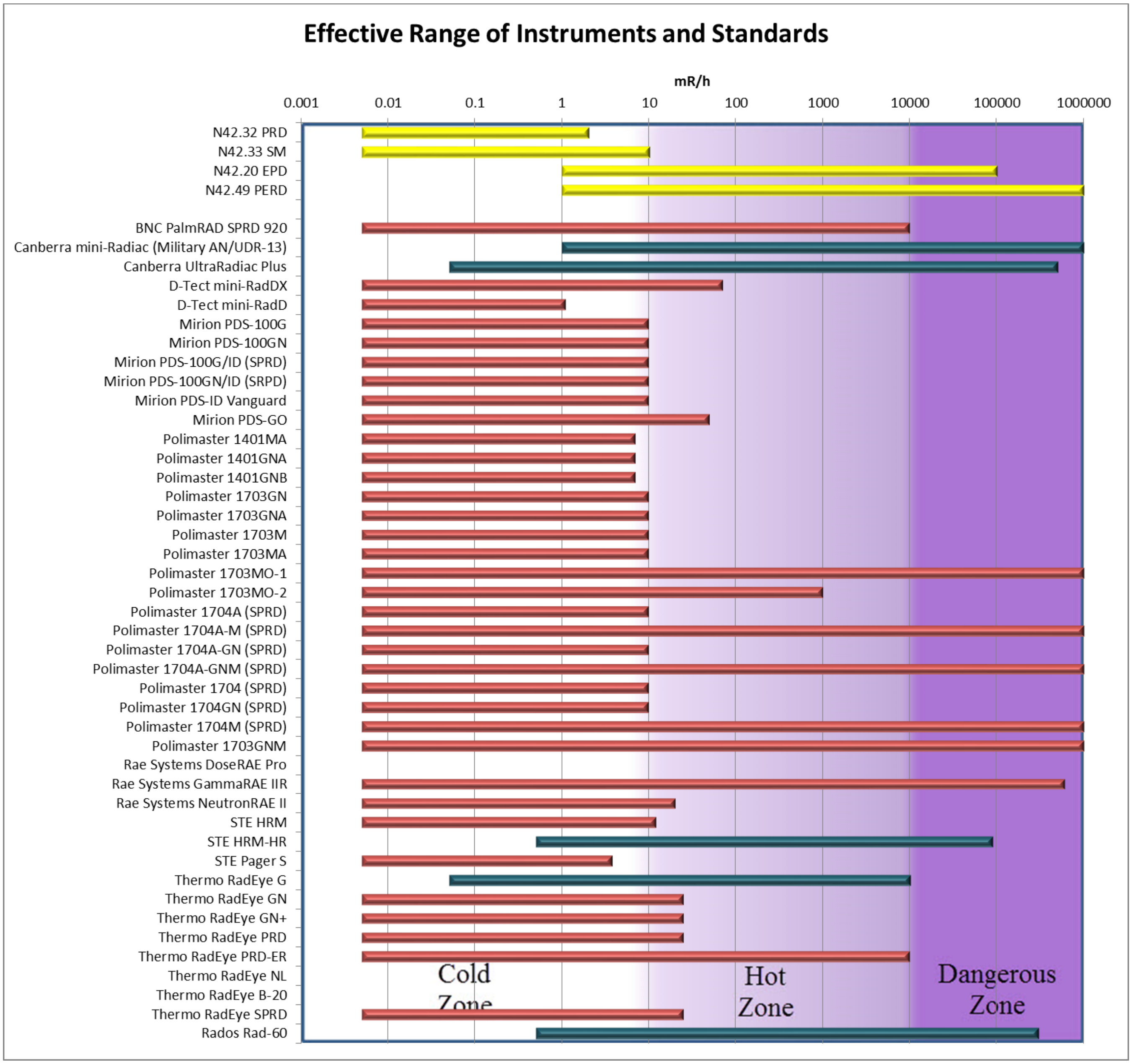

Figure 1: Operational range of common equipment acquired for the PRND mission

Proposed PRND Equipment Category Definitions

The following categories are based on the NIMS Equipment Typing used by DNDO, with additional clarifications to better refine equipment categories and provide for alternate equipment types.

PERSONAL RADIATION DETECTOR (PRD)

DESCRIPTION

An alarming personal radiation detector worn on the body to detect photon (and in some cases neutron) radiation. The device should be capable of passing the radiological performance tests indicated in ANSI N42.32 for gamma radiation, especially the ability to alarm at low exposure rates 50 µR/h. Typical devices will use a highly sensitive scintillator detector (e.g., CLYC, sodium iodide [NaI] and cesium iodide [CsI]).

COMMENTS

The PRD is a high sensitivity exposure/dose rate primary screening device that is used by law enforcement/public safety when monitoring for illicit radioactive materials (e.g. special nuclear material or source material for radiological terrorism). Similar in size to a message pager or mobile phone and can be worn on a belt or in a pocket for automated, hands-free operation for alerting the user. They can also be hand-held for searching close to a suspected item. In general, utilizing a PRD increases the passive detection capability in each area it is deployed without dramatically increasing the demands placed upon the wearer.

These instruments do not require extensive training to operate. Another advantage is the inherent mobility of PRDs, which allows a closer approach to a suspected radioactive source, when it is safe to do so. A PRD is based on a scintillation detector (cesium–iodide (CsI), sodium–iodide (NaI), or equivalent) to ensure high gamma sensitivity.

Figure 2: BNC NukeAlert 951

PRDs require minimal maintenance, are of rugged construction, weather resistant and battery operated with a battery life of at least 100 hours. The alarm threshold may be adjusted before use to account for the natural background radiation at a particular location. A PRD typically has three alarm annunciation modes: visual indicator (a flashing light and numerical display), audio tone, and vibration.

Figure 3: Polimaster 1703GN

Although similar in size and appearance to personal electronic dosimeters, a PRD should not be relied upon for personal monitoring when significant radiation fields are encountered.

There are over 40 PRD devices[2] currently on the market, examples include the BNC NukeAlert 951, Polimaster 1703GN, and Thermo Radeye-PRD.

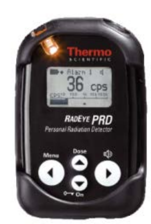

Figure 4: Thermo RadEye-PRD

Additional optional features: exposure rate, integrated exposure tracking, Bluetooth or wireless communication, ruggedized, network capable, GPS.

[2] Example equipment images used in this document do not imply an endorsement

REFERENCES

ANSI/IEEE N42.32-2006 American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.

ANSI/IEEE N42.48-2008 American National Standard Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security.

EXTENDED RANGE PERSONAL RADIATION DETECTOR (ER-PRD)

DESCRIPTION

Figure 6: Polimaster PM1703MO-1

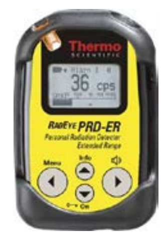

Figure 5: Thermo RadEye PRD-ER

An alarming personal radiation detector worn on the body to detect photon (and in some cases neutron) radiation that uses 2 detection elements or circuitry techniques for both low and high level exposure ranges. The device should still be capable of passing the radiological performance tests indicated in ANSI N42.32 for gamma radiation, with the additional capability to measure exposure rates up to 10 R/h. Typical devices will use both a highly sensitive scintillator detector (e.g., CLYC, sodium iodide [NaI] and cesium iodide [CsI]) and a secondary detector (typically solid state or GM detector) for the measuring higher exposure rates, often above 10 R/hr.

COMMENTS

PRD manufacturers have begun offering dual detector systems that allow the PRD to have an extended (high) dose rate range without sacrificing the lower dose rate sensitivity. This type of instrument does not have an associated standard but may be tested against multiple standards. Currently the PRD functionality is the dominant designed purpose, however the high range capability allows for emergency response applications.

Figure 7: RAE Systems: GammaRAE II

Currently, there are approximately10 ER-PRD devices currently on the market, examples include the Polimaster 1703MO-1, Thermo Radeye PRD-ER, and the RAE Systems GammaRAE II.

Additional optional features: neutron detection, isotope identification (spectroscopic), exposure rate display, integrated exposure tracking, bluetooth or wireless communication, ruggedized, network capable, GPS.

REFERENCES

ANSI/IEEE N42.32-2006 American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.

SPECTRASCOPIC PERSONAL RADIATION DETECTOR (SPRD)

DESCRIPTION

An alarming personal radiation detector worn on the body to detect photon (and in some cases neutron) radiation and identify the type of radioactive material through gamma ray spectral analysis. The device should be capable of passing the radiological performance tests indicated in ANSI N42.48 for gamma radiation, especially the ability to alarm at low exposure rates 50 µR/h and identify radionuclides. Typical devices will use a highly sensitive scintillator detector (e.g., CLYC, sodium iodide [NaI] and cesium iodide [CsI]).

Figure 8: Polimaster PM1704/GN/M

Figure 9: Mirion PDS-100GN/ID

COMMENTS

Manufacturers have begun offering these pocket sized detectors that offer both PRD and RIID functionality, though often at much greater expense. They are generally capable of distinguishing between naturally occurring radiation materials (NORM), medical isotopes, and industrial sources of radiation. Some have a simplified interface, but generally require a more highly trained user to take full advantage of the spectroscopic analysis.

SPRDs is a rapidly expanding area of device development. Currently, there are approximately 16 SPRD devices on the market, examples include the FLIR IdentiFINDER R300, Mirion PDS-100GN/ID, Thermo RadEye SPRD, and the Polimaster 1704A-GNM.

Figure 10: RadEye SPRD

Additional optional features: neutron detection, exposure rate display, integrated exposure tracking, bluetooth or wireless communication, ruggedized, network capable, GPS.

REFERENCES

ANSI/IEEE N42.38-2008 American National Standard Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security.

PERSONAL EMERGENCY RADIATION DETECTORS (PERDS) & MONITORS

DESCRIPTION

An alarming personal radiation detector worn on the body to detect photons and alarm if preset thresholds for either exposure rate or accumulated dose are exceeded. It is designed to be used in harsh environment with high exposures rates (> 10 R/h) for emergency response applications. The ANSI standard the PERD, N42.49A (ANSI, 2011), is fairly recent and not many manufactures have tested their devices to this standard. The standard for survey meters, ANSI-N42.33-2006 is often used instead.

Figure 11: Thermo RadEye GF

COMMENTS

Similar in appearance to PRDs and often mistakenly procured as PRND Equipment, this equipment does not have the sensitivity to react quickly to the low exposure rate tests of the ANSI standard for PRDs (N42.32). Designed for emergency response applications, this is an excellent tool for responder dose monitoring and exposure control. Devices designed to meet the PERD standard (N42.49A) have been ruggedized for the emergency environment and can track exposure rates and accumulated dose in radiation fields up to 1,000 R/h.

Figure 12: Canberra UltraRadiac

Designed to be both worn on the body and used as a hand held survey meter, these devices are often classified as survey meters by the manufacture.

There are many of these devices currently on the market, examples include the Thermo Radeye PRD-GF and Canberra UltraRadiac plus.

Figure 13: Polimaster PM03

Additional optional features: Audio (click rate) feedback, intrinsically safe design, neutron detection, bluetooth or wireless communication, network capable, GPS.

REFERENCES

ANSI N42.33 “American National Standard for Portable Radiation Detection Instrumentation for Homeland Security”

ANSI N42.49 “American National Standard for Performance Criteria for Alarming Electronic Personal Emergency Radiation Detectors (PERDs) for Exposure Control”

ELECTRONIC PERSONAL DOSIMETER (EPD)

DESCRIPTION

Designed to be worn on workers in planned exposure situations to measure personal dose equivalence for regulatory compliance. The EPD displays the dose and dose rate, and many will alarm if preset thresholds for either are exceeded. Performance requirements can be found in N42.20. These active dosimeters have several advantages over passive dosimeters and have begun to replace them in several industrial and medical settings.

Figure 14: Thermo EPD

COMMENTS

Similar in appearance to PRDs and often mistakenly procured as PRND Equipment, these devices are very insensitive and do not support the PRND mission. Because they are used for regulatory confirmation of occupational worker dose, ANSI standard N42.20 requires that the user be unable to change key alarm and dose parameters that would make them more useful in an emergency response situation.

Figure 15: Rados RAD-60

There are many of these devices currently on the market, examples include the Thermo EPD and Rados RAD-60.

Additional optional features: skin dose measurement, bluetooth or wireless communication, ruggedized, network capable, GPS.

Figure 16: MGP DMC 3000

REFERENCES

ANSI N42.20 (2003) “Radiation Protection Instrumentation: Performance Criteria for Active Personnel Radiation Monitors”

RADIO-ISOTOPE IDENTIFICATION DEVICE (RIID)

DESCRIPTION

A portable radiation detector with gamma spectroscopic capabilities. The device should be capable of passing the radiological performance tests indicated in ANSI N42.34 for gamma radiation, including the ability to measure exposure rates up to 2 mR/h. Note: also known as a radionuclide identifier.

COMMENTS

RIIDs are multifunctional devices used for searching and localizing radioactive sources and identifying radionuclides by gamma spectroscopy. For the PRND mission, hand-held RIIDs can be used either as the primary search (detection) device to survey pedestrians, packages, cargo, and motor vehicles for contraband material or as a secondary search device for verifying and characterizing alarms obtained with fixed/installed detectors or PRDs.

Figure 17: BNC SAM 940

For the Public safety mission, the RIID's ability to identify the radionuclide can help inform proper response protocols and safety considerations.

ANSI N42.34 standard addresses instruments that can be used for homeland security applications to detect and identify radionuclides, for gamma-ray exposure rate measurement, and for indication of neutron radiation. This standard requires RIIDs to have communication options to transfer the spectra to reachback/spectroscopy team.


Figure 18: FLIR Indentifinder

These devices are more expensive than other radiation detection equipment, with starting prices at around $10,000 and high resolution RIIDs can be more than $100,000. There are many RIIDs on the market, and examples include the BNC SAM 940 and FLIR Indentifinder.

Additional optional features: neutron detection, dose rate display, integrated dose tracking, bluetooth or wireless communication, ruggedized, network capable, GPS.


Figure 19: ORTEC Detective-DX (High Resolution)

REFERENCES

ANSI/IEEE N42.34-2006 American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides.

HAND-HELD SURVEY METER

Hand held survey meters are not considered PRND equipment. They are included here for completeness and to provide a comparison, but will not be part of the "PRND Equipment" evaluated for the CM mission.

DESCRIPTION

This is a broad category of radiation detection instrumentation that describes hand-held devices that detect radiation in the environment. Performance requirements the PRND mission can be found in ANSI N42.33, additional requirements can also can be found in N42.17A (normal conditions) and N42.17C (extreme conditions). These standards do not require a specific range, integrated exposure monitoring, or alarm criteria; although many survey meters may have these capabilities. For the purposes of this report, two types of survey meters are defined;

Figure 20: Ludlum model 3 micro-R meter (low range)

- Low range survey meters are designed to detect low level gamma radiation as defined by ANSI N42.33 (should operate up to 10 mR/h). Examples include meters based on NaI scintillators (often called micro-R meters) and "hot dog" and "pancake" GM detectors.
- High range survey meters are designed to operate above 10 R/h governed by ANSI N42.17A / N42.17C. Examples include meters based on ion chambers or small "peanut" GM detectors.

COMMENTS

Handheld survey meter have been the workhorse of the radiation protection industry for decades. Traditionally analog devices (like the micro-R meter pictured) that required the user to rotate the scale switch and multiply the reading by the selected scale are not well suited for use outside of radiation protection programs. Modern digital instruments that scale automatically and have the ability to alarm and record information are much more suitable in public safety and security. Additionally, multipurpose "smart" meters can operate with a variety of probes which offer the user the ability to measure different types and levels of radiation. For example the Thermo FH-40 G/GL can monitor and external low range probe, and its internal high range detector simultaneously.

Figure 21: Ludlum Model 9DP Ion Chamber (high range)

Additional optional features: external probes/detectors, integrated exposure tracking, ability to alarm at exposure rate or total exposure set points, bluetooth or wireless communication, ruggedized, network capable, GPS.

Figure 22: Thermo FH-40 Survey meter

REFERENCES

ANSI N42.17A (2003) "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Environmental Conditions"

ANSI N42.17C (2005) "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Extreme Environmental Conditions"

ANSI N42.33 "American National Standard for Portable Radiation Detection Instrumentation for Homeland Security"

HUMAN-PORTABLE DETECTOR (BACKPACK)

DESCRIPTION


Figure 23: BNC RD-100

Instrument composed of several radiation detection components that are placed inside a backpack or other similar enclosure with an optional external control device (IEC 45B/754/CDV-referred to as backpack-type radiation detector). The device should be capable of passing the radiological performance tests indicated in ANSI N42.43 for gamma radiation and have ability to operate in exposure rates up to 0.1 mR/h

COMMENTS


Figure 24: Nucsafe backpack

Backpack carried radiation detection instrumentation employs more sensitive gamma and (often) neutron detectors than hand-carried instruments. Backpack radiation detectors are designed for operators who need to quickly detect and locate a radiation threat in an unpredictable radiation background. The unit’s detectors and associated electronics are hidden inside a backpack (or vest), allowing the operator to inconspicuously search public areas. Backpack detectors can incorporate larger gamma (plastic, NaI, CsI, LaBr) and neutron (3H, 6Li glass) detectors and may have radioisotope identification capabilities. Some models are equipped with GPS and can transmit data to a command center.

Additional optional features: neutron detection, isotope identification (spectroscopic), secondary high range detector, exposure rate display, integrated exposure tracking, bluetooth or wireless communication, ruggedized, network capable, GPS.

REFERENCES

ANSI/IEEE N42.43-2006 American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security.

VEHICLE MOUNTED DETECTION SYSTEM

DESCRIPTION

A Vehicle-Mounted Detection System is an instrument transported on a vehicular platform (truck, boat or aircraft) for detecting radiological and nuclear material. The device should be capable of passing the radiological performance tests indicated in ANSI N42.43 for gamma radiation and have ability to operate in exposure rates up to 0.1 mR/h.

Figure 25: Thermo Scientific Mobile ARIS

COMMENTS

Additional optional features: neutron detection, isotope identification (spectroscopic), exposure rate display, integrated mapping capability, bluetooth or wireless communication, network capable, GPS.

Figure 26: SAIC Exploranium GR-460

REFERENCES

ANSI/IEEE N42.43-2006 American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security.

RADIATION PORTAL MONITORS

DESCRIPTION

Radiation portal monitors are detection devices that allow for passive or non-intrusive means to screen people, vehicles, or other objects for the presence of nuclear and radiological materials. Large portal monitors are usually deployed and set permanently at road checkpoints, cargo inspection stations, and ports. For the PRND Mission, the device should be capable of passing the radiological performance tests indicated in ANSI N42.35, however for the consequence management mission, FEMA-REP-21 can be used.

Figure 27: SAIC/Exploranium ST-20

COMMENTS

Additional optional features: neutron detection, isotope identification (spectroscopic), exposure rate display, transportable, network capable, GPS.

Figure 28: Thermo TPM-903

REFERENCES

ANSI N42.35 “American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors”.

Appendix 1: Determining an Instrument's Operational Range


Figure 29: The CDV-715 has a range of 0-500 mR/h on its most sensitive scale.

Defining the upper range for an instrument is straightforward. It is the highest exposure rate the instrument can accurately measure. However, any instrument could read zero in the absence of a radiation field, which technically means that the low end range of an instrument is always zero, regardless of whether it is a civil defense ion chamber or highly sensitive vehicle portal monitor. This is why the term ***operational*** is important as it allows us to define a ***useful*** measurement capability at the low end of the exposure rate to determine the ***operational range.*** In order to define the range minimum, one must consider the operation it is to be used for. For example, the most sensitive scale on the CD-715 ion chamber is 0-500mR/h, which means it would be very difficult to discern any exposure rate changes below 10 mR/h so its ***operational range*** is 10 mR/h – 500 R/h. With the advent of digital readouts, it is no longer possible to determine the operational range simply by observing the scale.

One potential definition of a useful measurement capability is the time it takes for an instrument to recognize a low exposure level. The minimum significant activity level, L_D, is the *a priori* (before the fact) activity level that an instrument can be expected to detect 95% of the time. In other words, it is the smallest amount of activity that can be detected at a 95% confidence level. When stating the detection capability of an instrument, this value should be used. This is also called the Lower Limit of Detection (LLD). Which can be defined as: $L_D = \frac{3}{T_s} + 3.29\sqrt{\frac{R_b}{T_b} + \frac{R_b}{T_s}}$

T_s=Sample Count Time, T_b=Background Count Time, R_b=Background count rate

The key parameters above are background count rate (the counts per minute produced by the detector) and the amount of time that the "sample" is counted. The Background count rate can be equated to the detectors sensitivity, often expressed as the detector's counts per second output per mR/h (cps/mR/h). For simplicity, this has been converted to to c/µR in the table below. Not all manufactures report their instrument's sensitivity, but the table below lists some key examples.

Table 2: (OUO) Example Sensitivities of Several Instruments

Instrument	Detector Type	Cs-137 Sensitivity (counts/µR)	ANSI N42.32 Test 6.3 Performance for Cs-137	Manufacture Reported Range (mR/h Equiv.)
Polimaster PM1703GNA	CsI (Tl) scintillator (4cm^3)	3,600	Pass level 2 (< 2s)	0.001 - 1
Polimaster PM1703M	CsI (Tl) scintillator (3cm^3)	3,060	Pass level 2 (< 2s)	0.001 - 1
STE Pager	CsI (Tl) scintillator (5cm^3)	6,480	Pass level 2 (< 2s)	.007 – 3.8
Thermo RadEye-PRD	NaI(Tl) Scintillator	5,400	Pass level 1 (< 4s)	0.001 - 25
NeutronRAE II	CsI (Tl) Scintillator (1cm^3)	1,080	Pass level 1 (< 4s)	0.001 - 20
Thermo RadEye-G	"Large" GM	61	Not tested	0.05 – 10,000
Canberra UltraRadiac +	GM (1.3 cm^3)	30	Did not pass	0.001 – 500,000
Thermo RadEye-GF	GM	5	Not tested	0.5 – 300,000

Applying the formula above, and making the following simplifying assumption:

- T_s=T_b
- There is no electronic noise generated counts (i.e., all counts are in response to radiation event)
- Background exposure rate is 10 uR/h

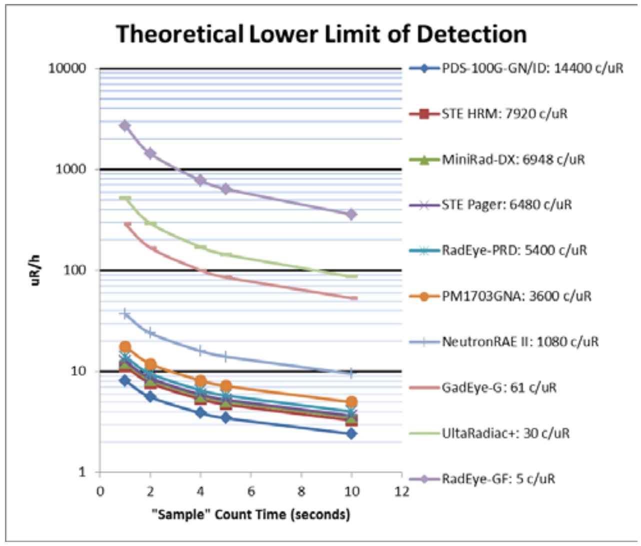

Figure 30: Theoretical lower limit of detection

We can plot some hypothetical Lower Limit of Detection for several PRDs instrument using their reported detector sensitivity. This is plotted against the detectors "count time" in Figure 30: Theoretical lower limit of detection Figure 30.

Of course many rate meter instruments (especially PRDs) do not use fixed count times (or integration periods), but rather have algorithms to adjust the integration time depending on the current count rate and detection objective. This makes testing the instrument's functional response for a specific application important.

For example, ANSI N42.32 defined an important test for the prevention mission in section 6.3 which tests that "The instrument shall alarm in ≤ 2 s after exposure to an increase in the ambient radiation level of 50 µR/h(0.5 µGy/h). The increase in the ambient radiation level shall be over a period of not more than 0.5 s."

Although the type of detector and software algorithms also play an important role, the inverse relationship between sensitivity and the lower limit of detection can be used to estimate a more realistic assessment of the operational range of an instrument.

Currently there is limited data on instrument sensitivity and the ability to pass ANSI test 6.3. In order to compare various equipment operationally, the sensitivity ranges in Table 3 will be used to define the lower limit of detection (LLD). These assumptions will be adjusted as more data becomes available.

Table 3: Assigned lower level of operational range

Detector Type	AND… Cs-137 Sensitivity (counts/uR)	*Presumed* ANSI N42.32 Test 6.3 Performance for Cs-137	Assigned Operational Lower Level of Useful Detection (mR Equiv.)
Scintillator (> 1 cc) or Very Large GM	> 1,000	Could pass	0.005
Small scintillators or GM	10-1,000	Unlikely to pass	0.05
Small GM or Solid State	< 10	Will not pass	0.5

With this practical lower limit of operational range established, the true operational range of various equipment can be compared.