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# TEST AND EVALUATION OF ISOTOPE IDENTIFIERS

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**Abstract**

*Three devices were tested against eighteen radio-isotopes ranging in activity from 0.37 kBq (K-40) to 93.24 GBq (Pu-239) to determine their effectiveness as isotope identifiers. Two of the devices were hand-held instruments using NaI(Tl) detectors and the third one was a bench-top instrument using a mechanically-cooled Ge detector. Details of the test and the test results are presented in this paper.*

## 1. Introduction

The dissolution of the Soviet Union has resulted in an increased risk of proliferation of special nuclear material (SNM) throughout the world. U.S. Customs Service is embarked on a program to detect and identify nuclear contraband as part of the its nuclear non-proliferation effort. The development, test and evaluation of radiation detection devices which can also identify the radio-isotopes is an essential part of this program.

The radiation detection and isotope identification devices used by the U.S. Customs Inspectors have to be small in dimensions (preferably hand-held), should not be heavy (about 2 kg) and should be easy to operate. The typical Customs Inspector does not have either the ability or the time to analyze the spectrum displayed by commercially available compact multi-channel analyzers. Hence, U.S. Customs Service has made it a requirement that the display of the instrument should indicate what the detected isotope is (e.g. Tc-99m, Cobalt-60 or U-235), and to what category it belongs (e.g., medical, industrial or SNM) and it should do so in a reasonably short time such as 30 to 45 seconds.

Actually, the U.S. Customs Service has a two-tier system for the interdiction of radioactive contraband in commercial traffic. The first tier consists of the Radiation Pager which not only detects the presence of low levels of radiation above background but can also be used to localize the source of radiation. The second tier consists of the Isotope Identifier which is used to identify the isotope and place it in one of the three categories: medical, industrial or SNM. The Customs Inspectors then have to follow a standard operating procedure based on what that category is.

## 2. Description of the test

The tests were conducted at the Remote Sensing Laboratory (RSL) at Las Vegas, Nevada and the Special Technologies Laboratory (STL) at Santa Barbara, California during December 1997 and April 1998. The list of radio-isotopes against which the instruments were tested is given in Table 1, arranged in the three categories mentioned above.

Table 1. Radio-Isotopes (and Their Half-lives) Used in the Test and Evaluation of Isotope Identifiers.

| Medical Radio-isotopes | | Industrial Radio-isotopes | | Special Nuclear Material | |
|---|---|---|---|---|---|
| Ga-67 | (79 h) | K -40 | (1.3e9 y) | U-233 | (1.6e5 y) |
| Tc-99m | (6 h) | Co-57 | (271 d) | U-235 | (7.04e8 y) |
| In-111 | (67 h) | Co-60 | (5.27) | Pu-239 | (2.41e4 y) |
| I-131 [a] | (8.05 d) | Ba-133 | (10.6 y) | | |
| Xe-133 | (5.2 d) | Cs-137 | (30.2 y) | | |
| Tl-201 | (73 h) | Ra-226 | (100 y) | | |
| | | Th-232 | (1.4e10 y) | | |
| | | U-238 | (4.47e9 y) | | |
| | | Am-241 | (432.2 y) | | |

a. The gamma-ray spectrum of I-131 was simulated with Ba-133 and Cs-137 in the right proportion by activity.

The following procedure was followed during the test: Activity, physical form and containment of each radioactive source was recorded in a specially prepared data sheet. Since the medical isotopes have very short half-lives, the time when they were used was also recorded. Each source was set at distances of 30, 60 and 120 cm from the instrument. For the reading at each distance, the dose rate at the front of the instrument was recorded using a separate survey meter. The spectral data was acquired for 30 seconds and the result displayed by the instrument was recorded in the data sheet. Shield materials of different type (aluminum, steel, cadmium and lead) and different thickness were used with SNM. The time allowed for the decision algorithm to come up with an answer was 10 seconds after the 30 seconds of data acquisition.

## 3. Brief description of the devices

Device 1 was a hand-held instrument containing a 38.1 mm x 38.1 mm x 5.08 mm NaI(Tl) scintillating crystal as the radiation sensing element. This instrument had the dimensions 101 mm x 228 mm x 89 mm and weighed 2.2 kg. Device 2 was also a hand-held instrument but it contained a 29 mm in diameter and 51 mm long NaI(Tl) scintillating crystal. Its dimensions were 168 mm x 158 mm x 73 mm and it weighed 2.95 kg. Device 3 was a bench-top instrument and it contained a small mechanically-cooled intrinsically pure germanium detector as the sensing element. It dimensions were 152 mm x 152 mm x 457 mm and it weighed 25 kg.

Device 1 and 2 had the control buttons and black-and-white liquid crystal display on top of the instrument. Device 3 used a note-book computer with colored liquid crystal display for operation . All three displays identified the isotopes with the category (medical, industrial or SNM) with some variations. In addition, Device 2 display had a bar indicator which told the operator to move closer to the source if the radiation level was too low or to move further away if the radiation level was too high for a proper determination before it displayed the result.

Calibration with a Cs-137 check source (Device 1 and Device 3) and a Bi-207 check source (Device 2) was required each morning when the instrument was turned on first thing in the morning.

## 4. Test Results and Discussion

A very large number of trials (~ 100) were made with each instrument. The overall success rate expressed in terms of percent correct determinations is given Table 2 for the three devices.

Table 2. The Overall Success Rate

| Device 1 | Device 2 | Device 3 |
|---|---|---|
| 78% | 66% | 84% |

The success rate for a given instrument depends on a number of factors. These include the sensitivity and the energy resolution of the detector element, the accuracy of the algorithm used for the spectral identification, the gamma-ray spectrum of the radio-isotope and the activity of the source. Since the sensitivity of the sensing element depends on its volume (other factors being the same), it is to be expected that Device 1 will be more sensitive than Device 2. This will result in a better success rate for Device 1 than for Device 2 as shown in Table 2.

Furthermore, since the energy resolution of NaI (Tl) crystals is about 7.5% and that of pure germanium crystal is 0.1%, the later will make more correct determinations simply because of the fact that the gamma-ray spectral lines are much sharper, assuming the same algorithm is used for identification. This is shown in Table 2 where the success rate for Device 3 is better than for either Device 1 or Device 2.

The detector efficiency of sodium iodide detectors varies inversely as the square root of the energy of the gamma-ray being detected. This means that photons of higher energy such as 1 MeV are detected with less efficiency than photons of lower energy such as 100 keV. For energies lower than 100 keV, say around 50 keV, the instrument casing begins to absorb the gamma-rays and associated x-rays more strongly so that not enough of them reach the sensing element, resulting in decrease in efficiency. This is important to know since the energies of the gamma-rays ranged from 80 keV to 2.2 MeV in the radio-isotopes used for the test and will have a bearing on the test results for a given instrument.

Ease of use is a very important attribute of any instrument which will be used in the field by Customs Inspectors. Device 1 was easier to handle than Device 2 because of more balanced construction, less weight, and the presence of a handle. Its display was also easier to read. *Device 3 is more suitable for use near conveyer belts carrying parcels and luggage. In this* scenario it can be operated remotely.

With the introduction of the Radiation Pagers, there are incidents of radiation alerts at Ports of Entry whereas these were non-existent before. These alerts are caused mostly by passengers who have received medical treatment with radio-isotopes. It is estimated that 90% of the alerts are situations like this. The rest are medical or industrial isotopes in shipping containers which do not have proper shipping labels. Even if a shipping container has labels or markings indicating that it contains a certain type of radioactive material, it may be necessary to verify the identity of the material in it because the label may contain false information. We are definitely interested in the interdiction of nuclear contraband; however, it is also imperative that nuisance alarms (false alarms) from passengers who have been treated with medical isotopes or improperly marked shipping containers of medical and industrial isotopes be eliminated as a possibility so that the Customs Inspector's time and effort is not wasted. Hence, more emphasis should be placed in quickly resolving situations which result in false alarms.

All three devices obtained the gamma-ray spectrum of the isotope presented to them and analyzed them to make an identification. It is well known that Pu-239 fissions spontaneously to give off high energy neutrons. The identification of this particular material can be made faster by incorporating a neutron detector in the same instrument which detects gamma rays.

## 5. Conclusions

Three devices were tested against a large number of radio-isotopes including SNM. The results show that these devices showed varying degrees of success rates due primarily to the type and size of the detector element and the sophistication of the algorithm used to identify the gamma-ray spectra.

## 6. Acknowledgments

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