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A GAMMA MONITOR FOR ASSAY OF RADIOACTIVE SOLID WASTE SHIPMENTS

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A GAMMA MONITOR FOR ASSAY OF RADIOACTIVE SOLID WASTE SHIPMENTS

INTRODUCTION

A gamma waste monitor has been developed and evaluated at the Savannah River Plant (SRP). The purpose of the monitor is to improve estimates of the radionuclides in solid wastes arriving at the plant's burial ground. This monitor, a computer-based spectrometer, quantitatively measures many radionuclides in SRP waste, including waste in heavily shielded shipping casks. Radionuclides emitting gamma rays of sufficient energy to penetrate the shipping container walls can be measured directly. Other radionuclides that are beta emitters or which emit gamma photons too weak to penetrate the walls of the waste containers can often be estimated by their association with measurable gamma photons.

Development of the monitor was initiated to find a more accurate method of estimating the quantities of radioactive materials accumulated in the burial ground and to ensure compliance with burial limits imposed by SRP technical standards. Another benefit from the monitor is that it provides specific radionuclide data which are essential to environmental impact evaluations and decommissioning planning.

Historically at SRP, the radionuclide content of waste packages has been determined by the use of portable survey instruments and the comparison of results with assays of typical waste shipments. This approach included taking an ionization chamber reading at a specific distance from the container and, after correction for shielding in the specific container, using conversion factors to relate the ion chamber measurement to the number of curies present. This method is accurate if the composition of the radionuclides in the waste package remains the same as that used for the calibration, but frequently this is not the case. The gamma waste monitor removes much of this uncertainty with its ability to identify and measure the gamma-emitting radionuclides that are present. Use of the new monitor greatly improves the accuracy of the waste burial records.

WASTE MONITOR DESCRIPTION

The gamma waste monitor is located inside the fenced area of the SRP burial ground. It consists of a tower to position the detector, an earth shield to protect the monitor operator from radiation exposure, and a trailer to provide a temperature-controlled environment for the analytical systems and office space for the operator (figure 1).

DETECTORS

An intrinsic germanium detector with an active volume of 55 cm^3 and a high efficiency for photon energies >100 keV is the primary detector normally used in the system. Another intrinsic germanium detector which is more efficient for photons <100 keV, and about 10 times less efficient for higher energies than the primary detector, is available. It can be used when radiation intensities are too high and cause saturation of the primary detector.

TOWER

The 100-foot-tall tower can accomodate a detector and its liquid nitrogen flask inside either one of the two weatherproof pods on the crossarm. One pod is directly above the road bed and the other is above the railroad spur (figure 2). Each pod has a set of cables to connect a detector to the electronic equipment in the trailer, but only one of the detectors can be connected at a time. The crossarm can be raised or lowered by the operator with an electric winch, either from the base of the tower or from inside the trailer, to obtain a wide selection of source-to-detector spacings and permit filling of the Dewar flask with liquid nitrogen. The height of the detector can be determined from an indicator at the base of the tower. If the tower does not provide enough distance to avoid saturation of the detector, greater source-to-detector distances can be achieved by moving the truck or rail car carrying the waste further away.

TRAILER

The trailer is located on the opposite side of the earth mound from the tower. It contains a 4096-multichannel analyzer, an interface, read-write memory, programmable calculator, printer, and other miscellaneous equipment. This equipment is shown in figure 3. The operator can perform all of the functions required to monitor a waste package from the trailer, including moving the crossarm and detector to a different elevation as needed to adjust the radiation intensity at the detector and to simplify geometric corrections for package size.

MONITOR OPERATION

Preparation of the monitor for measurement of waste packages requires a daily startup routine of about 30 minutes. After various equipment checks are made, the detector is positioned at the height to be used. A ^{152}Eu source (approximately 1.4 Ci) is then removed from its holder (buried in the earth mound) and placed on the top of the mound. A spectrum is then collected for 5 minutes for an energy calibration, using peaks at 344 and 1,408 keV. After the source is returned to its holder, a 10-minute background spectrum is collected which usually will only show a ^{137}Cs peak at 661.6 keV. The background is stored and a correction will be made on any subsequent counts. A new background count must be made when the detector height is changed. Table 1

shows the spectrum from a 50-minute count with the detector 36 feet above the road bed. With the exception of a large photopeak due to ^{137}Cs and two minor peaks due to ^{60}Co, all other peaks appear to be of natural origin. Most lightly shielded packages can then be counted in 5 to 10 minutes, while heavily shielded packages may require 30 minutes or more.

The monitor can detect specific gamma-emitting radionuclides if their photon energy is high enough to penetrate the waste container. For lightly shielded waste, practically all gamma-emitting isotopes can be identified if their photon energy exceeds about 200 keV. In heavily shielded containers, only a few of the higher energy gamma rays are available for isotope identification. Many radionuclides that are pure beta emitters or have photon energies too low to penetrate the container can be estimated by association, if the general type of activity associated with the package is known. Using this technique, a good approximation of the total radionuclides in the package can be made, but further development work is required before this becomes a part of the routine program.

OPERATING EXPERIENCE

The burial ground for management of solid waste at SRP is located near the geographic center of the 300-square-mile plantsite. A waste package arriving at the burial ground by truck or rail can be easily routed to the gamma waste monitor.

MONITORING PROGRAM

The monitor is located near the main entrance road and adjacent to a rail spur in the burial ground. Upon arrival of the waste in the burial ground, an identifying number and other data are entered in the record. Waste to be monitored is then positioned under the detector and counted before it is placed in a designated burial trench.

Counting data from the waste container are analyzed by a minicomputer. The radionuclides associated with the detected photopeaks are identified and corrections for the attenuation of the container and the height of the detector are made. Results are printed out in curies of each detected radionuclide and are included in the computerized record system.

WASTE PACKAGING

Solid wastes which are generated in various nuclear processes at SRP are composed of many different materials and arrive at the burial ground in many types of containers. Wastes must be packaged according to standards designed to prevent the spread of contamination during handling and to minimize radiation exposures to operating personnel. The containers range from cardboard boxes to heavily shielded steel and lead-lined casks. Typical contaminated materials include: reactor scrap metal (irradiated steel and aluminum components from reactor fuels), glassware, paper and cloth products,

pipe, vessels, pumps, resins, and miscellaneous scrap. Characterization of all of these wastes would be too voluminous for this discussion, but some typical packages will be discussed in more detail.

SCRAP METAL

Irradiated metal components from SRP reactor fuels are shipped to the burial ground in steel-lined lead casks with an effective shield thickness of 1 inch of steel and 3 inches of lead. The activity in this scrap is largely ^{60}Co (1,175 and 1,332 keV) which can penetrate the cask wall. Some ^{65}Zn is also directly detectable, but other radiation from radionuclides normally expected to be in the scrap is absorbed by the cask walls. Work has been done in estimating these radionuclides by a ratio method with some success. However, the limited memory and programming capabilities of the waste monitor require that most apportionment of nuclides not directly detected by the monitor be accomplished on a larger computer. This is part of a larger data interpretation study and, as mentioned earlier, requires further development work.

Because the scrap casks are used repetitively, corrections have to be made for any external contamination before shielding factors are applied. A factor to account for any residual contamination inside the cask must also be applied. The program corrects for external or surface radiation by comparing the two ^{60}Co peaks with the expected attenuation of the the known shield wall thickness. Monitoring of the empty cask is sometimes necessary to account for residual internal contamination.

During a 6-month period, the gamma waste monitor was used to monitor 54 shipments of scrap metal. As little as 1 Ci and as much as 1,800 Ci of ^{60}Co was measured, along with 5 to 260 Ci of ^{65}Zn. The estimates made by using an ionization chamber generally were low compared to the values determined by use of the gamma waste monitor as shown in table 2. Measured values from the monitor for ^{65}Zn and ^{60}Co were about 3 times higher than the estimated values.

SEPARATIONS AREAS WASTE

Most of the separations areas waste arrives at the burial ground in small packages, usually only lightly shielded, such as cardboard boxes or metal drums which normally contain less than 2 Ci per shipment. Some items, such as process vessels, filters, pumps, piping, etc., are more highly radioactive and receive special packaging and handling. Some large bulky waste items arrive by rail car. Because of the light shielding usually encountered and the broad mixture of fission products, usually 8 to 10 gamma-emitting radionuclides in a shipment, most of the radionuclides can be measured directly with the waste monitor. Nuclides with more than one gamma photon can generally be used to determine the effective attenuation of the package; if it is significant, corrections can then be made for all energies. Although the information to make these corrections is available from the monitor, considerable operator time is involved. As the use of the waste monitor is expanded to include monitoring of more waste packages, the corrections will be done on a larger computer.

Table 3 provides a summary of results obtained from monitoring several types of fission product waste packages. As shown, the monitor can resolve a relatively complex array of isotopes into a meaningful distribution. In each case, the estimate using ion chambers was considerably lower than the measured quantity and the estimate provided no spectrum information. Obviously, more accurate and detailed records of waste burials can be obtained with the monitor. However, these lists do not necessarily represent all nuclides that may be present and efforts to identify the nuclides by association with detectable nuclides have not been entirely successful. When longer-lived fission products were considered, a factor relating fission yield and half-life to that for ^{137}Cs provided a reasonable approximation for some additional nuclides. For example, the factor to estimate ^{90}Sr from the ^{137}Cs activity would be 0.98 when derived by this method. Other factors have been similarily derived.

MISCELLANEOUS WASTE

Miscellaneous low level wastes from a limited number of other DOE sites, meeting stringent specifications for content and Department of Transportation (DOT) packaging requirements, are also received at the burial ground. During the first quarter of 1982, these shipments were monitored with the gamma waste monitor and results of typical shipments are summarized in table 4. The table compares the shippers estimated quantities of gamma-emitting isotopes to the gamma monitor results. All shipments were in compliance with DOT shipping and packaging regulations, although there are variances in the shippers estimates and the monitor results. In several instances, the shippers estimated total was close to the monitor results but the nuclide distribution had differences.

CONCLUSIONS

The gamma waste monitor provides significant improvements in the estimates of quantities of specific radionuclides placed in the burial ground. In addition to those isotopes measured directly, many other beta and low energy gamma-emitting products can be estimated by association. Further study is required to improve the ability to estimate those nuclides that are not measured directly.

SRP is currently integrating the monitor into its routine waste management programs, with initial emphasis on monitoring all packages estimated to contain at least 1 Ci of gamma-emitting radionuclides.

ACKNOWLEDGEMENT

I wish to acknowledge the major contributions of J. E. Hoy, a retired Health Protection Process Engineer, to the design, development, and initial evaluation of the gamma waste monitor. His ideas and efforts are largely responsible for the monitor.

REFERENCE

Hoy, J. E., Evaluation of a Gamma Monitor for Survey of Waste for Shallow Land Burial. USDOE Report DP-1519. 1978. Savannah River Plant, E. I. du Pont de Nemours and Co., Aiken, South Carolina 29801.

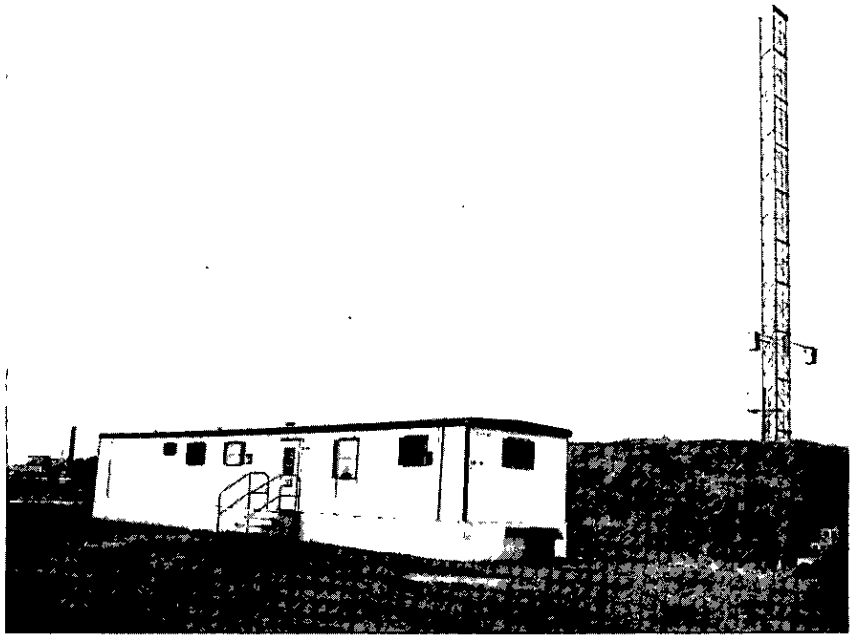

FIGURE 1. WASTE MONITORING FACILITY. DPSPF 33843-5.

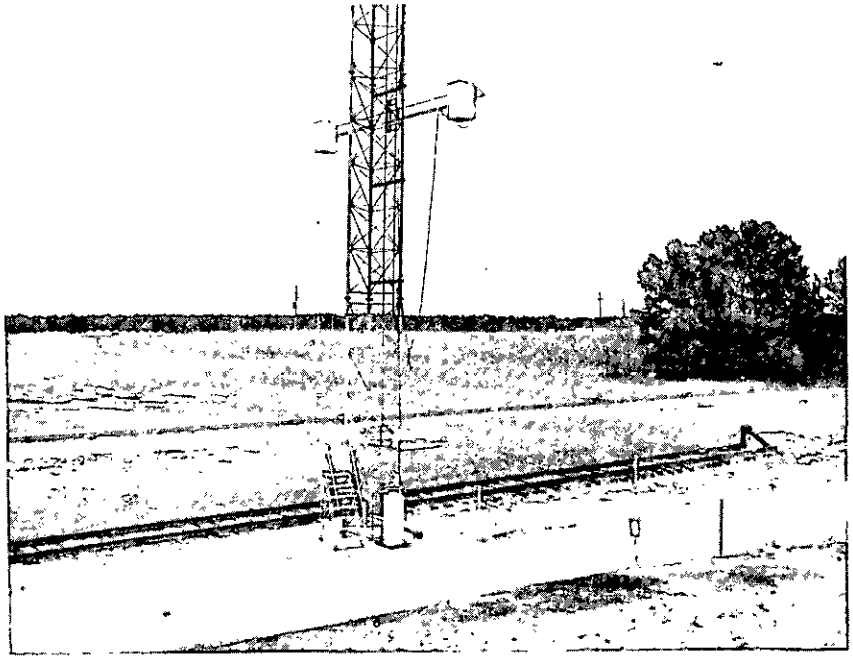

FIGURE 2. WASTE MONITOR TOWER.
DPSPF 33843-8.

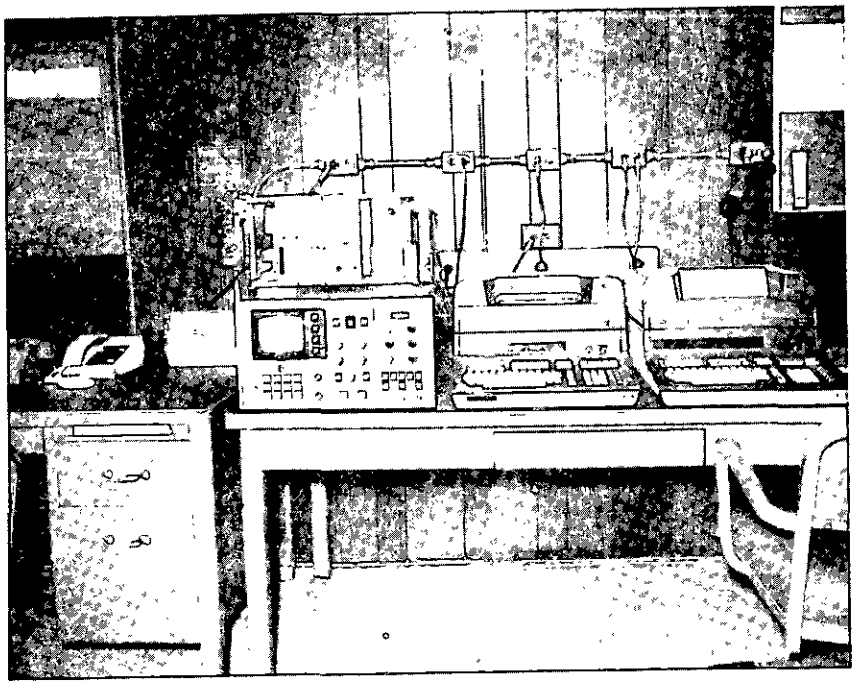

FIGURE 3. WASTE MONITOR ANALYZER.
DPSPF 33843-4.

TABLE 1

MAJOR PHOTOPEAKS IN THE BACKGROUND SPECTRUM

(Detector height, 36 ft; length of count, 50 minutes)

Isotope Identification	Photopeak Energy, keV	Peak Counts/50 Minutes
^{212}Pb	238.83	725
^{214}Pb	351.98	468
^{208}Tl	583.27	281
^{214}Bi	609.51	462
^{137}Cs	661.66	3,719
^{228}Ac	911.21	263
^{214}Bi	1,120.59	92
^{60}Co	1,173.30	79
^{60}Co	1,332.85	97
^{214}Bi	1,765.94	98

TABLE 2

REACTOR SCRAP CASK DATA

File No.	Estimated, Ci	Measured Ci	
		^{95}Zn	^{60}Co
99559	11.5	27.0	9.0
99586	6.9	0.0	3.5
99587	6.9	0.0	1.4
99588	6.9	16.0	11.1
99580	4.6	22.0	3.0
99591	80.5	118.4	81.5
99593	6.9	7.7	3.0
99596	5.7	58.6	24.2
97200	23.0	56.1	56.0
99607	6.9	66.5	47.7
102296	6.9	34.0	5.4
102764	6.9	96.1	25.1
91189	23.0	10.0	2.0
91190	23.0	12.0	1.6
91191	23.0	0.0	91.0
91193	23.0	0.0	5.0
91194	23.0	17.0	7.5
91196	23.0	0.0	161.0
91197	161.0	0.0	1,048.0
93794	17.5	0.0	645.0
93805	69.0	13.0	272.0
394229	2.1	2.0	2.0
93814	340.0	0.0	1,883.1
93815	69.0	131.7	428.9
93816	340.0	0.0	331.2
93818	338.0	145.0	541.1
93822	13.8	127.4	301.5
93824	6.9	205.5	72.9
93825	34.0	143.2	219.2
103116	230.0	236.5	354.1
99526	9.2	33.9	4.9
101012	138.0	266.0	453.1
101018	690.0	0.0	1,421.0
101021	11.5	72.6	207.2
101022	11.5	133.5	417.2
101029	184.0	108.2	400.0
101041	69.0	110.2	199.7
103106	34.5	134.0	254.2
101749	11.5	65.4	11.0
101048	230.0	103.7	337.3
103102	460.0	42.9	84.0
101047	115.0	32.2	230.7
97377	690.0	61.5	641.5
97812	12.5	0.0	19.0
97814	11.5	0.0	67.0
97821	11.5	16.6	3.1
97819	11.3	0.0	1.0
97823	11.5	26.0	7.5
97824	11.5	22.0	6.0
97825	11.5	24.0	12.0
97826	13.8	35.0	7.0
97827	11.5	18.0	15.0
97820	2.3	40.9	7.4
97807	2.3	13.8	5.4
504470	2.3	18.9	5.6
504445	2.3	13.2	2.7
504446	2.3	33.3	5.4
504814	27.6	0.0	5.2
101745	11.5	48.1	13.2
Total	4,744.3	3,019.6	11,452.3

TABLE 3
CONTENT OF TYPICAL WASTE PACKAGES, Ci

Source Description	Lab Dumpster Pans	Lab Dumpster Pans	Lab Dumpster Pans	Lab Dumpster Pans	Lab Dumpster Pans	Canyon Vessel	Waste Farm Pump	Canyon Filter
Estimate	0.08	0.08	0.0	0.0	-	-	-	-
Isotope								
^{144}Ce	0.44	8.92	0.01	0.86	0.33	-	-	-
^{103}Ru	0.01	0.02	-	0.02	0.05	0.01	-	-
^{106}Ru	0.22	4.35	0.01	0.46	0.17	1.33	-	-
^{137}Cs	0.03	0.09	0.01	0.27	0.10	0.18	3.0	9.4
^{95}Zr	0.26	1.20	-	0.29	0.17	0.23	-	-
^{95}Nb	0.24	0.35	-	0.66	0.32	0.73	-	-
^{134}Cs	0.003	0.62	-	0.04	0.01	-	0.03	0.2
^{154}Eu	0.01	0.05	-	0.04	-	0.04	-	-
^{125}Sb	-	0.08	-	-	-	0.06	-	-
^{60}Co	-	0.05	-	-	0.001	-	-	-
^{152}Eu	-	-	-	0.02	-	-	-	-
Total measured	1.213	15.73	0.03	2.66	1.151	2.58	3.03	9.6

TABLE 4
MISCELLANEOUS OFFSITE WASTES

Description[a]	^{60}Co	^{137}Cs[b]	^{134}Cs	^{58}Co	^{106}Ru	^{65}Zn	^{95}Zr-^{95}Nb	$^{152,154}Eu$	^{228}Pa
88-D	62(21)	-	-	-	-	30	-	-	-
8-B, 8-D	(7)	129(241)	23	-	-	-	7	-	-
2-C	272(3880)	4321	864	-	-	-	-	-	-
3-B, 47-D	0.1(trace)	37(1.2)	-	-	-	-	-	-	-
2-C	145(4850)	4777	682	-	-	-	247	11	-
2-C	26(1270)		-	-	-	-	-	14	-
8-B, 8-D	(trace)	<1(<1)	-	-	-	-	-	-	-
2-C	20(580)	-	-	-	-	-	-	-	5
8-B, 3-D	(trace)	2	-	-	-	-	-	-	-
2-C	<1(1450)	<1(trace)	-	-	-	-	-	-	-
5-B	(trace)	<1(trace)	-	-	-	-	-	-	-
7-B, 13-D	(trace)	7(<1)	-	-	<1	-	-	-	-
85-D	<1(11)	-	-	11	-	-	-	-	-
5-B	-	21(40)	<1	-	-	-	-	-	-

[a] D = steel drums.
B = wooden boxes.
C = concrete boxes.
[b] Shippers included ^{90}Sr estimates with ^{137}Cs.
[c] Shipper frequently listed a trace of mixed fission products (MFP) and other nuclides not directly detectable with the monitors.