Depleted Uranium Waste Assay at AWE

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ABSTRACT

The Atomic Weapons Establishment (AWE) at Aldermaston has recently conducted a Best Practical Means (BPM) study, for solid Depleted Uranium (DU) waste assay, in order to satisfy key stakeholders that AWE is applying best practice. This study has identified portable passive High Resolution Gamma Spectrometry (HRGS), combined with an analytical software package called Spectral Nondestructive Assay Platform (SNAP), as the preferred option with the best balance between performance and costs. HRGS/SNAP performance has been assessed by monitoring 200 l DU waste drum standards and also heterogeneous, high density drums from DU firing trials. Accuracy was usually within 30 % with Detection Limits (DL) in the region of 10 g DU for short count times. Monte Carlo N-Particle (MCNP) calculations have been used to confirm the shape of the calibration curve generated by the SNAP software procured from Eberline Services Inc.

INTRODUCTION

AWE has recently carried out a BPM study in order to identify the most suitable option for solid DU waste assay. This paper summarises the results from that study and the subsequent performance trials on the HRGS/SNAP option selected. The object of the exercise was to demonstrate acceptable performance, for the most challenging heterogeneous high-density waste streams encountered, whilst ensuring that the method was not grossly disproportionate in terms of money, time and trouble. A secondary objective was to confirm the shape of the calibration curve generated by SNAP using MCNP calculations.

BPM STUDY

The AWE BPM study has been published for internal distribution (1). Each assay option was scored against a set of assessment criteria covering costs (e.g. procurement, maintenance, training, operating time) and performance (e.g. accuracy, detection limit). Table I provides a simplified summary of the results, for the principal assay options, taken from a peer review of AWEs studies (2). The HRGS option was chosen because it provided high performance at moderate cost when compared to the alternatives. The other options were either too costly or had inferior performance.

Table I DU waste assay options BPM summary

Option	Costs	Accuracy	DL	Suitability
Passive Neutron Counting	Low	Medium	Poor	No
Passive Neutron Coincidence Counting	High	Medium	Poor	No
Active Neutron Counting	Very High	High	Good	Too expensive
Segmented Gamma Scanner (Low Resolution)	Medium	Medium	Good	Inferior accuracy
Segmented Gamma Scanner (High Resolution)	High	High	Good	Too costly and complex
Passive Low Resolution Gamma Spectrometry	Low	Medium	Good	Inferior accuracy
Passive High Resolution Gamma Spectrometry	Medium	High	Good	Yes
Gross activity	Low	Medium	Fair	No
Chemical analysis	Medium	Low	Good	No

The reader is referred to the Radiometric Non-Destructive Assay Guide for a detailed description of the assay options together with their ranges of application, advantages and limitations (3). Passive HRGS provides the best combination of relatively low costs and high performance.

PASSIVE PORTABLE HRGS

Table II summarises the key hardware and software components of the portable HRGS system. Figure 1 shows the HRGS monitoring a drum of waste situated on a rotating turntable.

Table II HRGS components

Component	Specification
Detector	High Purity Germanium N-type (45 % relative efficiency)
Collimator	20 mm lead (copper lined)
Multichannel analyser	ORTEC digiDART
Computer	Laptop with windows 98
MCA emulator	Maestro 32
Analytical software	SNAP (5)
Trolley	ORTEC ISOCART

Figure 1 HRGS monitoring a waste drum on a turntable

The SNAP analytical software corrects the detector calibration for counting geometry and gamma ray attenuation. It also has routines for differential peak analysis and uranium lump corrections. The reader is referred to the SNAP user's manual for a detailed description of SNAP features and analysis procedures (5).

HRGS PERFORMANCE

Waste drum standards

Waste drum standards were used in order to check the SNAP software calibration. For example, figure II shows DU drum calibration curves, derived from SNAP and MCNP, for a uniform distribution of waste and DU. Individual points on the SNAP curve were verified by making measurements on waste drum standards, containing thin disks of DU and waste packages, positioned to simulate uniform distribution. Table II shows reasonable agreement between SNAP and the standards. However, the MCNP curve was around 20% higher than the SNAP curve and this is believed to be due to the active volume of the germanium crystal being smaller than its specified dimensions. This has been attributed to imperfect electrical field throughout the crystal (4). Table III details the MCNP input file, developed in collaboration with LANL (6), that was used to describe the detector waste drum counting geometry as photographed in figure 1.

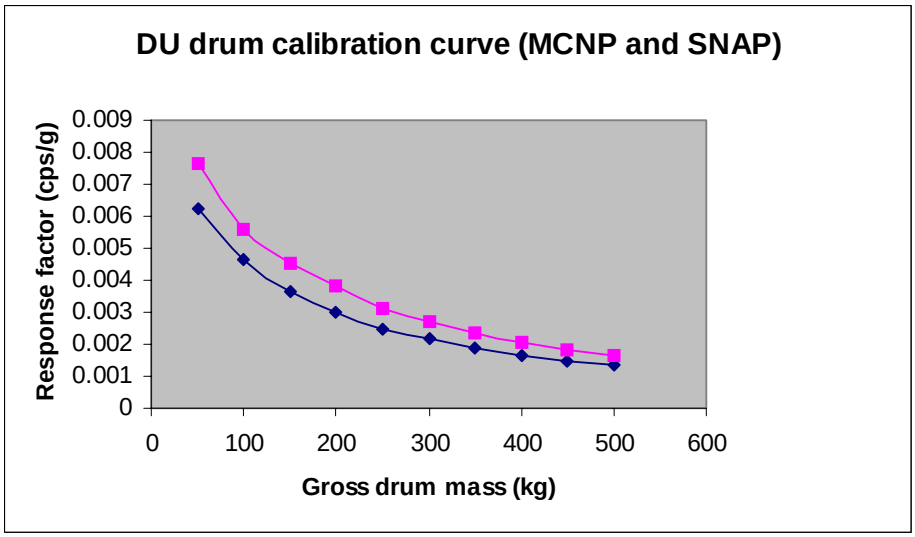

Figure 2 DU drum calibration curve (1 MeV Pa-234m photon)

Table II comparison of SNAP with DU drum standards

Gross drum mass (kg)	DU mass (g)	SNAP mass (g)	SNAP (%)
50	59.2	68.7	116
130	59.2	65.4	110

Table III MCNP input file for waste drum and HRGS

```
1     9 -5 -1 -12 11 imp:p=1 $ germanium crystal
2     2 -2.7 -3 2 -13 9 imp:p=1 $ aluminium shell
3     0 (-13 -2 10) (1:12:-11) imp:p=1 $ detector air
4     3 -1.84 -2 9 -10 imp:p=1 $ berylium window
5     4 -1 -4 -8 7 imp:p=1 $ polythene end cap
6     5 -8.96 -5 4 7 -13 imp:p=1 $ copper collimator lining
7     6 -11.35 -13 5 -6 7 imp:p=1 $ lead collimator
8     1 -0.00122 -14 #1 #2 #3 #4 #5 #6 #7 #10 #11 imp:p=1 $ universe
9     0 14 imp:p=0 $ outside universe
10    8 -0.875 -15 -18 17 imp:p=1 $ concrete waste
11    7 -7.86 15 -16 17 -18 imp:p=1   $ drum wall

1     c/y 0 41 3.07
2     c/y 0 41 4
3     c/y 0 41 4.1
4     c/y 0 41 5.2
5     c/y 0 41 5.3
6     c/y 0 41 6.8
7     py 68.5
8     py 68.75
9     py 68.85
10    py 68.9
11    py 69.15
12    py 77.15
13    py 88.82
14    so 150
15    cz 28.4
16    cz 28.5
```

Table III continued

```
17    pz 0
```

```
18      pz 82

mode    p
m1      6000 -0.00014 7000 -0.75519 8000 -0.23179 18000 -0.01288
m2      13000 1
m9      32000 1
m3      4000 1
m4      6000 1 1000 2
m5      29000 1
m6      82000 1
m7      26000 1
m8      1001 0.14 6000 0.0045 8016 0.49 20000 0.038 14000 0.143 12000     0.0005
        26000 0.005 13027 0.03 11023 0.008 28000 0.134 16032 0.0007 19000 0.0041
        22000 0.0022
sdef    pos=0 0 0 par=2 erg=1.001 rad=d1 axs= 0 0 1 ext=d2
si1     h 0 28.4
sp1     d -21 1
si2     h 0 82
sp2     d 0 1
f8:p    1
e8      0 0.001 1098i 1.1
ctme    60
```

Firing chamber drums

Figure 3 shows a typical hydrodynamics trial pre and post firing. The waste is collected and shredded with the larger (non-shreddable) material being placed in the bottom of the waste drum and the smaller material on top.

Figure 3 Firing Chamber (pre and post firing)

Each trial uses kilos of DU and generates around 20 drums of waste. These drums may subsequently be grouted. Table IV summarises the assay results for six firings. It can be seen that the SNAP results are generally within 30 % of the actual DU mass used in each trial.

Table IV DU assay results for firing trials

Average drum mass (kg)	100 % recovery (U-238 g/drum)	SNAP (U-238 g/drum)	SNAP (%)

135	233	269	115
139	345	379	110
324	354	403	114
296	195	265	136
308	133	255	192
245	392	511	130
252	262	331	126

DISCUSSION

The law of diminishing returns applies to DU assay. Acceptable performance (i.e. 30 % accuracy and 10 g detection level) can be achieved in minutes using portable passive HRGS equipment costing only a few tens of thousands of pounds. Spending hundreds of thousands of pounds on Segmented or Tomographic Gamma scanners may result in poorer detection levels and longer assay times: improvement is limited to cases where waste heterogeneity is severe. In the normally encountered waste streams the presence of DU as contamination, rather than a single source, reduces uncertainties associated with heterogeneity (3).

The results in table IV show that passive HRGS can achieve good results for even the most challenging 200 l waste drums encountered (i.e. high mass, high Z, heterogeneous, high DU content).

It is notable that the SNAP result tends to overestimate. The rationalisation for this is that large dense items within the drum (e.g. lead bricks) occupy only a small percentage of the drum volume and therefore offer little gamma ray attenuation in relation to their mass.

Another factor contributing to overestimation could be that some of the SNAP gamma ray yields are a little lower than some literature sources. For example, the Pa-234m 1001 keV yield is 0.0065 for SNAP and 0.00835 in the AEA Radiochemical Manual.

The presence of DU lumps and internal shielding within the drum could result in underestimation. However this would normally be obvious from a differential peak analysis. Table V summarises the peak area ratios for the principal gamma photons from DU. It can be seen that these ratios change in a predictable way and any unusual shielding effects show up with severe attenuation of the lower energy peak areas relative to the higher ones.

Table V Gamma peak (keV)area ratios

Item	kg	DU (g)	63	93	186	766	1001
HEPA filter	20	12	15.8	23.4	3.52	0.48	1
DU disks	0.0666	66.6	3.17	14.7	2.45	0.48	1
Drum	45	17.6	3.18	8.91	2.36	0.36	1
Drum	63	395	0.48	2.71	0.57	0.39	1
Drum	42	126	2.11	7.80	3.64	0.45	1
Drum	65	40	1.96	7.83	1.70	0.43	1
Drum	134	606	1.32	5.19	1.23	0.42	1
Drum	191	237	1.93	6.51	1.23	0.41	1
Drum	435	169	2.00	4.85	1.44	0.37	1

In HEPA filters attenuation is low and the 93/1001 keV ratio is high (23.4/1). This ratio drops to 14.7/1 for an 800 micron DU disk and falls from 8.91/1 in light drums (45 kg) to 4.85/1 in heavy drums (435 kg). However, it is not significantly affected by the mass of DU within the drum provided that this is present as contamination rather than lumps .

Heterogeneity is indicated, for the 63 kg drum, by a very low 93/1001 keV ratio of 2.71/1 in a light drum containing only low Z waste (PVC). A large lump correction (1300 microns) was required in order to get agreement between the 93 and 1001 keV peaks.

CONCLUSIONS

Portable passive HRGS, combined with an analytical software package, provides the best balance between high performance and low costs for solid DU waste assay.

REFERENCES

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