Results of Performance Tests on Chemical and Radiation Measurement Systems for Use at a Dig-Face

R. J. Gehrke
R. S. Lawrence
R. J. Pawelko

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Idaho National Engineering Laboratory
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415

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ABSTRACT

Chemical and radiation measurement systems are being developed for use at a dig-face to provide sensing capability during the excavation of previously buried waste. It is believed that on-line dig-face characterization will reduce environmental, health, and safety risks during the cleanup of buried waste sites as well as improve the efficiency of the cleanup process. This report describes progress in the development of three measurement systems: (a) a γ /neutron monitor that scans the dig-face for high levels of radiation prior to excavation, (b) a Ge spectrometer that identifies specific radionuclides located with the γ /neutron monitor, and (c) a prompt γ neutron activation analysis (PGNAA) system that measures the presence of chlorine and chlorinated compounds often associated with hazardous waste. The Ge spectrometer and PGNAA system also will provide off-line but on-site capability of radionuclide and elemental identification of excavated waste prior to handling, treatment, transportation, or disposal.

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Results of Performance Tests on Chemical and Radiation Measurement Systems for Use at a Dig-Face

1. INTRODUCTION

The Buried Waste Integration Demonstration Dig-Face characterization project was started in 1992 with the preparation of a conceptual design. Substantial development activities were initiated in 1993, and there are currently three main project subtasks: (a) demonstration of conceptual feasibility and development of data interpretation concepts, (b) development of robotics sensor deployment capability, and (c) development of prototype sensors for application at the dig-face.

Characterization tasks performed by the dig-face characterization system fall into two functional categories, hazard detection and object detection, based on differences in the ways they are likely to impact management of the retrieval operation. Each function has a clear corollary in conventional site characterization work. Just as in conventional site characterization, the two functions rely upon different sensor types and require different data collection strategies.

The hazard detection function in dig-face characterization corresponds with sampling and analysis efforts in conventional site characterization. The purpose of both activities is to identify the presence of hazardous substances. The substances of interest include radioactive, toxic, explosive, and combustible hazards of immense variety, many covered by regulations from the Environmental Protection Agency and the Occupational Safety and Health Administration. Detection of a hazard evokes an immediate response from managers of the retrieval operation and is the principal charter of the dig-face characterization system.

The object detection function in dig-face characterization forms a counterpart to geophysical investigation activities in conventional site characterization. These activities define the physical (rather than chemical) characteristics of the subsurface. Common objectives include delineating boundaries of solid waste, determining depth to waste, and locating individual objects or groups of objects. This information established guidelines on the size of the site and the presence and location of waste-free areas, and often provides a basis for subdividing the site into waste compartments having different characters although details may be vague. Information concerning the physical characteristics of the subsurface can create vital links to the historical record, which contains many details on hazardous substances from the time of their disposal. In some cases, the presence of hazardous substances may be confidently inferred by cross-referencing characterization data with historical records.

Figures A-1 and A-2 of Appendix A show the conceptual dig-face characterization system being deployed during overburden removal and waste seam retrieval. The present report addresses radioactivity characterization and prompt γ neutron activation analysis (PGNAA) for chlorine at an excavation site.

The PGNAA task was initiated midway through FY-93, resulting in initial measurements that demonstrated the ability to detect chlorine mixed with soil, stainless steel scrap, and lead located inside 55-gal drums. In addition to these measurements, measurements were also made on surrogate and actual transuranic waste in 55-gal drums in the TRUPACT building at the Stored Waste Experimental Pilot Plant,¹ with a Portable Isotopic Neutron Spectroscopy system developed with funding from the Office of Research and Development (NN20).

Based on the experience gained in FY-93, three characterization systems were proposed and developed in FY-94 under this task. These characterization systems were designed to characterize the neutron and γ -ray radiation fields and the presence of potentially hazardous materials in the overburden, sideburden, and material present in the burial site proper. They consist of a γ /neutron radiation mapper, a Ge spectrometer for radionuclide identification, and a PGNAA system. The latter system will be used primarily to identify potential plumes of chlorinated organics or containers with chlorinated organics.

This is a report of the progress made in FY-94 in the development of chemical and radiation measurement sensors that can be used on a dig-face characterization system during the excavation of radioactive and/or hazardous waste.

2. LABORATORY MEASUREMENTS

The test plan that was developed to evaluate the operation and performance of the three characterization systems specified the measurements to be made. They are described in Reference 2, which has been included in this report as Appendix A. The purchase order specifications are in Appendix B of Reference 2.

2.1 Gamma/Neutron Mapper

The γ /neutron mapper consists of two ^3He chambers and two plastic scintillators aligned so that they consist of two identical side-by-side detector systems capable of detecting low levels of γ or neutron radiation. The entire detector assemblies are mounted with their associated electronics inside a stainless steel box that is seamless on five sides with access from the sixth side through a hinged stainless steel door, as shown in Figure 1. Sealing clamps and a gasket on the door interior prevents water from seeping in the box. The output from the γ /neutron mapper is available as either an analog signal or as scaled counts. These output signals are available from designated pins of military-style connectors located at the top of the stainless steel box.

Tests were performed with the γ /neutron mapper to establish the extent to which it meets the specifications and original design parameters detailed in the purchase order and to measure its performance capabilities using check sources.

As required by Section 3.1.1 of the test plan (see Appendix A):

1. All documentation specified in the purchase order was received.
2. The total weight of the γ /neutron mapper was measured with an industrial scale to be 95 ± 5 kg.
3. The external case is made of welded, seamless, stainless steel 1.80 mm thick on five sides with a hinged stainless steel door with sealing clamps and an internal gasket; all electrical connectors pass through water-tight feed-throughs with military-style connectors.

From a visual inspection of the stainless steel case, it is believed to be more than sufficient for protecting the internal electronics during use at an excavation site and during its decontamination. However, the case was not washed or scrubbed with water or decontamination solution to verify that it is water tight.

4. The neutron detection is accomplished by two identical ^3He proportional counters 48.26 cm in length and 5.08 cm in diameter filled to 3 atmospheres pressure; each neutron detector is surrounded by a polyethylene plastic box with walls 2.54 cm thick on all sides but the front, which is covered by a polyethylene sheet 1.27 cm thick. The polyethylene plastic forms two ^3He chambers, each measuring 25.4 cm by 48.26 cm by 10 cm deep.

Figure 1. The γ /neutron mapper on a cart with the detachable hand controller/output device on top of the case.

5. The γ -ray detection is accomplished by two identical plastic scintillators, each 25.4 cm by 48.26 cm by 3.81 cm thick. These plastic scintillators cover and align with the neutron chambers as shown in Figure 2. The plastic scintillators are surrounded on all but the front side by a graded γ -ray shield consisting of a Sn sheet 0.32 cm thick and a Pb sheet 0.32 cm thick.
6. Examination of the detector system design, configuration, power requirements, and military-style connectors verified that the specifications of the purchase order were met.

As required by Section 3.1.2 of the test plan (Appendix A):

1. The γ -ray efficiency of each of the plastic scintillators, as measured with a ^{137}Cs source located 30 cm above the case and on the axis of the geometric center of the two scintillators, as shown in Figure 2, is 2.0%. The total efficiency from summing the individual detector efficiencies is 4%. This compares with the design specification for the summed efficiency for the two plastic scintillation detectors of $>2\%$ (a factor of two better than specified).
2. Above an average of 135,000 c/s, the count rate losses of the plastic scintillation detectors exceeded 10% due primarily to the recovery time of the scalars. The plastic scintillators were able to function at a counting rate of up to $\sim 600,000$ c/s before the count rate actually began to decrease with increasing source strength for plastic scintillation detectors #1 and #2. This performance falls short of the specification to function at counting rates as high as 1,000,000 c/s with less than 10% counting losses. This deficiency, believed to be due to the slow response of the pulse-processing circuitry, limits the performance of the scintillation detectors in high γ radiation fields to qualitative data. Figure 3 shows the ratio of measured to calculated counts as a function of ^{152}Eu activity.
3. The analog output tracked the count rate meter output over the usable range of the detector.
4. The energy range of the γ -ray detectors is set to be from 55 keV to 2,000 keV. The measurable maximum noise level is at ~ 40 keV.
5. The lower limit of detection (as specified by L. A. Currie³ for each plastic scintillation detector is measured to be 300 nCi for a 1-second count with a ^{137}Cs source located 30 cm above the case and on the axis of the geometric center of the plastic scintillators (see the measurement geometry in Figure 2).

As required by Section 3.1.3 of the test plan (Appendix A):

1. The neutron efficiency of each of the ^3He chambers, as measured with a source of ^{252}Cf emitting 92,850 n/s located 30 cm above the instrument case and on the axis of the geometric center of the ^3He chambers, is 0.36% and 0.31% for ^3He chambers #1 and #2, respectively. This yields a total efficiency from summing the individual detector efficiencies of 0.67%. This compares favorably with the design specification for the summed efficiency for the two neutron detectors of $>0.5\%$.

Front view

Side view

A α -ray graded shield of 0.32cm thick Sn and 0.32cm thick Pb surrounds the plastic scintillators on the back and sides

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Figure 2. Schematic of the γ /neutron mapper showing the plastic scintillators (or ^3He chambers) and the position of the source (^{137}Cs or ^{252}Cf) used to measure the detector efficiencies. The ^3He chambers are the same physical size as the plastic scintillators and are located directly behind them as shown in the side view.

Figure 3. Measured Count rate versus relative source strength for plastic scintillators #1 and #2.

2. At an average of 31,800 c/s, the count rate capability of the ^3He chambers deteriorated to the point that only $\sim 12,600$ c/s were observed from a bare ^{252}Cf source located 30 cm above the instrument case and on the axis of the geometric center of the ^3He chambers. This performance of the ^3He detectors falls short of the specification to function at counting rates as high as 50,000 c/s with less than 10% counting losses. The ^{252}Cf source had a neutron emission rate of $9.59 \times 10^6 \text{ s}^{-1}$. This deficiency, due primarily to the slow response of the pulse processing circuitry, limits the performance of the neutron chambers in high-neutron fields to qualitative data.
3. The analog output tracked the count rate meter output over the usable range of the detector.
4. The polyethylene moderator comprising the ^3He chamber and plastic scintillator covering it increases the sensitivity of the ^3He detector for nonthermal neutrons.
5. The lower limit of detection is deduced from the background count and detector efficiency to be $\sim 3,700$ n/s, which is equivalent to a sensitivity of $\sim 1,700$ pg of ^{252}Cf or ~ 40 g of plutonium comprised of 7% ^{240}Pu for a 1-second count for each of the ^3He chambers when a bare (fission spectrum) source is located 30 cm above the instrument on the axis of the geometric center of the ^3He chambers. This sensitivity for plutonium is acceptable since its material is significantly below the alert level of 200 g of plutonium in a 55-gal waste drum to address criticality concerns during excavation of buried transuranic waste.
6. A source of ^{252}Cf was moved across the γ /neutron mapper at a minimum distance of 33 cm from the instrument case at a speed of 3.5 ± 0.3 cm/s. Figures 4 and 5 show the analog output as a function of time recorded by a strip-chart recorder for the plastic scintillation and ^3He chamber detectors. The discrete values in the figures were generated directly from the strip-chart data. This test satisfies the requirement that the scanner be able to perform assays at a scan speed of 30 cm per 10 seconds.

At a scan speed of 3.5 cm/s and a source-to-detector distance of 30 cm, the detection of ~ 300 nCi of ^{137}Cs activity and/or the detection of $\sim 1,700$ pg of ^{252}Cf , or ~ 40 g of plutonium (7% ^{240}Pu) should be achievable. These values are from the deduced detection limits and need to be confirmed by measurement.

2.2 Ge Spectrometer for Nuclide Identification

The Ge spectrometer is an n-type Ge crystal. It has $\sim 40\%$ peak efficiency relative to a NaI(Tl) spectrometer 7.6 cm by 7.6 cm in diameter at a source-to-detector distance of 25 cm for the 1,332-keV γ -ray of ^{60}Co . The detector is mounted in an all-attitude dewar that holds liquid nitrogen for 4 days. Surrounding the detector housing is an annular-shaped bismuth germanate (BGO) scintillator to serve as a passive and an active shield. This entire assembly is mounted on an aluminum channel as shown in Figure 6. The weight of this assembly is 50.5 kg. The spectrometer is equipped with an INEL-developed dual-energy pulser^{4,5} research-grade linear amplifier, fixed 5- μs conversion time ADC and an Acquisition Interface Module (AIM). The AIM interfaces to a VAX model VLC 4000 computer.

Elapsed time (seconds)

Figure 4. Digitized analog (strip chart) recording from the plastic scintillation detectors of a scan with a 0.040 μg ^{252}Cf source passing over the neutron/ γ mapper at a speed of 3.5 cm/s at a minimum distance of 33 cm.

Figure 5. Digitized analog (strip chart) recording from the ^3He chamber detectors of a scan with a $0.040 \mu\text{g } ^{252}\text{Cf}$ source passing over the neutron/ γ mapper at a speed of 3.5 cm/s at a minimum distance of 33 cm.

Figure 6. Ge spectrometer and bismuth germinate annulus with support assembly for lifting with a crane or mounting on the dig-face trolley.

As required by Section 3.2.1 and 3.2.2 of the test plan (Appendix A):

1. The energy scale of the Ge spectrometer was adjusted to extend from 30 keV to 11 MeV. The 60-keV γ -ray of ^{241}Am lies above the lower level discriminator with any noise lying below the discriminator. A spectrum was acquired and energy calibrated as described in step 2 below. The spectrum was labeled and stored. (The "590" and HEAD command of VAXGAP carries out these functions.) All functions worked as intended.
2. A spectrum, extending from <50 keV to 11 MeV, was taken of a cylindrical solid piece of polyvinyl chloride (PVC) plastic by prompt γ -ray neutron activation analysis (PGNAA) using a $\sim 5\text{-}\mu\text{g}$ ^{252}Cf neutron source. The dominant γ -ray peaks from neutron capture by the chlorine were used to energy-calibrate the spectrum (see Table 1). The calibration equation measured energies within 0.4 keV for peaks between 1,165 keV and 8.5 MeV. Peaks outside this energy range but >50 keV were within ≤ 2 keV of the "known" energies. A more accurate energy measurement of the peak positions may require the use of a 16,000-channel conversion gain and a pulse-height nonlinearity correction curve. Further experience with the present system is needed to determine whether the expense of such an upgrade is justified.

Table 1. Computer printout of the output from an energy calibration of the dual-energy pulser using PGNAA-generated chlorine prompt capture γ -ray peaks.

CHLORINE PULSER CALIBRATION 7-SEP-1994 14:29:59.50

DETECTOR SYSTEM: a1

ZERO= 0.6449

ENERGY= -1.5744+ 1.40844(X)+-2.15019E-07(X)**2

WIDTH= 1.949+ 4.6822E-04(X)

ERROR MATRIX: 1.591103E-01 9.201995E-08 2.470512E-15 -1.125418E-04 1.667820E-08 -1.465810E-11

CHANNEL	ENERGY	CAL. ENG	D-ENG	WIDTH
827.628	1164.720	1164.851	-0.131	2.29
2034.425	2863.940	2863.811	0.129	2.83
4060.940	5715.260	5715.384	-0.124	4.18
5536.052	7790.160	7789.948	0.212	4.30
6096.562	8578.360	8577.991	0.369	4.84

LOW PULSER EQUIVALENT: 736.30 HIGH PULSER EQUIVALENT: 7515.13

LEGEND

1. X is channel number
 2. Width given in channels
 3. Energy given in keV
 4. Low pulser and high pulser equivalents given in energy
 5. D-ENG is difference between library energy and calculated energy (i.e., measured)
-

3. The same chlorine peaks used above in step 2 were used in the automated pulser energy calibration program (the "PEQCL" command steps the operator through the calibration) to determine the energy equivalents of the low- and high-energy pulser peaks. This automated calibration program locates the calibration peaks, measures their peak positions and full width at half maximum (FWHM), deduces the energy equation, and uses it to deduce the energy equivalents of the low- and high-energy pulser peaks. The automated pulser calibration program operated correctly. A sample output of the pulser energy calibration program is shown in Table 2 with annotations to describe some of the key information listed.
4. By acquiring subsequent spectra via PGNAA with the PVC plastic as the sample, the pulser energy calibration of each acquired spectrum was demonstrated to measure the peak positions within <2 keV (the ^{241}Am 59.5-keV γ -ray was measured to be 58.2 keV) and to be stable within ~ 1.5 channels over a period of days.
5. The spectra acquired in steps one and two were analyzed with a microVAX that also issued commands via Ethernet to the Acquisition Interface Module, which served, in conjunction with the ADC, as the multichannel analyzer. The analysis programs consisted of the VAXGAP^{6,7} family of programs developed by the Radiation Measurements and Development Unit at the INEL. These programs demonstrated their ability to locate peaks, fit the peaks, and correctly identify the associated radionuclides from decaying radionuclides or associated elements from the PGNAA peaks.
6. The program operated flawlessly as designed to display and examine spectra as they are accumulating or after they have been taken. (The display program is initialized with the "DAS" command.)
7. The ^{252}Cf was removed and a ^{60}Co source introduced. A spectrum was acquired and the energy resolution (FWHM) was measured at 1,332 keV. The energy resolution of the Ge detector as mounted with the BGO annulus (see Figure 6) was measured to be 2.2 keV FWHM. This resolution is marginally acceptable and lies outside the test plan requirement of being within 5% of the manufacturer's measured resolution of 1.95 keV FWHM. However, extraneous noise may have been introduced when the Ge detector was mounted on the aluminum support with the BGO annulus.
8. The results of these tests are reported herein and documented in the project log books and acquired spectra.

2.3 PGNAA Measurements

The PGNAA measurements were to demonstrate the use of a $^{252}\text{Cf}/\text{Ge}$ spectrometer to measure the presence of chlorine in a waste drum buried at an excavation site. The objective of these measurements was to determine at what depth chlorine could be identified with confidence.

A $\sim 5\text{-}\mu\text{g}$ ^{252}Cf source, doubly encapsulated in stainless steel, was used as the excitation source, and an n-type coaxial Ge spectrometer was used to accumulate the PGNAA spectral data. A Ge spectrometer similar in crystal size but different than the one mounted with the BGO

Table 2. PGNAA soil attenuation data. Experiment description: ^{252}Cf source: ID Number FTC-CF-120; sample: 8-gal drum containing a mixture of sand and salt (NaCl) with a chlorine concentration of 40%; live time: 3,600 seconds.

System geometry	γ peak (keV)	Soil depth (in.)					
		0	3	6	9	12	15
Transmission 1	1,165	1,453 $\pm$ 142	754 $\pm$ 75	406 $\pm$ 65	286 $\pm$ 56	192 $\pm$ 52	148 $\pm$ 49
Transmission 2	1,165	5,493 $\pm$ 285	2,604 $\pm$ 170	1,598 $\pm$ 206	726 $\pm$ 99	560 $\pm$ 147	391 $\pm$ 69
Backscatter	1,165	1,509 $\pm$ 164	514 $\pm$ 129	353 $\pm$ 120	411 $\pm$ 121	310 $\pm$ 115	334 $\pm$ 91
Transmission 1	1,778	2,566 $\pm$ 169	3,255 $\pm$ 215	3,266 $\pm$ 212	2,842 $\pm$ 162	2,476 $\pm$ 161	2,059 $\pm$ 121
Transmission 2	1,778	2,074 $\pm$ 159	8,389 $\pm$ 421	9,980 $\pm$ 561	7,817 $\pm$ 427	7,007 $\pm$ 351	5,342 $\pm$ 257
Backscatter	1,778	3,081 $\pm$ 128	19,912 $\pm$ 1003	26,815 $\pm$ 1615	27,977 $\pm$ 1809	27,914 $\pm$ 1816	28,391 $\pm$ 1700
Transmission 1	1,951	1,022 $\pm$ 60	672 $\pm$ 51	388 $\pm$ 49	274 $\pm$ 39	190 $\pm$ 34	161 $\pm$ 36
Transmission 2	1,951	3,257 $\pm$ 224	2,001 $\pm$ 137	1,295 $\pm$ 98	900 $\pm$ 72	628 $\pm$ 67	620 $\pm$ 73
Backscatter	1,951	1,091 $\pm$ 90	433 $\pm$ 104	352 $\pm$ 93	257 $\pm$ 78	215 $\pm$ 87	175 $\pm$ 75
Transmission 1	2,223	4,162 $\pm$ 333	2,839 $\pm$ 273	1,677 $\pm$ 191	1,285 $\pm$ 113	1,123 $\pm$ 94	946 $\pm$ 88
Transmission 2	2,223	35,226 $\pm$ 1,736	22,202 $\pm$ 1359	14,318 $\pm$ 889	9,023 $\pm$ 537	6,269 $\pm$ 267	6,267 $\pm$ 266
Backscatter	2,223	5,123 $\pm$ 298	5,387 $\pm$ 302	5,814 $\pm$ 564	5,962 $\pm$ 527	6,511 $\pm$ 624	6,608 $\pm$ 593
Transmission 1	3,539	200 $\pm$ 31	252 $\pm$ 34	275 $\pm$ 25	265 $\pm$ 25	395 $\pm$ 27	442 $\pm$ 27
Transmission 2	3,539	*** $\pm$ **	441 $\pm$ 53	650 $\pm$ 53	741 $\pm$ 84	924 $\pm$ 50	993 $\pm$ 51
Backscatter	3,539	206 $\pm$ 33	853 $\pm$ 68	1,253 $\pm$ 70	1,636 $\pm$ 99	1,783 $\pm$ 100	1,917 $\pm$ 88
Transmission 1	6,111	828 $\pm$ 55	581 $\pm$ 44	449 $\pm$ 31	296 $\pm$ 26	242 $\pm$ 22	216 $\pm$ 22
Transmission 2	6,111	1,966 $\pm$ 111	1,521 $\pm$ 83	1,230 $\pm$ 61	1,009 $\pm$ 76	840 $\pm$ 56	830 $\pm$ 59
Backscatter	6,111	475 $\pm$ 30	251 $\pm$ 40	193 $\pm$ 39	197 $\pm$ 38	177 $\pm$ 39	**** $\pm$ **

a. Transmission 1 geometry consists of a ^{252}Cf source located behind the waste drum with respect to the Ge spectrometer and the soil thickness between the waste drum and the Ge spectrometer. Transmission 2 geometry is similar to Transmission 1 geometry except that the ^{252}Cf source is at 90 degrees to the Ge spectrometer, soil alignment as shown in Figure 8. The backscatter geometry is shown in Figure 7.

annulus was used in the PGNA measurements in order to meet the PGNA measurement schedule. An 8-gal drum containing a mixture of sand and salt (NaCl) in which the chlorine concentration was 40% (65.6% NaCl) was used as the sample in all of the measurements. Three box-shaped aluminum containers 24 in. wide, 24 in. high, and 3, 6, and 6 in. deep, respectively, were filled with dirt from the INEL to simulate waste buried from 3 to 15 in. beneath the dig-face at an excavation site. These containers were located between the sample and the detector. Three detector-neutron source geometries were investigated: two transmission and one "backscatter" geometry. Specifically, these geometries are the following: (a) the source and the detector were located outside of the dig-face, and the sample drum was located behind the dirt-filled aluminum containers as shown in Figure 7; (b) the source was located on the side of the "buried" sample drum but with the detector on the outside surface of the dig-face as shown in Figure 8; and (c) the same geometry as (b) but with the source located behind the sample drum at a position most distant from the detector (i.e., ^{252}Cf source, chlorine sample in soil matrix, soil overburden and detector inline). All PGNA spectra were acquired for a 3,600-second live time.

The areas of several chlorine peaks as well as the aluminum, hydrogen, and silicon peaks from these measurements are presented in Table 2. Figures 9 through 11 show plots of the areas of the 1,165-, 1,951-, and 6,111-keV chlorine peaks as a function of soil depth. The "backscatter" geometry shows a statistically significant exponential attenuation in the chlorine peak areas due to insertion of soil containers only for data taken with no soil and 3 in. of soil covering the drum. Beyond a 3-in. cover of soil, the data are not statistically distinguishable. Both transmission geometries show an exponential attenuation for up to 12 in. of soil covering the drum, and the 1,165-keV data from the transmission #2 geometry shows an exponential attenuation for up to 15 in. of soil covering the drum.

Figures 12 through 14 show plots of the areas of the 1,778-keV peak [from 2.25 minutes ^{28}Al or $^{28}\text{Si} (n, n^1) ^{28}\text{Si}$], 2,223-keV H capture peak, and 3,539-keV Si capture peak as a function of soil depth for each geometry. The addition of aluminum, as added aluminum containers filled with soil are placed in the experimental arrangement, is observed by an initial large increase in 1,778-keV peak areas with the backscatter and transmission #2 geometries. The activation of the aluminum soil container and subsequent decay of ^{28}Al explains this large initial increase. In the transmission geometries, the 1,778-keV peak reaches a maximum value due to the countering effects of added sample farther from the detector and higher attenuation of γ -rays produced in the added sample and container. However, with the "backscatter" geometry, the 1,778-keV peak asymptotically reaches an asymptote as the neutrons and emitted prompt γ -rays for the most distant containers have larger and larger distances to travel for activation and detection as aluminum containers of soil are added. The 2,223-keV hydrogen capture peak indicates the presence of water in the sand/salt sample mixtures and in the added soil. The 2,223-keV peak area as a function of soil depth for data taken in the backscatter geometry is relatively constant but increases gradually as is the case for aluminum if the measurement with no soil (i.e., no aluminum container) is excluded. The transmission geometries show the 2,223-keV peak areas decreasing exponentially. In the transmission geometries, the hydrogen-capture γ -rays at 2,223 keV are produced primarily in the sample drum, which is in close proximity to the ^{252}Cf neutron source, and are attenuated in passing through the soil separating the sample and detector. The difference between the 2,223-keV and the chlorine data is that chlorine is present only in the waste drum, whereas the water is probably present in both the waste drum (sample) and the soil. The 3,539-keV Si capture peak as a function of soil depth behaves similar to the 1,778-keV peak for the "backscatter" geometry.

Figure 7. PGNA assay of an 8-gal drum containing a mixture of sand and salt (40% chlorine) in which the ^{252}Cf source is located on the same side ("backscatter" geometry) of the "dig-face" as the detector with the drum "buried" behind 15 in. of soil. The aluminum containers of soil provide a known thickness of soil.

Figure 8. PGNA assay of an 8-gal drum containing a mixture of sand and salt (40% chlorine) in which the ^{252}Cf source is located at the side of the "buried" drum (transmission geometry #2). The aluminum containers of soil provide a known thickness of soil.

Figure 9. Peak area of the 1,165-keV chlorine γ -ray as a function of soil depth from PGNAA of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Transmission #2 geometry is shown in Figure 8.

Figure 10. Peak area of the 1,951-keV chlorine γ -ray as a function of soil depth from PGNAAs of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Transmission #2 geometry is shown in Figure 8.

Figure 11. Peak area of the 6,111-keV chlorine γ -ray as a function of soil depth from PGNAA of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Transmission #2 geometry is shown in Figure 8.

Figure 12. Peak area of the 1,778-keV aluminum/silicon γ -rays as a function of soil depth from PGNAA of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Note that this peak is from multiple sources including the aluminum sheet comprising the soil containers, aluminum detector housing, and the presence of aluminum and silicon in the soil and sand. Transmission #2 geometry is shown in Figure 8.

Figure 13. Peak area of the 2,223-keV hydrogen γ -ray as a function of soil depth from PGNAA of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Transmission #2 geometry is shown in Figure 8.

Figure 14. Peak area of the 3,539-keV silicon γ -ray as a function of soil depth from PGNAA of an 8-gal waste drum containing 40% chlorine in a sand/salt mixture for the backscatter and two transmission geometries. Transmission #2 geometry is shown in Figure 8.

These results show that all geometries are acceptable for waste buried only 3 or 6 in. deep. However, for the "backscatter" geometry (i.e., Figure 7), the 6,111-keV Cl peak is not statistically different for soil depths of 3 to 15 in. For the transmission geometries (^{252}Cf neutron source behind or at the side of the sample drum), statistically significant results are obtained for all measured soil depths, especially to 12 in. of soil cover. However, the data from the geometry with the source at the side of the sample drum have the best statistics. We conclude that for the transmission geometries, a waste container with 40% chlorine present that is buried to a soil depth of 12 in. has sufficient statistics to permit detection at its lower limit-of-detection level (as defined by L.A. Currie³) in a 15-minute count with a ^{252}Cf neutron source of $\sim 5 \mu\text{g}$. Detection of 40% chlorine at 15 in. is also feasible. A spectrum of the 5,500- to 6,500-keV region of the PGNA spectrum taken with 15 in. of soil covering the 8-gal waste drum for the transmission #2 geometry is shown in Figure 15.

In practice, the experimental measurements with the source located at the side of the sample drum (transmission #2), can be achieved by placing the source in the tip of a metal rod or pipe that is then pressed, augered, or otherwise delivered to the side of a buried waste container. This can be done with little or no disturbance of the dig-face soil. Figure 16 illustrates this concept. Since location of the source near the sample drum when it is buried near the surface (i.e., $<1 \text{ m}$ deep), provides an improved analysis compared to the backscatter geometry, an Invention Disclosure Record (EGG-PI-780) was submitted for a device and a method of analysis that incorporates this technique.

Figure 15. Spectrum of the 5,500- to 6,500-keV region showing the 5,600-keV single escape and the 6,111-keV full-energy peaks of chlorine for the transmission #2 geometry with 15 in. of soil covering the waste drum.

Figure 16. Conceptual design of a penetrating probe for the PGNAA analysis of "buried" hazardous chlorinated waste.

3. DISCUSSION

Three systems have been developed and tested during FY-94 for use at the dig-face of an excavation site. Performance tests of these systems indicated that they have potential in offering added protection, via early warning to personnel, from both radiological and chemical hazards during the excavation of buried waste at a dig-face. The information gained from these instruments can also aid in on-site decisions to minimize contamination and increase productivity. Although each of these systems could be used in their present form, improvements and additional tests are strongly recommended to further enhance their robustness and function, and to simplify their use.

The following recommendations are proposed as a scope of work for improvement of the neutron/ γ mapper during FY-95:

1. The noise present in the γ /neutron mapper should be reduced to improve its sensitivity for the detection of low-energy γ -rays such as from ^{241}Am .
2. A titanium or other less-attenuating window should be installed in the door of the stainless steel case to replace the stainless steel as a window covering the plastic scintillators. The high strength and low atomic number of titanium makes it an excellent material for this window. This will allow the 60-keV γ -ray of ^{241}Am to be detected more efficiently. (A 0.040 "thick" titanium window attenuates a 60-keV γ -ray only ~20%.)
3. The count-rate capability of the γ /neutron mapper should be improved to meet the original specification. This will require rebuilding portions of the pulse processing circuitry.

The following recommendations are proposed as a scope of work for the Ge spectrometer during FY-95:

1. The bismuth germanate annulus for the Ge spectrometer should be installed in the Compton suppression mode and performance tested. This detector should serve to reduce the background level of the Ge spectrometer, provide Compton suppression to the spectrum, and, thereby, increase sensitivity.
2. Use of one energy scale that covers the entire energy range should be pursued through improved ADC pulse-height linearity or correction for nonlinearity. The possible use of a 16,000-channel conversion gain should be investigated to provide improved peak definition capability.

The following recommendations are proposed as a scope of work for the PGNAA measurements during FY-95:

1. The ability to extend the measuring depth to 24 in. soil depth should be investigated.
2. The ability to measure other elements associated with hazardous substances should be pursued including the preparation of surrogates.

3. Further development of the PGNAA probe submitted as an Invention Disclosure Record should be pursued, including scanning of waste as a function of depth with the ^{252}Cf probe and the practical construction of a robust probe to allow complete protection and integrity of the ^{252}Cf source at all times.

Finally, all of these instruments should be demonstrated in the field at an actual excavation site during the last quarter of FY-95.

4. CONCLUSIONS

The neutron/ γ mapper was found to be very useful as is but has not achieved all design criteria. The weight of the neutron/ γ mapper slightly exceeds the maximum specified. Noise also limits the low-energy performance of the plastic scintillators. The thick stainless steel case surrounding the detectors and pulse processing circuitry provides excellent protection from physical abuse to the instrument but also reduces the sensitivity of the plastic scintillators to low-energy γ -rays. (A 60-keV γ -ray emitted by ^{241}Am is attenuated 80% in passing through the window.) The neutron/ γ mapper is believed to be capable of identifying "hot spots" of radioactivity with activities as low as 300 nCi at a scanning speed of ~ 35 cm per 10 seconds and a distance to the dig-face surface of 30 cm. The count-rate performance of both the plastic scintillator and the ^3He chamber counting systems need to be improved to meet original performance criteria. The original count-rate specifications for the γ and neutron counters were based upon (a) achieving state-of-the-art performance from these systems and (b) the lack of any information on expected count rates. Efforts will be made in FY-95 to improve the count-rate performance of the γ and the neutron counters.

The Ge spectrometer in the singles mode (i.e., not incorporating the bismuth germinate annulus) performs as originally specified. The only significant change over other pulsered Ge spectrometers, however, is its being packaged for handling from a crane or the dig-face trolley. The ability of the pulsered Ge spectrometer to function dependably in all orientations will be measured in FY-95.

The PGNAA measurements and results offer the possibility of identifying waste containers or plumes containing hazardous chlorinated compounds prior to their excavation. These identifications can be made even when these wastes are covered by as much as 15 in. of soil.

These systems have demonstrated their potential to map both γ and neutron fields and to assay buried waste for hazardous materials containing chlorine at an excavation site. These systems will be further developed so that they can be successfully demonstrated at an actual waste site in FY-95.

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Appendix A

Plan for the Testing of Radiation Measurement Instrumentation Intended for Use at an Excavation Site

**Plan for the Testing of Radiation Measurement
Instrumentation Intended for Use
at an Excavation Site**

Robert J. Gehrke

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**Idaho National Engineering Laboratory
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415**

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Plan for the Testing of Radiation Measurement Instrumentation Intended for Use at an Excavation Site

Prepared by

Robert J. Gehrke

Nov 9, 1994
Date

Reviewed by

Michael D. Peters, Project Manager

Nov 9, 1994
Date

Approved by

Rudy J. Theriault, Program Manager

Nov 9, 1994
Date

ABSTRACT

This plan describes performance tests to be made with ionizing radiation measurement instrumentation designed and built for in-field assay at an excavation site. One instrument measures gross gamma-ray and neutron fields and the other identifies gamma-ray emitting radionuclides and also is capable of assaying for selected hazardous materials. These instruments will be operationally tested to verify that original specifications have been met and performance tested to establish and verify that they have the potential to function as intended at an excavation site.

SUMMARY

This plan describes objectives, instrumentation, and performance tests for ionizing radiation instrumentation that will be used at an excavation site. This instrumentation is being developed under the digface characterization project. The purpose of the digface characterization technology is to provide sensing capability that allows an adaptive approach to buried waste remediation. The use of characterization at the digface will ultimately reduce environmental, health, and safety risks during cleanup of buried waste sites as supported by published system design studies. The requirement for characterization at the digface results from the inability of current characterization technologies to provide sufficient location and characterization information when deployed from ground surface prior to the start of remediation operation. However, these same approaches, when deployed continuously during retrieval, may provide the information needed to meet production, operational, and safety needs.

An adaptive approach performs cleanup in small steps by alternately characterizing and then digging safe increments of the subsurface. The requirements for characterization within such a system are different than for conventional waste site remediation. Characterization is required only for a thin zone in the immediate subsurface of the digface. The digface monitoring technology that performs this function must be highly effective at screening this shallow zone for hazards, which can then be removed by cleanup equipment. The digface sensors provide constant surveillance and screening as hazards are gradually exposed by the cleanup operation. As cleanup proceeds, hazards are monitored from progressively closer viewpoints until complex features of the waste are resolved. This is the key technical advantage to the digface monitoring technology.

The Buried Waste Integrated Demonstration (BWID) characterization study was started in 1992 with the preparation of a conceptual design. Substantial development activities were initiated in 1993, and there are currently three main project subtasks: (1) demonstration of concept feasibility and development of data interpretation concepts, (2) development of robotics deployment capability, and (3) development of prototype sensors for application at the digface.

Digface characterization is only one unit of a complex remediation system. Therefore, support must be assumed from mobile laboratories as well as U.S. Environmental Protection Agency-certified laboratories. It is anticipated the digface system will only be providing screening level data. This is consistent with the safety primacy of the system. Analyses that are required to certify clean versus unclean soil are not expected to be made with a digface characterization system. If appropriate from a system point of view, the digface system could provide information for educated guesses that would require subsequent verification.

This plan describes performance tests to be made with ionizing radiation measurement instrumentation designed and built for in-field assay. One instrument measures gross gamma-ray and neutron fields and the other identifies gamma-ray emitting radionuclides and also is capable of assaying for selected hazardous materials. These instruments will be operationally tested to verify that original specifications have been met and performance tested to establish and verify that they have the potential to function at an excavation site.

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ACRONYMS

BWID	Buried Waste Integrated Demonstration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DQO	data quality objective
FY	fiscal year
INEL	Idaho National Engineering Laboratory
N&RP	Nuclear and Radiological Physics Unit
OTD	Office of Technology Development
PGNAA	prompt gamma neutron activation analysis
PI	principal investigator
PINS	Portable Isotopic Neutron Spectroscopy
PVC	polyvinyl chloride
RFP	Request For Proposal
RM&D	Radiation Measurements and Development Unit
TRA	Test Reactor Area
TS	Technical Specification

Plan for the Testing of Radiation Measurement Instrumentation Intended for Use at an Excavation Site

1. INTRODUCTION

The Buried Waste Integrated Demonstration (BWID) characterization study was started in 1992 with the preparation of a conceptual design.^{1,2} Substantial development activities were initiated in 1993 and there are currently three main project subtasks: (1) demonstration of conceptual feasibility and development of data interpretation concepts, (2) development of robotics sensor deployment capability, and (3) development of prototype sensors for application at the digface.

The prompt gamma neutron activation analysis (PGNAA) task was initiated midway through FY-93 resulting in initial measurements that demonstrated the ability to detect chlorine mixed with soil, stainless steel scrap, and lead located inside 55-gal drums. In addition to these measurements, measurements were also made on surrogate and actual transuranic waste in 55-gal drums in the TRUPACT building at the Stored Waste Experimental Pilot Plant³ with a Portable Isotopic Neutron Spectroscopy (PINS) system developed with funding from the Office of Research and Development (NN20).

Based on the experience gained in FY-93, three characterization systems were proposed for development in FY-94 under this task. Appendix A provides conceptual drawings of the sensors to be attached to the trolley or gantry crane for systematic characterization at an excavation site. These characterization systems, which were designed to characterize the neutron and gamma-ray radiation fields and the presence of potentially hazardous materials in the overburden, sideburden and material present in the burial site proper, consist of (a) a neutron/gamma radiation mapper to measure the neutron and gamma radiation fields, (b) a Ge spectrometer for radionuclide identification, and (c) a PGNAA system for identification of key elements associated with hazardous materials. The latter system will be used primarily to identify potential plumes of chlorinated organics or containers with chlorinated organics.

This plan, based on BWID guidance,⁴ describes performance tests to be made with the measurement instrumentation described above and designed and built for in-field assay at an excavation site. One instrument measures gross gamma-ray and neutron fields and the other identifies gamma-ray emitting radionuclides and also is capable of assaying for selected hazardous materials. These instruments will be operationally tested to verify that original specifications have been met and performance tested to establish and verify that they have the potential to function at an excavation site. This plan describes tests for two separate instruments used to perform three separate kinds of measurements.

The first instrument to be tested consists of a gamma-ray/neutron radiation monitor for rapid scanning of a digface for the purpose of mapping the gamma-ray and neutron radiation fields as a function of location and for the identification of radioactive hot spots. The instrument consists of two identical neutron chambers with a He-3 detector located within each chamber. The direction

of the chambers facing the excavation are each covered by a plastic scintillator of the same size as the neutron chamber. Analog signals from each He-3 and each plastic scintillator are read out as a function of time to provide a mapping of the gamma-ray and neutron radiation fields as a function of location.

The second instrument is a Ge gamma-ray spectrometer for use at the excavation site in the identification of the radionuclides present. This spectrometer is equipped with a dual-energy pulser for automatic energy calibration of every gamma-ray spectrum. The pulser also provides correction for pulse pile-up and monitors the noise and energy resolution of the spectrometer. This instrument with the addition of a Cf-252 source, reflector/moderator block, and active or passive shadow shielding can also be used to perform PGNAA at the excavation site.

1.1 Scope

The scope of this test is limited to laboratory evaluations of basic performance of radio analytical instruments (and associated software) being developed for use at an excavation site. These tests are being performed independent of other digface characterization tests being performed in FY-94. Weekly progress will be communicated to the principal investigator, N. E. Josten, who has overall responsibility for the digface characterization work.

1.2 Objectives

The objective of this plan is to perform a series of measurements to test the operation and performance of the gamma-ray/neutron radiation monitor and the gamma-ray spectrometer. A set of measurements will be performed for each type of measurement as described in Section 3, "Description of Tests." Whenever a specific parameter is to be measured, it shall be measured to an accuracy of at least $\pm 25\%$ (whenever higher accuracy is required from a performance test, it shall be specified). Specific objectives for the gamma-ray/neutron radiation monitor are:

- To verify that all specifications listed in the requisition have been met and to document those specifications that have not been met
- To measure the performance characteristics of the gamma-ray/neutron radiation monitor.

Specific objectives for the gamma-ray spectrometer as used to measure radionuclides present are:

- To verify that the Ge detector and pulse-processing electronics including the dual-energy pulser will operate as intended
- To verify that all associated software for control and analysis are functional
- To measure the performance characteristics of the Ge spectrometer.

The specific objective for the gamma-ray spectrometer as used to perform prompt gamma/neutron activation at the digface is to measure the PGNAAs sensitivity for chlorine as a function of soil depth for the Cf-252/Ge spectrometer system.

1.3 Technology Agreement

The Nuclear and Radiological Physics (N&RP) and Radiation Measurements and Development units of EG&G Idaho, Inc., participate in the BWID program to develop a digface characterization system that will provide mapping of ionizing radiation, identification and assay of the radionuclide inventory, and assay of certain key hazardous elements at an excavation site by PGNAAs. This project is a continuation of the FY-93 Technical Task Plan ID-132003, "Digface Characterization," and covers work needed to prepare the digface characterization system for use at an excavation site.

1.4 Customer Need

The instruments being developed for the digface characterization project are necessary to ensure the safe removal of radioactive and mixed waste from an excavation site.

2. ORGANIZATION AND RESPONSIBILITIES

This work is sponsored by the Office of Technology Development (OTD) through the BWID program at the Idaho National Engineering Laboratory (INEL) for the purpose of developing radiation measuring instrumentation. The organizational affiliations and responsibilities of the key personnel involved in the development and testing of the radiation measuring instrumentation for use at an excavation site are listed below in Section 2.1. Personnel from the N&RP and RM&D units of EG&G Idaho will perform all measurements.

2.1 Personnel Responsibilities

Nicholas E. Josten, the primary principal investigator (PI), will be responsible for the overall technical management of the project. He will also direct the field testing and the data analysis activities during and after the field tests.

Robert J. Gehrke, PI, will be responsible for the overall scientific development of the radiation instrumentation to be used at an excavation site. He will be also responsible for carrying out the performance tests on the gamma-ray spectrometer. He has 29 years experience in basic and applied research in the areas of x-ray and gamma-ray spectrometry with over 60 journal publications.

Robert S. Lawrence, PI, will be responsible for carrying out the performance tests on the gamma/neutron monitor and for setting up the gamma-ray spectrometer. He has over 35 years experience in the design, building, testing, and maintenance of electronic circuits and their control including that for fast pulse circuitry. Lawrence is the technical leader of the electronics personnel in the RM&D Unit.

E. Wayne Killian, PI, will be responsible for the development of the software that has been and may need to be developed for control and analysis of data taken with the gamma-ray spectrometer. Specifically, he has developed the VAXGAP family of programs that control the analyzer, calibrate the spectra, and analyze the dual-energy pulser data.

Gehrke and Lawrence also will be responsible for carrying out this test plan. Any other individuals who participate in making measurements in support of this test plan shall be under the direct supervision of either Gehrke or Lawrence. All personnel making measurements shall be radiation workers working under a Radioactive Work Permit. Support from Health Physics personnel will be specified in the Radioactive Work Permit. Josten, the primary PI, will inspect the test plan activities and associated documentation at least once during the test.

2.2 Personnel Support Requirements

All experimental work will be performed by the PIs, or by personnel from the RM&D and N&RP units of EG&G Idaho who are functioning under the direction of the PIs. These staff are senior-level, technically degreed scientists and engineers with experience in radiation instrumentation and in the measurement of ionizing radiation. Interface with other units will be through Josten, the PI with overall responsibility for the digface project. Experiments will be

performed at the Test Reactor Area (TRA). Selected sites for demonstration of the instruments and equipment associated with the digface project will be evaluated in a subsequent test plan.

2.3 Monitoring and Surveillance

Monitoring of measurement activities will be provided by program project management through Josten, the primary PI. Monitoring will be performed at the RM&D facility as required by the PI or by independent sources designated by the PI.

3. DESCRIPTION OF TESTS

These tests are designed to verify basic operational and performance characteristics for the intended use of this equipment at an excavation site. Appendix A, Sections 3.2, 3.3, 3.6, and 3.8 of the *Buried Waste Integrated Demonstration Technology Test Plan Guidance*³ are addressed below.

The tests to be conducted are described in detail in Sections 3.1, 3.2, and 3.3. If quality data are acquired, tests will not be repeated. Any individual test will be repeated if the measured data are of questionable quality as determined by the PI in charge of the test. These tests will be conducted in the physics or electronics laboratories at TRA and shall be completed prior to the end of FY-94. All equipment is available. No contingency plan will be made. Any tests that cannot be carried out due to major deficiencies in the equipment will be documented. These tests will evaluate the capability to carry out characterizations at the digface of an excavation site to provide a margin of safety to the excavation personnel. Uncertainty requirements will be judged individually by the PI in charge of the test. When not specified by the test plan, measurement uncertainties should be equal to or less than $\pm 25\%$ (one standard deviation).

Table 1 lists the full-scale operation estimates based upon present brief experience with the equipment.

3.1 Test of the Gamma-Ray/Neutron Monitor

The tests for the gamma-ray/neutron monitor are divided into three primary sections. These are: (1) system tests (these tests check the properties of the system that are common to both the gamma-ray and neutron detector sections of the system and include procedures that are outlined in the vendor's *Operating and Service Manual* (the pertinent sections are attached in Appendix B) for the gamma-ray/neutron monitor), (2) gamma detector tests (these tests check the properties of the system that are peculiar to the gamma detector portion of the system), and (3) neutron detector tests (these tests check the properties of the neutron detector portion of the system). Each of these primary sections are subdivided into two subsections. The subsections are: (1) acceptance tests to verify the system meets the technical specifications (TS) required in the Request For Proposal (RFP) (specifications reprinted in Appendix B) and (2) additional characterization tests not required in the RFP. Data from these tests will subsequently be used to develop calibration procedures and to determine if any system modifications are required to optimize the system for the specific application at the INEL. The results of all tests shall be recorded in a formal logbook.

Perform the setup and calibration procedures outlined in Sections 2 (Inspection and Setup) and 5 (Maintenance) of the vendor's *Operating and Service Manual* prior to the following sections of this test plan: systems, gamma detector, and neutron detector tests. Sections 2 and 5 of the vendor's *Operating and Service Manual* are attached to this plan as Appendix C.

Table 1. Full-scale operation estimates.

a	Operation and maintenance cost for the life cycle of the technology is estimated to be \$50,000 per year plus 120 labor hours each year for seven years.
b	Acquisition cost for equipment is approximately \$120,000.
c	NA
d	NA
e	NA
f	NA
g	NA
h	NA
i	Longest procurement lead times for custom or engineered components is estimated to be 6 months.
j	The dual-energy pulser and its respective analog-to-digital converter (ADC) interface, and the spectral analysis and control software are custom from INEL.
k	Two hours per month should be anticipated as unscheduled maintenance.
l	One hour per month should be scheduled for maintenance.
m	It is estimated that this technology will be available for field demonstration in one year.
n	It is estimated that this technology will be available for full operation in two years.
o	Senior support technician personnel with radiation measurement training are required to operate this equipment.
p	The labor hours to operate this equipment is two per clock hour of operation.
q	Not known.
r	No permits are required beyond a license to possess and use a 5 to 10 μ g Cf-252 neutron source.
s	Allow two months to customize the commercially purchased equipment.
t	Electrical power in the form of 110 volts is needed to operate this equipment.
u	To train technicians to operate the equipment would take two weeks but does not include full capability to interpret the data.
v	Allow \$45,000 of equipment funds and 120 labor hours each year to cover contingencies.

3.1.1 System Tests

3.1.1.1 Acceptance Tests. The following acceptance tests are required:

- Verify that all required system documentation is available. This includes, but may not be limited to, detector drawings, schematic diagrams, specifications, operational and maintenance manuals, external connector drawings and schematics, and output conversion factors (reference TS 3.11 of Appendix B).
- Verify the following system physical requirements. Verification shall be by inspection of documentation, visual inspection of the system, and/or appropriate tests, measurements or checks.
 - Verify that the total weight of the operational system as delivered by the subcontractor does not exceed 200 lb. Verification shall be by weighing the system and recording the actual weight (reference TS 3.1).
 - Verify that the external case is water resistant so that it can be easily decontaminated and still be easily opened for maintenance (reference TS 3.9).
 - Verify that the detection system consists of two each plastic gamma scintillation detectors and two each He-3 neutron proportional counter detectors. The He-3 neutron detectors shall be in separate side-by-side neutron chambers separated by a 2.54-cm thick polyethylene wall. Verify that the neutron chambers are covered by a 1.27-cm thick sheet of polyethylene. The plastic gamma scintillators lay on the polyethylene sheet and shall each cover a neutron chamber (reference TS 3.3 and TS 3.4).
 - Verify that the four detectors (two each gamma and two each neutron) are totally independent such that there are four separate and independent analog outputs (reference TS 3.7).
 - Verify that a graded shield of tin and lead covers the back and sides of the plastic scintillation detectors (reference TS 3.5).
 - Verify that military style connectors are used in the system. Verify that separate connectors are used for power and signals. Verify that mating cable connectors have been supplied along with spare connectors for each connector used in the system (reference TS 3.10).
- Verify that input system power is +24 Vdc. Verification shall be by documentation inspection and visual inspection of system wiring (reference TS 3.6).

3.1.1.2 Characterization Tests. None.

3.1.2 Gamma Detector Tests

3.1.2.1 Acceptance Tests.

3.1.2.1.1 Gamma Efficiency—The gamma efficiency of the plastic scintillators shall be measured using a Cs-137 source located 30 cm from the front face of the detector assembly. The efficiency shall be defined as the counting rate of each scintillation detector divided by the gamma-ray emission rate of the source. The emission rate of the gamma-rays is calculated from the output activity of the source at the last assay date, the gamma-ray emission probability, and the half-life of the isotope. The summed efficiency of the two plastic scintillators shall be equal to or greater than 2% (reference TS 3.4).

3.1.2.1.2 Count Rate—The count rate capability of the gamma-ray electronics shall be measured to verify a count rate capability of 1,000,000 counts per second with less than 10% counting losses. Input counts to the electronics will be ideally from a pulser unit to a test input, if available. If no input point is available, an attempt should be made to attach the pulser to an acceptable point in the existing electronics circuit. If necessary, a check source (for example, Cs-137) can be used. Note, however, that the use of a check source will include the response of the scintillator. The technical specification of the RFP requires a minimum count rate capability for the electronics only. As a last resort, minor modifications to the electronics may be made to attach a pulser, but only after all other tests have been performed and accepted (reference TS 3.7).

3.1.2.1.3 Analog Output—The analog output signals from both gamma-ray detectors shall be measured to verify that (a) the analog output voltage is linearly proportional to count rate from -5 Vdc (zero count rate) to $+5$ Vdc (1,000,000 counts per second) and (b) the output is capable of driving a 1 megohm load. These tests should be made using a pulser unit. Input rates in steps of 100,000 counts per second will be acceptable (reference TS 3.8).

3.1.2.2 Characterization Tests.

3.1.2.2.1 Neutron Efficiency—The neutron efficiency of the gamma-ray scintillation detectors shall be measured. Efficiency shall be defined in the same manner as in Section 3.1.2.1.1 above. An unmoderated Cf-252 source shall be used for this test. If time and resources permit, the efficiency shall also be measured with one or more (up to five) plutonium accident dosimeter (NAD) 1-g sources.

3.1.2.2.2 Energy Range—The energy range of the gamma-ray detectors shall be measured and recorded. A series of different isotope check sources can be used for this test. Recommended check sources are Am-241 (59 keV), Cs-137 (662 keV), and either Co-60 (1173 + 1332 keV) or Th-228 (2.614 MeV). These tests may be performed in either of two ways. If a linear analog amplifier output is available whose maximum amplitude is known, the amplifier output amplitude can be measured as a function of energy. The maximum energy range would be equal to the product of the energy of the selected isotope and the ratio of the maximum output amplitude to the amplitude of the isotope pulses. Amplitudes can be measured using an

oscilloscope. A similar method to determine the energy range is the use of the single channel analyzer built into the system. If the maximum full-scale discriminator setting is known, then the maximum energy can be determined by using a selected isotope, such as Cs-137, and adjusting the low-level discriminator to the point where counts just begin to appear for the isotope and measuring the discriminator voltage. The maximum energy is the product of the isotope energy and the ratio of the maximum discriminator voltage and the voltage at which counts just begin to appear.

3.1.2.2.3 Lower Limit of Detection—For the purposes of this test, the lower limit of detection is defined as the maximum distance from the face of the detector assembly for a given check source that results in a count rate at the analog count rate output that is at least twice the output of the ambient background at the location of the test. This definition requires the measurement of the background prior to the measurement of the lower limit of detection. Measurements should be such that the check source is placed normal to the center of the front face of the plastic scintillator and begin 30 cm from the front face of the assembly and increase in 10-cm increments. The check source should be Cs-137. Alternatively, all measurements will be made at a 30-cm distance from the front face of the detector and the source strength lowered until the strength of a source that is $4.65\sqrt{B}$ can be deduced where B is the background.

3.1.2.2.4 Scan Speed—Scan speed is defined as the rate in feet per minute at which a given source can be moved parallel to the face of the detector assembly at a given distance and be detected with a count rate that is at least 50% of the count rate of that check source when located at the position normal to the center of the scintillator. The recommended distance is 30 cm.

3.1.3 Neutron Detector Tests

3.1.3.1 Acceptance Tests.

3.1.3.1.1 Neutron Efficiency—The neutron efficiency of the He-3 detectors shall be measured using a Cf-252 source located 30 cm from the front face of the detector assembly. The efficiency shall be defined as the counting rate of each neutron detector divided by the neutron emission rate of the source. The emission rate of the neutrons is calculated from the output activity of the source at the last assay date, the neutron emission probability (neutrons per fission), and the half-life of the isotope. The summed efficiency of the two He-3 detectors shall be equal to or greater than 0.5% (reference TS 3.2).

3.1.3.1.2 Count Rate—The count rate of the neutron electronics shall be measured to verify a count-rate capability of 50,000 counts per second with less than 10% counting losses. Input counts to the electronics will ideally be from a pulser unit to a test input, if available. If no input point is available, an attempt should be made to attach the pulser to an acceptable point in the existing electronics circuit. If necessary, a check source (Cf-252) can be used. Note, however, that the use of a check source will include the response of the He-3 detectors. The technical specification of the RFP requires a minimum count rate for the electronics only. As a last resort, minor modifications to the electronics may be made to attach a pulser, but only after all other tests have been performed and accepted (reference TS 3.7).

3.1.3.1.3 Analog Output—The analog output signals from both neutron detectors shall be measured to verify that (a) the analog output voltage is linearly proportional to count rate from -5 Vdc (zero count rate) to $+5$ Vdc (50,000 counts per second) and (b) the output is capable of driving a 1 megohm load. These tests should be made using a pulser unit. Input rates in steps of 5,000 counts per second will be acceptable (reference TS 3.8).

3.1.3.2 Characterization Tests.

3.1.3.2.1 Energy Range—The energy range of the neutron detectors shall be measured. The possible methods available to make this measurement are identical to those used to measure the energy range of the gamma detectors. See Section 3.1.2.2.2 above.

3.1.3.2.2 Lower Limit of Detection—For the purposes of this test, the lower limit of detection is defined as the maximum distance from the face of the detector assembly for a given check source that results in a count rate at the analog count rate output that is at least twice the output of the ambient background at the location of the test. This definition requires the measurement of the background prior to the measurement of the lower limit of detection. Measurements should be such that the check source is placed normal to the center of the front face of the neutron detector and begin 30 cm from the front face of the assembly and increase in 10-cm increments. The check source shall be Cf-252. Alternatively, all measurements will be made at a 30-cm distance of the source from the front face of the detector and the source strength lowered until the strength of a source that is $4.65\sqrt{B}$ can be deduced, where B is the background.

3.1.3.2.3 Scan Speed—The scan speed is defined as the rate in feet per minute at which a given source can be moved parallel to the face of the detector assembly at a given distance and be detected with a count rate that is at least 50% of the count rate of that check source when located at the position normal to the center of the scintillator. The recommended distance is 30 cm. The recommended source is Cf-252.

3.2 Test of the Gamma-Ray Spectrometer

3.2.1 Installation of Gamma-Ray Spectrometer

The following steps are to install a gamma-ray spectrometer:

1. Using a source of Am-241 verify the 60-keV gamma-ray peak lies above the lower-level discriminator with the gain set for ~ 11 MeV full scale (maximum gamma-ray channel).
2. Using a PGNA setup (see arrangement used for assay of chemical agent with PINS⁵), with a polyvinyl chloride (PVC) plastic sample, and a ~ 5 μ g Cf-252 neutron source set the gain of the Ge spectrometer so that an acquired spectrum covers the energy range of interest (i.e., ~ 200 to $\sim 11,000$ keV) and verify that no undesirable noise is entering the spectrum.

3. Remove the Cf-252 source. Reintroduce the Am-241 source and verify that the 60-keV gamma-ray peak lies above the lower-level discriminator.
4. Remove the Am-241 source. Reintroduce the Cf-252 using the PGNAA setup described above and reacquire a PGNAA spectrum of the PVC sample. Verify that the pulser peaks are in the upper portion of the spectrum reserved for them.
5. Verify that the VAXGAP family of programs are loaded and operating on the Microvax by the acquisition and analysis of a spectrum. Check that the display is operating, while a spectrum is being acquired, by entering the DAS command.

Suggestion: Use the DAS routine during spectral acquisition to check that the pulser peaks are in the correct channel regions reserved for them and that their widths are sharp with no apparent gain shifts.

6. Document the results of these measurements.

3.2.2 Automatic Energy Calibration with Dual-Energy Pulser

The following steps are used for automatic energy calibration with dual-energy pulser:

1. With a PGNAA setup as described in Step 2 of Section 3.2.1, acquire a spectrum that is suitable for energy calibration of the dual-energy pulser peaks (~50,000 to 100,000 counts in the peak channel of the strongest gamma-ray peaks of interest). A plastic PVC cylinder provides a source of prompt capture gamma-rays of chlorine extending across the entire energy range from 516 keV to above 8 MeV.
2. Store the acquired spectrum in its associated spectrum slot (with the *S90* command) and energy calibrate the pulser peaks with the automatic pulser energy calibration routine (using the *PEQCL* command).
3. Verify that the pulser pulses have been calibrated correctly by acquiring a second spectrum and scanning the stronger peaks of the entire spectrum—the energies of the gamma-ray peaks should lie within 1 keV of the true energy.
4. Automatically analyze the spectrum with one of the automatic analysis programs (e.g., GNUL) and compare the known chlorine energies with the measured values; document the differences. Compare the energy resolution with that quoted by the manufacturer. It should lie within 5% of the manufacturer's measured value.
5. Verify that the radionuclide identification program is working properly by checking that the chlorine peaks are so identified (use CHEMLIBS isotope library). Label the spectrum using the HEAD command and save the spectrum in the save area. The spectrum ID should follow the following format: ADC ID (2 digits), month data acquired (2 digits), date data acquired (2 digits), year data acquired (2 digits), and the sequence of the count for that day (3 digits). Refer to the VAXGAP *User's Manual* for help with these or other commands.

6. Disassemble the Cf-252 source/moderator/shielding assembly, remove the PVC sample, and introduce a Co-60 source. Acquire a spectrum and analyze it with the automatic spectral analysis program or the interactive analysis program GINA. Measure the energy resolution of the 1,332-keV peak and compare to the manufacturer's measured and warranted value. The measured energy resolution should be within 5% of the warranted value. Measure the full-width-at-fiftieth maximum and compare to the manufacturer's warranted value. The measured value should lie within 5% of the warranted value.
7. Remove the Co-60 source and replace it with a radioactive source of a radionuclide expected to be present in excavated waste (e.g., Cs-137, Eu-152). Acquire a spectrum and measure the deviations of the energies of the peaks from their true values. Analyze the spectrum using a decay data library (e.g., MASTER) tailored for long-half-life radionuclides expected at a waste excavation site. The objective is for these peaks to lie within 1 keV of their true values but this may not be the case for energies below 500 keV or above 8 MeV.
8. Document these results.

3.2.3 Suitability of One Gain to Cover Entire Energy Range of Ge Spectrometer

One important determination to be made in order for the Ge spectrometer to meet its operational technical specifications is to determine if one gain setting is sufficient to cover the entire required energy range from 60 keV (Am-241) to 11 MeV (nitrogen prompt gamma-ray). If both gamma-ray decay data and prompt gamma-ray data can be acquired with one gain setting, the operation of the Ge spectrometer can be simplified. If not, other provisions will be required to permit the Ge spectrometer to be used to acquire both types of data.

1. With the above gain setting covering the energy region from ~40 keV to 11 MeV acquire a spectrum of Am-241.
2. Examine the spectral data for the 60-keV peak of Am-241. It should be defined by at least four channels. Analyze the spectrum using one of the analysis programs.
3. With the same gain setting and with the PGNAA setup, insert a sample containing hydrogen, chlorine, iron, or other high cross-section material with a number of prompt capture gamma-rays covering the energy range from ~500 keV to ~11 MeV. Acquire a spectrum and analyze it with the CHEMLIBS radionuclide library. Verify that the energies of the strong gamma-rays are within 1.5 keV of the "true" values listed in the library. The energy values may not achieve this accuracy.
4. Record the results.

3.3 PGNAA Measurements with the Gamma-Ray Spectrometer

PGNAA measurements with this system, which employs a ~5 μ g Cf-252 source, will be used to measure chlorine in waste or as a plume as a function of depth with a Cf-252-based PGNAA

system using as a sample an 8-gal drum containing ~40% chlorine (in the form of NaCl) and sand. The soil thicknesses are simulated with the use of rectangular-shaped aluminum containers of ~21 in. height by ~21 in. width and 3 in., 6 in., or 12 in. in depth. These containers can be filled with soil and assayed singly or in a stack to simulate soil depths from 3 in. to 15 in. These measurements will also measure the depth of soil (up to 15 in.) that will attenuate the chlorine capture gamma-rays to the point that they cannot be observed ($LLD = 4.65\sqrt{B}$) in a 3,600-second count. The chlorine gamma-rays will be produced with a Cf-252 source located either at the drum (transmission geometry) with the containers of soil between the drum and the Ge spectrometer or at the side of the Ge spectrometer (backscatter geometry) with the neutrons having to penetrate the containers of soil to interact with the chlorine in the drum. Results from these measurements shall be documented.

3.3.1 PGNA Measurements

The following procedure is recommended for PGNA measurements:

1. After setting up the PGNA Ge spectrometer and source assembly, energy calibrate the PGNA Ge spectrometer as described in Section 3.2.2.
2. Set up an 8-gal drum containing a mixture of sand and chlorine about 9 in. to 12 in. above the floor with room for the containers of soil to be placed between the detector and the 8-gal drum.
3. With the Cf-252/poly block/shadow shield in the backscatter geometry acquire counts with no soil covering the drum, and 3 in., 6 in., 12 in. and 15 in. of soil covering the drum. Save the spectra.
4. Repeat Step 3 for the transmission geometry.
5. Analyze the spectra for peak areas of the stronger gamma-ray peaks.
6. Plot the peak areas as a function of the soil depth.

4. SEQUENCE OF ACTIVITIES

The basic sequence of activities for the FY-94 performance tests and PGNAA measurements will be as follows:

1. Requisition the neutron/gamma mapper with a specification that will meet the needs of the digface characterization project.
2. Rebuild aluminum soil containers constructed in FY-93 so that they can be stacked and so that they can be handled safely (anchored to a base plate when in experimental use or in storage).
3. Upon delivery of the neutron/gamma mapper, check that all deliverables are present and that no visual damage has occurred in shipment.
4. Milestone: delivery of neutron/gamma mapper to be by July 1, 1994.
5. Install dual-energy pulser on Ge spectrometer and modify ADC to accommodate dual-energy pulser interface.
6. Develop a support mechanism for the Ge spectrometer with bismuth germinate (BGO) annulus so that this spectrometer can be either suspended from a crane or from the digface trolley.
7. Commence experimental PGNAA measurements.
8. Commence experimental measurements on neutron/gamma mapper.
9. Install gamma-ray spectral analysis software on Microvax computer.
10. Commence experimental measurements on Ge spectrometer without testing BGO annulus.
11. Complete FY-94 scope of work by August 31, 1994.

5. SAMPLING AND DATA

No sampling is conducted. Data collection will be with standard radiation measurement equipment in the form of pulses or an analog signal that will be connected to a strip chart recorder. Standard acquisition techniques will be employed. Ge spectra will be analyzed with the VAXGAP family of spectral analysis programs.

BWID has pursued development of the digface concept based on the belief that it will contribute to protection of human health and environment during cleanup of certain types of hazardous sites. Table 2 attempts to summarize the applicability of the digface characterization system to this purpose in the context of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria listed in the *BWID Test Plan Guidance*.⁴ The data being collected during the FY-94 digface characterization field tests are needed to understand the system's basic capabilities for detecting dangerous or unexpected conditions during excavation of a hazardous site.

Table 2. Applicability of digface characterization to CERCLA criteria.

Criteria	Applicability
1	The digface characterization system will provide possible warning of hazardous conditions during site cleanup. The alternative is to detect these conditions after they have been released and dispersed into the local environment, which may be a containment structure of open air.
2	NA
3	Long-term effectiveness of site cleanup is not impacted by digface characterization.
4	Digface characterization can potentially identify hazards before they are disturbed. The alternative approach cannot, leading to the probability that employment of digface characterization can reduce the spread of contaminants and thus the volume requiring treatment.
5	Short-term effectiveness of site cleanup is not impacted by digface characterization.
6	The alternative is easily implemented since it involves essentially a "no action" approach.
7	The alternative to digface characterization costs nothing since it is essentially a "no action" approach. However, the costs for (a) down time due to encountering sudden dangerous conditions and (b) additional treatment due to spreading of contamination by excavation equipment may be large. Digface characterization is aimed at avoiding these costs.
8	NA
9	NA

6. DOCUMENT CONTROL

6.1 Data

Copies of all data and validated data will be recorded in INEL registered logbooks or stored on personal or VAX computers. The PIs will be responsible for their respective data and store it in a project file. Copies of all data will be forwarded to BWID for backup storage. Reports of data and results of tests will be documented through letters or informal reports. The results of major findings will be reported at technical meetings or published in the open literature. All software programs and spectral data are copied bimonthly to a backup tape.

6.2 Test Plan

This test plan will be revised as required and controlled by the PIs responsible for these tests. Only the PIs can authorize deviations from this test plan. Deviations from this test plan will be documented in laboratory notebooks. Any changes that would represent a significant modification to the technical methodology and thereby impact other tasks within the digface characterization project will be discussed first with the primary PI, N. E. Josten.

7. ANALYTICAL METHODS

No samples are analyzed.

8. DATA REDUCTION, VALIDATION, AND VERIFICATION

8.1 Data Quality Objectives

Data quality objectives (DQOs) of the FY-95 work focus on determining the accuracy and precision that can be expected of the operational parameters for the gamma-ray/neutron and the gamma-ray spectrometer. These determinations will allow evaluation of the capability and performance achievable with these digface characterization instruments and methods. The DQOs for all specific parameter measurements should be at least $\pm 25\%$. All of the data shall be internally consistent and representative of similar data taken for other projects as determined by the PI in charge of the measurements. Data will be validated by review of the test measurements by a second PI.

The data objectives for the gamma-ray/neutron radiation mapping and hot spot detector are listed below:

- a. The scanner shall be able to assay a surface at a scan speed of 30-cm per 10 seconds.
- b. The plastic scintillation detectors shall have a summed efficiency for Cs-137 of 2% with an uncertainty of 15%.
- c. The neutron detectors shall have a summed efficiency for Cf-252 fission neutrons of 0.5% with an uncertainty of 25%.
- d. The gamma-ray/neutron detector shall be able to be decontaminated with decontamination solution under field conditions without solution entering the protective encasement.
- e. The analog signal from the above detectors will be sensitive to variations of $\pm 10\%$ in the signal and be visibly discernable from a chart recorder at both high and low count rates.

The data objectives for the gamma-ray spectrometer are listed below:

- a. The gamma-ray spectrometer shall operate over a range of 50 keV to ~ 11 MeV and still permit the measurement of gamma-rays as low as 60-keV (Am-241) and as high as 10.8 MeV (nitrogen prompt gamma-ray).
- b. The gamma-ray energy scale shall be automatically calibrated (under program control) with a sample of PVC plastic and a Cf-252 source providing the spectrum from which the pulser pulses are calibrated to be energy equivalent. The automatic calibration shall determine the energy scale from 50 keV to 11 MeV to within 2 keV for all energies within this range.
- c. The library used for the identification of radionuclides in waste at an excavation site shall be installed with the analysis program.

The DQO for the PGNA system is to determine the maximum depth of soil that can cover a waste container or waste plume and still detect ($LLD = 4.65\sqrt{B}$, where B is the background) chlorine by an assay on an 8-gal drum filled with sand containing 66% softener salt (NaCl), 40% chlorine, with 95% confidence.

8.2 Data Reduction Scheme

Data from the Ge spectrometer will be analyzed using the principles described in American National Standard N42.14 for the "Calibration and Use of Ge Spectrometers." The VAXGAP⁶ family of gamma-ray analysis programs will be used in conjunction with spectral plotting programs to analyze the Ge gamma-ray data. Energy calibration of the Ge spectrometer will be performed using the method developed by E. W. Killian and described in the VAXGAP *User's Manual*.⁷ The gamma-ray/neutron data will be analyzed using techniques described in Reference 8.

The PI in charge of the specific test will be responsible for validating the acquired data.

8.3 Data Reporting

Data collected during these tests will be evaluated, peer reviewed, and documented in a letter to N. E. Josten, the primary PI of the digface characterization project. Copies of the letter will be distributed by the PI of the digface characterization project.

9. QUALITY ASSURANCE

The quality level for these instruments and tests will be Level 3. All activities will follow the guidance in the EG&G Idaho *Quality Manual*. The Quality Program Plan is QPP-044. The policies described in QP-15, "Control of Nonconforming Items," are invoked with the clarifications described in Sections 9.1-9.5. Quality control will be maintained by checking the condition of each instrument prior to taking measurements. In some cases this will be done with a check source. In other cases it will be done by inspection of the spectral data. All data will be inspected for consistency. Energy measurements will be made with gamma-rays whose energies are accurately known. When specific parameters are to be measured, the data quality objective shall be at least $\pm 25\%$. Changes in any of the instrumentation will be the authority of the PI in charge of the test. The primary PI, N. E. Josten, will inspect the test activities and documentation at least once.

10. EQUIPMENT AND INSTRUMENTS

The equipment required to run the test are:

1. Neutron/gamma mapper with power supply (24-Vdc, 2-amp power supply).
2. Ge spectrometer including detector, high voltage bias supply, amplifier, analog-to-digital converter, acquisition interface module, and VAX workstation or comparable computer (e.g., Radiation Measurements Laboratory computer, MAX).
3. Neutron excitation sources of Cf-252 and gamma-ray sources of Co-60, Eu-152, and Am-241.
4. Neutron and gamma-ray shielding.
5. Strip chart recorder with built in voltage calibration.

All of the above equipment must be able to function in a laboratory environment.

11. SUPPLIES, UTILITIES, AND FACILITIES

Implementation of this test plan is dependent on the timely arrival of the neutron/gamma mapper, and availability of a machinist. The remainder of the work will be performed by the authors of this test plan or by other staff members within their organizations. The equipment requires 110 Vac power. The facilities for performing this work are available in the TRA laboratories.

12. HEALTH AND SAFETY

Safety is a priority concern with all measurements and experiments. These measurements will be performed under standard practices and procedures in accordance with the attached categorical exclusion (see Appendix D). These practices include Independent Safety Review Group approval and the operation under a Radiation Work Permit whenever a Cf-252 or other calibration or check sources are in use. All measurements will be in accordance with the TRA Health and Safety Plan.

13. RESIDUALS MANAGEMENT

No hazardous wastes or residuals will be produced as a result of this activity.

14. REFERENCES

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4. L. C. Rounds and J. K. McDonald, *Buried Waste Integrated Technology Test Plan Guidance*, EGG-WTD-9800, Rev. 1, January 1994.
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6. E. Wayne Killian and J. K. Hartwell, *VAXGAP: A Code for the Routine Analysis of Gamma-Ray Pulse-Height Spectra on a VAX Computer*, EGG-2533, U.S. Department of Energy, May 1988.
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Appendix A

Conceptual Drawings Showing Use of Sensors at an Excavation Site

A-3

Overburden Removal

1. Systematic, controlled excavation of soil only
2. Avoid contamination of clean soil
3. Repetitive, precision, planar, multi-level scans performed by dig-face characterization system under ideal conditions

Dig-face Characterization during overburden removal

1. Provide estimates of depth to waste - basis for achieving maximum removal of clean overburden
2. Construct map of waste "compartment" boundaries and berms in plan view - useful for planning barrier locations or stopping points
3. Establish general characteristics of each waste compartment - link to historical records
4. Locate major radioactive or volatile contaminant hot spots and unusual waste objects - used to plan retrieval strategy

Waste Seam Excavation

1. Heavy construction style digging in hostile, uncontrolled environment of the waste seam
2. Assume all recovered material will require assay, but only a portion will require expensive processing or treatment
3. Waste seam environment changes constantly

Dig-face characterization during waste seam excavation

1. Routine scanning to monitor radioactive and volatile contaminant hot spots
2. In-depth in situ assay of exposed suspicious containers
3. Occasional systematic geophysical surveys to locate important objects such as reactor cores, vehicles etc.

1.

DFC system performs systematic surveys with geophysical and hazard sensors within a predefined search area. The objective is to locate two hot spots (one radioactive source, one volatile organic source) by either detecting them directly or by detecting unique containers or waste configurations associated with them. If hot spots prove undetectable from the original ground surface, overburden is stripped in small increments followed by renewed characterization.

Complete Overburden Stripping

A-6

Remainder of overburden removed to form work space around each hot spot. DFC system performs systematic surveys to estimate proximity of waste to avoid contacting objects with excavator. PNL radar system may prove ideal for this purpose. At end of this phase, waste seam is exposed and hot spot has been precisely located in X-Y plane. Also boundaries, berms, waste-free areas etc. are determined to assist in planning retrieval approach.

Waste Retrieval

Access to hot spot gained by construction of trench into waste. Non hot spot waste removed and conveyed using full suite of BWID technologies. DFC system begins performing assay of exposed containers when retrieval nears hot spot location. At the end of this phase, a positive visual identification has been made of the hot spot source and plans are made for surgical removal.

Surgical Removal of Hot Spot

Source container removed by crane deployed equipment. DFC system then rescans dig-face to detect any contamination spread or presence of additional sources.

Appendix B

Specifications in Request for Proposal for Gamma/Neutron Radiation Mapper

3.0 Requirements

- 3.1 The entire monitor assembly shall not exceed 200 pounds total weight.
- 3.2 Neutron detection shall be accomplished using two identical helium-3 proportional counters. These detectors shall be equal to or greater than 45 centimeters but less than 61 centimeters in length and shall be either 2.54 or 5.04 centimeters in diameter. Detectors of 2.54 centimeter diameter shall be filled with ten atmospheres absolute of helium-3. Detectors of 5.04 centimeter diameter shall be filled with three atmospheres absolute of helium-3. The summed efficiency of the detectors in their experimental configuration shall be measured with neutrons emitted from a Cf-252 source located 30 centimeters from the front face of the detector assembly and shall be greater than or equal to 0.5%.
- 3.3 The two helium-3 detectors shall be installed side-by-side inside a box-shaped neutron chamber constructed of polyethylene sides and back with thickness equal to or greater than 2.54 centimeters. A polyethylene wall the same thickness as the sides and back shall be placed between the two detectors. This effectively creates two identical neutron chambers, each containing a single helium-3 detector. The front face of the neutron chambers shall be a single sheet of 1.27 centimeter thick polyethylene.
- 3.4 Gamma ray detection shall be accomplished using two identical plastic scintillation detectors. The thickness of each scintillation detector shall be equal to or greater than 2.54 centimeters but shall not exceed 3.81 centimeters. The area of the front face of each scintillation detector shall be approximately equal to the area of a single neutron chamber (see 3.3 above) such that a single scintillation detector shall approximately cover a single neutron chamber. The summed efficiency from both gamma ray scintillation detectors shall be equal to or greater than 2.0% for gamma rays emitted from a Cs-137 source located 30 centimeters from the front face of the detector assembly.
- 3.5 A graded shield of 2 millimeter thick tin and 0.32 to 0.63 centimeter thick lead shall be placed around the sides and back of the plastic scintillation detectors. This shield is desirable to reduce the background gamma ray signals from sources not facing the front of the instrument. Deviations from this specification

(due to overall weight restrictions) may be allowed but must be approved by the contractor. The plastic scintillator assembly with the tin and lead shield shall be placed in front of the 1.27 centimeter thick polyethylene front face of the neutron chambers assembly such that the tin/lead shield on the back of the scintillators is between the polyethylene and the plastic scintillators.

- 3.6 The gamma ray - neutron monitor shall accept +24 volt direct current for primary power. The design shall provide internal power and signal conditioning and incorporate accepted design practices to optimize signal to noise ratio. The design shall minimize interference from external noise sources including gasoline engine spark, rf and microwave radio transmission, etc.
- 3.7 Each of the four radiation detectors (two each neutron and two each gamma ray) shall have independent and complete electronic signal processing systems such as preamplifiers, amplifiers, counters, etc. The helium-3 neutron detector electronics shall be capable of count rates to 50,000 counts per second with less than 10% counting losses. The plastic scintillator gamma ray detector electronics shall be capable of count rates to 1,000,000 counts per second with less than 10% counting losses.
- 3.8 The electronics for each of the four detectors shall be designed as pulse counting systems. The output signals for each detector shall be proportional to counts per unit time. The unit shall provide an analog output signal for each detector. Digital output may also be provided at the discretion of the subcontractor, but is not mandatory. Analog signals shall be linearly proportional to count rate and shall be from -5Vdc to +5Vdc at the maximum count rate. Analog outputs shall be capable of driving a 1 megohm load.
- 3.9 The entire detector assembly, including electronics, shall be hermetically sealed inside an external case material (material to be approved by contractor scientists) that is easily decontaminated by scrubbing or submersion within a decontamination solution. The external case shall be capable of being easily opened for detector and/or instrumentation maintenance.
- 3.10 Connectors for power and signals shall be military style connectors. Separate power and signal connectors shall be provided. However, signals for all four detectors may use a single connector. The

subcontractor shall provide three identical spare connectors for each connector used in the system plus mating connectors for all installed and spare connectors.

- 3.11 Documentation consisting of detector drawings, schematic diagrams, assembly drawings, specifications, and operational and maintenance manuals shall be provided by the subcontractor. External connection schematics and analog output conversion factors shall be explicitly provided in the documentation.

4.0 Deliverables

There are two specific deliverables for this procurement. The first is a working gamma ray - neutron monitor built to the specifications and requirements described in this Technical Specification Document. The second deliverable is documentation describing calibration procedures, input and output schematics, theory of operation (i.e. time lags and constants), and analog to digital conversion factors in concert with Section 3.11 of this specification.

- 4.1 The system shall be delivered to the contractor on or before July 1, 1994.

Appendix C

Chapters 2 and 5 of GNM-620 Operating and Service Manual (Gamma/Neutron Radiation Mapper)

2. INSPECTION AND SET-UP

2.1. INSPECTION

The following procedures should allow on-site personnel to correctly set up the GNM-620 for normal operation. Follow the procedures in the order given.

2.1.1. Incoming Inspection

Immediately inspect the instrument for mechanical damage, scratches, dents or other defects. It should be examined for evidence of concealed, as well as external damage.

2.1.2. Damage Claims

If the instrument is damaged in transit or fails to meet specifications upon receipt, notify the carrier and TSA Systems, Ltd. immediately. Shipping cartons, packing materials, waybills and other such documentation should be preserved for the carrier's inspection.

TSA will assist in providing replacement or repair of the instrument if necessary.

2.1.3. Storage

The GNM-620 should be stored in a dry, temperature constant location, and care should be taken to avoid subjecting it to severe mechanical or environmental shock.

2.1.4. Shipping

Before returning the instrument for any reason, notify TSA Systems of the difficulty encountered, giving the model and serial numbers of the equipment. TSA will furnish specific shipping instructions.

2.2. SET-UP

NOTE: THE GNM-620 IS NOT EQUIPPED WITH A POWER SWITCH. IT IS ON WHENEVER IT IS CONNECTED TO POWER.

Connect the hand-held terminal to J3 on the GNM-620.

The GNM-620 requires 18 to 36 Vdc power at approximately 5 amps. Connect the power cable to the host vehicle power system. Observe polarity, pin A is positive and pin B is negative.

The terminal will turn on, run a power-on self-test and begin displaying the counts from the four detectors.

Press "F1" on the terminal to view or set the full-scale value for the gamma channels. The default is 50,000 counts for +5 volts out. Input a new value from the keypad and press "ENTER". Press "ENTER" to accept the displayed value.

Press "F2" on the terminal to view or set the full-scale value for the neutron channels. The default is 500 counts for +5 volts out. Input a new value from the keypad and press "ENTER". Press "ENTER" to accept the displayed value.

This utility allows the operator to calibrate the GNM-620 to the analog recording device. The analog output will swing from maximum negative to 0 to maximum positive output. Press F5 on the terminal to access the DAC control utility. All four DACs are all loaded with 0s, the analog outputs will be -5 volts. Pressing "F5" again will load the DACs with 127, the analog outputs will be 0 volts. A third press on "F5" loads 255, the analog outputs will be +5 volts.

2.3. DISCRIMINATOR ADJUSTMENT

The discriminator adjustments are located on the barrier plate on the right side of the enclosure. They are labeled to indicate upper and lower for both the gamma and the neutron channels.

2.3.1. GAMMA DISCRIMINATORS: The GNM-620 has two controls which may be used to "tailor" it to specific site applications. The controls are the Upper Level Discriminator (ULD), and the Lower Level Discriminator (LLD) for the gamma channels. The factory settings will not cover all operating conditions. The discriminator window may be optimized for site specific requirements. See Drawing 3 for the location of the discriminator controls.

The upper level discriminator (ULD) and lower level discriminator (LLD) set the range of energy levels in which the system takes counts. The maximum range is between 0 keV and 2 MeV. Multiplying the dial setting by 200 will yield the nominal KeV level; i.e. a setting of .3 on the LLD will indicate a low level discriminator setting of 60 KeV above the noise level of the amplifier.

NOTE: THIS RELATIONSHIP IS AN APPROXIMATION. DUE TO MINOR VARIATIONS IN THE DETECTORS AND ELECTRONICS, THE EXACT VALUES WILL VARY SLIGHTLY. AS EXACT VALUES ARE SITE SPECIFIC AND MUST BE VERIFIED EMPIRICALLY, ALL VALUES GIVEN IN THIS MANUAL ARE RECOMMENDATIONS ONLY.

Factory settings are as follows:

LLD: 0.2 turns = 20 keV
ULD: 10 turns = 2 MeV

2.3.2. NEUTRON DISCRIMINATORS

The neutron discriminators are electronically similar to the gamma discriminators, but serve a different purpose. The neutron discriminators allow the system to only count neutrons that fall within the proportional operating region of the detectors. The GNM-620 is shipped with the neutron discriminators set as follows:

LLD = 1.0 volt
ULD = 10.0 volts

In most circumstances, these settings should not require further adjustment.

3. OPERATING INSTRUCTIONS

WARNING: THE GNM-620 IS MOUNTED IN A WATER TIGHT CASE WITH LIMITED PENETRATIONS. ALL PENETRATIONS ARE SEALED WITH SILICON SEALER. IF THE BOLTS OR CABLES THAT PENETRATE THE ENCLOSURE ARE DISTURBED, THEY MUST BE RESEALED TO PRESERVE THE INTEGRITY OF THE ENCLOSURE.

The system was designed to withstand submersion in water for brief periods to allow decontamination. Do not leave the system submersed in liquid for extended periods of time.

3.1. POWER-UP AND SELF-TEST

When the unit is powered up, it performs a memory test on the RAM, and automatically begins counting.

3.2. NORMAL OPERATION

After the set-up has been performed, normal operation involves mounting the GNM-620 onto the host vehicle, connecting the input power and the analog recording device. The GNM-620 is now ready for operation.

5. MAINTENANCE

5.1. CALIBRATION

WARNING: THIS PROCEDURE INVOLVES HIGH VOLTAGE AND SHOULD ONLY BE DONE BY QUALIFIED PERSONNEL!!!

Equipment needed:

- Gamma test source (5 - 10 μCi ^{137}Cs)
- Neutron test source (TSA uses 100 mCi AmBe)
- DVM
- Oscilloscope
- High voltage probe 5 kVdc, $\geq 1,000\text{ m}\Omega$ input Z

5.1.1. Gamma Channels

The gamma channels use HHV-448 and SCA-452 number 2 in the system. For the other HHV-448 and SCA-452 refer to the neutron channel calibration, section 5.2 in this manual.

5.1.1.1. HHV-448

The HHV boards are located under the barrier plate. Remove the two outer screws and swing the barrier plate in to gain access to the board.

While following this procedure refer to the schematic diagram and component designator (drawings 4 & 5).

Connect the high voltage probe (+) to the H.V. connection on the HHV-448 board and the ground to chassis ground or the COM. connection on the HHV-448 board. Turn on the DVM.

Adjust R1 on the board to achieve a reading of 1050 ± 50 volts DC. If the voltage will not reach this level or is not stable within ± 5 volts, the board must be replaced.

Perform this procedure on each HHV-448 board in the system.

5.1.1.2. SCA-452

CAUTION: BEFORE PROCEEDING MAKE SURE THAT THE HIGH VOLTAGE TO THE DETECTORS IS SET TO 1050 VDC PER THE HHV-448 CALIBRATION PROCEDURE.

While following this procedure refer to the schematic diagram and component designator (drawings 7 and 8 respectively).

Disconnect the inputs from the SCA board by removing the wires from J1, J2 and J3*. Connect the DVM from ground jumper X4 (-) to R94 (+) on the end closest to J6, then by adjusting R95 obtain a reading of 10.00 volts on the DVM. This is the reference voltage to the discriminators.

Leave the common lead of the DVM on the ground jumper X4, and move the other lead to TP2 on the SCA board. Adjust R14 to obtain a reading of -5.0 millivolts on the DVM. Move the lead from TP2 to TP4 and adjust R43 to obtain a reading of -5.0 millivolts. Move the lead to TP6* and adjust R77 for a reading of -5.0 millivolts. This adjusts the offset of the gain stages.

Connect the oscilloscope to the SCA-452 board and set as follows: vertical input to TP2 and probe ground to X4. Set vertical deflection to 1 volt/division, horizontal sweep speed to 0.5 microseconds/division and positive edge triggering. Place the source in the center of the chamber to be calibrated. The signal seen should resemble drawing 14 "Typical Pulse Profile."

If not, adjust R7 on the SCA board to obtain a $3.3 \text{ volt} \pm .3 \text{ volts}$ pulse height. Move the probe to TP4 and ensure that the source is in the center of the chamber being calibrated. Adjust R37 for the same pulse height. Move the probe to TP6* and ensure that the source is in the center of the chamber that is being calibrated. Adjust R68 for the same pulse height. The other adjustments are factory set and should not be attempted in the field.

Repeat this procedure for all SCA-452 boards in the system.

*TP6 will only be installed on three channel SCA boards.

5.1.2. Neutron Channels

The GNM-620 has been designed to require very little maintenance. However, the calibration should be checked periodically and whenever any repairs have been made.

NOTE: ALWAYS CALIBRATE THE HIGH-VOLTAGE BEFORE ADJUSTING THE AMPLIFIERS ON THE SINGLE CHANNEL ANALYZER. THE HIGH VOLTAGE SETTING WILL CHANGE THE PULSE AMPLITUDE THAT IS SENT TO THE SCA-452.

CAUTION: THE FOLLOWING PROCEDURES INVOLVE HIGH VOLTAGE AND SHOULD ONLY BE PERFORMED BY QUALIFIED PERSONNEL!

5.1.2.1. HHV-448

The HHV boards are located under the barrier plate. Remove the two outer screws and swing the barrier plate in to gain access to the board.

While following this procedure refer to the schematic diagram and component designator (drawings 7 & 8).

Measure the high voltage at the output of the HHV-448 board using a high voltage probe and a DVM. The high voltage should be $+1,350 \pm 50$ Vdc. If it is not, adjust R1 to obtain the proper output.

If the output cannot be properly adjusted, or if it is not stable within ± 5 Vdc the board must be repaired or replaced.

5.1.2.2. SCA-452

Remove the inputs from the SCA board by unplugging the wires from J1 and J2.

Discriminator Reference Voltage

Connect a DVM between ground jumper X4 and R94 on the end closest to J6. Adjust R95 for a reading of 10.000 ± 0.005 Vdc.

Amplifier Offset Adjustment

Connect the DVM between ground jumper X4 and TP2 on the SCA-452 board. Adjust R14 for a reading of -0.005 ± 0.001 Vdc.

Connect the DVM between ground jumper X4 and TP4 on the SCA-452 board. Adjust R43 for a reading of -0.005 ± 0.001 Vdc.

Amplifier Gain Adjustment

Reconnect the SCA-452 input cables to J1 and J2.

Connect an oscilloscope probe from ground jumper X4 on the SCA board and TP2.

Place a test source on the right hand gamma detector.

The peak pulse amplitude should be +6 volts ± 0.2 volts. If necessary, adjust R7 to obtain the proper pulse amplitude.

Move the oscilloscope probe from TP2 to TP4 on the SCA-452 board.

Place a test source on the left hand detector.

The peak pulse amplitude should be +6 volts ± 0.2 volts. If necessary, adjust R37 to obtain the proper pulse amplitude.

This completes the calibration of the neutron channels.

Appendix D

Documentation for NEPA Categorical Exclusion (CX) for Radiation Measurements Laboratory at Test Reactor Area

Memorandum

DATE: August 19, 1992

SUBJECT: Categorical Exclusion (CX) for Radiation Measurements Laboratory
(AM/SES-ESD-92-329)

TO: Carol M. Borgstrom, Director
Office of NEPA Oversight
DOE-HQ, EH-25

DOE-ID has reviewed and approved the subject CX (attached). This approval is based on Section "D" NEPA determination authority delegated by the Assistant Secretary for Nuclear Energy. This CX supports indoor bench-scale research projects in the Radiation Measurements Laboratory at INEL's Test Reactor Area.

DOE-ID is forwarding the approved CX for EH-25 review. Please direct any comments or questions to Roger Twitchell at (208) 526-0776.

A. A. Pitrolo
Manager

Attachment

cc w/att: R. Sharma, DOE-HQ, NE-47

AUG 19 1992
AM/SES-ESD-92-329\

EXTERNAL bcc DISTRIBUTION:

N/A

ID DISTRIBUTION:

ESD File (y)
ESD Reading File (g)
Peggy Hinman
Teresa Perkins
Roger Twitchell
Bob Jones, MS 1133

CONCURRENCE:

AM/SES RT for TP 7/30/92
AM/NP 1/1/92 8/1/92
AM/EP CRN 7/31/92
DMO _____

RECORD NOTES:

1. The attached CX was prepared to cover routine laboratory operations and bench scale research at the Radiation Measurements Laboratory. The specific event that made the preparation of this CX advisable was a Work-for-Others (WFO) project for the National Institute of Standards and Technology (NIST). With the approval of this CX, future bench scale research projects at the radiation measurements lab can be undertaken with a letter to the file documenting that the project fits within limits of this particular CX.
2. This CX was prepared by EG&G in coordination with Roger Twitchell (SES) and the NEPA Compliance Officer Teresa Perkins (SES).
3. The attached correspondence has no relation to the Naval Nuclear Propulsion Program. Naval Reactors concurrence is not required.

RLTwitchell (SE&S): rrrhickey, x6-6521, 7/29/92, A:SAMPLTR.CX (File 6-1-6-4

AND
6-9

EVALUATION OF ENVIRONMENTALLY SENSITIVE AREAS

RESOURCE CONCERN	AFFECTED		COMMENT
TERRESTRIAL	YES	NO	
Threatened/Endangered Wildlife		X	
Threatened/Endangered Plants		X	
Wildlife/Vegetation		X	
Soils/Erosion		X	
Cultural/Historical		X	
Wilderness/Scenic Areas		X	
Prime/Unique Farmland		X	
WATER RESOURCES			
Wild/Scenic Rivers		X	
Lakes/Floodplains/Wetlands		X	
Domestic/Groundwater		X	
T & E Fish		X	
AIR RESOURCES/QUALITY			
		X	
HUMAN HEALTH/SAFETY			
		X	
Socioeconomic Concerns		X	

COMMENTS: _____

ATTACHMENT TO ENVIRONMENTAL CHECKLIST
RADIATION MEASUREMENTS LABORATORY

Brief Project Description:

The Radiation Measurements Laboratory (RML) conducts the following on-going activities:

1. Determination of radionuclide content on various sample media using high-resolution gamma-ray spectroscopy;
2. Design, fabrication, and repair of electronic instrumentation; including development and testing of systems used for non-invasive assay;
3. Computer software development;
4. Applied research in radiation physics which includes support of fuel and target development for the MHTGR, evaluation and applications testing of instrumentation to support waste management and remediation efforts, development of advanced concepts for the Office of Arms Control.

The fundamental components of these activities have been a part of the existing operations of the RML since the early 1960's. These activities involve standard laboratory operations and bench-scale research and development. The waste streams and effluents involved with these activities have either remained relatively constant over the years or have been significantly reduced. The amounts and quantities of radioactivity and hazardous materials used and the associated wastes generated have been decreasing over the years as the mission of the INEL has developed more in the environmental arena and nuclear operations are decreasing.

Sources of Impacts:

The following impacts have been identified as being either generated and involved in the RML operations and a brief explanation of each is provided.

1. Solid waste is generated in the form of waste paper and alkaline batteries.
2. Radioactive waste is generated in small amounts in both the liquid and solid form primarily from research and development activities.
3. Hazardous waste is generated in very small quantities from the use chemicals or disposal of outdated chemicals.
4. Chemical storage and use is involved in the handling of chemicals used for electronic cleaning and soldering, film development and various research and development activities.

Sources of Impacts (continued):

5. Radiation exposure could be involved due to the handling of sealed sources or due to the requirements that a job be performed in a radiation area. ALARA goals are established and maintained and reviews are conducted of high exposure activities to minimize exposures received.

The above impacts are involved with RML operations and no new waste streams are identified, no effluents are increasing, and no environmental impacts have been identified based on the RML's operations. Waste streams and missions will remain unchanged if not actually decreased by waste minimization and recycling.

ENVIRONMENTAL CHECKLIST
U.S. DEPARTMENT OF ENERGY - IDAHO FIELD OFFICE

PROJECT TITLE: Radiation Measurements Laboratory PROJECT NUMBER: TRR-92-063

PERFORMING ORGANIZATION: Radiation Measurements Unit CURRENT DATE: 20 July 1992

DOE PROJECT TECHNICAL MANAGER: J.H. Nadler TELEPHONE NUMBER: 526-0796

PERFORMING ORGANIZATION CONTACT: L.V. East TELEPHONE NUMBER: 526-0364

A. BRIEF PROJECT DESCRIPTION: See Attached

(Continuation in Comments or an attachment)

B. SOURCES OF IMPACTS: DOES THE PROJECT/ACTIVITY HAVE THE POSSIBILITY OF INVOLVING, GENERATING, OR RESULTING IN CHANGES TO ANY OF THE FOLLOWING?

	YES	NO	EXPLANATION
1. AIR POLLUTANTS	☐	☒	
2. LIQUID EFFLUENTS	☐	☒	
3. SOLID WASTE	☒	☐	<u>not applicable</u>
4. RADIOACTIVE WASTE	☒	☐	
5. HAZARDOUS WASTE	☒	☐	
6. MIXED WASTE	☐	☒	
7. CHEMICAL STORAGE/USE	☒	☐	
8. PETROLEUM PRODUCTS STORAGE	☐	☒	
9. ASBESTOS WASTE	☐	☒	
10. WATER USE/DIVERSION	☐	☒	
11. SEWAGE SYSTEM	☐	☒	
12. CLEARING/EXCAVATION	☐	☒	
13. CONSTRUCTION/RENOV.	☐	☒	
14. EXCESS NOISE LEVELS	☐	☒	
15. PESTICIDE USE	☐	☒	
16. RADIATION EXPOSURE	☒	☐	

C. CATEGORY EVALUATION CRITERIA

1. Will this action contribute to a cumulative impact with on-going activities?	YES ☐	NO ☒
2. Is this action related to a proposed action with potentially significant impacts?	YES ☐	NO ☒
3. Will the project create uncertain, unique, or unknown risks?	YES ☐	NO ☒
4. Will the project require siting, construction, or expansion of a waste facility?	YES ☐	NO ☒
5. Will the project impact a RCRA-regulated unit or facility?	YES ☐	NO ☒
6. Will the project adversely affect any environmentally sensitive areas? (See reverse)	YES ☐	NO ☒
7. Will the project threaten or violate any statute, regulation, or DOE Order?	YES ☐	NO ☒
8. Will the project require any federal, state, or local permits, approvals, etc.?	YES ☐	NO ☒
9. Has this action/area been previously assessed under NEPA?	YES ☐	NO ☒
10. Will the action take place in an area of previous or on-going disturbance?	YES ☒	NO ☐

D. DOE CONTRACTOR NEPA CATEGORY RECOMMENDATION: ☒ CX ☐ EA ☐ EIS ☐ NOT COVERED IN SECTION D
REFERENCES:

10 CFR 102.1 (57, 5155); Appendix B to Subpart D,
Section B3-6

NAME: Paul S. Moser

SIGNATURE: [Signature]

DATE: 7/21/92

TELEPHONE NO: 525-3919

CATEGORICAL EXCLUSION FOR
RADIATION MEASUREMENTS LABORATORY
IDAHO NATIONAL ENGINEERING LABORATORY (INEL)

Proposed Action: Radiation Measurements Laboratory (RML), Laboratory operations

Location of Action: Test Reactor Area (TRA), Idaho National Engineering Laboratory (INEL), Idaho

Proposed By: Energy Technology Division, DOE-ID

Description of Proposed Action:

The proposed action entails laboratory operations and bench-scale research and development conducted on a routine basis at the Radiation Measurements Laboratory (RML). Fundamental activities including the following: 1) Determination of radionuclide content on various sample media, using high-resolution gamma-ray spectroscopy; 2) Design, fabrication, and repair of electronic instrumentation; including development and testing of systems used for non-invasive assay; 3) Computer software development; and, 4) Applied research in radiation physics which includes support of fuel and target development for the Modular High Temperature Gas Reactor, evaluation and applications testing of instrumentation to support waste management and remediation efforts; and development of advanced concepts for the Office of Arms Control.

The following impacts are involved with RML operations: 1) Solid waste is generated in the form of waste paper and alkaline batteries; 2) Radioactive waste is generated in small amounts in both the liquid and solid form, primarily from research and development activities; 3) Hazardous waste is generated in very small quantities from chemical use or disposal of outdated chemicals; 4) Chemical storage and use is involved in the handling of chemicals used for electronic cleaning and soldering, film development and various research and development activities; and, 5) Radiation exposure could be involved due to the handling of sealed sources, or due to the requirements that a job be performed in a radiation area. As low as reasonably achievable goals are established and maintained to minimize personnel exposure.

Categorical Exclusion to be Applied:

DOE NEPA Regulations, 10 CFR 1021 at 57 FR 15155, Appendix B to Subpart D, as follows:

- Section B3.6: "Indoor bench-scale research projects and conventional laboratory operations (for example, preparation of chemical standards and sample analysis) within existing laboratory facilities."

The proposed action would not: 1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, including requirements of DOE Orders; 2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment facilities; 3) disturb hazardous substances, pollutants, contaminants, or CERCLA-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; or 4) adversely affect environmentally sensitive resources.

Determination:

I have determined that the proposed action for the Radiation Measurements Laboratory at the INEL, meets the requirements for the CX referenced above. Therefore, I have determined that the proposed action is categorically excluded from further NEPA review and documentation.

Approval:

A. A. Pitrolo, Manager
DOE Idaho Field Office

Date:

8/19/92