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In-Situ Radiation Measurements of the C1 and C2 Waste Storage Tank Vault

L. K. Yong
P. C. Womble
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D. R. Anderson

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Applied Radiation Measurements Department
Waste Management and Remedial Action Division

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L. K. Yong [†]
P. C. Womble [†]
L. D. Weems [†]
F. J. Schultz [†]
D. R. Anderson [††]

[†] Applied Radiation Measurements Department,
Waste Management and Remedial Action Division
[††] Office of Radiation Protection

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Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
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EXECUTIVE SUMMARY

In August of 1996, the Applied Radiation Measurements Department (ARMD) of the Waste Management and Remedial Action Division (WMRAD) at Oak Ridge National Laboratory (ORNL) was tasked with characterizing the radiation fields in the C1 and C2 Liquid Low Level Waste (LLLW) tank vault located at ORNL. These in-situ measurements were made to provide data for evaluating the potential radiological conditions for personnel working in or around the vault during future activities. Measurements were made using a Teletector, Shonka-Wyckoff ionization chamber, thermoluminescent dosimeters (TLDs), neutron bubble dosimeters, and Sodium Iodide (NaI) and High Purity Germanium (HPGe) detectors for gamma spectrometry. The Teletector and Shonka-Wyckoff ionization chamber were used to measure gamma-ray exposure rates. The TLDs measured gamma and beta doses, while the neutron bubble dosimeters measured the neutron dose. Gamma spectrometry was performed to identify the dominant radionuclides contributing to the radiation field. The tank vault was accessed through six boreholes (three on each East and West sides of the vault). Of the three boreholes on each side of the vault, two were directly above the tanks, while the third and middle borehole was located in between the tanks. Radiation measurements were made using the dose and exposure rate instruments at several points down the boreholes located over the tanks, up to the surface of the tank. For the middle boreholes radiation measurements were made using TLDs and the Shonka-Wyckoff ionization chamber down to the floor of the vault. A neutron bubble dosimeter measurement was made at the bottom of the vault as well. Telector measurements were made down the middle borehole to within 7 feet of the vault floor. Within the vault the radiation dose rates range from 2 rem/hr to 11.6 rem/hr. The highest readings were observed near the bottom of the tanks, ostensibly where the radioactive sludge is concentrated. The dose rate readings observed at the top of the tanks to the roof of the vault were nominally in the range of 2 to 3 rem/hr. The elevated dose rates of above 5 rem/hr observed over the C1 tank at borehole E1 is probably due to the proximity of very radioactive piping to the measurement location. Gamma spectrometry measurements using a NaI detector were performed for all the bore holes on the East side of the vault. On the West side of the vault, gamma spectrometry was performed using a HPGe detector on boreholes W1 and W2 (over the tanks). Dose measurements made at the top of the borehole openings generally resulted in low gamma exposure and dose rate readings. Exposure rate measurements taken on top of the shield, with the borehole plugs inserted, were less than 0.1 mR/hr. Gamma spectrometry of the C1 tank showed mostly ^{137}Cs, with ^{152}Eu present at half the intensity of the ^{137}Cs. The C2 tank indicated the presence of ^{137}Cs, with ^{60}Co at approximately 60 times less intensity than the ^{137}Cs. Neutron dose rate measurements made with neutron bubble detectors (within the tank vault) showed that the neutron dose rate, if any, is below the 2 mR/hr sensitivity limit of the bubble detectors. No contamination was found on the measurement equipment after it was extracted from the tank vault.

1.0 INTRODUCTION

In August of 1996, the Applied Radiation Measurements Department (ARMD) of the Waste Management and Remedial Action Division (WMRAD) at Oak Ridge National Laboratory (ORNL) was tasked with characterizing the radiation fields in the C1 and C2 Liquid Low Level Waste (LLLW) tank vault located at ORNL. These in-situ measurements were made to provide data for evaluating the potential radiological conditions for personnel working in or around the vault during future planned activities. This report describes the locations where measurements were made, the types of radiation detection instruments used, the methods employed, the problems encountered and resolved, and discusses the results obtained.

1.1 Description of the C1 and C2 Tanks

The C1 and C2 waste storage tanks were built in 1964 to accommodate hot (thermal) waste with activities up to 2,800 Curies per gallon [WM 91]. The two tanks are located in an underground reinforced concrete vault. Modifications to the tanks were made in 1984 to allow for their use as feed tanks. The tanks are presently being used to store LLLW.

1.2 Measurement Locations

Exposure rate and dose readings were taken at six locations in the C1 and C2 tank vault. These locations are 3-inch boreholes made through the roof of the vault. The roof of the tank vault is made of three feet thick reinforced concrete. There are three boreholes on each side of the tank vault (i.e., East and West). For each set of three boreholes, two are located directly above the tank centerline, while the third borehole was made over the middle of the two tanks. The bore holes on the Eastern side of the vault are named E1, E2, E3 and the boreholes on the Western side of the vault W1, W2, and W3. Boreholes E1 and W1 are directly over the C1 tank while E2 and W2 are over the C2 tank. The boreholes E3 and W3 are located over the middle of the space between the C1 and C2 tanks. Figure 1.1 shows the location of the six boreholes. Figure 1.2 shows a photograph of the Eastern boreholes.

Figure 1.1 Borehole Locations

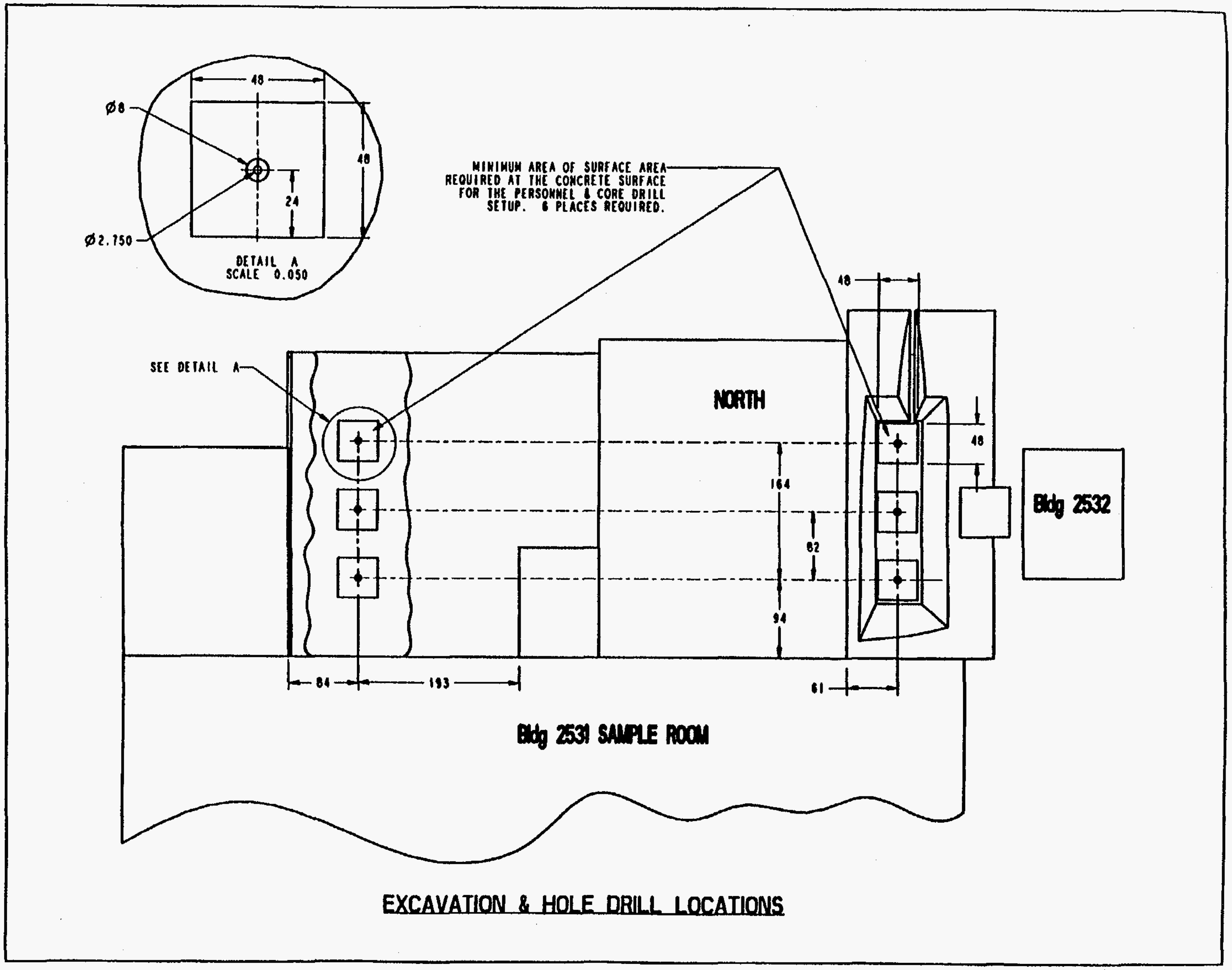
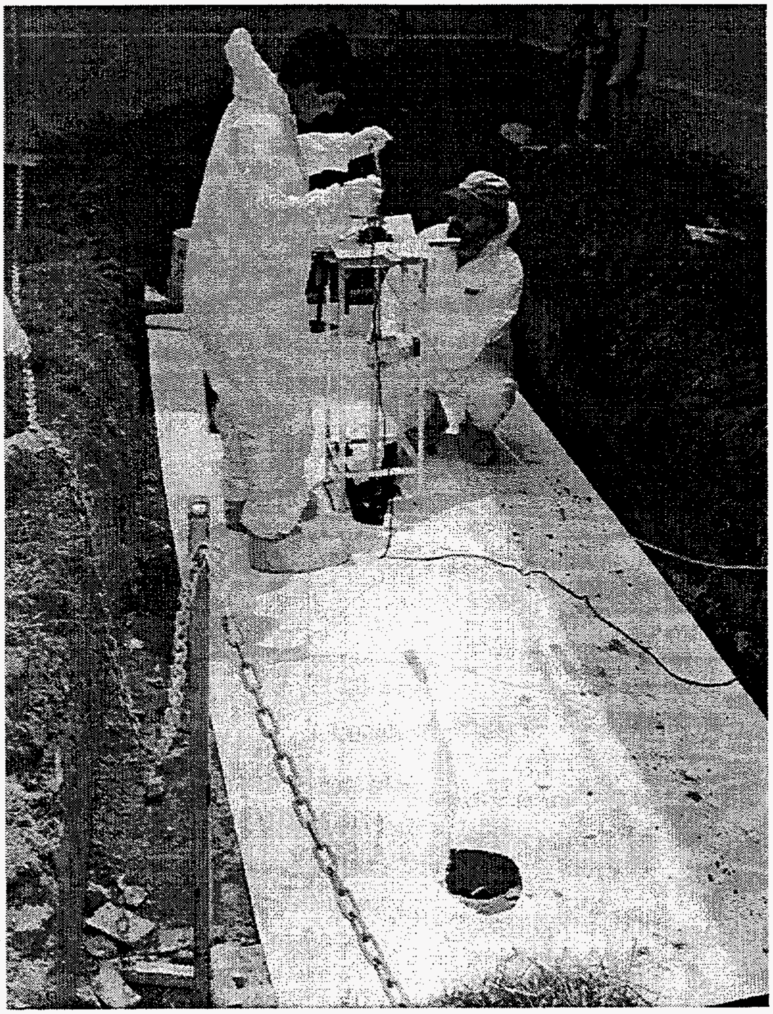


Figure 1.2 Photograph of Eastern Boreholes



1.3 Work Conditions

The work was performed in a radiologically controlled area, both from the standpoint of contamination control and direct radiation exposure to personnel. Dress-out in a Tyvek suit and cotton work gloves was required in weather conditions ranging from sunny (with temperatures of 90°F) to heavy rain. The background radiation where the work was performed was approximately 0.5 mR/hr. Detectors, cabling, and associated hardware within the controlled area were bagged-out (placed inside plastic sleeving) for the duration of the measurements. All the equipment lowered into the tank vault was checked for contamination after removal from the vault. No contamination was detected on any of the equipment.

2.0 INSTRUMENTATION

In order to perform a thorough characterization of the radiation fields present around the C1 and C2 tanks, two types of penetrating radiation were measured - neutrons and gamma-rays. Other types of radiation, such as alpha and beta particles, are non-penetrating. The presence of the non-penetrating radiation was checked by collecting swipes of the portions of measurement equipment which were believed to have come in contact with the tank surface and vault floor. The swipes were then checked for the presence of "transferable activity" or loose contamination. The instruments used to measure the neutrons and gamma-rays are described in this section.

2.1 Gamma-ray Dose Rate

Three types of instruments were used to measure the gamma-ray dose rates in the vicinity of the tanks. The instruments included thermoluminescent dosimeters (TLDs), a Shonka-Wyckoff ionization chamber, and a Xetex Teletector survey meter.

Harshaw TLDs (TLD-700) were used to measure beta-gamma doses. After each use, the TLDs are processed with a TLD reader to determine the absorbed dose equivalent. The TLDs are designed to be worn by radiation workers and are optimized for radiation protection usage. The manner in which the TLDs were used in this project is considered "non-standard" and, hence, the results must be interpreted with this in mind.

The Shonka-Wyckoff ionization chamber is an air-equivalent chamber used for making accurate measurement of exposure and exposure rates. This instrument is used with an electrometer to measure the charge collected by the detector. Using a calibration factor, the charge - expressed in Coulombs - is converted to an exposure or exposure rate.

The Teletector is a radiation survey instrument with an extendable Geiger Mueller probe designed for use in special radiation measurement situations, e.g., for hard to reach locations or where more distance between the radiation source and surveyor is desired. This hand-held instrument can be used to make measurements in gamma radiation fields ranging up to 1,000 R/hr.

2.2 Neutron Dose Rate

Neutron dose rates were measured using neutron bubble dosimeters. The bubble dosimeters are transparent tubes, approximately 3 inches long, containing "tiny, superheated droplets of a detector liquid uniformly dispersed in a firm, elastic polymer" [Ing 84]. Neutrons stiking a droplet result in the local formation of gas bubbles within the polymer matrix. These bubbles can then be visually counted to obtain the neutron dose, after employing a suitable calibration constant.

2.3 Gamma-ray Energy Spectra

Gamma-ray energy spectra were acquired with a sodium iodide (NaI) scintillation detector. The detector is 2 inches in diameter and the detector crystal is approximately 2 inches long. The resolution of the detector is approximately 10% at 662 keV (energy of ^{137}Cs). This detector was chosen due to its small size for insertion into the borehole. This detector was used in conjunction with an ORTEC Nomad™ system. The Nomad™ is capable of delivering bias voltage (+1000 V for this detector) and contains an amplifier and analog-to-digital convertor (ADC). The amplifier had a shaping time of 1 μs and a gain of 50. The ADC has conversion time of 5 μs for 512 channels. With these shaping and conversion times, the count rate limitation is approximately 1/5 μs or 2 E+5 counts per second for 100 % deadtime. The detector used in these measurements had a 50% deadtime, and thus we conservatively estimate that the detector produced a count-rate of 100,000 counts per second.

A High Purity Germanium (HPGe) detector was also used to collect gamma-ray energy spectra. This detector has a lower efficiency (25% of the NaI detector) but higher resolution (2 keV at 1332 keV) compared to the NaI detector. The gain setting for the amplifier used with this detector was set to 28. The HPGe was utilized to corroborate the lower resolution spectra taken at the East side of the tank vault. The higher resolution allows greater discrimination between the various gamma rays, resulting in more accurate radionuclide identification.

3.0 METHODS

To obtain the gamma-ray dose profile in the C1 and C2 tank vault, TLDs were attached to a weighted string, placed in protective plastic sleeving to prevent contamination of the TLDs, and lowered into the tank vault. The dosimeter string, with TLDs placed at 1 to 2 foot intervals, would reside in the vault for a period of approximately 30 minutes (see Figure 3.1). Once the planned irradiation interval had elapsed, the dosimeter string would be retrieved from the vault. The plastic sleeving would then be wiped and checked for contamination. Thereafter, the plastic sleeving would be removed. The TLDs are then collected and sent to the ORNL External Dosimetry Group for processing.

A neutron bubble dosimeter was attached to the end of each dosimeter string used for the middle boreholes (E3 and W3). The neutron dosimeters had minimum detection sensitivities of approximately 2 mrem, i.e., each bubble that is generated corresponds to a dose equivalent of 2 mrem. After the dosimeter string is removed from the vault, the neutron dosimeters were removed from the dosimeter string and visually inspected for the appearance of bubbles.

Exposure rate readings were obtained using the Shonka-Wyckoff ionization chamber. The Shonka chamber and the signal cable was encased in plastic sleeving (to prevent contamination) and lowered down into the tank vaults. The electrometer used with the Shonka chamber was positioned outside the contamination area. Exposure readings were taken at several depths and locations, e.g., on top of each tank, at the roof of the vault, and on the floor of the vault. Typically, exposure readings were taken for a 3 to 5 minute duration. For measurements made on the West side of the tanks, the "counting time" had to be reduced to 3 minutes to accommodate job scheduling.

Additional exposure rate readings were obtained by a Radiation Control Technician (RCT) using a Teletector. These readings were made at the top of each borehole, at the roof of the tank vault (3 feet below the top of the borehole), at the top of each tank on the West and East sides of the tank vault, and at several locations down the two middle boreholes.

The NaI scintillation detector was placed with the majority of the crystal over the borehole or to a point where the deadtime in the analog-to-digital converter (ADC) did not exceed 50%. In all cases, the detector was *not* inserted within the borehole. A spectrum was accumulated for a count-time of 5 minutes. The HPGe detector was used in the same fashion as the NaI detector. A photograph of the NaI detector is shown in Figure 3.2.

An energy calibration for both detectors had previously been computed with small check sources. The large presence of ^{137}Cs allowed an "in-beam" energy calibration. Due to the large uncertainty in source geometry and borehole collimation, no absolute efficiency (i.e. conversion to curies of ^{137}Cs) was possible. It was, however, possible to produce a relative efficiency calibration (i.e. the amount of ^{137}Cs compared to another isotope) using data from a table of isotopes [Lederer 78].

Figure 3.1 Photograph of a Dosimeter String

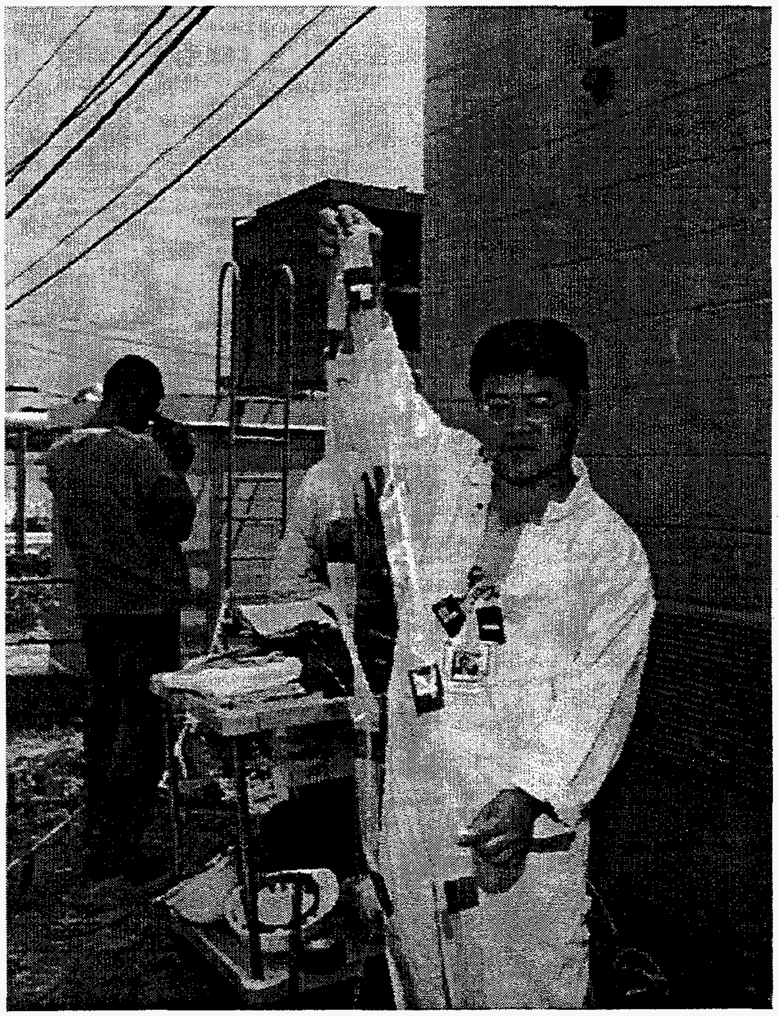
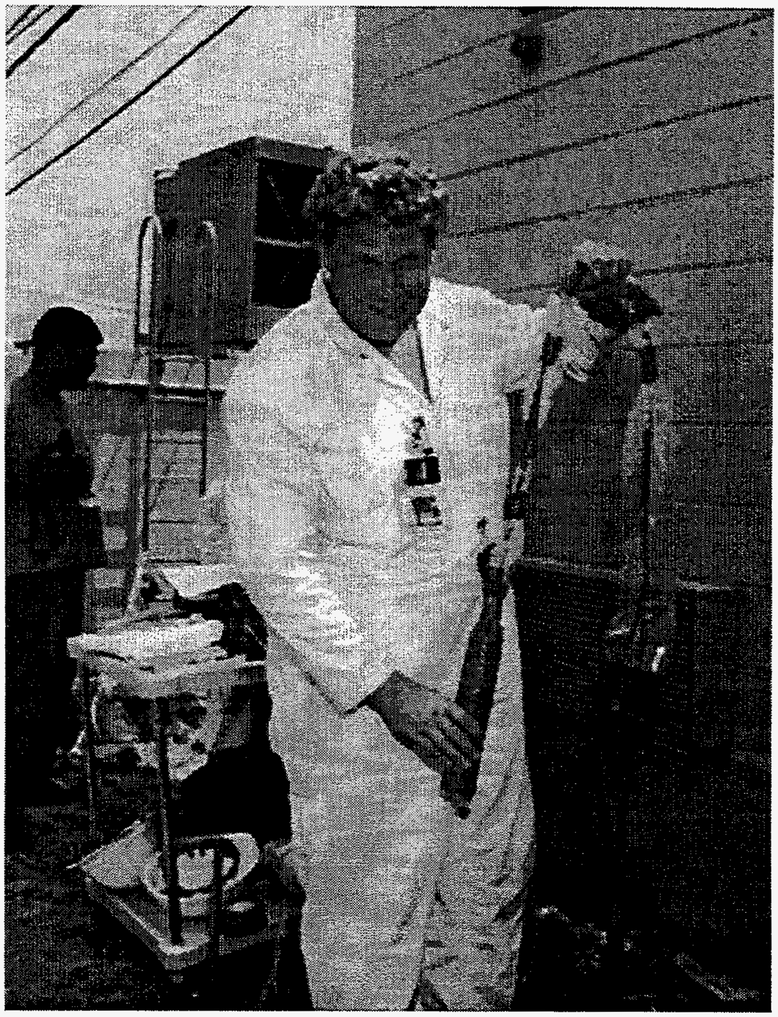


Figure 3.2 Photograph of the NaI Detector



4.0 RESULTS

4.1 Dose and Exposure Rate Results

The gamma-ray dose[1] and exposure[2] rates for the C1 and C2 tank vault are presented in Tables 4.1 to 4.6 below. The first column of each table is the vertical distance from the bottom of the vault (i.e., the floor of the vault) at which the radiation measurement was obtained. The second column shows the TLD results expressed in dose equivalent units of rem/hr. The third column contains the results of measurements made using the Teletector. Although photon exposure rates were measured using the Shonka-Wyckoff ionization chamber, the results obtained were deemed unreliable and were discarded. The Shonka-Wyckoff ionization chamber is an air equivalent ion chamber that measures charge. This instrument is very sensitive to temperature and pressure fluctuations. The large disparity between atmospheric conditions at the top of the vault shield and the interior of the well-enclosed vault adversely affected the Shonka chamber measurements. These results are provided in Appendix B. It should be noted that the measurements made within the vault showed fairly good consistency. However, with the availability of the Teletector results, it was decided that a third data set (provided by the Shonka chamber) for comparative purposes was not needed.

Overall, the TLD results provided the best representation of the radiation profile in the tank vault. This was due to the number of TLDs used (more data points spread over the vertical axis) and the consistency of the results obtained. As noted in Section 2.0, the TLDs were used in a "non-standard" geometry. However, the Teletector results can be used as a rough benchmark for accuracy, taking into account the geometry and detector response differences. Figure 4.1 through 4.6 show the dose profile (TLD and Telector data) in each borehole. The TLD dose readings as reported by the ORNL External Dosimetry Group are provided in Appendix C.

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[1] The absorbed dose is the energy absorbed per unit mass from any kind of ionizing radiation in any kind of matter. The absorbed dose is often referred to as the dose. When the absorbed dose is expressed in rad, the unit of dose equivalent is called the rem ("roentgen -equivalent-man") [Turner 86].

[2] Exposure is defined for gamma and X-rays in terms of the amount of ionization they produce in air. The unit of exposure is called the roentgen (R) [Turner 86].

Table 4.1 Gamma-ray Dose and Exposure Rates for Borehole E1

Height from Vault Floor (feet)	**WEAF TLD Reading (rem/hr)**	**RCT Teletector Reading (R/hr)**
18	0.001	0.04
15	5.2	5
14	5.3	-
13	5.7	5

Table 4.2 Gamma-ray Dose and Exposure Rates for Borehole E2

Height from Vault Floor (feet)	**WEAF TLD Reading (rem/hr)**	**RCT Teletector Reading (R/hr)**
18	0.0	0.008
15	2.7	2.5
14	2.7	-
13	2.9	2.5

Table 4.3 Gamma-ray Dose and Exposure Rates for Borehole E3

Height from Vault Floor (feet)	WEAF TLD Reading (rem/hr)	RCT Teletector Reading (R/hr)
18	0.002	0.002
15	4.9	5
14	5.3	-
12	5.7	6
10	6.1	-
8	6.0	-
7	-	5
6	6.6	-
4	7.6	-
2	11.6	-
0	6.0	-

Table 4.4 Gamma-ray Dose and Exposure Rates for Borehole W1

Height from Vault Floor (feet)	**WEAF TLD Reading (rem/hr)**	**RCT Teletector Reading (R/hr)**
18	0.0	0.014
15	2.0	2
14	2.1	-
13	1.9	2

Table 4.5 Gamma-ray Dose and Exposure Rates for Borehole W2

Height from Vault Floor (feet)	**WEAF TLD Reading (rem/hr)**	**RCT Teletector Reading (R/hr)**
18	0.0	0.016
15	2.2	2
14	2.7	-
13	2.9	2

Table 4.6 Gamma-ray Dose and Exposure Rates for Borehole W3

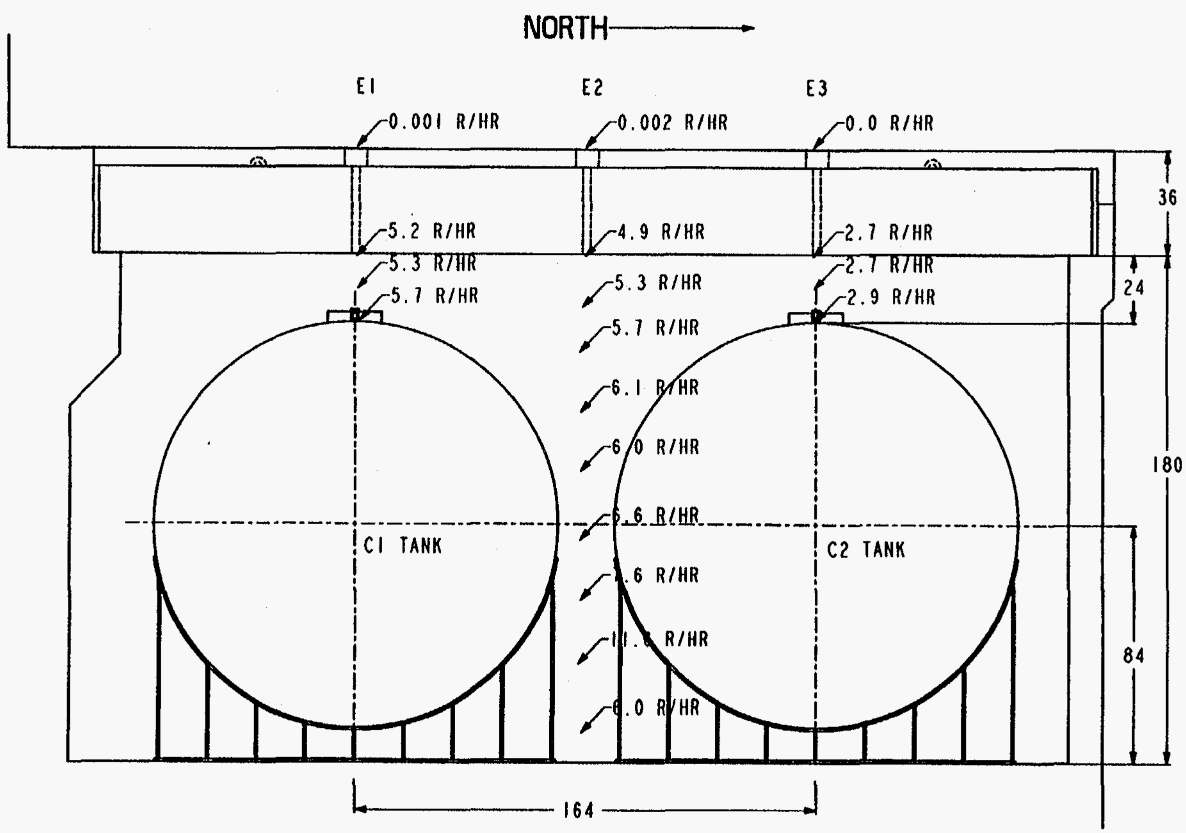
Height from Vault Floor (feet)	WEAF TLD Reading (rem/hr)	RCT Teletector Reading (R/hr)
18	0.0	.001
15	2.3	2
14	2.6	-
12	2.7	2.7
10	3.0	-
8	2.5	-
7	-	3.0
6	3.0	-
4	6.6	-
2	10.0	-
0	8.6	-

Results of the measurements show that gamma-ray dose rates ranging from 2 to 11.6 rem/hr were detected in the vault at the measurement locations. The observed gamma radiation levels at both ends of the C2 tank were consistent, ranging from 2.2 R/hr to 2.9 R/hr at the ceiling of the vault to the top of the tank, respectively. For the C1 tank, readings of approximately 2 R/hr were observed under the W1 borehole while readings in the 5 R/hr range were observed in the area under the E1 borehole. The elevated readings are probably due to the presence of radioactive piping nearby the E1 measurement locations. Based on the vertical dose rate profile, there appears to be an association between dose rate and the sludge height. The highest dose rate readings were observed towards the bottom of the tanks. A pictorial depiction of the tanks and the dose rates measured is shown in Figures 4.1 and 4.2.

4.2 Gamma Spectrometry Results

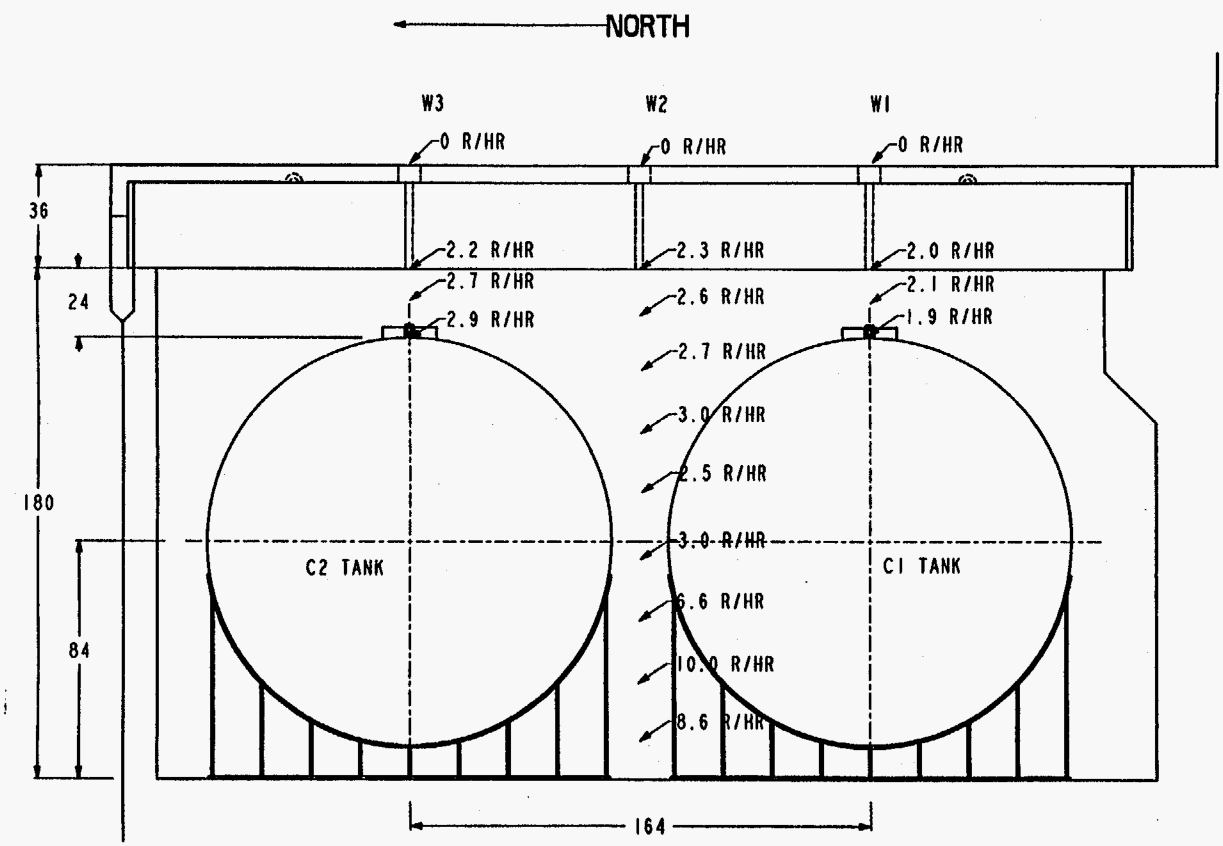
Two spectra were obtained for tanks C1 and C2. The eastern end of the tanks was examined using a 2-inch by 2-inch NaI scintillation detector. A HPGe detector was employed to characterize the gamma rays originating at the western end of these two tanks.

Figure 4.1 Tank Dose Rates and Measurement Locations on the East Side of the Vault



EAST END OF C1/C1 TANK VAULT

Figure 4.2 Tank Dose Rates and Measurement Locations on the West Side of the Vault



WEST END OF C1/C1 TANK VAULT

Gamma-ray measurements at both the eastern and western ends of tank C2 indicate the presence of ^{137}Cs (662 keV). Cobalt-60 was also detected, but it is estimated to be 60 times less than the intensity of ^{137}Cs. A 795 keV from ^{134}Cs was also detected, but there was no other identifiable corroborating gamma ray such as the 604 keV line. In the HPGe spectrum, typical background gamma rays from ^{40}K and U and Th daughters were obsercerd. The intensity of these gamma-rays are not significantly above background levels. No corroboration for the presence of ^{134}Cs exists in the HPGe spectrum, but there is a "hump" at the point where the major ^{134}Cs gamma rays are expected to lie in the spectrum (see Figures 4.3 and 4.4).

Spectra taken at the eastern and western end corroborate that the C1 tank contains ^{137}Cs (662 keV) with a few other gamma-emitters. Europium-152 is present but with half of the intensity of the Cs present within the tank. Six gamma rays from ^{152}Eu were found in the C1 tank, corroborating its presence. Also, ^{60}Co appeared in the HPGe spectrum of the western end of the tank. Several gamma rays from ^{154}Eu were also detected. Estimation of the relative concentration of the ^{154}Eu is roughly 25-30% of the ^{137}Cs concentration present within the tank. The ^{60}Co strength is estimated to be less than 10% of ^{137}Cs activity (see Figures 4.5 and 4.6).

A single NaI spectrum was obtained between the tanks at the eastern end. This spectrum is rather disappointing due to the presence of significant Compton scattering. The spectrum shows a continuum of gamma rays and no discrete gamma rays. This is due to the large distance from the tank and the fact that the gamma rays must scatter many times to reach the detector (see Figures 4.7 and 4.8).

The concentration of Eu is estimated to be half that of Cs in the C1 tank. This means that the average energy of the gamma rays is higher than that for ^{137}Cs. The Bicron RSO-50 is calibrated for ^{137}Cs and consequently will not correctly read the total dose in this case. Hence, it may be appropriate that personnel monitoring account for the higher than average gamma ray energy.

4.3 Vault Contamination and Surface Exposure Rates

All detectors and associated cabling that were introduced into the MVST vaults were wrapped in high-density plastic sheets and plastic sleeving. No contamination was found on the plastic sleeving or on the items introduced into the vaults.

Exposure rates were measured on top of the vault (at about 1 m above ground). Using a Bicron RSO-50, the exposure rates measured below 0.1 mR/hr.

Figure 4.3 NaI Gamma Spectra of Tank C2

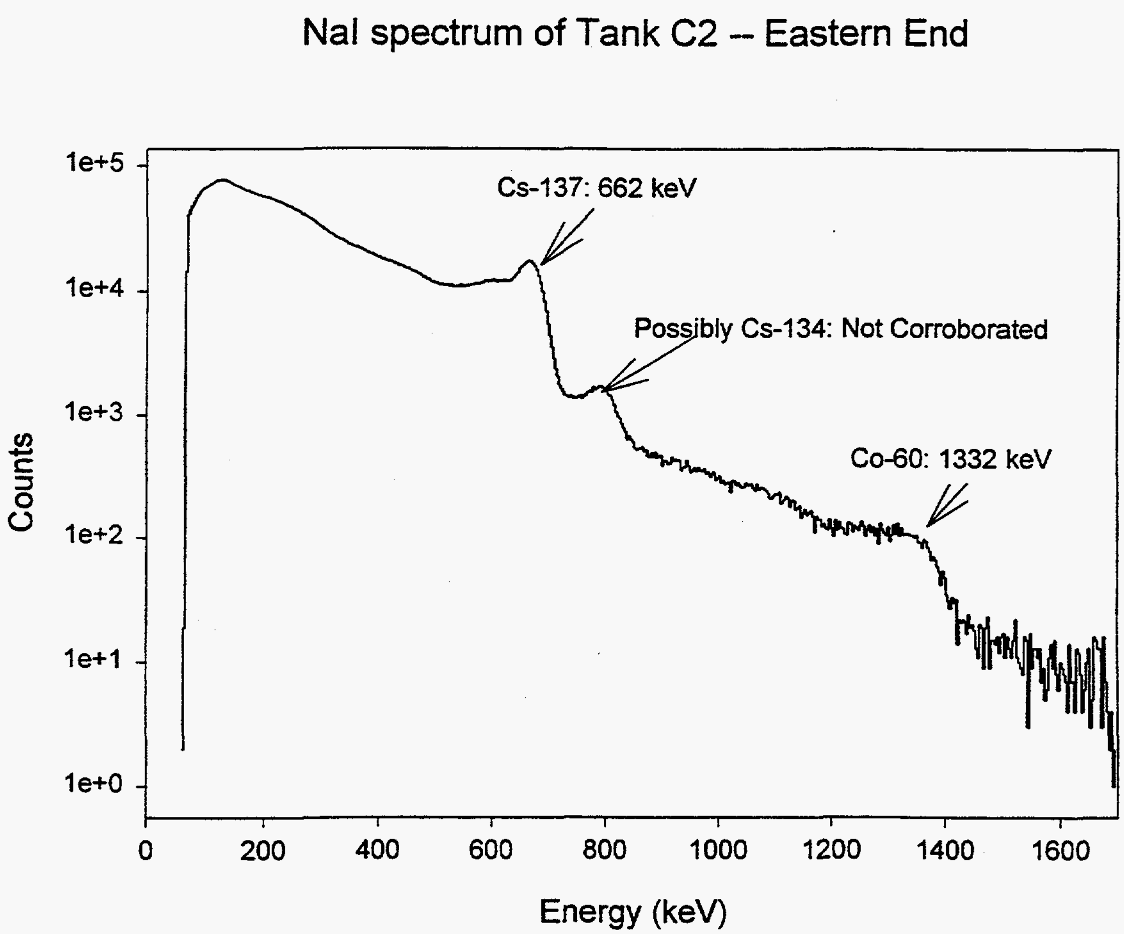


Figure 4.4 HPGe Gamma Spectra of Tank C2

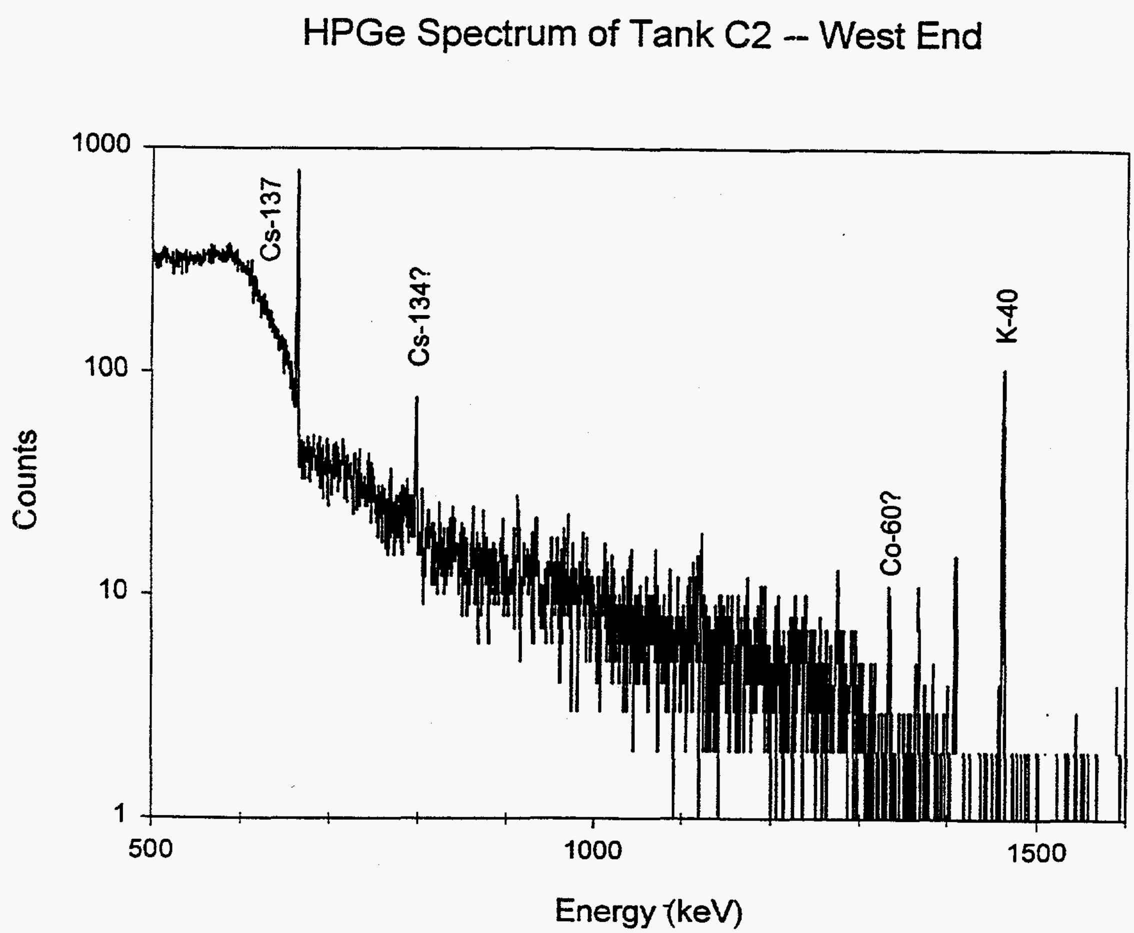


Figure 4.5 NaI Gamma Spectra of Tank C1

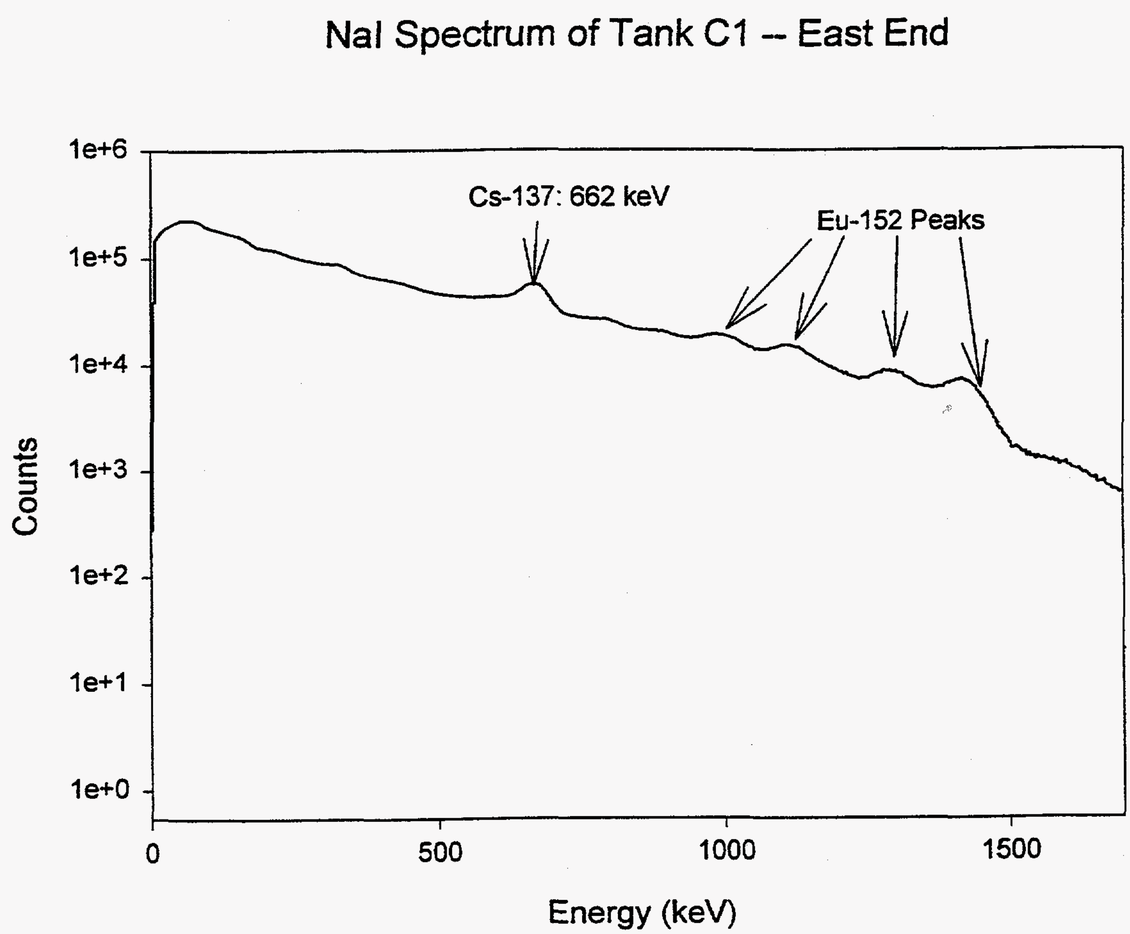


Figure 4.6 HPGe Gamma Spectra of Tank C1

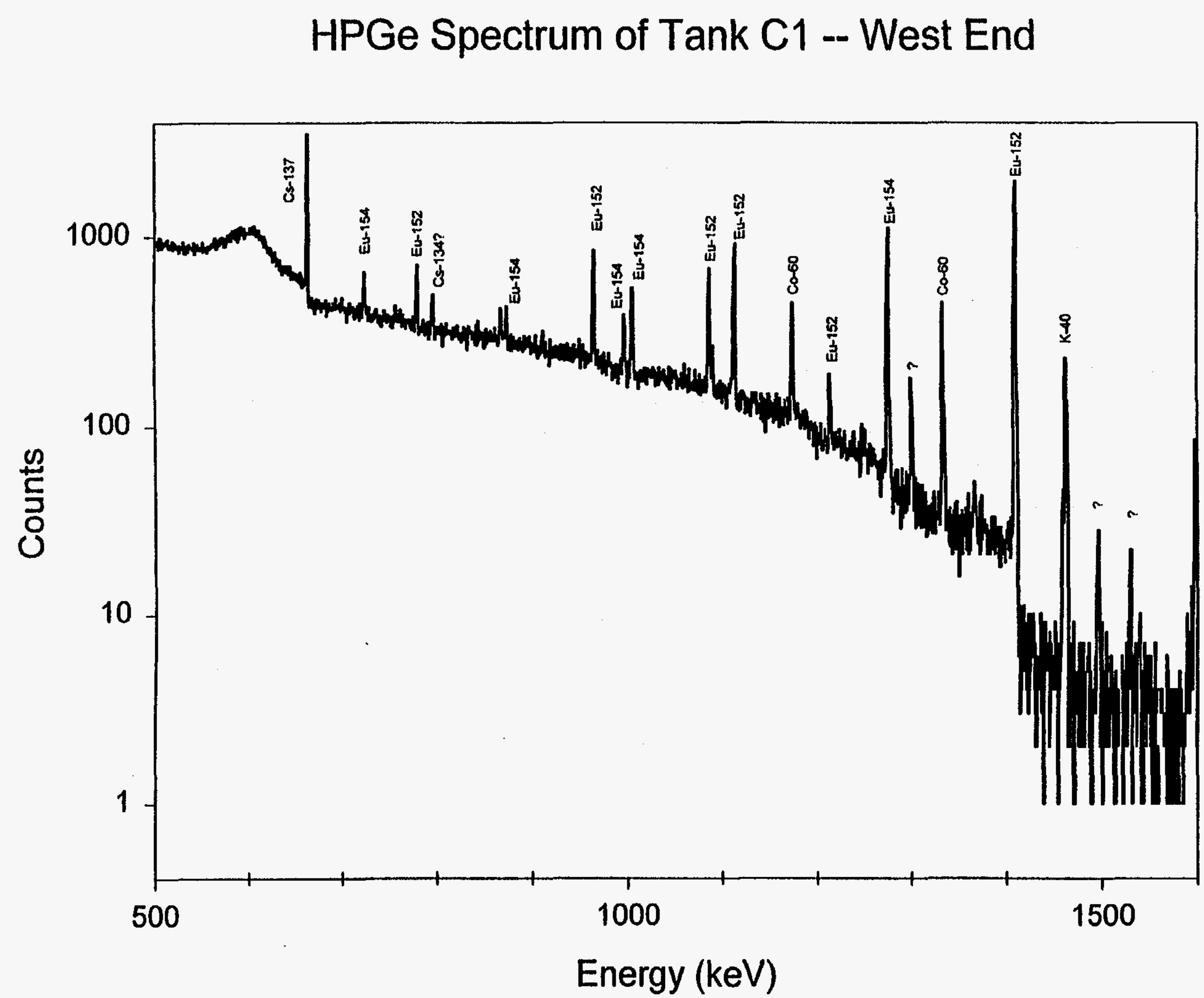
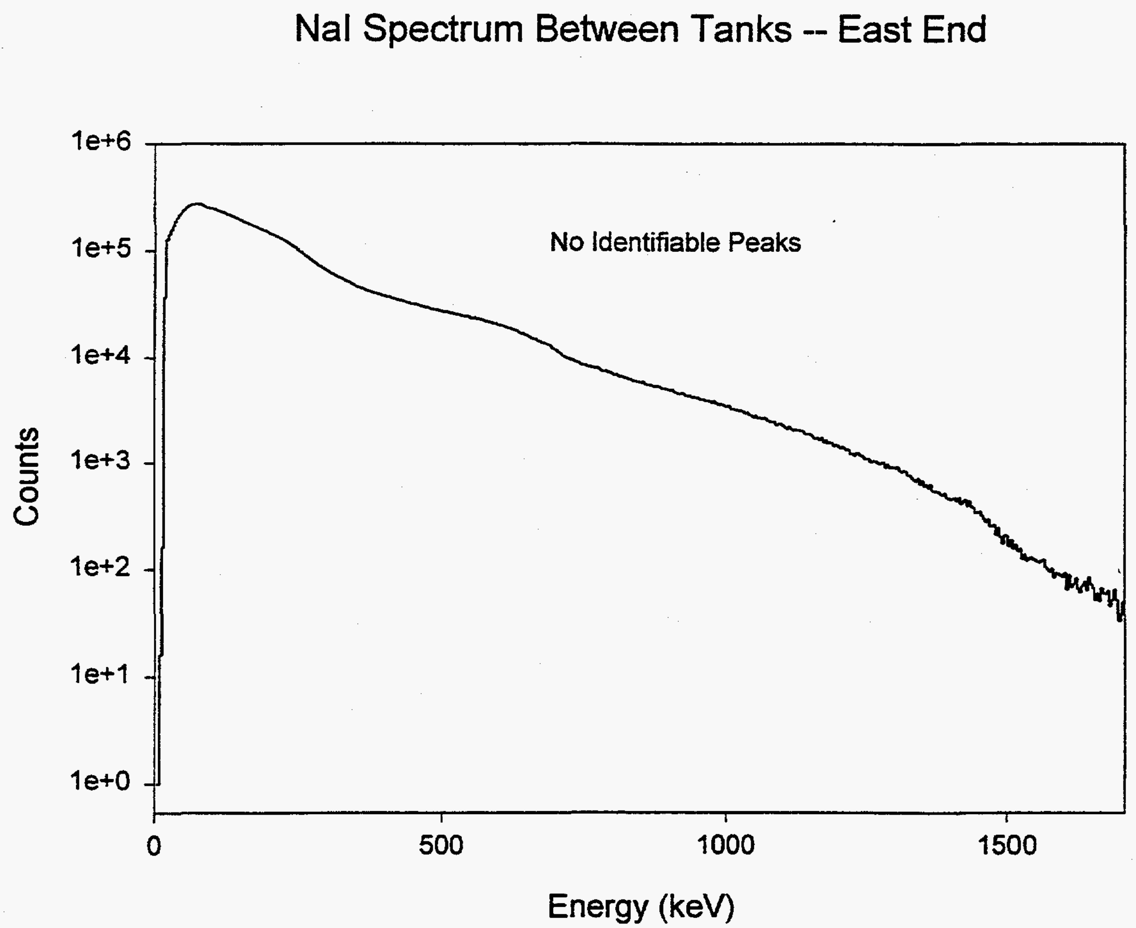


Figure 4.7 NaI Gamma Spectra of Tanks C1 and C2



5.0 CONCLUSION

The radiation measurements obtained within the tank vaults showed gamma radiation exposure rates ranging from 2 R/hr to 3 R/hr at the top of the tanks to the ceiling of the vault, with the exception of readings in the 5 R/hr range in the area under the E1 borehole. The elevated readings are probably due to the presence of radioactive piping nearby the E1 measurement locations. Radiation measurements performed between the tanks on the East side ranged from 4.9 R/hr at the ceiling of the vault to a high value of 11.6 R/hr, registered near the bottom of the tank. On the West side, the in-between tanks measurements ranged from 2.3 R/hr to 10 R/hr. Once again, the lowest reading was at the ceiling of the vault and the highest readings were observed towards the bottom of the tank.

Dose measurements obtained at the top of the borehole openings generally resulted in low gamma exposure and dose rate readings. Exposure rate measurements taken on top of the shield, with the borehole plugs inserted, were less than 0.1 mR/hr.

Gamma spectrommetry of the C1 tank showed mostly ^{137}Cs, with ^{152}Eu present at half the intensity of the ^{137}Cs. The C2 tank measurements indicated the presence of ^{137}Cs, with ^{60}Co at approximately 60 times less than the ^{137}Cs.

Neutron dose rate measurements made with neutron bubble detectors (within the tank vault) showed that the neutron dose rate, if any, is below the 2 mR/hr sensitivity limit of the bubble detectors. Finally, no contamination was found on the equipment inserted into the tank vault.

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APPENDIX A. EQUIPMENT LIST

- Bicron NaI(Tl) scintillation detector with Bicron P214 Voltage Divider
- Ortec HPGe Detector
- Nomad™ Acquisition System
- Aptec Gamma-ray Analysis Software
- IBM Thinkpad 755CDV Computer
- 50' of RG 62 A/U Cable (BNC)
- 50' of RG 59 A/U Cable (SHV)
- 40 Thermoluminescent Dosimeters (Beta/Gamma)
- Harshaw TLD Processor
- Xetek Teletector
- Shonka-Wycoff Ionization Chamber
- Keithly 617 Programmable Electrometer

APPENDIX B. SHONKA-WYCKOFF EXPOSURE RATE RESULTS

Ht. from Vault Floor	E1 mR/hr	E2 mR/hr	W1 mR/hr	W2 mR/hr
18'	42.08	38.02	32.56	30.17
15'	179.57	24.36	19.65	27.20
13'	164.08	31.08	25.26	34.86

Ht. from Vault Floor	E3 mR/hr	W3 mR/hr
18'	19.39	34.06
15'	47.06	43.26
13'	52.43	71.68
9'	67.61	83.39
6'	64.67	89.37
3'	139.08	3039.74
0'	114.89	56.90

APPENDIX C. TLD DATA

TLD Numbers versus Measurement Location

Ht. from Vault Floor	Borehole E1	Borehole E2	Borehole W1	Borehole W2
18'	125768	118488	161757	132999
15'	189774	137888	176242	176875
14'	121977	116233	117253	190667
13' (Top of Tank)	140949	110750	202391	112078

Ht. from Vault Floor	Borehole E3	Borehole W3
18'	176867	16110
15'	119076	112413
14'	175515	165561
12'	161726	102874
10'	141005	160986
8'	112196	162530
6'	165270	109357
4'	144348	101706
2'	162592	138846
0'	190234	100542

"Test" Dosimeters
(Loong Yong)

LOCKHEED MARTIN ENERGY SYSTEMS
Centralized External Dosimetry System
Algorithm Transaction Log

9608231.X101

08/23/96
Page: 1

				step	field info				element values					
Tld #	Hs	Hd	He	case	photon		beta		L1	L2	L3	L4	Fn	flag
188732	QC Card Reading		Date: 08/23/96		Time : 08:03:29				251.78	257.92	262.52	248.94		
162592	5579	5775	5295	9C	HEPH:	1.00	NONE		6087.70	6178.43	6199.80	6054.92	1.01	A
rep:	5775	5775	5775	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
121977	2279	2676	2315	9C	HEPH:	1.00	NONE		2823.25	2976.64	2541.07	2649.61	1.01	AH
rep:	2676	2676	2676	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
140949	2722	2864	2758	9C	HEPH:	1.00	NONE		3020.94	3133.86	3033.07	3155.93	1.01	A
rep:	2864	2864	2864	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
112196	3012	2999	2808	9C	HEPH:	1.00	NONE		3163.51	3255.67	3353.99	3213.68	1.01	A
rep:	3012	2999	2999	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
175515	2449	2649	2364	9C	HEPH:	1.00	NONE		2794.67	2825.82	2729.86	2706.39	1.01	A
rep:	2649	2649	2649	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
176242	763	992	777	9C	HEPH:	1.00	NONE		1049.11	1060.22	860.23	893.22	1.01	AH
rep:	992	992	992	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
119076	2222	2427	2144	9C	HEPH:	1.00	NONE		2560.46	2685.85	2478.69	2454.63	1.01	A
rep:	2427	2427	2427	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
110750	1419	1428	1356	9C	HEPH:	1.00	NONE		1507.79	1622.18	1588.33	1553.73	1.01	A
rep:	1428	1428	1428	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
189774	2228	2579	2194	9C	HEPH:	1.00	NONE		2720.61	2906.38	2485.43	2511.95	1.01	AH
rep:	2579	2579	2579	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
109357	1499	1500	1568	9C	HEPH:	1.00	NONE		1583.86	1641.25	1676.19	1796.91	1.01	A
rep:	1500	1500	1500	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
161726	2710	2867	2543	9C	HEPH:	1.00	NONE		3023.70	3253.54	3019.68	2910.33	1.01	A
rep:	2867	2867	2867	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
118488	2	0		8B	NONE		SRTL:	1.00	3.83	3.74	16.44	25.56	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
112060	0	0		9C	HEPH:	1.00	NONE		3.54	3.24	11.46	23.28	1.01	
				LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
117253	963	1031	949	9C	HEPH:	1.00	NONE		1089.69	1114.09	1082.09	1089.66	1.01	A
rep:	1031	1031	1031	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
165270	3115	3293	2791	9C	HEPH:	1.00	NONE		3473.18	3677.23	3468.80	3193.92	1.01	A
rep:	3293	3293	3293	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		

				step	field info				element values					
Tld #	Hs	Hd	He	case	photon		beta		L1	L2	L3	L4	Fn	flag
112413	1163	1134	1152	12A	MIXED: 1.00		NONE		1219.62	1207.99	1418.55	1294.45	1.01	A
				LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
137888	1227	1369	1223	9C	HEPH: 1.00		NONE		1446.18	1491.11	1374.96	1402.37	1.01	A
ep:	1369	1369	1369	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
176875	1071	1081	1047	9C	HEPH: 1.00		NONE		1142.47	1200.20	1201.76	1201.77	1.01	A
ep:	1081	1081	1081	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
161757	0	0		9C	HEPH: 1.00		NONE		3.51	3.11	9.03	23.42	1.01	
				LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
190234	2966	2981	2919	9C	HEPH: 1.00		NONE		3143.95	3192.64	3303.73	3340.32	1.01	A
ep:	2981	2981	2981	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
202391	958	945	914	9C	HEPH: 1.00		NONE		999.81	1116.05	1076.70	1049.22	1.01	A
ep:	958	945	945	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
161687	3	0		8B	NONE		SRTL: 1.00		3.39	3.44	17.19	24.70	1.01	
ep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
138846	5010	5013	4849	9C	HEPH: 1.00		NONE		5285.24	5774.06	5568.95	5545.23	1.01	A
rep:	5013	5013	5013	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
182653	QC Card Reading		Date: 08/23/96		Time : 08:17:56				240.19	248.79	267.14	264.22		
116233	1046	1412	1148	9C	HEPH: 1.00		NONE		1491.68	1516.07	1174.11	1316.60	1.01	AH
rep:	1412	1412	1412	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
176867	0	1		12A	MIXED: 1.00		NONE		4.39	4.02	10.96	24.82	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
161110	16	0		8B	NONE		SRTL: 1.00		3.75	3.04	26.68	25.12	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
102874	1264	1337	1269	9C	HEPH: 1.00		NONE		1412.25	1403.44	1415.71	1455.13	1.01	A
rep:	1337	1337	1337	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
110573	1	0		8B	NONE		SRTL: 1.00		3.02	3.31	15.21	27.50	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
101706	3284	3309	3021	9C	HEPH: 1.00		NONE		3490.04	3438.86	3655.77	3456.45	1.01	A
rep:	3309	3309	3309	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
144348	3547	3781	3366	9C	HEPH: 1.00		NONE		3987.30	3879.55	3947.32	3850.75	1.01	A
rep:	3781	3781	3781	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		

Tld #	Hs	Hd	He	step case	field info photon		beta		element values L1	L2	L3	L4	Fn	flag
162530	1255	1252	1142	9C	HEPH: 1.00		NONE		1322.61	1491.95	1406.69	1309.46	1.01	A
rep:	1255	1252	1252	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
177060	0	0		12A	MIXED: 1.00		NONE		3.92	3.45	13.32	26.92	1.01	
				LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
141005	2999	3042	3007	9C	HEPH: 1.00		NONE		3208.09	3315.54	3339.92	3440.67	1.01	A
rep:	3042	3042	3042	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
132999	14	0		8B	NONE		SRTL: 1.00		3.37	3.54	24.80	25.57	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
125768	6	1		12B	MIXED: 1.00		NONE		5.21	4.60	22.46	24.39	1.01	
rep:	0	0		LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
190667	1181	1327	1157	9C	HEPH: 1.00		NONE		1401.31	1387.88	1324.38	1327.48	1.01	A
rep:	1327	1327	1327	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
112078	1247	1444	1309	9C	HEPH: 1.00		NONE		1524.79	1479.10	1397.77	1500.27	1.01	AH
rep:	1444	1444	1444	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
160986	1326	1473	1348	9C	HEPH: 1.00		NONE		1555.09	1571.00	1484.53	1544.80	1.01	A
rep:	1473	1473	1473	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
100542	4357	4286	4095	9C	HEPH: 1.00		NONE		4518.87	4919.23	4845.06	4683.40	1.01	A
rep:	4357	4286	4286	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
165561	1202	1296	1219	9C	HEPH: 1.00		NONE		1369.52	1411.45	1346.94	1397.78	1.01	A
rep:	1296	1296	1296	LRL:	1.60	1.60	12.32	2.59	3.75	3.75	14.75	4.90		
189857	QC Card Reading		Date: 08/23/96		Time : 08:27:31				254.35	269.37	259.68	250.00		

Hs : shallow dose equivalent (mrem)
Hd : deep dose equivalent - photons (mrem)
He : eye dose equivalent (mrem)
Hn : neutron dose equivalent (mrem)

These fields were selected upon invocation:
BETA : SRTL PHOTON: HEPH NEUTRON: CFM

NUMBER OF FIELD CARDS IN THIS FILE : 40
NUMBER OF QC CARDS IN THIS FILE : 3

Step descriptions -

STEP	description
8	beta only
9	high energy photon
10	beta plus high energy photon
11	beta plus low energy photon
12	mixed photon

For case, refer to specific step in algorithm documentation

Table 1 (Pure Field Calibration Normalization Constants):

Ks factor = 1.46	K1 = 942 gU/rem
Kd Factor = 1.43	K2 = 919 gU/rem
	K3 = 976 gU/rem
	K4 = 991 gU/rem

FLAGS:	no
A : Exceeds CEDS action level (500 Hd, 5000 Hs)	30
E : Used invalid ECC	0
H : (Hd - Hs) > (20 + 0.1 * Hd)	5
N : Hn > 10 mrem	0
S : Suspect element ratios	0
Z : Hs or Hd zero, but L1 or L2 or L3 > 100	0

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