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**Westinghouse Hanford Company** Richland, Washington

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# CHARACTERIZATION OF MOBILE RADIATION DETECTION SYSTEMS AT THE HANFORD SITE

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## ABSTRACT

The use of vehicle-mounted radiation detection systems for characterizing large areas contaminated with radioactive materials were examined. Detection capabilities as a function of vehicle speed, detector-source geometry, and source characteristics were evaluated for each of the three systems currently used at the Hanford Site. Large-area radioactive sources (1 $ft^2$) with varying source strengths containing gamma- and beta-emitting radionuclides were used to measure detection-system performance.

Detection capability was found to be most influenced by vehicle speed and detector-source geometry. As the vehicle's speed was increased, the probability of detecting a given source decreased dramatically. The probability of detecting a given source was significantly lower under "poor" geometry conditions. Each vehicle's monitoring performance was found to compare favorably with portable survey instrument capabilities. The use of vehicle-mounted detectors proves to be far more economical for surveying large surface areas.

## INTRODUCTION

Currently, three configurations of vehicle-mounted radiation detection systems are being used at the Hanford Site.

The vehicle-mounted radiation detection system, operated and maintained by Pacific Northwest Laboratory (PNL Road Monitor), is used for monitoring both roads and railways. This vehicle consists of four sodium iodide detectors mounted on the rear bumper of a four-wheel-drive Ford truck. The detectors are mounted 0.46 m (1.5 ft) above the ground. The detectors send signals to an instrument rack located behind the driver's seat. This instrument rack includes:

- Four combination amplifier/single-channel analyzer modules
- Adjustable rate meter

- High-voltage power supply located at the base of the instrument rack
- Strip-chart Recorder.

The signals are also recorded on a strip-chart for review and documentation after the survey is completed. The strip-chart is read in percent with 100% being compared to 5,000 cpm.

The vehicle-mounted radiation detection system referred to as the road monitor, operated and maintained by Westinghouse Hanford Company (WHC Road Monitor), is used for monitoring roads and radioactive waste sites where gamma contamination is suspected. This vehicle consists of a series of five lead-shielded, 2-in. x 2-in. sodium iodide detectors mounted 18 in. above the ground and positioned on the bumper of a 3/4-ton truck. The electronics consist of a rate meter and voltage supply. The rate meter responds to all five detectors and can be switched to monitor background.

The third vehicle-mounted radiation detection system, referred to as the Mobile Surface Contamination Monitor (MSCM), is also operated and maintained by Westinghouse Hanford Company. It is used for monitoring radioactive waste sites where a high probability of gamma and beta contamination is suspected. The MSCM consists of on-board radiation detection instruments that respond to gamma- and beta-emitting radionuclides beneath its detectors. Distinguishing features of the MSCM are:

- It can reliably detect and annunciate $^{137}Cs$ and $^{60}Co$

- It has a 10-ft-wide sensitive area for gamma detection

- Its design clearly distinguishes it as an "indication of contamination only." Its purpose is to locate contamination much faster than a slower analytical type vehicle.

The MSCM is mounted on a farm tractor with a modified cab.

The gamma detector array is installed on the rear three-point lift. It consists of 5 4-in. x 4-in. sodium iodide detectors for detection and 1 2-in. x 2-in. sodium iodide detector for background. Gauge wheels on this lift allow the gamma array to automatically follow the terrain at a predetermined height. The five gamma detectors are mounted on an implement utility bar. (Note that each gamma detector assembly weighs about 200 lb.) The detectors are shielded from gamma activity other than that on or near the surface of the ground beneath them.

The detectors send signals to an alarm panel located inside the tractor cab. The alarm panel contains the detector support electronics and a small computer. The main function of this computer is to act as a single-channel analyzer for each gamma detector. The computer initiates an alarm if the count rate of any of the five detectors exceeds that of the background detector by a statistically determined amount.

The beta detector array is installed on an off-the-shelf front-mounted hydraulic three-point lift. This allows the operator to raise and lower the beta array to clear obstructions. Three beta detectors are mounted on an implement utility bar. Each of the three beta detection systems house an array of four Geiger-Mueller (G-M) tubes. They are sensitive primarily to beta activity on the surface of the ground beneath them.

The beta detectors send signals to three analog alarm ratemeters. Each ratemeter provides operating voltage for its respective G-M tube array, visual indication of the G-M tube concentration, and an audible and visual alarm when the count rate exceeds a preset limit.

These three types of vehicle-mounted radiation detection systems were tested to determine the characteristics they exhibit and compare them. The testing is also to determine if the detection systems had deteriorated since they were first built.

## EXPERIMENT DESCRIPTION FOR THE CHARACTERIZATION

This is a description of the experimental process used in characterizing the various vehicle-mounted radiation detection systems used at the Hanford Site. The questions to be answered for each road monitor will be:

- What is the detection curve associated with each monitor relating to the speed of the vehicle as source strengths and geometries are varied?
- Can relationships be drawn to the various mobile monitors in comparison to instruments used for release?

# METHOD

## SITE LAYOUT

The site chosen for this test was an abandoned airplane runway located near the 622-G building, Meteorological Station, east of the 200 West Area. The layout allowed one source of the four-source set to be positioned every 40 feet, far enough apart to prevent increased count rates in the vicinity of other sources. The sources were placed in permanently marked locations to ensure duplication of the experiment. The path of travel was be permanently marked by applying paint to the surface of the runway.

## PRELIMINARY MEASUREMENTS

The background of the test area was measured by taking 30 readings of displays from the vehicles to be tested, a G-M with a P-11-type probe and a Micro-R Meter, within a 15-minute interval. This information was recorded on the Background Sheet. These observations were averaged, and represent the average background in the test area for the instruments to be used in determining net measurement values.

After measuring the height of the vehicle detectors (face to ground) each source was placed at contact, at half height, and at ground level to the detector and readings taken and recorded on the Stationary Reading Data Sheet. This was repeated for each source type and each activity. Measurements were recorded as gross counts.

## EXPERIMENTAL MEASUREMENTS

**NOTE: All measurements are recorded as gross counts in the specified units.**

Sources of the same radionuclide and of varying activity were placed in the designated locations on the runway, and positions recorded. The sources were measured using a G-M with a P-11-type probe and a Micro-R Meter on contact, at approximately 1 ft high, and as the instruments are typically used in an area survey. These observations were recorded on the Comparative Reading Data Sheet.

On each run the vehicle traveled the designated path at a controlled, constant speed. The speed was estimated from the speedometer or RPM gauge with the related chart and recorded. The vehicle's travel time along the path was measured using a stopwatch, recorded, and the average speed was calculated using the known distance and time. The calculated speed was the accepted value for the record.

As the vehicle passed over the source, the highest level indicated by the meters was recorded. This was repeated for two more data sets. These data were recorded on the Mobile Reading Data Sheet. The vehicle then passed down the right side of the designated path repeating the same procedure with the data being recorded. The vehicle then passed down the left side of the path repeating the same procedure.

Variable speed ranges were used in performing some of the mobile readings (i.e., 1 to 3 mph, 4 to 6 mph) to determine the relationship between speed and detection capability.

## RESULTS

Tables 1 through 5 show the results of the test conducted using four $^{137}$Cs and the four $^{90}$SrY sources of varying strengths.

Table 1. Pacific Northwest Laboratory Road Monitor.

| $^{137}Cs$ | P-11 (Walking Stick) | 5.50 mph | 4.75 mph | 2.34 mph |
|---|---|---|---|---|
| 0.05 uCi | 300 cpm | BKGD | BKGD | BKGD |
| 0.38 uCi | 1,000 cpm | BKGD | 24% | 24% |
| 2.75 uCi | 10,000 cpm | 27% | 27% | 30% |
| 19.99 uCi | 50,000 cpm | 49% | 45% | 49% |

BKGD = Background 23 ± 2%
100% of Scale 5,000 cpm
Background
P-11 50 cpm
Micro Rem 6 uRem
Micro R 4 uR

Table 2. Westinghouse Hanford Company Road Monitor.

| $^{137}Cs$ | P-11 (Walking Stick) | 2.70 mph | 1.38 mph | 0.51 mph |
|---|---|---|---|---|
| 0.05 uCi | 300 cpm | BKGD | BKGD | BKGD |
| 0.38 uCi | 1,000 cpm | BKGD | BKGD | BKGD |
| 2.75 uCi | 10,000 cpm | 400 cpm | 400 cpm | 600 cpm |
| 19.99 uCi | 50,000 cpm | 1,000 cpm | 1,200 cpm | 1,250 cpm |

BKGD = Background 246 cpm
Background
P-11 50 cpm
Micro Rem 6 uRem
Micro R 4 uR

Table 3. Westinghouse Hanford Company Mobile Surface Contamination Monitor.

| $^{137}Cs$ | P-11 (Walking Stick) | 2.33 mph | | 1.89 mph | | 1.30 mph | |
|---|---|---|---|---|---|---|---|
| | | Gamma | Beta | Gamma | Beta | Gamma | Beta |
| 0.05 uCi | 300 cpm | BKGD | BKGD | BKGD | BKGD | BKGD | BKGD |
| 0.38 uCi | 1,000 cpm | BKGD | BKGD | BKGD | BKGD | BKGD | BKGD |
| 2.75 uCi | 10,000 cpm | 60 cps | 300 cpm | 150 cps | 180 cpm | 200 cps | 200 cpm |
| 19.99 uCi | 50,000 cpm | 110 cps | Full Scale | 600 cps | Full Scale | 900 cps | Full Scale |

BKGD = Background
Gamma 48 cps
Beta 118 cpm
Full Scale = 500 cpm
Background
P-11 50 cpm
Micro Rem 6 uRem
Micro R 4 uR

| $^{90}SrY$ | P-11 (Walking Stick) | 2.33 mph | 1.89 mph | 1.30 mph |
|---|---|---|---|---|
| 0.05 uCi | 400 cpm | 160 cpm | BKGD | 160 cpm |
| 0.38 uCi | 2,000 cpm | 200 cpm | 160 cpm | 180 cpm |
| 2.76 uCi | 10,000 cpm | 300 cpm | 450 cpm | Full Scale |
| 20.07 uCi | 70,000 cpm | Full Scale | Full Scale | Full Scale |

BKGD = Background Beta 118 cpm
Full Scale = 500 cpm
Background
P-11 50 cpm
Micro Rem 6 uRem
Micro R 4 uR

Table 4. Portable Instrument Readings.

| $^{137}Cs$ | P-11 (Walking Stick) | Micro Rem Meter (Survey at 1 m) | Micro R Meter (Survey at 1 m) |
|---|---|---|---|
| 0.05 uCi | 300 cpm | 6 uRem | 10 uR |
| 0.38 uCi | 1,000 cpm | 5 uRem | 10 uR |
| 2.75 uCi | 10,000 cpm | 5 uRem | 14 uR |
| 19.99 uCi | 50,000 cpm | 40 uRem | 140 uR |

| $^{90}SrY$ | P-11 (Walking Stick) | Micro Rem Meter (Survey at 1 m) | Micro R Meter (Survey at 1 m) |
|---|---|---|---|
| 0.05 uCi | 400 cpm | BKGD | BKGD |
| 0.38 uCi | 2,000 cpm | BKGD | BKGD |
| 2.76 uCi | 10,000 cpm | BKGD | BKGD |
| 20.07 uCi | 70,000 cpm | BKGD | BKGD |

Background
P-11 50 cpm
Micro Rem 6 uRem
Micro R 4 uR

Table 5. Stationary Readings Comparison.

| μCi | PNL Road Monitor % | WHC Road Monitor cpm | WHC MSCM cps/cpm | | P-11 Contact cpm | | Micro R Meter uR | | Micro Rem Meter uRem | |
|---|---|---|---|---|---|---|---|---|---|---|
| Isotope | $^{137}Cs$ | $^{137}Cs$ | $^{137}Cs$ | $^{90}SrY$ | $^{137}Cs$ | $^{90}SrY$ | $^{137}Cs$ | $^{90}SrY$ | $^{137}Cs$ | $^{90}SrY$ |
| ≈0.05 | BKGD | BKGD | BKGD | 200 | 550 | 750 | 9 | 9 | BKGD | BKGD |
| ≈0.38 | 25 | 300 | 157 | 1,000 | 4,000 | 3,000 | 17 | 9 | 10 | BKGD |
| ≈2.70 | 29 | 600 | 324 | 8,000 | 30,000 | 30,000 | 50 | 11 | 70 | BKGD |
| ≈20 | 55 | 3,500 | 1,900 | 60,000 | Full Scale | Full Scale | 1,000 | 60 | 600 | 110 |

BKGD PNL Road Monitor 23 ± 2%
WHC Road Monitor 246 cpm
WHC MSCM 48 cps
118 cpm
P-11 50 cpm
Micro R Meter 4 uR
Micro Rem Meter 6 uRem

As expected, the sodium iodide detectors did not respond to the $^{90}$SrY sources. The results of passing the vehicles alongside the sources were inconclusive. Only the higher activity $^{137}$Cs source was detected; there was no response to the lower activity sources or the lower energy $^{90}$SrY source.

## CONCLUSIONS

The questions posed at the beginning of the study were found to be only partially answered. It is felt by the persons conducting the experiment that more data are needed to determine the actual characteristics of the different mobile monitoring systems.

- What is the detection curve associated with each monitor relating to the speed of the vehicle as source strengths and geometries are varied?

By examining the data collected, the relationship of speed verses the detection capabilities of the differing monitors can be seen. In all cases, as the speed was reduced, the detection capabilities increased, indicating that the operating speed of the vehicle is a very important factor in maintaining a highly successful monitoring program.

- Can relationships be drawn to the various mobile monitors in comparison to instruments used for release?

In terms of release limits, the surface area of the sources can be equated to a standard smear size of 100 cm$^2$. If we calculate equivalency the following occurs:

$$(2.22E+6 \text{ dpm/uCi}) \times (1 \text{ ft}^2/144 \text{ in}^2) \times (15.5 \text{ in}^2/100 \text{ cm}^2) \times (\text{activity/ft}^2)$$

The source strength equivalents would then be:

0.05 uCi source = 11,948 dpm/100 cm$^2$
0.38 uCi source = 90,804 dpm/100 cm$^2$
2.75 uCi source = 657,135 dpm/100 cm$^2$
2.76 uCi source = 659,525 dpm/100 cm$^2$
19.99 uCi source = 4,776,777 dpm/100 cm$^2$
20.07 uCi source = 4,795,894 dpm/100 cm$^2$.

As a basis for understanding the survey results and/or evaluating release criteria, this test is not conclusive. Instrument efficiencies and correction factors need to be established. This will allow us to compare response of the instrument with the source strength. Additional testing with additional sources is needed. At first glance, the results indicate that the monitors cannot see the level of activity required for basing personnel protection decisions.

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