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# RAD/COMM "Cricket" Test Report

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# RAD/COMM "Cricket" Test Report

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## CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

# RAD/COMM "Cricket" Test Report

## 1. INTRODUCTION

A series of tests were performed at Oak Ridge National Laboratory (ORNL) to evaluate and characterize the radiological response of a "Cricket" radiation detection system. The "Cricket" is manufactured by RAD/COMM Systems Corp., which is located in Ontario, Canada. The system is designed to detect radioactive material that may be contained in scrap metal. The Cricket's detection unit is mounted to the base of a grappler and monitors material, while the grappler's tines hold the material. It can also be used to scan material in an attempt to isolate radioactive material if an alarm occurs. Testing was performed at the Environmental Effects Laboratory located at ORNL and operated by the Engineering Science and Technology Division.

Tests performed included the following:

a. Background stability,
b. Energy response using $^{241}$Am, $^{137}$Cs, and $^{60}$Co,
c. Surface uniformity,
d. Angular dependence,
e. Alarm actuation,
f. Alarm threshold vs. background,
g. Shielding,
h. Response to $^{235}$U,
i. Response to neutrons using unmoderated $^{252}$Cf, and
j. Response to transient radiation.

This report presents a summary of the test results. Background measurements were obtained prior to the performance of each individual test.

## 2. TEST SUMMARY

<u>Background Stability</u>

A. Description
   The Cricket was switched on and permitted to go through its power-up sequence. After allowing five minutes for all readings to settle, ten single-background measurements for each channel (A and B, and T) were recorded in the following sequence – A, B, T, A, B, T… It should be noted that each channel "T" measurement is an average of the total counts per second value from channels "A" and "B." Readings from channels (detectors) "A" and "B" are single count rate readings. The ambient background reading was also taken using a Bicron microrem meter.

B. Results
   Table 1 contains the list of measurements taken. No instability was observed.

**Table 1. Background Stability Measurements**

**Microrem Reading 3 uR/hr**

| Reading # | Cricket Readout A | B | T |
|---|---|---|---|
| **1** | 525 | 535 | 1107 |
| **2** | 550 | 682 | 1113 |
| **3** | 535 | 697 | 1156 |
| **4** | 556 | 566 | 1167 |
| **5** | 606 | 732 | 1173 |
| **6** | 455 | 596 | 1191 |
| **7** | 470 | 535 | 1174 |
| **8** | 515 | 601 | 1139 |
| **9** | 657 | 581 | 1134 |
| **10** | 540 | 586 | 1129 |
| **Average** | 541 | 611 | 1148 |
| **Standard Deviation** | 59 | 69 | 28 |
| **Coefficient of Variation** | 10.9% | 11.2% | 2.4% |

Energy Response

A. Description

Energy response data was obtained using a series of gamma emitters - $^{241}$Am, $^{137}$Cs, and $^{60}$Co. Data was taken with the sources placed at 2.5, 1, and 0.5 meters, and on contact with the detection surface oriented from the center of the detection unit. Readings were recorded from each channel (A, B, T). Readings were also obtained with each source placed adjacent to each side of the detection unit at 2.5, 1, and 0.5 meters from the surface. For each set of measurements, a microrem reading was taken at the surface of the detector in line with the source. For the side surface measurements, each source was centered along the edge being measured beginning with the photo multiplier tube (PMT) edge and progressing clockwise when viewed from above.

B. Results

The Cricket was most efficient for the detection of $^{60}$Co, which was expected. It was least efficient for $^{241}$Am. Differences in efficiency are attributable to the mechanical design of the detection system. In the background conditions at the test facility, $^{241}$Am was essentially undetected unless placed directly on the surface of the detector over one of the holes that were formed in the protective plate that surrounds the detection area. These holes are not visible from the outside of the detector.

Figure 1 shows the Cricket's energy response corrected for gamma photon emission. Figure 2 uses the same information presented by isotope. Note that each figure also includes results obtained from $^{235}$U.

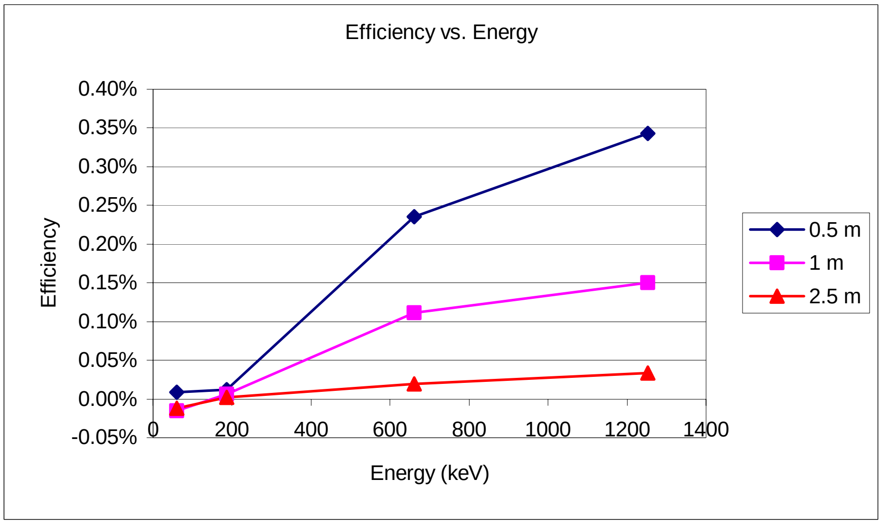



**Figure 1. Response Efficiency vs Gamma Energy**

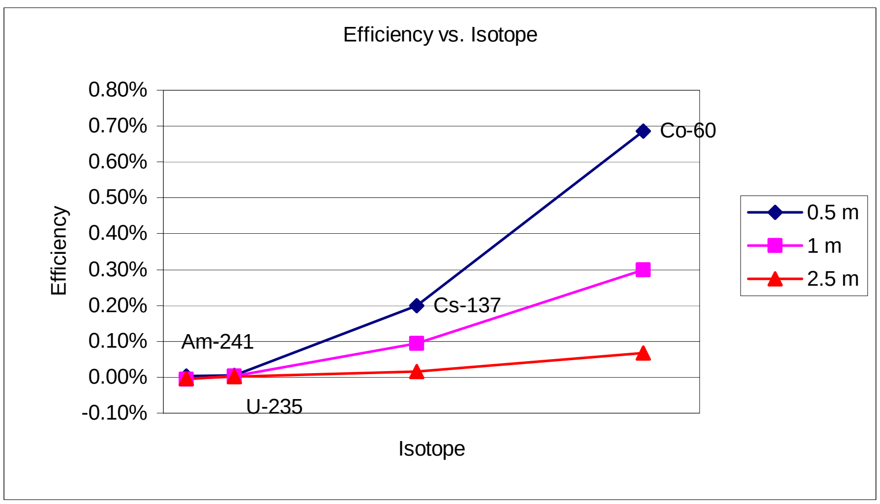



**Figure 2. Response Efficiency vs Isotope**

Uniformity

A. Description

The detector surface was divided into sixteen square sections. The analysis was performed using a $^{137}$Cs source placed in the center of each section. Data from each channel was obtained and used to develop a surface plot.

B. Results

Table 2 shown below contains the counts per second (cps) values obtained from each of the sixteen positions used for the test. Figure 3 shows the response from each channel. There are obvious and expected areas with less efficiency at different locations over the detection surface. Moving the source off the surface increased the response, which in turn reduces the size of the area with reduced efficiency as can be seen in Shielding section.

**Table 2. Uniformity Measurements**

| | | | | | |
|---|---|---|---|---|---|
| A | 805 | 911 | 493 | 517 | |
| B | 513 | 490 | 884 | 1266 | |
| T | 1352 | 1473 | 1448 | 1817 | |
| | **16** | **12** | **8** | **4** | |
| A | 4688 | 3617 | 549 | 536 | |
| B | 505 | 505 | 3520 | 3552 | |
| T | 5217 | 4017 | 4039 | 3913 | |
| | **15** | **11** | **7** | **3** | **PMT** |
| A | 3739 | 3299 | 527 | 492 | **END** |
| B | 470 | 557 | 2947 | 3646 | |
| T | 4130 | 3714 | 3483 | 4283 | |
| | **14** | **10** | **6** | **2** | |
| A | 2569 | 1700 | 525 | 537 | |
| B | 477 | 473 | 1551 | 2592 | |
| T | 2990 | 2160 | 2072 | 3059 | |
| | **13** | **9** | **5** | **1** | |

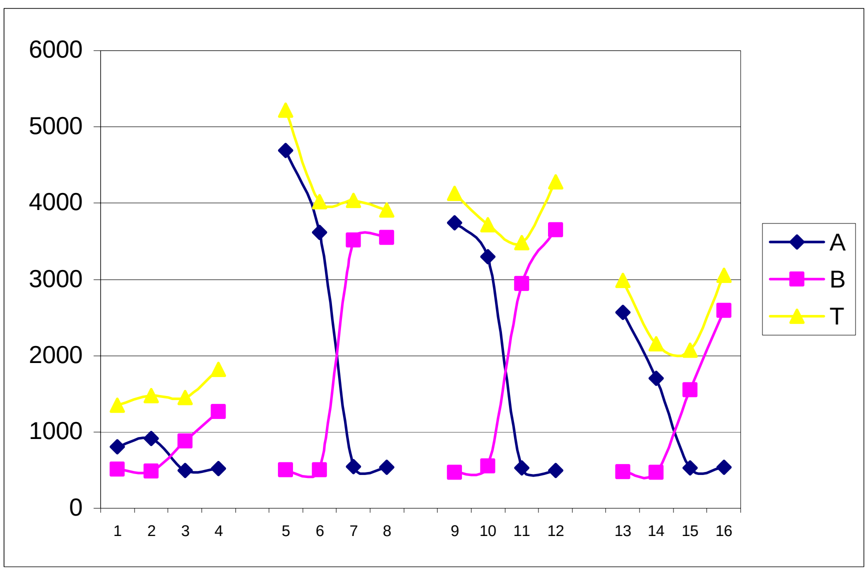



**Figure 3. Uniformity**

<u>Angular Dependence</u>

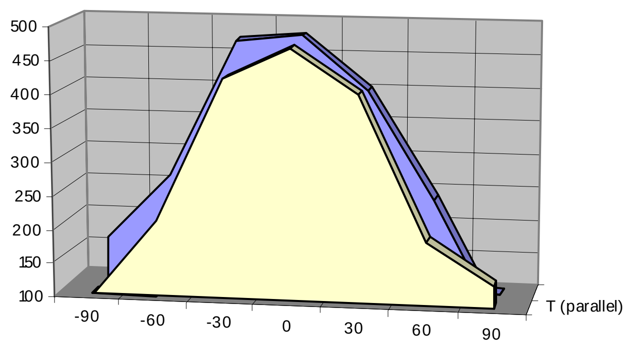
A. Description

For the angular dependence analysis, a $^{137}$Cs source was positioned 1.5 meters from the center of the detector and readings were recorded from channels A, B, and T. The source position was then rotated 30° clockwise about the center of the detector when viewed from the PMT end and readings were again recorded from each channel. This was repeated at 60° and 90° from the vertical with the final source position roughly in the same plane as the top surface of the detector. The entire operation was then performed going counterclockwise.

The orientation assembly was rotated 90° relative to its original vertical position and repeated.

B. Results

The result of the analysis is shown in Figure 4 below. Although measurements were recorded from channels A, B, and T, only T is shown. “T parallel” data was obtained with the source moving in parallel with the PMTs, or long axis of each detector. “T perpendicular” shows data obtained with the source moving in a plane that was perpendicular to the PMTs. Data obtained from each detector channel is skewed based on the orientation of the source as it moves from one detector to the other.




| | -90 | -60 | -30 | 0 | 30 | 60 | 90 |
|---|---|---|---|---|---|---|---|
| T (parallel) | 93 | 214 | 427 | 472 | 410 | 196 | 133 |
| T (perpendicular) | 165 | 264 | 470 | 480 | 399 | 239 | 50 |

**Figure 4. Channel T Angular Dependence**

<u>Alarm Actuation</u>

A. Description

This test was performed in two different operating modes, “normal” and “tines closed.” The test made use of a movement-controlled liner positioning system to ensure that once an alarm occurred, the radiation source remained in the same position, allowing for a more controlled analysis and greater confidence in the stability of the readings recorded.

In addition to recording each channel’s response, the source was left in position after alarm activation to ensure that the alarm remained activated or latched.

B. Results

<u>Normal Mode</u> – A total of three $^{137}$Cs sources were combined at different times though the test. Two sources (10 µCi total activity) were required for alarm activation when operated without altering the background. When the ambient background was increased by a factor of two, an additional 6 µCi were added. The sources were placed at a distance of 0.5 meters from the detection surface and moved over the surface until an alarm occurred. The background was approximately 550 cps for channels A and B. The alarm was activated at a net count rate of approximately 1100 cps. The alarm remained on until manually cleared. Post-exposure count rates were compared with those recorded prior to the test with minimal differences observed.

Tines Mode – The test was performed using two $^{137}Cs$ sources. Alarms were activated at a much lower value when compared to activation in normal mode. It must be assumed that the alarm algorithm functions differently when the tines are closed. In the unaltered background, the tines-mode alarm was activated at a level that was approximately 68% of the normal mode level.

Alarm Threshold vs. Background

A. Description

The goal of this test was to determine how the alarm level is affected by changing background levels. Alarms were actuated in both the normal and tines-closed mode and readings from each channel were recorded at the actuation point. This test was performed using $^{137}Cs$ and microrem readings were recorded at each alarm point. Since the alarm function latches, it was necessary to have the unit set a new alarm level using its learn/update function.

B. Results

With the background unaltered (approximately 5 μR/hr), the tines-closed alarm activated at approximately 46% of the normal-mode activation level (5 and 10 μR/hr, respectively). When the background was approximately doubled, the alarm level for the tines-closed mode was essentially the same (4% higher than normal mode) although the net count rates from each detector were substantially different. The approximate dose rate levels at the alarm points were 17 and 16 μR/hr (normal and tines-closed, respectively). Figures 5 and 6 show a comparison between each mode of operation and background levels.

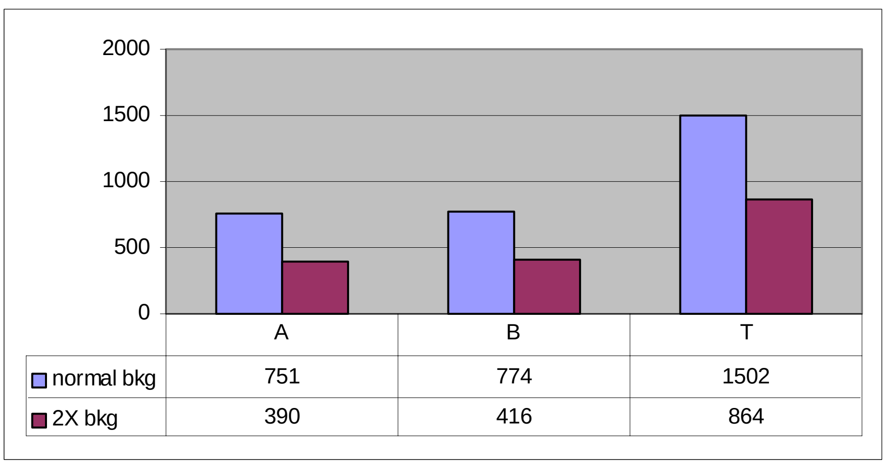
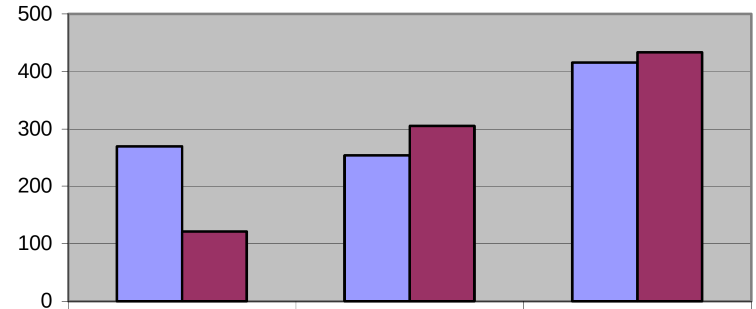



**Figure 5. Normal Mode Alarm Comparison**




| | A | B | T |
|---|---|---|---|
| normal bkg | 269 | 254 | 416 |
| 2X bkg | 121 | 306 | 433 |

**Figure 6. Tines Mode Alarm Comparison**

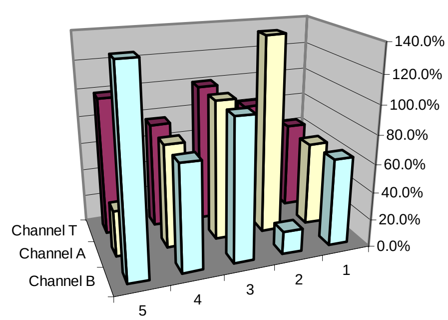
<u>Shielding</u>

A. Description

For the shielding test, the indicated radiation level was increased by approximately a factor of ten using $^{137}Cs$. Readings were obtained from each channel both prior to and after the background was increased. A four-inch by four-inch by one-quarter inch thick steel plate was then inserted between the source and detection surface and the count rates recorded again. This process was performed with the source 35 cm over the detection surface at the center position and in the same relative orientation at approximately six inches from each side edge of the detection surface. The total activity used was 33 µCi.

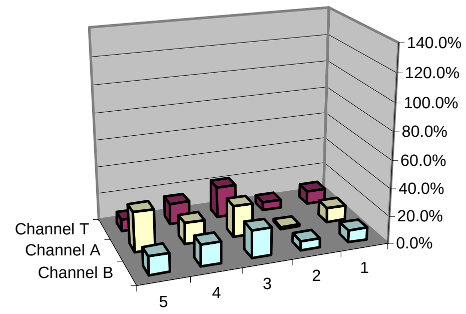
B. Results

Figures 7 and 8 show the difference in count rates between the unshielded and shielded source. These results indicate the degree of change shielding can have on the detection capability of the Cricket, or any other similar system.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Channel T | 63.0% | 82.1% | 1 | 76.1% | 98.6% |
| Channel A | 60.9% | 148.2% | 100.0% | 74.1% | 33.0% |
| Channel B | 62.8% | 16.3% | 100.0% | 75.0% | 155.4% |

**Figure 7. Response Without Steel Plate**




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Channel T | 9.6% | 6.1% | 22.5% | 15.2% | 8.7% |
| Channel A | 10.7% | 1.7% | 22.6% | 15.7% | 29.1% |
| Channel B | 8.8% | 6.5% | 20.2% | 15.7% | 13.6% |

**Figure 8. Response With Steel Plate**

Response to $^{235}$U

A. Description

This test made use of a 99% enriched $^{235}$U source. Readings were obtained with the source at 2.5, 1, and 0.5 meters from the surface of the center of the detection unit. Readings were also taken with the source in contact with the detection surface.

B. Results

Figure 9 shows the test results. The Cricket is more efficient due to its design when a source of radiation is at some distance away from the surface of the detection unit. This is very apparent when comparing the contact efficiency with that obtained at the 0.5-meter distance.

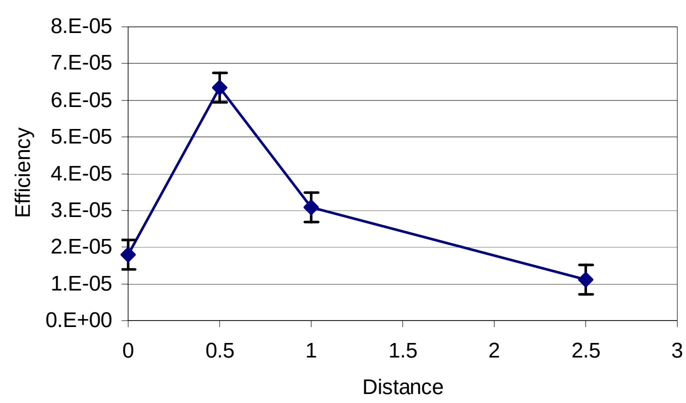



**Figure 9. Enriched Uranium Efficiency**

Response to Neutrons Using Unmoderated $^{252}Cf$

A. Description

Readings from each channel were obtained with an unmoderated 22-µCi $^{252}Cf$ source at 2.5, 1, and 0.5 meters from the surface of the center of the detector.

B. Results

Efficiencies obtained from the tests are shown in Figure 10.

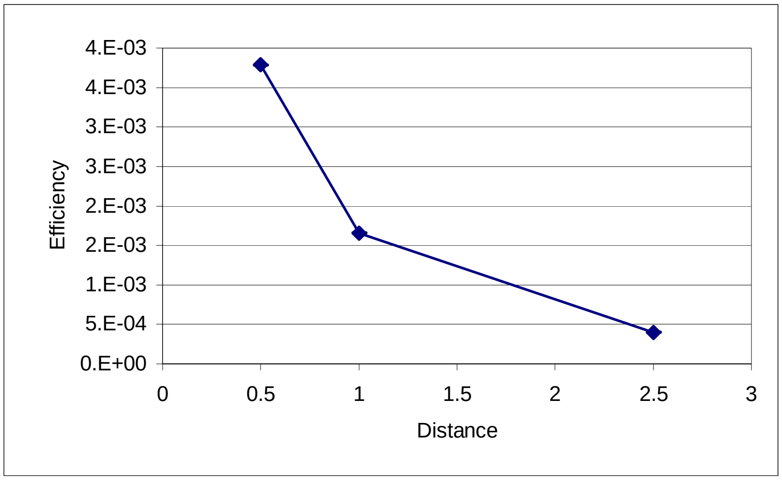



**Figure 10. Neutron Efficiency ($^{252}$Cf)**

Response to Transient Radiation

A. Description

The evaluation was performed using a $^{137}Cs$ source placed on the linear positioning sled. A total activity of 10 µCi was used at a distance of 1 meter from the detection surface. Readings for channels A and B were recorded while the sled was moving over the centerline of the detection unit. It was not possible to record channel T readings without the optional data logging capability. The transit speeds were 25, 50, and 75 cm/second (0.6, 1.1, and 1.7 mph).

B. Results

Figure 11 shows the totaled responses (channel A + B) based on transient speed.

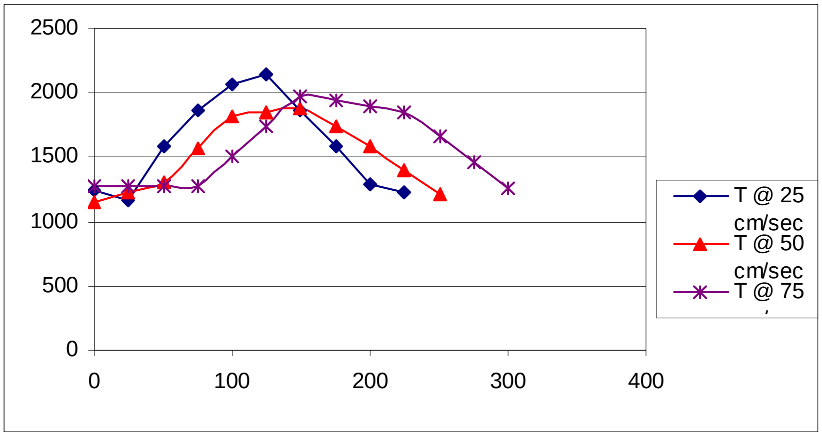



**Figure 11. Response to Moving Sources**

<u>General Comments</u>
The Cricket was very simple to operate and functioned well. Unfortunately, the schedule did not allow for a more in-depth analysis of its operations. In addition, certain operational information was not available including alarm function algorithms. This limited the development of appropriate tests and analysis of operation. The test results indicate that some functions need to be understood further, including surface or area sensitivity and background affects.

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