ANSI N42.34 Testing of Canberra Hand-Held Identifiers

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Abstract

Canberra Industries recently developed a new hand-held gamma spectrometer for Homeland Security applications for the detection and identification of radionuclides. This instrument, the Inspector 1000, uses Sodium Iodide probes. The performance requirements for hand-held identifiers for Homeland Security applications are defined in Standard N42.34, recently issued by the American National Standards Institute (ANSI). Based on a draft of this new standard, a test plan was developed to evaluate the performance of the Inspector 1000 with respect to the indicated criteria. The results of the subsequent measurements and analyses are presented. Challenges encountered during the evaluation are discussed.

Introduction

To meet the new security challenges presented by terrorist threats, a new generation of inexpensive yet capable hand-held instruments for the detection and identification of radionuclides is required. This necessity has been recognized, along with the need to have performance criteria to drive the development and appraisal of such instruments. One of the primary standards in this regard is the recently issued American National Standards Institute Standard N42.34 – Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides (ANSI N42.34) [1]. Canberra Industries, Inc. has recently developed a new hand-held gamma spectrometer, the Inspector 1000, designed for Homeland Security applications in accordance with ANSI N42.34. A test plan to evaluate the performance of the Inspector 1000 per a draft of ANSI N42.34 was implemented, with the resulting measurements and results presented in this report.

Method

ANSI N42.34 describes the full range of requirements for hand-held instruments intended for the detection and identification of radionuclides, including the specific user interface, gamma dose rate and neutron count rate requirements. However, the scope of this report is limited to only those requirements specified for radionuclide identification.

ANSI N42.34 includes a recommended list of radionuclides of greatest interest. Table 1 shows this list, the majority of which are specified for testing.

Table 1 – ANSI N42.34 recommended radionuclide library list

CATEGORY	RADIONUCLIDES
Special Nuclear Material (SNM)	^{233}U, ^{235}U, ^{237}Np, Pu
Medical	^{67}Ga, ^{51}Cr, ^{75}Se, ^{99m}Tc, ^{103}Pd, ^{111}In, ^{123}I, ^{125}I, ^{131}I, ^{201}Tl, ^{133}Xe
Naturally Occurring Radioactive Materials (NORM)	^{40}K, ^{226}Ra, ^{232}Th and daughters, ^{238}U and daughters
Industrial	^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{204}Tl, ^{226}Ra, ^{241}Am

The following are short descriptions of the ANSI N42.34 specified radionuclide identification tests:

- Single radionuclide identification testing consists of exposing individual radionuclides (^{40}K, ^{57}Co, ^{60}Co, ^{67}Ga, ^{99m}Tc, ^{125}I, ^{131}I, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{201}Tl, ^{226}Ra, ^{232}Th, ^{233}U, ^{235}U, ^{238}U, Pu, and ^{241}Am) to the instrument such that the gamma dose rate at the instrument is 50 μR/hr, regardless of any shielding. Passing the test requires correctly identifying the radionuclide without any false identifications in 8 of 10 consecutive trials. This is done without shielding and then with 5 mm steel shielding.
- Simultaneous radionuclide identification testing consists of exposing both ^{133}Ba and Pu at the same time to the instrument such that each produces 50 μR/hr individually. In 8 of 10 trials, both radionuclides must be identified without any false identifications.
- Interfering ionizing gamma radiation testing consists of exposing the instrument to a source of natural thorium producing a 50 μR/hr dose rate. With this interference present, correctly identify ^{241}Am and ^{60}Co in separate tests where they produce an additional 50 μR/hr at the detector, without any false identifications in 8 of 10 trials.
- Interfering ionizing beta radiation testing consists of exposing the instrument to a shielded beta emitter (^{32}P or ^{90}Sr/^{90}Y) producing a photon radiation of 50 μR/hr dose rate at the detector. With this interference present, correctly identify ^{137}Cs producing an additional 50 μR/hr at the detector, without any false identifications in 8 of 10 trials. Remove the ^{137}Cs source and verify no identifications in 8 of 10 trials.

- False identification testing consists of exposing the instrument to a normal low ambient background, with a maximum 10 μR/hr dose rate. No unexpected, non-naturally occurring radionuclides shall be identified in 8 of 10 trials.
- Interference from surrounding material testing consists of exposing the instrument to a ^{137}Cs source that produces a 500 μR/hr dose rate at the detector, with a 1 cm thick steel plate on the side of the source opposite the detector. Passing this test requires correct identification of the ^{137}Cs without any false identifications in 8 of 10 trials.
- Variation of identification based on angle of incidence testing consists of exposing ^{241}Am, ^{60}Co, and ^{137}Cs separately to the detector such that each produces 50 μR/hr dose rate at the detector. Correctly identify each source in 8 of 10 trials without any false identifications. For each source, repeat this test with the source at 0°, +45°, and -45° angle of incidence, with the 45° positions in orthogonal planes to one another.

A summary of the required radionuclide identification testing is shown in Table 2.

Table 2 – Summary of ANSI N42.34 radionuclide identification testing

TEST	SOURCE	INTERFERENCE	CONDITIONS
single	^{40}K, ^{57}Co, ^{60}Co, ^{67}Ga, ^{99m}Tc, ^{125}I, ^{131}I, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{201}Tl, ^{226}Ra, ^{232}Th, ^{233}U, ^{235}U, ^{238}U, Pu, ^{241}Am	none	8 of 10, 50 μR/hr, unshielded and shielded (5 mm steel)
simultaneous	^{133}Ba and Pu	none	8 of 10, 50 μR/hr
interfering gamma	^{241}Am, ^{60}Co	natural thorium	8 of 10, 50 μR/hr
interfering beta	^{137}Cs, none	^{32}P or ^{90}Sr/^{90}Y	8 of 10, 50 μR/hr
false identification	none	background	8 of 10, 50 μR/hr
backscatter	^{137}Cs	backscatter	8 of 10, 500 μR/hr, 1 cm steel
angle of incidence	^{241}Am, ^{60}Co, ^{137}Cs	none	8 of 10, 50 μR/hr, 0°, ±45°

While the descriptions of the ANSI N42.34 tests are taken from the final released version of the standard, the test plan for evaluating the Inspector 1000 was developed prior to the release and was based on an earlier draft of the standard. The test plan has been updated to reflect the final standard, but many of the measurements are still being performed. Also, many of the specified sources or spectra are still in the process of being procured. The results reflect the current state of testing.

The Inspector 1000 instrument is a Canberra hand-held radionuclide identifier that uses a variety of sodium iodide probes (1.5×1.5, 2×2, and 3×3) for radionuclide identification [2]. The testing was conducted with a 2×2 probe and the spectra were acquired with 512 channels. For all of the spectral analyses, the same nuclide library was used and no parameters were changed from test to test. The acquisition live time for all unshielded measurements was for 60 to 120 seconds and for all shielded measurements was for 120 seconds.

Results

Table 3 shows currently available testing results.

Table 3 – Results of ANSI N42.34 testing with Inspector 1000 2×2 NaI probe.

TEST	SOURCE	STEEL SHIELDING	# OF TESTS	CORRECT IDs	FALSE IDs	% PASSED
single	^{241}Am	none	10	10	0	100%
single	^{241}Am	3 mm	9	9	0	100%
single	^{133}Ba	none	10	10	0	100%
single	^{133}Ba	5 mm	9	9	0	100%
single	^{57}Co	none	10	10	0	100%
single	^{57}Co	3 mm	10	10	0	100%
single	^{57}Co	5 mm	10	10	0	100%
single	^{60}Co	none	34	34	0	100%
single	^{60}Co	5 mm	10	10	0	100%
single	^{137}Cs	none	21	21	0	100%
single	^{137}Cs	5 mm	10	10	0	100%
single	^{235}U	none	10	10	1	90%
single	^{235}U	3 mm	9	9	0	100%
single	^{235}U	5 mm	10	10	0	100%
single	^{238}U	none	10	10	2	80%
single	^{238}U	3 mm	9	9	0	100%
single	^{238}U	5 mm	10	10	0	100%
single	Pu	none	10	0	0	0%
single	Pu	5 mm	13	13	0	100%
interfering gamma	^{241}Am (with low enrichment U)	none	10	7	0	70%
false identification	background	none	10	10	0	100%
angle of incidence	^{241}Am	none	40	40	0	100%
angle of incidence	^{60}Co	none	40	40	0	100%
angle of incidence	^{137}Cs	none	40	40	0	100%
		TOTALS:	364	351	3	95.6%

Discussion

The testing is currently incomplete. Single radionuclide tests are still required for: ^{40}K, ^{67}Ga, ^{99m}Tc, ^{125}I, ^{131}I, ^{192}Ir, ^{201}Tl, ^{226}Ra, ^{232}Th, and ^{233}U (both unshielded and with 5 mm steel shielding). Simultaneous radionuclide testing with ^{133}Ba and Pu are needed. Interfering gamma radionuclide testing with ^{241}Am with a significant natural thorium background and ^{60}Co with a significant natural thorium background is still required. Interfering beta testing with ^{137}Cs is still required. Finally, interference from surrounding material testing with ^{137}Cs with 1 cm of steel behind the source is still required. While these results are for the 2×2 NaI probe, tests with the 1.5×1.5 and 3×3 probes are also pending. However, the results already gathered provide an initial indication of the performance of the Inspector 1000 with respect to the ANSI N42.34 standard.

As shown in Table 3, several of the single tests were performed with 3 mm of steel shielding. This was required in the draft standard but is not required in the released standard. All of these tests were performed with 1 or 2 minute acquisition time limits, restrictions that were imposed in the draft standard, but are not now required by the released standard.

As specified by the draft standard, testing was conducted to determine the effect of gamma interference with low enrichment uranium as the source of interference, rather than the natural thorium required in the released standard. During the 10 trials, ^{238}U + daughters was identified 10 times, but ^{241}Am was identified only 7 times with the 1 minute tests.

Perhaps the most striking results were those shown for single radionuclide testing with plutonium as the source. Without any shielding, plutonium was never identified (0 of 10), while with 5 mm of steel shielding, plutonium was identified in 13 of 13 trials. The reason for this seems to be that this particular test was not established strictly within the guidelines of the standard. The source used had a significant source of ^{241}Am that dominated the unshielded spectrum. In fact in 10 of the 10 unshielded trials, ^{241}Am was correctly identified. However, the dose rate at the detector (required to be 50 μR/hr from the specified radionuclide, Pu) was primarily from ^{241}Am, not Pu. With the shielding in place to ameliorate the effect from ^{241}Am, Pu was consistently identified.

In some of the tests, extraneous radionuclides were identified, but were not listed as false identifications since they were expected naturally occurring radionuclides that were indeed seen in the spectrum, such as ^{40}K. During the tests with ^{235}U and ^{238}U, high and low enrichment uranium were used as sources. When ^{235}U was identified during the ^{238}U testing or ^{238}U was identified during the ^{235}U testing, they were not listed as false identifications, since they were expected radionuclides actually present in the source and represented in the spectrum.

Conclusions

While a more comprehensive test plan that more strictly adheres to the released version of the ANSI N42.34 standard is being pursued, the currently available results indicate a very promising start. The released standard specifies that the testing should be performed with acquisition times indicated by the manufacturer. The 1 to 2 minute acquisition times used during this testing seem initially to be sufficient, at least with the 2×2 probe. The lower efficiency 1.5×1.5 probe may require longer preset times for the same performance.

A typical concern with scintillation/PMT detectors is the variability of gain under different environmental conditions. Effective gain may shift up to 40-50% during extreme changes in temperature (-20°C to 50°C). Under the controlled conditions of the testing already performed, all of the spectra exhibited gain shifts less than 4-5%. The nuclide identification algorithms may not perform as well with more extreme gain shifts. A gain stabilization or recalibration scheme is likely required and is provided with the Inspector 1000. ANSI N42.34 does require radionuclide identification of ^{241}Am and ^{60}Co testing under a variety of environmental conditions (battery charge, moisture, vibration, mechanical shock, temperature, radio frequency, etc.). Such testing is also in the process of being performed. ANSI N42.34 also requires that the instrument be able to detect and alarm when exposed to neutrons, with sufficient sensitivity. An optional integrated neutron probe designed to meet the standard is being tested to verify that the sensitivity requirements are met.

Many of the sources required by the standard for testing are difficult to obtain, particularly some of the short-lived medical radionuclides. For the purposes of nuclide identification algorithm testing, an industry standard set of spectra encompassing all of the required tests for standard size

NaI crystals (such as 2×2 and 3×3) would be useful. While this might be accomplished with synthesized spectra using something like MCNP [3] or Pacific Northwest National Laboratory's Synth software [4], not all of the required conditions or system responses can necessarily be accurately modeled.

While a final version of ANSI N42.34 has been released, the standard is relatively new and changes to the requirements are likely to occur. The Inspector 1000 ANSI testing plan will probably need to be modified to accommodate such changes in the future.

References

[1] ANSI N42.34-2003, "American National Standard – Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides", 30 January 2004

[2] Inspector 1000 User's Manual Rev B1, Canberra Industries, Inc. 2003

[3] MCNP4C, Monte Carlo N-Particle Transport Code System, Los Alamos National Laboratory

[4] Synth for Windows, version 5.1, October 2002, Pacific Northwest National Laboratory, copyright 1994-2002 Battelle Memorial Institute