EVOLUTION OF A HAND-HELD DEVICE FOR HOMELAND SECURITY PURPOSES

Presented at INMM 46, 2005, Paper 251

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ABSTRACT

Over the course of the last two and a half years, Canberra has designed and launched a Hand-Held Radioisotope Identification Device (HHRIID) called InSpector 1000 for use in many fields. The primary requirements (usability, reliability, portability) were taken into account with the intent of addressing the specific needs of field health physics applications. In an effort to address the growing need of Homeland Security type applications for specialized instrumentation, Canberra has already made several improvements to the original design and a further effort to "ruggedize" the instrument for harsh environments is underway. This paper describes Canberra's development activities of the "Ruggedized" InSpector 1000 to date and the results obtained with the prototypes so far.

1. Introduction

Many of the current handheld radionuclide identification devices were originally designed to meet the 1989 version of ANSI standard N42.17A[1]. It was expedient to use them in Homeland Security applications because they were available. Canberra's InSpector 1000 was originally designed to meet the same standard as well as the International Atomic Energy Agency (IAEA) recommendation for HHRIID. In 2003, ANSI published a new standard, ANSI N42.34[2] specifying the performance requirements for radionuclide identifying devices used in Homeland Security. The release of this standard has led to the commencement of new initiatives to modify existing radionuclide identification devices to comply with its specifications.

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[1] "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Environmental Conditions", N42.17A-1989, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

[2] "Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides", N42.34-2003, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

In addition to the specific performance requirements defined in this new standard, the new generation of HHRIIDs for Homeland Security applications must be generally capable of operating in harsh weather conditions, against wind and temperature, and against rough handling. These harsh environments include: screening cargo and pedestrian traffic at sea, air and rail terminals across the world; monitoring access to key government and economic infrastructure nodes; surveying suspected "hot spots" of terrorist activity even in the most hostile areas; and responding to emergencies and managing the consequences of radiological events. Emergency response situations may include exposure to disaster conditions, including intense heat, radiation, pressure, and possible hostilities.

The new ANSI standard provides guidance as well as an incentive to create and adapt existing devices for use in Homeland Security applications. In response, Canberra Industries started several developments to enhance the Inspector 1000's performance. Before embarking on a new ruggedized enclosure design, two new probes have been defined; a stabilized gamma probe and a neutron probe, both backward compatible with the existing instrument. This paper describes our progress in ruggedizing the InSpector 1000 towards further application in the Homeland Security arena.

2. InSpector 1000 Design

The InSpector 1000 uses Digital Signal Processing (DSP), a feature previously available only in high-end computer-based laboratory systems. In fact, the Inspector 1000 outperforms some laboratory-based DSP electronics in key areas. DSP technology improves the overall signal acquisition performance and thereby provides increased stability, accuracy and reproducibility for consistent results in this smart probe instrument. A smart new nuclide identification algorithm minimizes false positive identifications while improving sensitivity for low level, shielded and mixed sources, or sources hidden by natural or legitimate radioactive materials. In addition to the sound basic technology employed, the InSpector 1000 accommodates different detector/probe sizes in order to provide a flexible, application-specific response.

Two usability factors were taken into account in designing the InSpector 1000. First, it is capable of measuring both gamma and neutron radiation in the field. Second, it is designed for use by individuals without extensive training, making it especially applicable in customs, border patrol, and first responder applications. Its user interfaces are user-friendly and intuitive and designed to be as informative as possible without overloading the user with data. It can serve as a secondary detection unit or in a primary role in areas where the permanent installation of more powerful radiation monitors is precluded.

3. Progress towards a Ruggedized Unit

3.1 Mechanical and Environmental Testing

The existing InSpector 1000 design with attached gamma and/or neutron probes was subjected to a series of mechanical and environmental tests, as shown in Table 1. Details of the mechanical shock tests are shown in Table 2. These types of tests help us define improvements to make the unit even more rugged.

Test	Procedure	Outcome
Vibration Test in the 10-21 Hz range	Vibrated at 2g for 15 min in 3 axes (side to side, back to front, and up & down).	Identified ^{137}Cs in all positions. Falsely identified neutron source under vibration.
Vibration Test in the 22-33Hz range	Vibrated at 2g for 15 min in 3 axes (side to side, back to front, and up & down).	Identified ^{137}Cs in all positions. Falsely identified neutron source under vibration.
Mechanical Shock Test	Subjected to ten 50g acceleration pulses in 3 orthogonal directions.	Identified ^{137}Cs source and neutron source in all positions.
Moisture Protection Test	Water spray at 4 liter.min^{-1} directed at device for 2 min at 2 m distance.	Accurately registered ^{137}Cs source throughout and after test procedure.
Ambient Temperature Influence Test (High)	Stabilized temperature of 22°C (72°F) raised at 10°C per hour to 50°C (122°F). Instrument exposed for a period of 8 hours with readings recorded during last 30 minutes.	Exposure rate reading out of acceptable rate 50°C.
Ambient Temperature Influence Test (Low)	Stabilized temperature of 22°C (72°F) lowered at 10°C per hour to 20°C (-4°F). Instrument exposed for a period of 8 hours with readings recorded during last 30 minutes.	Exposure rate reading within acceptable range.
Temperature Shock Test	Subjected to 1 hour of rapid temperature changes (20°C to -20°C and back, 22°C to 50°, 50°C to 20°C).	Exposure rate indication out of range at 22°C to 50°C for readings taken 45 and 60 minutes after transition.

Table 1: Summary of Mechanical and Environmental Tests

Amplitude (g's)	50
Duration (ms)	18
Pulse Shape	Half Sine
# of Pulses	10
Number of Axes	3
Total # of Pulses	30
Control Accel. Location	Fixure
Response Accel. 1 Location	N/A
Response Accel. 2 Location	N/A
Response Accel. 3 Location	N/A

Table 2: Mechanical Shock Test Details

3.2 Probe Design and Testing

The ANSI neutron detection specifications require that the user be warned of detected neutrons within 2 seconds after being exposed to an un-moderated ^{252}Cf source emitting about 20,000 ns^{-1} at a distance of 25 cm, and that false alarms occur no more than once per hour. Using MCNP™ calculations, Canberra has designed a ^{3}He probe to meet these requirements. The unit was then subjected to a series of tests to insure the compliance of the new neutron probes with these ANSI detection requirements. These included testing alarm response time, detection margin of error and the InSpector 1000's capabilities in the presence of interference radiation. Mechanical testing in line with ANSI requirements was also undertaken.

The ANSI standard alarm criterion is equivalent to a dose rate of about 0.3 $mrem.h^{-1}$. A 1 $mrem.h^{-1}$ source is capable of producing the specified 25 cm dose rate at the detector when placed at a distance of 42 cm. Such a ^{252}Cf test source was placed at 42 cm in front of the neutron probe 10 times during testing. With the measured neutron background level of 0-1 counts per second and an alarm threshold of 5 counts per second, an alarm was produced from 5 to 10 out of 10 times depending on the instrument settings. The recommended settings for the InSpector 1000 are those that produced an alarm 10 times out of 10 during testing.

The standard also calls for no measurable neutron probe response to a gamma radiation when exposed to a 100 mSv gamma dose rate. Our strongest source was 1 mSv, which produced no observable response.

To test the identification capability with the gamma probe, the unit was exposed to a number of radionuclides to test its single radionuclide identification capabilities. These included, among others, reactor grade plutonium (>6% ^{240}Pu), ^{241}Am, and ^{60}Co. All sources were tested unshielded as well as when shielded by 5 mm steel. The instrument's ability to identify the list of required nuclides (when unshielded as well as when shielded by 5 mm steel) was judged acceptable, although only one of the 3 test units identified both shielded and unshielded ^{241}Am.

The instrument passed the ANSI standards for radiation detection response and alarm thresholds, with a gamma alarm threshold of 2 m $R.h^{-1}$, an exposure rate 3 m $R.h^{-1}$, time to alarm 1 second, and a neutron dose rate 0.3 $mrem.h^{-1}$ time to alarm of 2 seconds.

The ANSI standard requires that the relative intrinsic error in responding to a source not exceed ±30% for exposure rates from 0.1 m $R.h^{-1}$ up to the maximum exposure rate. The unit's intrinsic error was tested using a Cs-137 source, with exposure rates of 0.1, 5 and 8000 m $R.h^{-1}$. The average responses were .103, 5.6, and 8823 m $R.h^{-1}$, within the permitted margin of error.

A number of tests were undertaken in order to evaluate the InSpector 1000's identification capabilities in the presence of interference. The InSpector 1000 was found capable of detecting a ^{137}Cs source within two minutes when in the presence of a beta-emitting ^{90}Sr background source. The identifier's ability to identify radionuclides in the presence of backscattered radiation was also proven.

The instrument passed the testing for over-range characteristics for dose rate identification, with a maximum exposure rate of 1 $R.h^{-1}$ and an over range test exposure rate of 10 $R.h^{-1}$. The time to indicate over range was 3 seconds, duration of over range exposure 5 minutes, and maximum recovery time 3 seconds. To test the InSpector 1000's identification capabilities at angles of incidence, the unit was exposed to ^{60}Co, ^{137}Cs, and ^{241}Am at a variety of angles of incidence between 0° and ±45°. The test units detected the sources at the required angles.

In its original design the InSpector 1000 employed a thallium doped sodium iodide NaI(Tl) scintillation detector to accomplish gamma detection and identification. While the original NaI(Tl) probe was sensitive enough to meet the minimum requirements of the ANSI standard, its performance was judged insufficient in certain areas. Because NaI(Tl) crystals are subject to gain drift and a lack of resolution, while the InSpector 1000 was capable of detecting and identifying the gamma nuclides specified by ANSI when measured one nuclide at a time, identification was sometimes less than optimal in the presence of multiple nuclides. In order to correct this shortcoming, a stabilized probe minimizing gain drift and capable of higher detection resolution was therefore developed. The stabilized gamma probe allows the elimination or minimization of any gain drift and uses a Light Emitting Diode (LED) stabilization technique in order to eliminate the need for a radioactive source. Accurate to ± 2% across a temperature range of -20C° to +50C°, the stabilized probe is backward-compatible with all existing Inspector 1000 units. In addition to updating the probes, identifier's software and firmware were updated to handle both the neutron probe and the stabilized gamma probe; a new algorithm was developed to allow full compliance with N42.34 requirements.

With individual temperature characterization tables, the stabilized probes exhibit a peak shift of less than ± 2% as shown in Figure 1. For comparison, the observed peak shift without the stabilization and with the stabilization is shown in Figure 2.

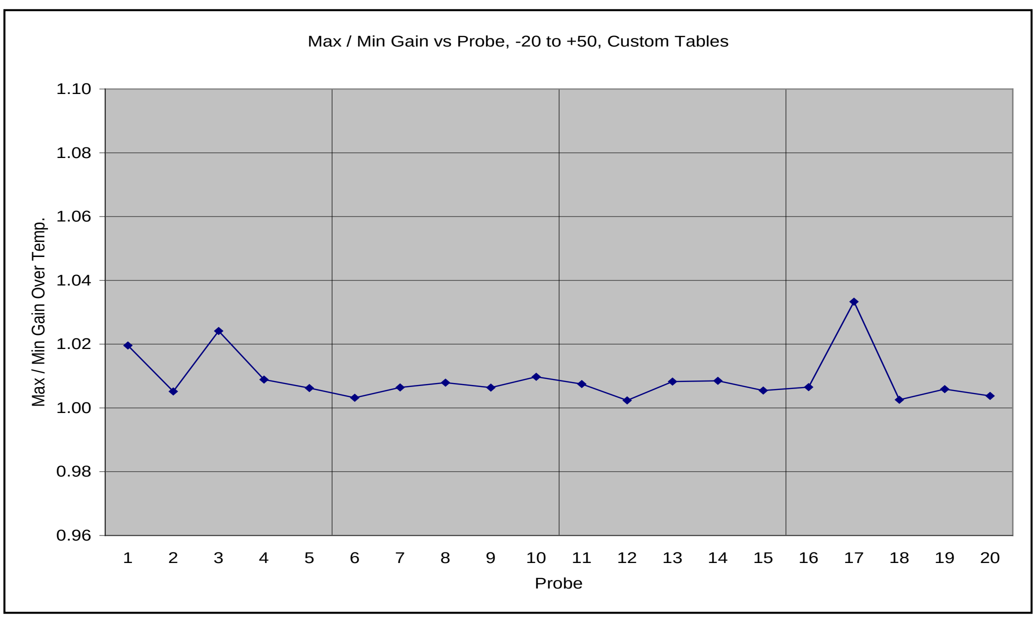

Figure 1. The total peak shift from -20C to +50 for a production run of 20 probes.

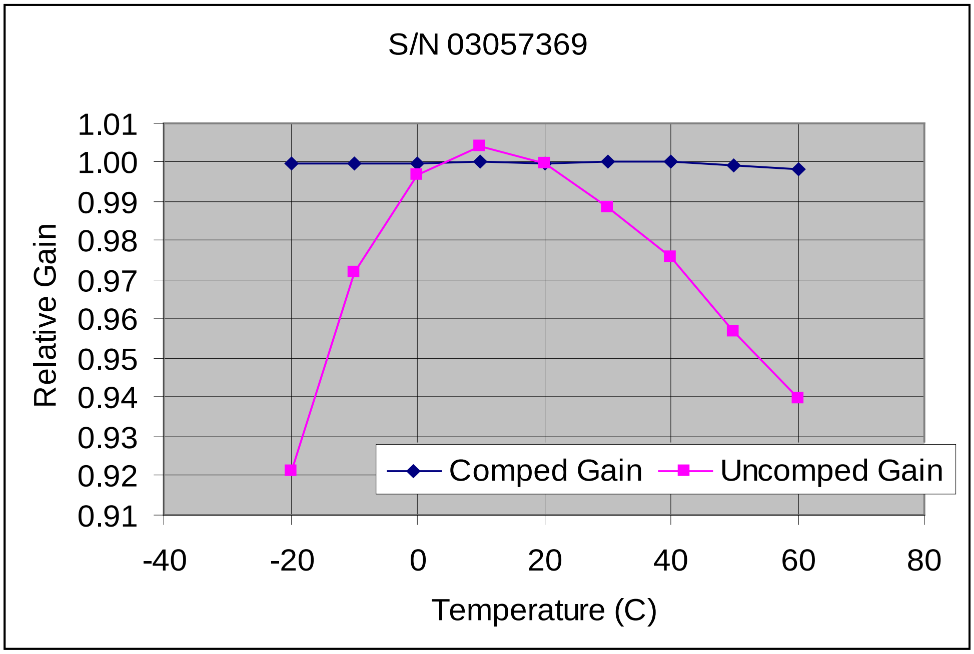

Figure 2. Comparison of compensated and uncompensated detector peak shift.

While the stabilized probe currently uses a NaI(Tl) crystal, the implementation of a lanthanum halide ($LaCl_3$ and $LaBr_3$) stabilized probe is underway in order to further increase identification resolution. Lanthanum halides, a relatively new class of room-temperature scintillation crystal materials, have about the same efficiency as NaI crystals but provide better resolution. Although the $LaCl_3$ probe will use the same instrument design, hardware, and firmware as the existing probe, implementing this new crystal will require the reevaluation and optimization of the identification algorithms.

In its current configuration, the InSpector 1000 provides a flexible and portable solution to hand-held nuclide identification. However, efforts have been undertaken to make the identifier capable of withstanding rough handling and environmental extremes. The development of a ruggedized shell is underway in order to increase the applicability of the identifier in Homeland Security environments. Although the InSpector 1000's use of a relatively fragile NaI(Tl) crystal rules out compliance with some military performance standards, it will at a minimum be compliant with military standards for vibration, shock, and temperature[3]. Ruggedization efforts will identify the harsh environments in which Homeland Security identifiers can be used (e.g., Coast Guard or First Response applications in order to define the specific enclosure requirements. The crystal, moderated ^{3}He proportional counter, instrument boards, screen, and board will be integrated into this new shell. The unit will be redesigned according to the requirements and specifications for the user interface. A portion of this redesign will be carried out with key end-users in order to ensure the usability of the enclosure and the interface. The ruggedized enclosure will allow submerging of the identifier in water at depths of up to 1 meter. The requirements of standards for devices to be used in fire environments will also be taken into account. As a result of these efforts, the InSpector 1000 will be reliable and proven for use in any Homeland Security application. This new identifier will be effective, reliable, and durable at a reasonable price.

[3] "Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests", MIL-STD-810F, Defense Standardization Program Office (DLSC-LM)
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5. Conclusions

The experience gained in the modification of the InSpector1000 provides insight into the challenges encountered in adapting handheld radiation identifiers developed for general use in the nuclear measurements field towards specific application in the Homeland Security arena. In addition to specific technical specifications, operator usability requirements must be examined in order to develop a robust, versatile, and effective applications-specific identifier. As the technology requirements of the Homeland Security market grow and evolve, more technologies developed for use in separate applications will emerge as being appropriate for use in Homeland Security-specific applications.