PNL-10849
UC-606

A Research Report for
Westinghouse Hanford Company

Feasibility Study for Transuranic Nuclide Measurement on Long-Length Contaminated Equipment Using Neutron Detection

D. C. Stromswold
A. J. Peurrung
R. J. Arthur
R. L. Brodzinski

October 1995

Prepared for
the U. S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

DISCLAIMER

DISCLAIMER

Summary

The feasibility of measuring the transuranic (TRU) nuclide content of equipment removed from Hanford's high-level radioactive-waste tanks has been established for components heavier than about 30 kg/m (20 lbs/ft). This conclusion has been reached based on experience with the TRU assay of waste burial boxes, planned improvements to the assay equipment design and assay methodology, and experimental investigation of neutron detector performance in high gamma-ray fields. The experiments indicate that the neutron detectors presently used with Pacific Northwest Laboratory's box scanner perform correctly in gamma-ray exposure rates of at least 3 R/h. The design of equipment proposed for measuring TRU content incorporates multiple, BF_3-gas-filled neutron counters in a configuration that is approximately 0.5 m wide and 2 m long, with polyethylene to moderate high-energy neutrons down to thermal energy. Specially developed electrical systems are used to eliminate response to gamma-rays. Performance of the assay would require 10 to 14 hours of time during which close-range access is provided to the waste and its burial container. A standard neutron source will be placed within the burial container (before inserting components) to allow calibration of the detector. Final calculation of the TRU contamination will utilize plausible conservative assumptions concerning the spatial, isotopic, and elemental distributions of any TRU present. For long-length equipment, the detector array collects data at various positions along the length of the equipment. Separate monitoring of the cosmic-ray-induced neutron background during the assay period will provide confidence that observed changes in counts at the equipment are not related to changing background. Background measurements using the burial container and equipment "skid" will allow compensation for neutrons that are created by cosmic-ray spallation within the burial container.

Contents

Figures

Tables

1.0 Introduction

1.1 Equipment Removed from Hanford Waste Tanks

Equipment removed from the interior of high-level radioactive waste tanks at Hanford is contaminated with radioactive waste. Typical items from Hanford's tanks have dimensions that are long and thin. This allows the objects to be inserted into the tanks through access holes while still reaching to the bottom of the tanks, a distance of up to about 18 m (60 ft). Table 1.1 contains a list of some items in the tanks.

Table 1.1 Items in Hanford Waste Tanks Requiring TRU Survey

Item	Diameter (in)	Length in Waste (ft)	Weight (lb)
Air circulator	11	9	500
Air lift circulator	35	22	3300
Salt well screen	9	23	1100
Salt well casing	11	15	1600
Heel pump	11	21	2800
Agitator pump	7	32	2800
Waste recovery pump	33	30	10000
Mixer pump	39	35	13500

As each piece of equipment is removed from the tanks, it will be rinsed to remove as much contamination as possible, and it be surveyed by a gamma-ray detector (Roach, 1995). A flexible container (heavy-duty bag) will enclose the equipment as it is lifted from the tank. The bagged equipment, along with a supporting skid, will be placed into a long, cylindrical burial/storage tube mounted horizontally on a transport trailer (Figure 1.1). Table 1.2 gives the dimensions and composition of the various tubes for storing or burying the long-length contaminated equipment. The TRU assay must take place after the equipment is in its tube, but before the voids in the tube are filled with grout.

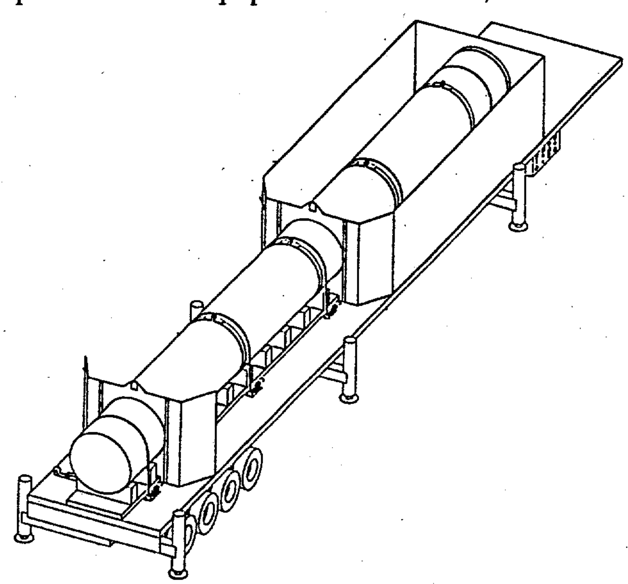

Figure 1.1 Long-Length, Contaminated Equipment on Trailer

Table 1.2 Storage Tubes for Long-Length Contaminated Equipment

Outside diameter cm (in)	Wall Thickness cm (in)	Length m (ft)	Composition
170 (67)	1.4 (0.57)	21 (70)	fiberglass
160 (63)	4.9 (1.9)	21 (70)	polyethylene
160 (63)	4.9 (1.9)	16 (52)	polyethylene
140 (54)	4.5 (1.8)	21 (70)	polyethylene
91 (36)	3.0 (1.1)	21 (70)	polyethylene
91 (36)	3.0 (1.1)	16 (52)	polyethylene
66 (26)	2.0 (0.8)	21 (70)	polyethylene
66 (26)	2.0 (0.8)	16 (52)	polyethylene

1.2 Assay Requirements for Burial/Storage

The amount and type of radioactive contamination and hazardous constituents on the equipment removed from the waste tanks determines whether the equipment will be placed into a waste burial site or stored for later disposal. Although most of the radioactivity associated with the contamination on the removed items is expected to be directly measurable using gamma-ray detectors, the potential presence of transuranic nuclides makes evaluation of neutron detection desirable. (Some transuranics do emit gamma rays, but the emission rate is generally low and easily masked in the presence of stronger gamma-ray emitters such as ^{137}Cs and ^{60}Co.) Transuranics (TRU) present special problems in detection, and they have relatively low limits for acceptance by waste storage and disposal sites. Any TRU (as defined in the next paragraph) in the waste will require the contaminated equipment to be handled and disposed of as transuranic mixed (TRUM) waste. Low level mixed waste (LLMW) items will transferred to a disposal site for burial. However, TRUM waste items will be stored for later disposal.

Transuranic waste, for the purposes of waste disposal, is defined to be any waste contaminated with alpha-emitting TRU radionuclides with half-lives greater than 20 years and combined concentration greater than 100 nCi/g. For waste in the tanks, the relatively long storage times (up to about 50 years) effectively reduces the concentrations of short-half-life TRU nuclides. Neutron measurements provide a means for calculating an upper limit on the total TRU present, based on the observed count rates and conservative assumptions about which specific radionuclides emit the neutrons.The assay alone cannot discriminate between the various TRU nuclides.

1.3 Neutron Counting for TRU

Radioactive decay of TRU material results in the emission of alpha particles, gamma rays, and neutrons. (Some neutrons are produced by nuclear reactions of the relatively high-energy TRU alpha particles with light nuclei in the waste matrix.) Of these three types of radiation, only neutrons are unique to TRU material and have the penetrating power sufficient to escape from large waste objects and allow a quantitative assay. Alpha particles have a very short range and cannot be detected through shielding.

The measured neutron signal is a direct indicator of the waste's TRU content. The only other significant "natural" sources of neutrons, cosmic rays and cosmic ray spallation, will be explicitly accounted for during performance of the assay and later data analysis.

The fast neutrons (energy ~ 2 MeV) emitted by TRU have the ability to penetrate large distances within high-Z materials such as steel and lead and moderate distances within hydrogenous materials such as water and polyethylene. Neutrons must be slowed ("moderated") before they can be detected. Ordinarily this is accomplished by placing a moderating material such as polyethylene at the detector. In the present case, the burial container may provide some moderation, reducing the need for a moderator at the detector.

2.0 Existing Equipment for Use with Burial Boxes and Barrels

Equipment designed and built by the Pacific Northwest Laboratory (PNL) has operated at Hanford for several years to assay the contents of waste containers (Arthur, 1991; Brodzinski et al. 1986). Although different sets of mobile equipment are used for assaying barrels and boxes, the radiation detectors, supporting electronics, and data processing are similar for both applications. A high-purity germanium detector collects data on the gamma-ray-emitting waste, and a neutron-detector array collects data on the TRU waste. Both types of detectors are calibrated using known sources. Results of the surveys are used for certifying the contents of the barrels and boxes for shipping and disposal.

2.1 Flat Detector Array for Boxes

The neutron detector used to survey closed boxes of waste contains an array of 10 BF_3 detectors (each 5 cm in diameter, 1.8 m long) arranged side-by-side and encased in high-density polyethylene, as shown in Figure 2.1. This design is similar to the slab detector design used at the Los Alamos National Laboratory (Sprinkle, 1991). A 2.5-cm-thick sheet of polyethylene at the front face of the detectors helps to moderate neutrons down to thermal energies where the detectors are most efficient. Additional sheets of polyethylene behind the detectors serve as neutron reflectors to enhance the sensitivity to neutrons by reflecting them back to the detectors. They also shield the detectors from background entering from behind the array.

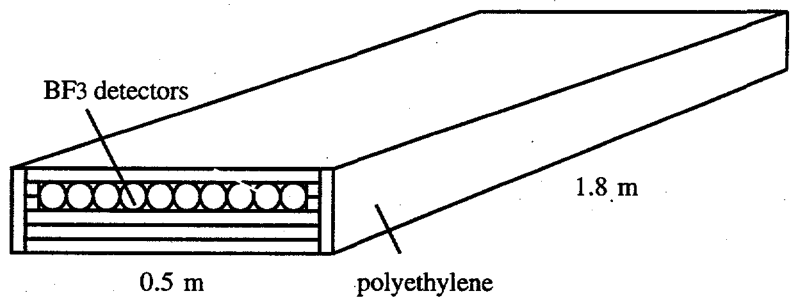

Figure 2.1 Neutron Detector Array for Surveying Waste Burial Boxes

The neutron detector typically surveys boxes of dimension 1.2 x 1.2 x 2.4 m (4 x 4 x 8 ft). The neutron detector is generally placed 46 cm from the center of a large side of the box with the neutron tubes oriented vertically. If the waste can not be assumed to be uniformly distributed within the box, the detector can be placed near other faces of the box also. Typical counting times are 600 sec.

Calibration of the detector is based on using a PuO_2 neutron source with known output, and counting the neutrons from this source transmitted through the box containing the waste. Counting for various distances of the source behind the box enables calculating the efficiency for detecting neutrons from the center of the box (which is not accessible to the calibration source).

Counting the neutron background adjacent to an empty waste box placed in the same location used for the filled box provides the neutron background counts for subtraction during the data analysis to determine the TRU content of a box.

2.2 Curved Array for Barrels

The neutron detector for use with barrels uses 62 BF_3 detectors (5 cm in diameter x 61 cm long) arranged in partial arcs around a barrel, as shown in Figure 2.2. A gamma-ray detector (not shown in the figure) measures gamma rays exiting the barrel through a gap in the neutron detectors. The barrel is placed on a rotating platform that spins the barrel to average the signal from locations within the barrel.

A calibrated source of neutrons provides the means for determining the efficiency of the neutron detectors. The neutron background is obtained by recording counts with an empty barrel placed at the center of the detector array.

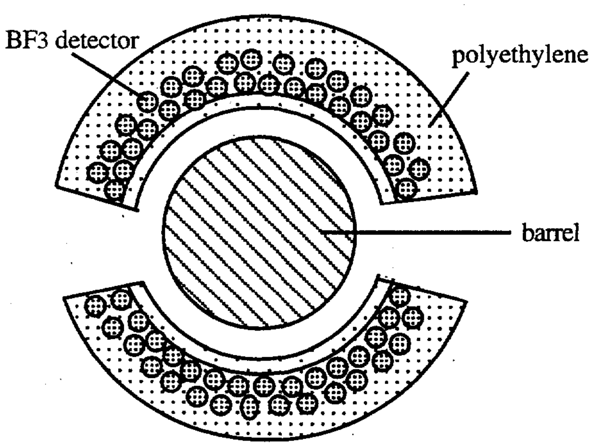

Figure 2.2 Neutron Detector Array for Surveying Barrels

3.0 Equipment for Proposed Use with Contaminated Equipment

3.1 Neutron Detectors

The need to operate the neutron detectors in potentially high gamma-ray fields (3 R/h), combined with the availability of numerous BF_3 detectors at Hanford, led to the selection of BF_3 detectors for use in the proposed assayer of long-length contaminated equipment. In addition, experience with using these detectors in the existing box and barrel scanners has been favorable. Figure 3.1 shows a single BF_3 detector proposed for use. Each detector is a stainless steel tube (5 cm in diameter, 1.8 m long) filled with BF_3 gas at a pressure of about 1 atm. A central wire held at approximately 2500 V collects the electrical charge produced when neutrons interact with the gas. Associated electronics process the charge to produce pulses that are counted each time a neutron is detected.

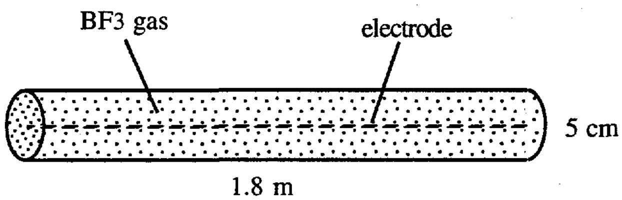

Figure 3.1 Neutron Detector, Single BF_3 Tube

Approximately 10 BF_3 detectors, arranged side-by-side, with polyethylene moderator surrounding them (similar to the box scanner configuration shown previously in Figure 2.1) will form the neutron counter array. The sensitive portion of the array will be approximately 0.5 m wide by 1.8 m long (1.7 x 6 ft). During counting of the contaminated equipment removed from the waste tanks, the detectors will be oriented with their long dimension parallel to the storage tube, as shown in Figure 3.2. Producing a curved array of detectors to match the curvatures of storage tubes would be possible; however, the additional cost for making such an array is not deemed worthwhile, particularly because storage tubes of various diameters will be used to hold the contaminated equipment.

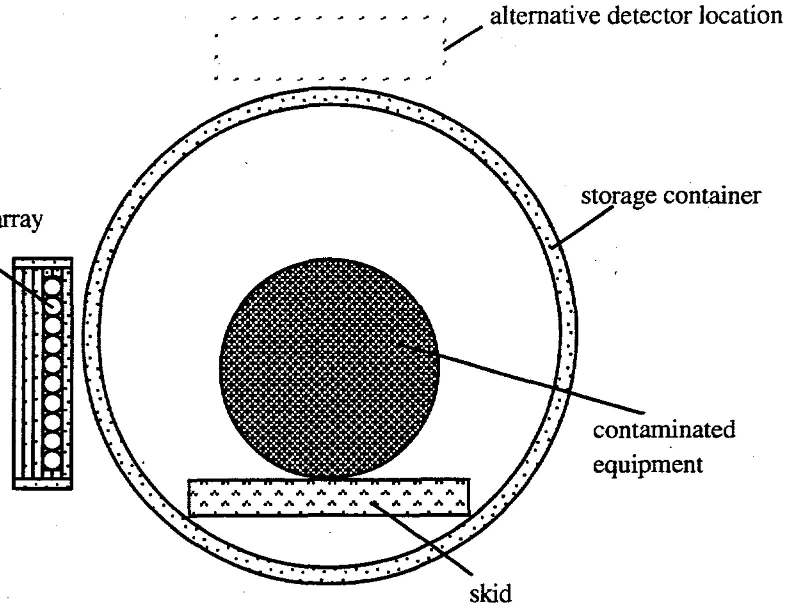

Figure 3.2. Position of Detectors While Counting Contaminated Objects

3.2 Electronics

Figure 3.3 shows the proposed electronics for processing the signals from the neutron detectors. These electronics are essentially identical to those used with the box scanner when it operates in potentially high gamma-ray fields. The output signals from the detectors will be connected in parallel, as will the high-voltage inputs. Special preamplifier/discriminators for operation in high gamma-ray conditions will reduce the gamma-ray background signal, compared to signal processing with conventional preamplifiers.

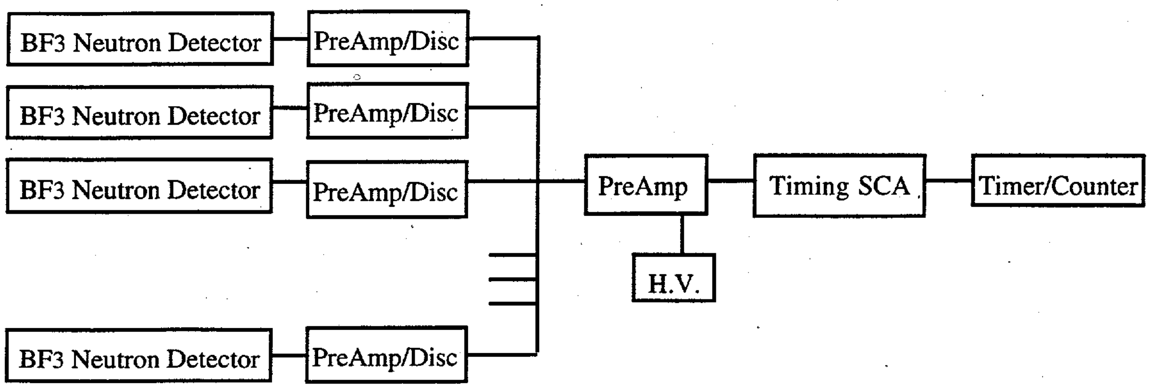

Figure 3.3 Electronics for Neutron Detectors

3.3 Tests in High Gamma-Ray Fields

To check the gamma-ray sensitivity, an array of 10 BF_3 tubes (each 5 cm in diameter, 1.8 m long) was tested in known gamma-ray fields produced by ^{60}Co and ^{137}Cs sources in Building 318 at Hanford. This facility is normally used for calibrating survey meters and dosimeters, and it has a pneumatic system for bringing high-activity sources into a shielded room. The detector array was located at distances of about 4 to 6 m from the sources, exposing it to fields of approximately 1 to 8.3 R/h, plus background runs at 0 R/h. For the gamma-ray tests, the 10 BF_3 tubes from the PNL box scanner were removed from their polyethylene enclosure and operated "bare." The tubes were stacked horizontally, side-by-side on a movable platform for changing the distance to the gamma-ray sources. Gamma-ray-suppression preamplifier/discriminators were present on the tubes during the tests, and all 10 tubes were wired in parallel.

As an illustration of the sensitivity of the detector array to neutrons, the initial "background" run produced a count rate of about 400 c/s. Electronic noise problems were suspected because the background should have been less than 7 c/s. The cause of the enhanced counts was traced to a ^{252}Cf source in use in the laboratory above the detector. That source had a moderating polyethylene shield around it, and a concrete floor about 30 cm thick separated the two rooms. When the ^{252}Cf source was returned to its storage location, the background count rate dropped to a normal value.

Figure 3.4 shows the count rates obtained with the neutron detector array in the high gamma-ray fields. Table 3.1 lists data plotted in the figure. The array starts to show the effects of the gamma rays at an exposure rate of about 3.5 R/h. The measured background count rate with no gamma-ray source present was 1.7 c/s. This background is less than that encountered in field measurements (~ 7 c/s), due to shielding from the building where the test took place.

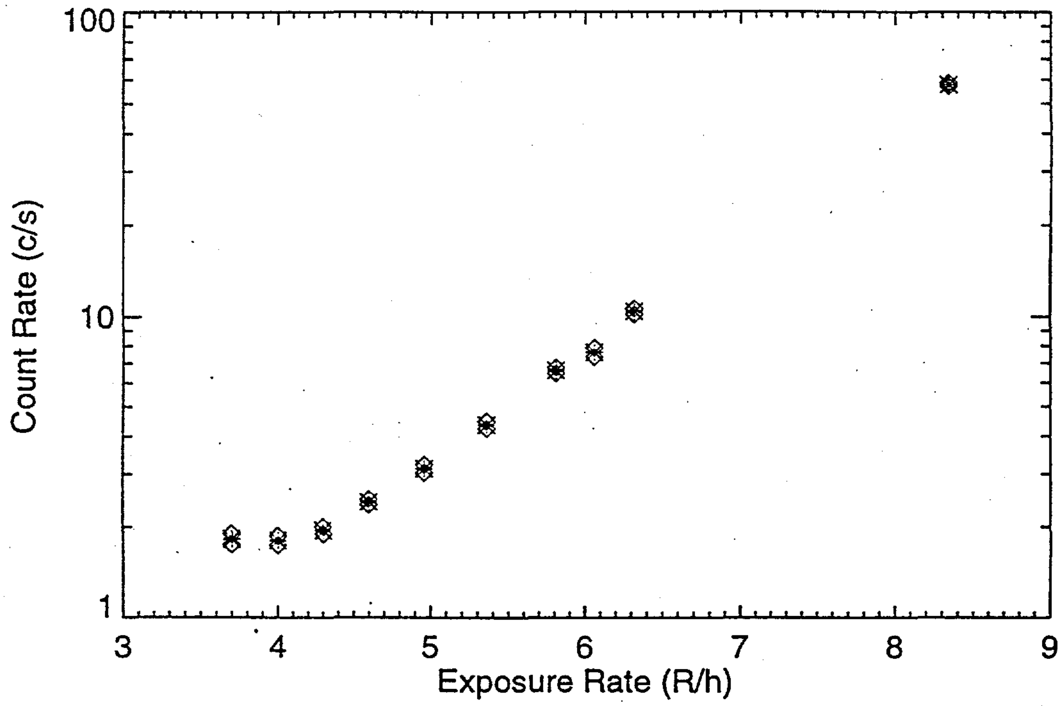

Figure 3.4 Gamma-Ray Sensitivity of Neutron Detector Array

Table 3.1 Gamma-Ray Sensitivity Data

Exposure Rate (R/h)	Count Rate (c/s) ± 1 std. dev.	Source
0 (background)	1.67 ± 0.03	none
1.0	1.62 ± 0.09	^{137}Cs
3.7	1.83 ± 0.08	^{60}Co
4.0	1.81 ± 0.06	^{60}Co
4.3	1.95 ± 0.05	^{60}Co
4.6	2.42 ± 0.05	^{60}Co
5.0	3.12 ± 0.10	^{60}Co
5.4	4.35 ± 0.12	^{60}Co
5.8	6.62 ± 0.15	^{60}Co
6.1	7.61 ± 0.27	^{60}Co
6.3	10.4 ± 0.2	^{60}Co
8.3	57.6 ± 0.8	^{60}Co

3.4 Background Monitor

Experience with the box and barrel scanners, combined with preliminary calculations of anticipated count rates, indicates that measurement of the fluctuating neutron background will be essential for accurate assays of TRU at the 100 nCi/g level, particularly for lightweight objects.

Because the neutron background is largely determined by cosmic-ray-induced reactions, a separate, "on-line" neutron monitor will allow background corrections to be made while the equipment is being surveyed. This background detector will consist of an array of BF_3 detectors similar to that used for assaying the contaminated equipment. The detector array presently used for either box or barrel scanning would be more than adequate for this task.

3.4.1 Neutron Spallation Produced by Cosmic-Ray Interactions

Cosmic-rays will produce neutrons via spallation within and around the contaminated equipment. This portion of the background will be indistinguishable from the "real" signal arising from neutron-emitting contaminants on the equipment. However, neutron spallation arising from interactions with the trailer, the skid supporting the equipment, and the storage tube can be measured before the contaminated equipment is inserted, provided access to the equipment and time are allotted for such measurements. Neutron spallation from the contaminated equipment can be approximated by inserting a "dummy" object, such as a bundle of steel reinforcing bars, that has a mass similar to that of the real object. Fluctuations in neutrons emitted from the equipment due to cosmic-ray interactions will be correlated to the measured "on-line" background and thus correctable during data analysis.

3.4.2 Neutron Spallation Experiments

Data on the production of neutron spallation from cosmic-ray interactions are limited. Kimura (1990) published neutron spallation rates for various materials, including Al, Fe, and Pb, from cosmic-ray interactions at sea level in Japan. The measurements provided information on neutron backgrounds for cold-fusion experiments. Reported neutron production rates were 1×10^{-2} n/s/kg for Fe and 3×10^{-2} n/s/kg for Pb. R. Arthur used the PNL barrel scanner at Hanford to obtain a value of $\sim 7 \times 10^{-2}$ n/s/kg for Pb.

For the present TRU-measurement feasibility study, additional experiments using the barrel scanner were performed to quantify the rate of neutron spallation from cosmic rays. A known mass of Fe {1090 kg (2400 lb)} was counted with the neutron detector array of the barrel scanner. Based on prior experience with the barrel scanner, its neutron detection efficiency is known to be 12%. The measured neutron emission rate was 0.027 ± 0.002 n/s/kg for Fe. If experimental compensation for spallation is not possible, this value will be used for the steel items during data analysis to compensate for neutron spallation.

As a comparison of the order of magnitude of neutron emission rates from TRU and spallation, consider a steel object contaminated with weapons-grade PuO_2 at 100 nCi/g. Using the relation 1350 n/s/Ci for weapons-grade PuO_2 (Reilley 1991), this contamination will produce a neutron emission rate of 0.135 n/s per kg of the contaminated object. Thus the cosmic-ray spallation (0.027 n/s/kg) is 20% as strong as that corresponding to the maximum permissible level of TRU contamination.

4.0 Data Analysis Method

Data analysis will incorporate the proven methods used for the PNL barrel and box scanner systems (Arthur, 1991). These methods use measured neutron count rates, calibration using known neutron sources, and conservative assumptions about the specific TRU nuclides and their distribution in the waste.

Neutron emission rates from TRU arise from two mechanisms: 1) spontaneous fission, in which neutrons are emitted directly, and 2) alpha-neutron (α,n) reactions, in which alpha particles emitted from the TRU react with other nuclei (such as oxygen) to produce neutrons. The neutron emission rate for spontaneous fission varies according to TRU nuclide, and the neutron emission rate from (α,n) varies both with TRU nuclide and chemical form. Table 4.1 shows neutron emission rates for two isotopic compositions of Pu. As shown in the fist group of figures in the table, for weapons-grade Pu (6 wt.% ^{240}Pu), the majority of neutrons come from ^{240}Pu, due to that isotope's large spontaneous fission contribution.

Table 4.1 Neutron Production Rates for Plutonium

Isotope	Wt.%	Neutron production rate (n/s) for 100 g of Pu — Spontaneous fission	(α,n) for PuO_2
^{238}Pu	0.01[a]	36	188
^{239}Pu	94.4[a]	2	3596
^{240}Pu	5.5[a]	5606	775
^{241}Pu	0.09[a]	0	0
^{242}Pu	0.01[a]	24	0
^{241}Am	0.5[a,b]	0	1286
	Totals	5668	5845
^{238}Pu	0.02	62	322
^{239}Pu	89.7	2	3416
^{240}Pu	9.6	9838	1360
^{241}Pu	0.6	0	1
^{242}Pu	0.1	187	0
^{241}Am	0.3[b]	0	880
	Totals	10089	5979
^{238}Pu	0.06	153	791
^{239}Pu	82.1	2	3416
^{240}Pu	16.3	16623	2298
^{241}Pu	1.2	0	2
^{242}Pu	0.3	578	1
^{241}Am	0.2[b]	0	436
	Totals	17356	6655

[a] Hanford fuel after 40-year decay, wt.% based on ORIGEN2 code (Oak Ridge 1987)
[b] ^{241}Am wt.% relative to Pu
Reference for spontaneous fission and (α,n) rates: Reilly et al. (1991)

Neutron counting does not yield a separate measure of each specific radionuclide present, as is generally possible with gamma-ray measurements. For a mixture of TRU nuclides, such as in the Hanford waste tanks, specific prior knowledge about the ratios of nuclides present and their chemical forms is necessary to quantify the amount of each nuclide based on neutron counting. Such prior information could come from knowledge of the process that produced the waste or from prior analysis of samples collected from specific tanks. However, even without such information, it is possible to determine an upper limit on the amount of TRU present in a mixture by making conservative assumptions about the isotopic and chemical distributions. For example, the assumption that the neutrons come from weapons-grade Pu, which emits the smallest quantity of neutrons, as shown in Table 4.1, has been used successfully in data analysis for the barrel and box scanners at Hanford. If the assumption turns out to be too conservative, resulting in waste being incorrectly classified as TRU, process knowledge or prior tank samples might justify less conservative assumptions.

5.0 Anticipated Sensitivity and Count Rates

The goal of any TRU assay system is to be able to certify (with 95% probability) that the TRU contamination on an object is less than 100 nCi per gram of waste. TRU contamination with weapons-grade plutonium at 100 nCi/g produces a neutron emission rate of 0.135 n/s for every kg of waste. Thus, the neutron assay must be sufficiently accurate to determine with 95% probability that the TRU neutron emission coming from the waste is less than this quantity.

A statistical analysis of the assay is straightforward. Each 6-ft segment of the component is assayed for 1800 sec (nominal) with a neutron detection efficiency of ~2%. The background count rate in previous work has been ~7 c/s. Assuming that no TRU is actually present on a contaminated component, the mean number of counts that will be observed is 1800 x 7 = 12,600 counts. Should this number of counts actually be observed from a survey item, the statistical uncertainty corresponding to 95% certainty (1.645 σ using "one-sided" statistics) would be 185 counts, or 0.103 c/s. (In this calculation, the background is assumed to be well known with negligible statistical uncertainty. However, if the background has an uncertainty comparable to that of the measurement on the contaminated object, the statistical uncertainty will be larger by a factor of $\sqrt{2}$. Specifically the uncertainty will be about 0.145 c/s. This larger uncertainty will also propagate through the following calculations.) Since it must be assumed that these counts originate from TRU on the contaminated object, the neutron rate that must be assumed to arise from TRU is 5.13 n/s, accounting for the 2% efficiency for neutron detection.

The result of critical importance is that for every 1.8-m length of waste component, it would be just barely possible for a mass of 38 kg to determine with 95% confidence that less than 100 nCi/g of TRU waste was present {(5.13 n/s) / 0.135 n/s/kg = 38 kg}. This corresponds to a linear mass density of ~20 kg/m (14 lbs/ft). Thus, an assay performed on a component lighter than this is likely to be insufficiently precise, whereas a heavier component, say 30 kg/m (20 lbs/ft), may be assayed with greater ease.

It is important to note that the following three assumptions have been made during the above calculation:

1) There is **NO** TRU waste actually on the component.

2) The background count rate was constant.

3) There was no neutron generation from non-TRU sources.

Each of these assumptions must be examined to determine the consequences that would result should the assumption not be valid. Keeping the same numbering sequence as above,

1) If any TRU waste is actually present on the component, then the count rate will be elevated, and the precision required of the assay must be increased. For example, if 50 nCi/g of TRU waste were actually present, then the assay must be twice as precise to find that the component is below 100 nCi/g. In other words, such an assay is likely to succeed only for components with weights above 40 kg/m (28 lbs/ft).

2) If the background rate were to rise during the course of an assay, this might be taken to indicate the presence of TRU on the component. Correspondingly, if the rate falls, real TRU might not be detected. Changes of 5% are sometimes observed in the background during the

an 8-h day, especially during times of changing weather. As an example of the effect of a changing background, suppose that the background rate rose only 1% between the time that initial background measurements are performed and the time of the assay. This would correspond to 126 counts during 1800-s assay, or roughly 70% of the total assay uncertainty. Clearly, this contribution to the uncertainty cannot be allowed to occur. A separate background monitor must be continuously operated during the entire assay operation to allow nearly complete compensation for changes in the cosmic-ray induced background count rate.

3) As discussed in Section 3.4.2, cosmic-ray spallation results in the generation of 0.027 n/s for every kilogram of steel in the waste component. A 1.8-m length of the component weighing 38 kg would therefore generate 1 n/s, or roughly 20% of the neutron count rate arising from statistical uncertainly that must be ascribed to TRU contamination. The situation would be far worse if neutron spallation from the skid that holds the waste component were not present during the background measurement period. Because of this, it is necessary to perform extensive background measurements with the burial container, skid, and a mass equivalent to the waste component already in place. In this way, the cosmic-ray spallation arising from the skid and component can be accounted for as part of the background measurement.

Although ideally these calculations indicate that a component weighing 20 kg/m (14 lbs/ft) could be assayed successfully, in practice it would be wise to attempt assays only for components with masses somewhat larger than this value. In the field, it may be necessary to count neutrons across the entire length of the component once in a first "sweep" and subsequently return for more counting time at those locations where excessive counts were observed.

Reducing the background count rate, which is about 7 c/s for the detector array that assays waste boxes, would improve the system performance. The statistical uncertainties in the TRU assays are dominated by the background counts that must be subtracted during analysis. Adding additional shielding, perhaps in the form of cadmium sheets to absorb neutrons entering from the back and sides, should reduce the background.

Another change from the present detector array that could improve performance is allowing variable moderator thickness on the front side of the detector. Because the tubes for storing the contaminated equipment have various thicknesses of polyethylene, the optimum thickness for moderating high energy neutrons down to thermal energy for detection may need to be achieved by adjusting the amount of polyethylene on the detector assembly. Computer modeling and experiments with a neutron source in the storage tubes can guide proper selection of polyethylene thickness.

6.0 Operational Procedure

The proposed data collection method will include the following steps:

• Pre-survey of storage container, skid, and trailer prior to introduction of contaminated equipment. This must occur before the contaminated equipment is placed into the storage container. The survey will provide data on the background, including cosmic-ray induced neutron spallation from all equipment present at the time of measurement. Steel reinforcing bars of the same approximate linear mass as the contaminated object may be inserted during this measurement to estimate the neutron spallation expected from the contaminated object. At this time the separate background monitor will also collect data in order to determine the relative efficiency the two detectors.

• Calibration of neutron detectors for a specific storage container, skid and trailer assembly, prior to introduction of contaminated equipment. A known neutron source will be placed inside the storage container at the location to be occupied by the contaminated equipment. This will be done on the day(s) preceding removal of the contaminated equipment from the tank.

• Survey of contaminated equipment inside its storage container (before grout is added, which interfere with the neutron measurement) on the trailer. The neutron detector array will be placed adjacent to one side (or top) of the container (Figure 3.2), with the BF_3 tubes parallel to the length of the container. Successive data collections approximately every 1.8 m (6 ft) will be made along the length of the container in order to survey the entire length of the contaminated equipment. During these data collections, the separate background monitor will also collect data so that corrections can be made for background fluctuations.

Operational details for the detector placement and data collection include the following anticipated items:

• The detector array will be held in the appropriate position near the container using a forklift. Alternatively, the detector can be suspended from a crane or cherry picker. Anticipated detector weight is less than 100 kg.

• Movement of the detector along the length of the container will be accomplished by moving the trailer on which the storage container is located. Alternatively, the forklift can move the detector, but this may be less desirable because of enhanced radiation exposure to the operator.

• Supporting electronic equipment and operating personnel will be located in a vehicle or trailer approximately 25 m from the contaminated equipment. Greater distance is possible if needed to reduce radiation exposure to personnel. The support location will be occupied continuously for the duration of data collection. The support location should preferably be a non-contamination zone. The neutron detector arrays and cables can be wrapped in plastic to facilitate decontamination, if necessary. The background neutron detector should be located in a non-contamination zone, if possible.

• At least 10 to 14 hours will be available for performing the neutron measurements on the contaminated equipment.

- The ground surrounding the detector will be sufficiently level and hard to allow operation of a forklift (provided by Westinghouse).

- Gamma-ray exposure rate at the outside of the container holding the contaminated equipment will be less than 3 R/h. Higher exposure rates may interfere with the neutron measurements.

7.0 Conclusions

It will be possible to successfully assay the TRU content of long-length contaminated items with weights exceeding ~30 kg/m (20 lbs/ft) in 10 to 14 hours. Although this assay will utilize a great deal of existing equipment, several improvements and methodology changes are necessary. A separate background monitor will allow compensation for changing background. Extensive pre-assay background measurements will allow compensation for neutrons produced by cosmic-ray spallation within the contaminated component. Calibration of the detector will involve placing a well-characterized neutron source inside, rather than behind, the burial container. Special gamma-ray sensitivity suppression electronics will be used to ensure that gamma-ray radiation fields as large as 3 R/h do not affect the neutron detectors. The detector itself will consist of 10 BF_3 tubes assembled within layers of polyethylene, the thicknesses of which will take account of the pre-existing moderation arising from the burial container. Positioning this array at successive positions along the length of the contaminated equipment will give a profile of possible TRU content.

8.0 Acknowledgements

M. D. Winterrose, PNL, assisted in measuring the neutron spallation rate from steel, and G. L. Carter, PNL, helped with the high-gamma-ray exposure measurements on the neutron detectors. Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

8.0 References

Arthur, R. J. 1991. *Calibration and Operation of the PNL Barrel Assayer,* PNL-7739, Pacific Northwest Laboratory, Richland, Washington.

Brodzinski, R. L., R. W. Perkins, H. G. Rieck, and N. A. Wogman. 1986. *Measurement of Radionuclides in Waste Packages,* U. S. Patent # 4,617,169.

Kimura, T. 1990. "Quantitative Evaluation of Multiple Production of Neutrons Induced by Cosmic Rays in Materials," *J. Nucl. Sci. Tech.* **27**(12), 1147-1150.

Oak Ridge. 1987. Origen2: Isotope Generation and Depletion Code; MATRIX EXPONENTIAL METHOD, CCC-371 (updated 11/3/87), Radiation Shielding Information Center (RSIC) Computer Code Collection, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Reilly, D., N. Ensslin, and H. Smith, Jr., eds. 1991. *Passive Nondestructive Assay of Nuclear Materials,* NUREG/CR-5550, U. S. Nuclear Regulatory Commission, Washington, DC (also LA-UR-90-732, Los Alamos National Laboratory, Los Alamos, New Mexico).

Roach, H. L. 1995. *Disposal of Tank Farm Long Length Contaminated Equipment: Radiological and Chemical Characterization Plan.* Rev 0 4/95, WHC-SD-WM-TCP-007, Westinghouse Hanford Company, Richland, Washington.

Sprinkle, J. 1991. "Total Neutron Counting Instruments and Applications," In: *Passive Nondestructive Assay of Nuclear Materials*, D. Reilly, N. Ensslin, H. Smith, Jr., Eds., NUREG/CR-5550, LA-UR-90-732.

Distribution

No. of Copies

Offsite

2 DOE Office of Scientific and Technical Information

Onsite

3 *DOE Richland Operations Office*
M.J. Royack
C.O. Ruud
A.B. Sidpara

2 *ICF Kaiser Hanford Company*
F. R. Fisher
H. L. Roach

4 *Westinghouse Hanford Company*
P. A. Gagnon
D. C. Hetzer
J. E. Meisner
P. A. Titzler

22 *Pacific Northwest Laboratory*
R. J. Arthur
M. Bliss
R. L. Brodzinski
A. J. Peurrung (5)
P. L. Reeder
D. E. Robertson
D. C. Stromswold (7)
Technical Report Files (5)