MOBILE SURFACE CONTAMINATION MONITOR

FOR LARGE AREA RADIOLOGICAL SURVEILLANCE

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ABSTRACT

The Mobile Surface Contamination Monitor (MSCM) was developed by Rockwell Hanford Operations (Rockwell) to satisfy the need for a mobile vehicle capable of surveying large areas for radioactive contamination. The MSCM utilizes both a computerized gamma detection system and a beta detection system to seek radioactive surface contaminants on both on and off-road surfaces. It is designed for use in deep sandy soil, typical of the Hanford Site, and is believed to be one of the most sensitive surveillance vehicles of its kind in existence.

INTRODUCTION

At the Hanford Site, ground surfaces overlying old inactive waste disposal sites, such as burial grounds, cribs, ponds and ditches, have become contaminated, mostly as a result of penetration into the waste by deep-rooted vegetation, such as tumbleweeds. Surface stabilization of these contaminated surfaces is performed by adding up to a meter of soil to the site and revegetating with shallow rooted grasses, which prevent the establishment and growth of deep-rooted vegetation. The MSCM was developed specifically for the purpose of monitoring newly stabilized sites. To perform the required radiological surveys, it is necessary to traverse the stabilized area without damaging the newly planted vegetation. Before the development of the MSCM, the only feasible method of doing this was walking the area with small hand-held survey instruments.

Traveling 4 km per hour and monitoring an area 3-m wide, the MSCM will make it possible to replace expensive, time consuming, and labor intensive hand survey methods at Hanford. For example, the MSCM can monitor a hectare in about 50 minutes, compared to the 150 manhours required for manual surveillance.

^{137}Cs and ^{90}Sr are, typically, the radioactive contaminants of Hanford site surfaces. The MSCM can automatically and routinely survey these contaminants at the following detection limits:

Detection Limits

Contaminant	Areal	Spot
^{137}Cs	1 Bq Cm^{-2} (28 pCi Cm^{-2})	1.73×10^3 Bq (45 nCi)
^{90}Sr	5 Bq Cm^{-2} (130 pCi Cm^{-2})	370 Bq (10 nCi)

MSCM DESCRIPTION

The MSCM is the realization of many ideas derived from years of experience in surface monitoring at Hanford. A common farm tractor with a cab was selected as the best available vehicle. Its inherent ruggedness and ability to traverse off-road terrain at slow, steady, and repeatable speeds render it superbly adaptable to surface monitoring. The availability of relatively low cost special purpose attachments helped to make the tractor the most cost effective option.

Five ground sensitive NaI gamma detectors are attached to an off-the-shelf front mounted hydraulic lift (Fig. 1). Controls in the cab allow the operator to raise and lower the front detection array to clear obstructions. A sixth gamma detector, mounted aft of the others, is dedicated to real-time gamma background monitoring.

Fig. 1. Gamma Detector Array on Front of MSCM.

Wide equipment tires on the front of the tractor and dual turf tires on the rear allow the tractor to negotiate the sandy Hanford terrain with minimal topsoil disturbance.

A weather-tight instrument cabinet, attached to the right side of the cab, houses the gamma Computer Control Unit (CCU), the Power Control Panel, and the nucleonics for the beta detection arrays on the rear lift. This instrument cabinet is cooled by an instrument air conditioner for summer operation and warmed by a heater for winter operation.

A portion of the left side of the cab is extended to provide space for an instructor for training purposes. An air conditioner is installed atop the cab to make it inhabitable by the operator during the summer months. Front and rear lighting allow nighttime operations. A portable generator (Fig. 2) is installed on the rear of the cab to provide operating power for the instruments and the air conditioners.

Fig. 2. Portable Generator and Beta Detector Array on rear of MSCM.

Three beta detection arrays are mounted on the rear lift. Since distance from the source is very important to detection of beta radiation, gauge wheels on this lift allow the beta detectors to follow ground contours at a fixed distance.

The tractor, thus equipped, can carry its 1600 kg payload of lead-shielded detectors and associated equipment across the rugged sandy Hanford terrain while doing little, if any, damage to the environment.

RADIATION DETECTION SYSTEMS

Selection of Detection Systems

The detection systems used in the MSCM were selected on the basis of field tests with a standard American four-wheel drive vehicle which employed either a lead-shielded four detector array of Geiger-Muller (G-M) tubes mounted beneath the front bumper, or four detector arrays of lead-shielded NaI scintillation detectors mounted across the rear bumper. One series of tests (Table I) was conducted to determine the sensitivity of the G-M tube and the NaI systems for detecting known concentrations of ^{90}Sr or ^{137}Cs dispersed in standard configurations (i.e., spot or areal). Results of these sensitivity tests were used to design radiation detection equipment and systems for the MSCM; as noted in Table I, the sensitivity of the MSCM detection systems is substantially improved over that noted in the early field tests.

Gamma Detection System

The Gamma Detection System is comprised of six scintillation detectors and the CCU. Each of the detectors utilizes a NaI(Tl) scintillation crystal (0.1-m high, 0.1-m wide, and 0.075-m thick), which is optically coupled to an 0.075-m diameter photomultiplier tube. The sealed detector assembly is protected from both thermal and mechanical shock by approximately 0.025-m of foam material on all sides. The detector and its protective foam are housed in an environmentally-sealed housing. The five ground sensitive detector assemblies on the front lift are each shielded on four sides by 0.025-m of lead. Each gamma detector is thus collimated so that only the bottom crystal surface is sensitive to gamma radiation on or near the ground surface beneath it.

When the ground sensitive detectors are mounted on the front lift of the MSCM, the bottom surface of the NaI(Tl) crystals is approximately 0.28-m from the ground surface.

TABLE I

Detection Limits of Various Systems for Monitoring Surface Contamination

Detection/Configuration	Detection Limit			
	^{137}Cs		^{90}Sr	
	Spot[(a)] (Bq)	Areal[(b)] (Bq cm^{-2})	Spot[(a)] (Bq)	Areal[(b)] (Bq cm^{-2})
G-M Tube Type	(c)	(c)	2.3×10^4	407
NaI Surface Monitor	5.6×10^3	3	(c)	(c)
MSCM	1.7×10^3	1	370	5

(a) Infinitesimally small points of contamination
(b) Infinitely large area of evenly dispersed surface contamination
(c) Not applicable

The ground sensitive detector assemblies were spaced by first placing a ^{137}Cs standard source on the ground directly beneath a detector and recording the count rate. The standard ^{137}Cs source was then moved away from the detector until the count rate was reduced by 50 percent. The five ground sensitive detectors were thus spaced approximately 0.6-m apart across the front of the MSCM. This arrangement provides the MSCM with a sensitive area approximately 3-m wide.

The sixth gamma detector is dedicated exclusively to the real-time monitoring of gamma background. It is identical to the ground sensitive detectors except that it is shielded on the bottom by a 0.025-m thickness of lead and on the four sides. This detector can be mounted in any convenient place on the MSCM.

Computer Control Unit

The CCU provides all of the components necessary for independent operation of the six gamma detectors. The CCU is located in an environmentally controlled instrument enclosure. The CCU contains six each of the following components: High Voltage Power Supply, Detector Signal Decoupler, Spectroscopy Amplifier, and Single Channel Analyzer (SCA). Negative-going tail pulses from each detector are thus separated from the High Voltage line, amplified and fed into the appropriate SCA which is adjusted to respond only to pulse heights that are typical of ^{137}Cs and ^{60}Co. For each tail pulse that occurs in this energy window, the SCA outputs a square wave pulse into the appropriate CCU channel.

The CCU utilizes a running average technique to calculate the average count rate of each of the six gamma detectors. The five ground sensitive detector channels have counting periods that are keyboard adjustable from one second to four seconds in 0.5-s intervals. The CCU stores the counts that occur during each 0.5-s sample time and then divides the total stored counts by the time over which the counts were stored. For example, if a two-second time period is selected, counts from four 0.5-s sample times are stored in four different memory locations. The CCU then sums the counts from each of the four sample times and divides by two to arrive at counts per second. During the next 0.5-s interval, counts from most recent sample time are stored in a memory location while the counts from the earliest sample time are discarded. Again, the CCU sums the counts and divides by two to arrive at the updated counts per second. This "running average" technique serves to dampen variations in the count rates and thus discourages false alarms. Selecting the proper counting period involves a trade between detection response time if a long period is selected and false alarms if a short period is selected.

For stabilization purposes, the background detection channel has counting periods ranging from ten seconds to forty seconds with one-second sample times. Again, the "running average" technique is employed for determining the average count rate in counts per second. At one-second intervals, the CCU determines the alarm point by: (1) computing the updated background standard deviation, (2) multiplying the standard deviation by a constant (generally three, but user selectable from one to ten), and (3) adding this number to the average background count rate to determine background plus three background standard deviations in counts per second. If the count rate of any of the five ground sensitive detectors exceeds this value, the CCU initiates the audible and visual alarms.

The count rates of each of the six gamma detectors are displayed on a Cathode Ray Tube (CRT), both numerically and graphically via bar graphs (Fig. 3). When an alarm occurs, a blinking cursor on the CRT identifies the offending detection channel and a pulsating audible alarm sounds.

The capability to vary the statistical alarm point and the time over which the count rates are averaged makes false alarms virtually nonexistent. Real-time monitoring of the gamma background serves to further reduce the potential for false alarms by automatically compensating for local background variations. This system automatically detects and annunciates gamma-emitting contaminants on or near the ground surface and is in no way dependent on operator judgment or interpretation.

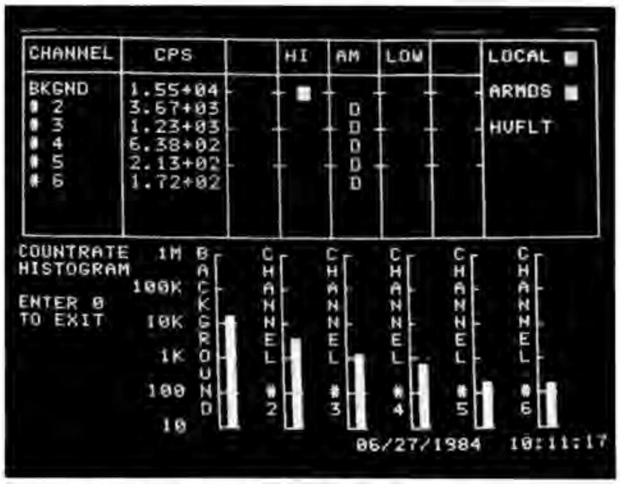

Fig. 3. Numerical and Graphical Count Rate Display on CRT.

Beta Detection System

The beta detection system for the prototype MSCM consists of three lead shielded detectors, each of which contains four thin wall G-M tubes. Each of the detectors is monitored and manually controlled by a standard analog electronic package which provides operating voltage, signal decoupling and discrimination, analog count rate indication, percent of scale alarm, and a chart recorder output.

The beta detection system was designed with conventional equipment to:

1) Compare the operational characteristics of the two types of systems. (Computerized versus Manually Monitored)

2) Establish a practical method of controlling the beta detector-to-ground distance while in operation.

After a year of field operation, the computerized system has proven satisfactory in all respects. It is easy to operate and maintain, improves operational sensitivity, rarely generates a false alarm, and occupies a small space.

Gauge wheels on the rear lift of the MSCM are ideal for controlling the detector-to-ground distance of the beta array. In operation, the gauge wheels allow the beta array to follow the ground contours at a fixed distance of 0.15-m.

COST CONSIDERATIONS

The total cost of the MSCM is approximately \$265,000 or about \$53,000 per year for its estimated five-year operating life. Labor costs are estimated at \$35,000 yr^{-1}; maintenance costs are estimated to be \$10,000 yr^{-1} for parts and labor. Thus, the total cost of operation for the MSCM is estimated at \$98,000 yr^{-1}, which corresponds to approximately \$185 $hectare^{-1}$ for 530 hectares.

CONCLUSIONS

Although the prototype MSCM is not the answer to all problems associated with radiological surface surveillance, it is certainly a step in the right direction. The prototype MSCM proves the practicality and advantages of mobile computerized detection systems. It also provides valuable insight into the problems of transporting heavy detection arrays across off-road surfaces. The beta detection system must be upgraded by increasing the size of the detector array and by incorporating a computer-controlled nucleonics system similar to that of the gamma system. In cases when only ^{137}Cs or ^{90}Sr are anticipated, the dual beta and gamma systems provide preliminary information about which radionuclide has been located.

Other potential refinements involve increasing the efficiency of the MSCM by providing four-wheel drive, reduced noise levels, and instrument panel lighting for nighttime operation.