

Gamma Analyst Performance Characteristics (MDAs)

Introduction

With so much attention being given to environmental issues, the process of sample characterization is challenging today's analytical laboratories. The ever changing and increasingly stringent method sensitivity requirements have created a demand for more efficient utilization of laboratory instrumentation. Knowing the sensitivity of your instrument prior to loading the first sample is the first step to effectively maximizing instrument throughput.

Canberra's ProLine Gamma Analyst provides the complete application solution for automated high throughput gamma spectroscopy. Each standard Gamma Analyst is provided with guaranteed performance specifications, defining achievable detection limits for several factory calibrated sample geometries. This predictable performance is possible because each instrument is of a completely standardized, low background design. Knowing the instruments capability ahead of time takes the guess work out of estimating laboratory sample throughput.

To further optimize the instrument throughput the instrument also makes use of the "Count to MDA" feature. This tool allows each individual sample to be counted to its own specific set of MDAs automatically. Once acquisition has started the computer automatically reads these desired detection limits from the nuclide library and calculates the optimum counting time, based on the actual sample background. This method of counting ensures that no valuable counting is wasted.

Guaranteed Application Performance

The instrument is available in two basic models, the GAM-AN1 for general applications and the GAM-AN2 for applications requiring higher sensitivity and shorter counting times. Each instrument is available with guaranteed performance specifications (Minimum Detectable Activities), when purchased with optional factory calibrations.

The data acquired for the determination of the instrument performance specifications were collected using a standard Gamma Analyst instrument configuration. The detectors were

carefully characterized during manufacturing to allow for the utilization of the MCNP (Monte Carlo Neutron Proton) calculation techniques for the determination of the efficiencies for each of the counting geometries. These mathematically derived efficiencies were then used in conjunction with the nuclide library (listed in Appendix A) to determine the detection limits for each of the specified geometries. The detection limits for soil geometries were calculated based on background counts measured on actual background soil samples. All other geometries are based on an empty shield background. The MDA values derived were based solely on the sample containers listed in Table 1. They presume sea level operation, single analyte in the sample and a typical background field.

Tables 2 through 7 contain a summary of the performance specifications for the various factory calibrated sample geometries listed in Table 1 for fixed acquisition times of 1,000, 10,000 and 50,000 seconds for each of the standard instrument designs. Use of sample containers other than those listed in Table 1 may yield different results.

Table 1
Gamma Analyst Standard Geometries

<u>Geometry</u>	<u>Part No:</u>	<u>Manufacturer</u>
1 liter Marinelli beaker	130G	GA-MA Associates, Inc.
1 liter Marinelli beaker	138G	GA-MA Associates, Inc.
500 ml Marinelli beaker	590G	GA-MA Associates, Inc.
500 ml Marinelli beaker	530G-E	GA-MA Associates, Inc.
125 ml Poly bottle	2089-0004	Nalgene
20 ml Poly scint. vial	6001075	Packard
2 in. petri dish with 47 mm filter	7242 (dish)	Gelman
	1882-047 (filter)	Whatman

Table 2

Model GAM-AN1 Detection Limits
1,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	130G	130G	530G	530G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.0 liter	1600 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	3.8E+01	7.9E-02	6.3E+01	1.1E-01	3.5E+02	1.4E+03	7.6E+00
K-40	4.7E+02	7.3E-01	7.6E+02	6.3E-01	4.1E+03	1.6E+04	1.7E+02
Cr-51	2.1E+02	4.0E-01	3.4E+02	5.3E-01	1.5E+03	5.7E+03	5.1E+01
Mn-54	3.8E+01	7.0E-02	6.3E+01	9.2E-02	3.0E+02	1.2E+03	1.1E+01
Co-57	1.8E+01	4.1E-02	2.9E+01	5.4E-02	1.2E+02	4.1E+02	3.8E+00
Co-58	4.1E+01	6.3E-02	6.6E+01	9.2E-02	3.2E+02	1.3E+03	1.2E+01
Fe-59	7.3E+01	1.4E-01	1.1E+02	2.0E-01	6.0E+02	2.4E+03	2.3E+01
Co-60	3.8E+01	7.0E-02	6.3E+01	1.0E-01	3.5E+02	1.4E+03	1.4E+01
Zn-65	8.2E+01	1.9E-01	1.3E+02	2.7E-01	7.0E+02	2.7E+03	2.7E+01
Nb-95	9.5E+01	2.4E-01	1.5E+02	3.3E-01	7.0E+02	3.0E+03	2.3E+01
Zr-95	6.3E+01	1.1E-01	9.8E+01	1.6E-01	4.7E+02	1.9E+03	1.8E+01
Ru-106	3.1E+02	5.6E-01	5.0E+02	7.4E-01	2.3E+03	9.2E+03	8.5E+01
Ag-110m	3.5E+01	6.0E-02	5.7E+01	7.9E-02	2.6E+02	1.0E+03	9.5E+00
Sb-125	7.6E+01	1.5E-01	1.2E+02	2.0E-01	5.4E+02	2.1E+03	1.9E+01
I-131	2.7E+01	5.4E-02	4.4E+01	7.0E-02	2.0E+02	8.2E+02	7.0E+00
Ba-133	4.1E+01	9.2E-02	6.6E+01	1.4E-01	3.0E+02	1.1E+03	1.0E+01
Cs-134	3.1E+01	6.3E-02	5.1E+01	8.5E-02	2.3E+02	8.8E+02	8.2E+00
Cs-137	4.1E+01	7.0E-02	6.6E+01	9.5E-02	3.2E+02	1.2E+03	1.1E+01
Ce-144	1.4E+02	3.2E-01	2.3E+02	4.1E-01	9.8E+02	3.5E+03	3.2E+01
Pm-144	3.2E+01	5.7E-02	5.1E+01	7.3E-02	2.4E+02	9.2E+02	8.5E+00
Eu-152	5.4E+01	1.3E-01	8.5E+01	1.6E-01	3.5E+02	1.2E+03	1.1E+01
Eu-154	3.8E+01	8.8E-02	6.3E+01	1.1E-01	2.6E+02	9.2E+02	8.5E+00
Eu-155	5.7E+01	1.4E-01	9.2E+01	2.2E-01	3.3E+02	1.2E+03	1.1E+01
Tl-208	3.8E+01	4.7E-02	6.3E+01	6.6E-02	2.9E+02	1.1E+03	1.0E+01
Pb-212	5.7E+01	6.6E-02	9.2E+01	1.4E-01	4.2E+02	1.5E+03	1.4E+01
Bi-214	7.6E+01	1.1E-01	1.2E+02	1.8E-01	5.7E+02	2.2E+03	2.1E+01
Pb-214	7.9E+01	1.5E-01	1.3E+02	2.0E-01	5.7E+02	2.1E+03	2.0E+01
Ra-226	5.7E+02	1.0E+00	9.2E+02	1.8E+00	4.1E+03	1.5E+04	1.3E+02
Ac-228	1.4E+02	2.1E-01	2.3E+02	3.5E-01	1.1E+03	4.4E+03	4.4E+01
Pa-234	6.0E+01	1.7E-01	9.8E+01	2.1E-01	3.7E+02	1.3E+03	1.2E+01
Pa-234m	6.0E+03	1.2E+01	9.5E+03	1.7E+01	4.9E+04	1.9E+05	1.9E+03
Th-234	6.3E+02	1.8E+00	1.0E+03	2.5E+00	3.5E+03	1.2E+04	1.1E+02
U-235	3.5E+01	6.3E-02	5.7E+01	1.1E-01	2.5E+02	8.8E+02	8.2E+00
Am-241	7.6E+01	2.4E-01	1.2E+02	3.5E-01	3.8E+02	1.4E+03	1.3E+01

Table 3

Model GAM-AN1 Detection Limits
10,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	130G	130G	530G	530G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.0 liter	1600 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	1.2E+01	2.5E-02	2.0E+01	3.4E-02	1.1E+02	4.3E+02	2.4E+00
K-40	1.5E+02	2.3E-01	2.4E+02	2.0E-01	1.3E+03	5.2E+03	5.4E+01
Cr-51	6.6E+01	1.3E-01	1.1E+02	1.7E-01	4.8E+02	1.8E+03	1.6E+01
Mn-54	1.2E+01	2.2E-02	2.0E+01	2.9E-02	9.6E+01	3.8E+02	3.6E+00
Co-57	5.7E+00	1.3E-02	9.2E+00	1.7E-02	3.8E+01	1.3E+02	1.2E+00
Co-58	1.3E+01	2.0E-02	2.1E+01	2.9E-02	1.0E+02	4.0E+02	3.8E+00
Fe-59	2.3E+01	4.5E-02	3.6E+01	6.2E-02	1.9E+02	7.5E+02	7.4E+00
Co-60	1.2E+01	2.2E-02	2.0E+01	3.2E-02	1.1E+02	4.4E+02	4.5E+00
Zn-65	2.6E+01	6.1E-02	4.2E+01	8.5E-02	2.2E+02	8.6E+02	8.6E+00
Nb-95	3.0E+01	7.7E-02	4.9E+01	1.0E-01	2.2E+02	9.6E+02	7.4E+00
Zr-95	2.0E+01	3.6E-02	3.1E+01	5.0E-02	1.5E+02	5.9E+02	5.6E+00
Ru-106	9.9E+01	1.8E-01	1.6E+02	2.3E-01	7.4E+02	2.9E+03	2.7E+01
Ag-110m	1.1E+01	1.9E-02	1.8E+01	2.5E-02	8.2E+01	3.2E+02	3.0E+00
Sb-125	2.4E+01	4.8E-02	3.9E+01	6.4E-02	1.7E+02	6.6E+02	6.1E+00
I-131	8.6E+00	1.7E-02	1.4E+01	2.2E-02	6.3E+01	2.6E+02	2.2E+00
Ba-133	1.3E+01	2.9E-02	2.1E+01	4.4E-02	9.4E+01	3.5E+02	3.2E+00
Cs-134	9.7E+00	2.0E-02	1.6E+01	2.7E-02	7.2E+01	2.8E+02	2.6E+00
Cs-137	1.3E+01	2.2E-02	2.1E+01	3.0E-02	1.0E+02	3.9E+02	3.6E+00
Ce-144	4.5E+01	1.0E-01	7.3E+01	1.3E-01	3.1E+02	1.1E+03	1.0E+01
Pm-144	1.0E+01	1.8E-02	1.6E+01	2.3E-02	7.5E+01	2.9E+02	2.7E+00
Eu-152	1.7E+01	4.0E-02	2.7E+01	5.0E-02	1.1E+02	3.9E+02	3.6E+00
Eu-154	1.2E+01	2.8E-02	2.0E+01	3.5E-02	8.3E+01	2.9E+02	2.7E+00
Eu-155	1.8E+01	4.5E-02	2.9E+01	7.0E-02	1.1E+02	3.7E+02	3.4E+00
Tl-208	1.2E+01	1.5E-02	2.0E+01	2.1E-02	9.1E+01	3.5E+02	3.3E+00
Pb-212	1.8E+01	2.1E-02	2.9E+01	4.3E-02	1.3E+02	4.8E+02	4.4E+00
Bi-214	2.4E+01	3.6E-02	3.9E+01	5.7E-02	1.8E+02	6.9E+02	6.5E+00
Pb-214	2.5E+01	4.8E-02	4.0E+01	6.4E-02	1.8E+02	6.7E+02	6.2E+00
Ra-226	1.8E+02	3.2E-01	2.9E+02	5.7E-01	1.3E+03	4.6E+03	4.2E+01
Ac-228	4.5E+01	6.8E-02	7.2E+01	1.1E-01	3.6E+02	1.4E+03	1.4E+01
Pa-234	1.9E+01	5.3E-02	3.1E+01	6.5E-02	1.2E+02	4.1E+02	3.8E+00
Pa-234m	1.9E+03	3.8E+00	3.0E+03	5.4E+00	1.6E+04	6.1E+04	6.0E+02
Th-234	2.0E+02	5.8E-01	3.3E+02	7.9E-01	1.1E+03	3.8E+03	3.6E+01
U-235	1.1E+01	2.0E-02	1.8E+01	3.5E-02	7.8E+01	2.8E+02	2.6E+00
Am-241	2.4E+01	7.5E-02	3.9E+01	1.1E-01	1.2E+02	4.3E+02	4.2E+00

Table 4

Model GAM-AN1 Detection Limits
50,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	130G	130G	530G	530G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.0 liter	1600 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	5.1E+00	1.1E-02	8.1E+00	1.6E-02	4.3E+01	1.7E+02	1.7E+00
K-40	6.4E+01	1.0E-01	1.0E+02	1.3E-01	5.6E+02	2.2E+03	2.3E+01
Cr-51	3.1E+01	5.7E-02	5.0E+01	7.7E-02	2.3E+02	8.2E+02	7.7E+00
Mn-54	5.1E+00	9.2E-03	8.2E+00	1.3E-02	4.0E+01	1.6E+02	1.5E+00
Co-57	2.5E+00	5.8E-03	4.0E+00	7.4E-03	1.6E+01	5.8E+01	5.3E-01
Co-58	4.7E+00	8.7E-03	7.4E+00	1.2E-02	3.6E+01	1.4E+02	1.4E+00
Fe-59	9.0E+00	2.0E-02	1.4E+01	2.8E-02	7.5E+01	2.9E+02	2.9E+00
Co-60	5.0E+00	9.4E-03	7.9E+00	1.3E-02	4.3E+01	1.7E+02	1.7E+00
Zn-65	9.5E+00	2.7E-02	1.5E+01	3.7E-02	7.9E+01	3.1E+02	3.1E+00
Nb-95	1.5E+01	3.6E-02	2.4E+01	4.8E-02	1.1E+02	3.2E+02	3.6E+00
Zr-95	8.2E+00	1.6E-02	1.3E+01	2.3E-02	6.3E+01	2.4E+02	2.3E+00
Ru-106	4.5E+01	7.6E-02	7.3E+01	1.1E-01	3.4E+02	1.3E+03	1.2E+01
Ag-110m	4.4E+00	8.2E-03	7.0E+00	1.2E-02	3.3E+01	1.3E+02	1.2E+00
Sb-125	1.2E+01	2.1E-02	2.0E+01	2.9E-02	8.8E+01	3.3E+02	3.1E+00
I-131	4.2E+00	7.6E-03	6.7E+00	1.0E-02	3.0E+01	1.0E+02	1.0E+00
Ba-133	5.0E+00	1.3E-02	8.1E+00	1.8E-02	3.7E+01	1.4E+02	1.3E+00
Cs-134	4.4E+00	8.3E-03	7.1E+00	1.2E-02	3.3E+01	1.3E+02	1.2E+00
Cs-137	4.9E+00	9.4E-03	7.8E+00	1.3E-02	3.7E+01	1.4E+02	1.3E+00
Ce-144	1.8E+01	4.5E-02	2.9E+01	5.8E-02	1.2E+02	4.3E+02	4.0E+00
Pm-144	4.4E+00	7.6E-03	7.1E+00	1.0E-02	3.3E+01	1.3E+02	1.2E+00
Eu-152	7.5E+00	1.8E-02	1.2E+01	2.2E-02	5.0E+01	1.8E+02	1.6E+00
Eu-154	5.2E+00	1.2E-02	8.5E+00	1.6E-02	3.5E+01	1.2E+02	1.1E+00
Eu-155	8.1E+00	1.7E-02	1.3E+01	2.2E-02	4.8E+01	1.7E+02	1.6E+00
Tl-208	3.9E+00	9.1E-03	6.2E+00	1.0E-02	2.9E+01	1.1E+02	1.0E+00
Pb-212	5.9E+00	8.9E-03	9.6E+00	1.2E-02	4.3E+01	1.6E+02	1.5E+00
Bi-214	9.7E+00	2.3E-02	1.6E+01	2.1E-02	7.2E+01	2.8E+02	2.6E+00
Pb-214	8.9E+00	1.6E-02	1.4E+01	3.2E-02	6.5E+01	2.4E+02	2.2E+00
Ra-226	8.1E+01	1.3E-01	1.3E+02	1.6E-01	5.9E+02	2.1E+03	1.9E+01
Ac-228	1.8E+01	4.1E-02	2.9E+01	4.7E-02	1.5E+02	5.7E+02	5.6E+00
Pa-234	8.5E+00	2.3E-02	1.4E+01	3.0E-02	5.4E+01	1.9E+02	1.7E+00
Pa-234m	9.3E+02	1.7E+00	1.5E+03	2.3E+00	7.5E+03	3.0E+04	2.9E+02
Th-234	8.5E+01	2.8E-01	1.4E+02	4.2E-01	4.6E+02	1.5E+03	1.5E+01
U-235	4.9E+00	7.7E-03	8.0E+00	9.5E-03	3.6E+01	1.3E+02	1.2E+00
Am-241	1.1E+01	3.3E-02	1.8E+01	4.7E-02	5.7E+01	2.0E+02	2.0E+00

Table 5

Model GAM-AN2 Detection Limits
1,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	138G	138G	590G	590G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.6 liter	2560 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	1.8E+01	4.4E-02	1.2E+02	6.6E-02	2.1E+02	8.8E+02	1.0E+01
K-40	1.9E+02	2.7E-01	1.2E+03	1.4E+00	2.3E+03	9.5E+03	1.1E+02
Cr-51	1.6E+02	3.8E-01	7.7E+02	1.4E+00	1.8E+03	7.4E+03	7.3E+01
Mn-54	1.8E+01	3.2E-02	1.1E+02	1.5E-01	2.4E+02	9.8E+02	1.1E+01
Co-57	1.6E+01	3.8E-02	6.0E+01	1.0E-01	1.8E+02	6.6E+02	6.6E+00
Co-58	1.7E+01	3.2E-02	1.0E+02	1.5E-01	2.2E+02	9.2E+02	9.8E+00
Fe-59	2.9E+01	6.0E-02	1.9E+02	3.0E-01	3.8E+02	1.6E+03	1.8E+01
Co-60	1.6E+01	3.8E-02	1.1E+02	2.0E-01	2.3E+02	9.8E+02	1.1E+01
Zn-65	3.8E+01	7.0E-02	2.4E+02	3.5E-01	4.1E+02	1.7E+03	2.0E+01
Nb-95	6.6E+01	1.4E-01	2.9E+02	4.5E-01	9.6E+02	3.8E+03	3.8E+01
Zr-95	3.2E+01	6.3E-02	2.0E+02	3.0E-01	4.1E+02	1.7E+03	1.8E+01
Ru-106	2.0E+02	5.1E-01	1.2E+03	2.2E+00	1.9E+03	8.0E+03	8.2E+01
Ag-110m	2.1E+01	6.0E-02	1.3E+02	2.7E-01	2.1E+02	8.7E+02	9.2E+00
Sb-125	5.7E+01	9.8E-02	3.1E+02	3.9E-01	5.7E+02	2.4E+03	2.3E+01
I-131	2.1E+01	4.4E-02	1.1E+02	1.3E-01	2.1E+02	8.5E+02	8.2E+00
Ba-133	2.5E+01	4.7E-02	1.3E+02	1.8E-01	2.7E+02	1.1E+03	1.1E+01
Cs-134	1.8E+01	3.1E-02	1.1E+02	1.3E-01	2.0E+02	8.2E+02	8.5E+00
Cs-137	2.1E+01	3.8E-02	1.3E+02	1.7E-01	2.4E+02	9.8E+02	1.0E+01
Ce-144	1.2E+02	2.8E-01	4.7E+02	7.2E-01	1.5E+03	5.4E+03	5.4E+01
Pm-144	1.6E+01	3.1E-02	9.8E+01	1.4E-01	1.9E+02	7.9E+02	7.9E+00
Eu-152	4.7E+01	1.1E-01	1.8E+02	3.0E-01	5.7E+02	2.1E+03	2.0E+01
Eu-154	3.5E+01	7.9E-02	1.3E+02	2.2E-01	3.9E+02	1.4E+03	1.4E+01
Eu-155	5.1E+01	1.5E-01	2.0E+02	4.4E-01	7.0E+02	2.5E+03	2.6E+01
Tl-208	2.0E+01	3.5E-02	1.1E+02	1.5E-01	2.8E+02	1.2E+03	1.2E+01
Pb-212	3.2E+01	6.6E-02	1.4E+02	2.2E-01	4.0E+02	1.6E+03	1.5E+01
Bi-214	4.1E+01	6.6E-02	2.4E+02	2.9E-01	4.1E+02	1.7E+03	1.7E+01
Pb-214	4.1E+01	8.5E-02	2.1E+02	3.1E-01	4.7E+02	1.9E+03	1.9E+01
Ra-226	3.5E+02	8.2E-01	1.5E+03	2.4E+00	4.7E+03	1.8E+04	1.8E+02
Ac-228	6.6E+01	1.2E-01	4.2E+02	5.9E-01	7.5E+02	3.1E+03	3.5E+01
Pa-234	7.9E+01	1.8E-01	3.0E+02	4.9E-01	6.3E+02	2.3E+03	2.3E+01
Pa-234m	3.2E+03	5.7E+00	2.1E+04	2.8E+01	3.5E+04	1.4E+05	1.6E+03
Th-234	5.1E+02	1.4E+00	2.0E+03	4.3E+00	5.7E+03	2.1E+04	2.3E+02
U-235	2.2E+01	5.1E-02	9.2E+01	1.5E-01	2.9E+02	1.1E+03	1.1E+01
Am-241	7.0E+01	2.0E-01	2.7E+02	6.1E-01	7.9E+02	3.0E+03	3.2E+01

Table 6

Model GAM-AN2 Detection Limits
10,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	138G	138G	590G	590G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.6 liter	2560 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	5.7E+00	1.4E-02	3.8E+01	7.1E-02	6.7E+01	2.8E+02	3.2E+00
K-40	5.9E+01	8.5E-02	3.9E+02	4.3E-01	7.2E+02	3.0E+03	3.5E+01
Cr-51	5.0E+01	1.2E-01	2.4E+02	4.4E-01	5.8E+02	2.3E+03	2.3E+01
Mn-54	5.6E+00	1.0E-02	3.5E+01	4.9E-02	7.5E+01	3.1E+02	3.4E+00
Co-57	5.1E+00	1.2E-02	1.9E+01	3.3E-02	5.8E+01	2.1E+02	2.1E+00
Co-58	5.4E+00	1.0E-02	3.3E+01	4.7E-02	6.9E+01	2.9E+02	3.1E+00
Fe-59	9.1E+00	1.9E-02	5.9E+01	9.5E-02	1.2E+02	5.1E+02	5.7E+00
Co-60	5.2E+00	1.2E-02	3.4E+01	6.2E-02	7.3E+01	3.1E+02	3.5E+00
Zn-65	1.2E+01	2.2E-02	7.6E+01	1.1E-01	1.3E+02	5.5E+02	6.2E+00
Nb-95	2.1E+01	4.3E-02	9.3E+01	1.4E-01	3.0E+02	1.2E+03	1.2E+01
Zr-95	1.0E+01	2.0E-02	6.2E+01	9.4E-02	1.3E+02	5.4E+02	5.7E+00
Ru-106	6.2E+01	1.6E-01	3.7E+02	7.1E-01	6.1E+02	2.5E+03	2.6E+01
Ag-110m	6.7E+00	1.9E-02	4.0E+01	8.4E-02	6.7E+01	2.8E+02	2.9E+00
Sb-125	1.8E+01	3.1E-02	9.8E+01	1.2E-01	1.8E+02	7.5E+02	7.4E+00
I-131	6.8E+00	1.4E-02	3.5E+01	4.2E-02	6.7E+01	2.7E+02	2.6E+00
Ba-133	8.0E+00	1.5E-02	4.1E+01	5.6E-02	8.7E+01	3.5E+02	3.4E+00
Cs-134	5.7E+00	9.8E-03	3.4E+01	4.2E-02	6.2E+01	2.6E+02	2.7E+00
Cs-137	6.6E+00	1.2E-02	4.0E+01	5.4E-02	7.5E+01	3.1E+02	3.2E+00
Ce-144	3.8E+01	8.9E-02	1.5E+02	2.3E-01	4.7E+02	1.7E+03	1.7E+01
Pm-144	5.1E+00	9.7E-03	3.1E+01	4.5E-02	6.0E+01	2.5E+02	2.5E+00
Eu-152	1.5E+01	3.6E-02	5.8E+01	9.4E-02	1.8E+02	6.5E+02	6.4E+00
Eu-154	1.1E+01	2.5E-02	4.1E+01	6.9E-02	1.2E+02	4.5E+02	4.5E+00
Eu-155	1.6E+01	4.9E-02	6.2E+01	1.4E-01	2.2E+02	7.9E+02	8.1E+00
Tl-208	6.2E+00	1.1E-02	3.6E+01	4.8E-02	8.8E+01	3.6E+02	3.7E+00
Pb-212	1.0E+01	2.1E-02	4.5E+01	6.9E-02	1.3E+02	5.0E+02	4.8E+00
Bi-214	1.3E+01	2.1E-02	7.6E+01	9.3E-02	1.3E+02	5.3E+02	5.5E+00
Pb-214	1.3E+01	2.7E-02	6.8E+01	9.7E-02	1.5E+02	6.0E+02	5.9E+00
Ra-226	1.1E+02	2.6E-01	4.7E+02	7.6E-01	1.5E+03	5.8E+03	5.6E+01
Ac-228	2.1E+01	3.8E-02	1.3E+02	1.9E-01	2.4E+02	9.9E+02	1.1E+01
Pa-234	2.5E+01	5.6E-02	9.4E+01	1.5E-01	2.0E+02	7.2E+02	7.4E+00
Pa-234m	1.0E+03	1.8E+00	6.6E+03	8.9E+00	1.1E+04	4.6E+04	5.1E+02
Th-234	1.6E+02	4.5E-01	6.2E+02	1.4E+00	1.8E+03	6.8E+03	7.3E+01
U-235	6.9E+00	1.6E-02	2.9E+01	4.6E-02	9.3E+01	3.6E+02	3.4E+00
Am-241	2.2E+01	6.2E-02	8.6E+01	1.9E-01	2.5E+02	9.5E+02	1.0E+01

Table 7

Model GAM-AN2 Detection Limits
50,000 second count time

Geometry	Marinelli	Marinelli	Marinelli	Marinelli	125ml bottle	20ml vial	47mm filter
Model	138G	138G	590G	590G	Nalgene	Packard	Gelman
Matrix	Water	Soil	Water	Soil	Water	Water	Filter
Density	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.6 g/cc	1.0 g/cc	1.0 g/cc	N/A
Volume	1.6 liter	2560 gram	0.5 liter	800 gram	0.125 liter	0.020 liter	1 filter
Isotope	pCi/L	pCi/g	pCi/L	pCi/g	pCi/L	pCi/L	pCi/filter
Na-22	2.9E+00	6.1E-03	1.9E+01	3.1E-02	3.7E+01	1.6E+02	1.8E-00
K-40	2.6E+01	4.7E-02	1.7E+02	2.4E-01	3.8E+02	1.6E+03	1.9E+01
Cr-51	2.5E+01	4.4E-02	1.2E+02	1.6E-01	3.1E+02	1.2E+03	1.2E+01
Mn-54	2.9E+00	4.7E-03	1.8E+01	2.3E-02	4.2E+01	1.7E+02	1.9E+00
Co-57	2.5E+00	5.8E-03	9.6E+00	1.6E-02	2.9E+01	1.1E+02	1.0E+00
Co-58	3.0E+00	5.8E-03	1.9E+01	2.7E-02	4.9E+01	2.1E+02	2.2E+00
Fe-59	5.3E+00	8.8E-03	3.5E+01	4.4E-02	7.0E+01	2.9E+02	3.3E+00
Co-60	3.1E+00	6.5E-03	2.0E+01	3.3E-02	4.0E+01	1.7E+02	1.9E+00
Zn-65	6.7E+00	1.0E-02	4.3E+01	5.1E-02	7.4E+01	3.1E+02	3.5E+00
Nb-95	1.1E+01	2.3E-02	4.9E+01	7.7E-02	1.6E+02	6.3E+02	6.1E+00
Zr-95	7.9E+00	8.3E-03	4.9E+01	3.9E-02	6.3E+01	2.6E+02	2.8E+00
Ru-106	3.6E+01	4.5E-02	2.1E+02	2.0E-01	3.8E+02	1.6E+03	1.6E+01
Ag-110m	4.7E+00	4.5E-03	2.8E+01	2.0E-02	3.6E+01	1.5E+02	1.6E+00
Sb-125	9.0E+00	1.5E-02	4.9E+01	5.9E-02	1.0E+02	4.2E+02	4.1E+00
I-131	3.4E+00	5.3E-03	1.7E+01	1.6E-02	4.0E+01	1.6E+02	1.6E+00
Ba-133	4.2E+00	6.7E-03	2.1E+01	2.5E-02	4.9E+01	2.0E+02	1.9E+00
Cs-134	3.2E+00	4.4E-03	1.9E+01	1.9E-02	4.3E+01	1.8E+02	1.8E+00
Cs-137	4.8E+00	5.1E-03	2.9E+01	2.3E-02	4.1E+01	1.7E+02	1.8E+00
Ce-144	1.8E+01	4.3E-02	7.1E+01	1.1E-01	2.4E+02	8.9E+02	8.8E+00
Pm-144	3.2E+00	4.3E-03	1.9E+01	2.0E-02	3.9E+01	1.6E+02	1.7E+00
Eu-152	7.6E+00	1.8E-02	2.9E+01	4.7E-02	8.6E+01	3.2E+02	3.1E+00
Eu-154	5.2E+00	1.2E-02	2.0E+01	3.3E-02	6.0E+01	2.2E+02	2.2E+00
Eu-155	8.6E+00	1.4E-02	3.3E+01	4.0E-02	1.1E+02	3.8E+02	4.0E+00
Tl-208	3.2E+00	5.0E-03	1.9E+01	2.2E-02	7.1E+01	2.9E+02	3.0E+01
Pb-212	5.1E+00	1.0E-02	2.3E+01	3.3E-02	6.4E+01	2.5E+02	2.4E+00
Bi-214	7.7E+00	9.3E-03	4.5E+01	4.1E-02	8.7E+01	3.6E+02	3.7E+00
Pb-214	7.2E+00	1.2E-02	3.6E+01	4.3E-02	8.5E+01	3.4E+02	3.4E+00
Ra-226	6.1E+01	1.3E-01	2.5E+02	3.8E-01	7.7E+02	3.0E+03	2.9E+01
Ac-228	1.5E+01	1.6E-02	9.5E+01	7.8E-02	1.3E+02	5.4E+02	5.9E+00
Pa-234	1.2E+01	2.7E-02	4.5E+01	7.4E-02	1.0E+02	3.6E+02	3.7E+00
Pa-234m	5.1E+02	8.1E-01	3.3E+03	4.0E+00	6.4E+03	2.7E+04	3.0E+02
Th-234	9.1E+01	2.1E-01	3.6E+02	6.3E-01	1.1E+03	3.9E+03	4.2E+01
U-235	3.7E+00	8.0E-03	1.5E+01	2.3E-02	4.7E+01	1.8E+02	1.7E+00
Am-241	1.3E+01	2.8E-02	5.2E+01	8.7E-02	1.4E+02	5.2E+02	5.6E+00

Appendix A
Gamma Analyst Nuclide Library⁽⁴⁾

Nuclide Name	Half-Life (Seconds)	Energy (keV)	Yield (%)	
Na-22	8.21E+07	1274.5	179.8	
K-40	4.03E+16	1460.8	10.7	
Cr-51	2.39E+06	320.1	10.1	
Mn-54	2.70E+07	834.8	100.0	
Co-57	2.35E+07	122.1	85.9	
Co-58	6.13E+06	810.8	99.4	
Fe-59	3.84E+06	1099.3	56.5	
Co-60	1.66E+08	1332.5	100.0	
Zn-65	2.11E+07	1115.6	50.7	
Nb-95	3.12E+05	235.7	24.1	
Zr-95	5.53E+06	756.7	54.5	
Ru-106	3.18E+07	621.8	9.8	
Ag-110m	2.16E+07	657.8	94.6	
Sb-125	8.62E+07	427.9	29.4	
I-131	6.95E+05	364.5	81.2	
Ba-133	3.32E+08	356.0	62.1	
Cs-134	6.51E+07	604.7	97.6	
Cs-137	9.47E+08	661.7	85.2	
Ce-144	2.46E+07	133.5	11.1	
Pm-144	3.14E+07	696.5	99.5	
Eu-152	4.27E+08	121.8	28.4	
Eu-154	2.71E+08	123.1	40.4	
Eu-155	1.48E+08	86.5	32.8	
Tl-208	4.42E+17 ⁽¹⁾	583.2	84.5	*U-232
Pb-212	4.43E+17 ⁽¹⁾	238.6	44.6	*U-232
Bi-214	5.05E+10 ⁽²⁾	609.3	46.3	*Ra-226
Pb-214	5.05E+10 ⁽²⁾	351.9	35.8	*Ra-226
Ra-226	5.05E+10	186.1	3.5	
Ac-228	4.43E+17 ⁽¹⁾	911.6	27.7	*U-232
Pa-234	1.41E+17 ⁽³⁾	946.0	20.0	*U-238
Pa-234M	1.41E+17 ⁽³⁾	1001.0	0.6	*U-238
Th-234	2.08E+06 ⁽³⁾	63.3	4.5	*U-238
U-235	2.22E+16	185.7	57.5	
Am-241	1.37E+10	59.5	35.9	

- (1) Half-life secular equilibrium with U-232
(2) Half-life secular equilibrium with Ra-226
(3) Half-life secular equilibrium with U-238
(4) All nuclide information (except as noted above) was attained from the National Nuclear Data Center, 1992.



Canberra Industries Inc., Nuclear Products Group, 800 Research Parkway, Meriden, CT 06450 U.S.A.
Tel: (203) 238-2351 Toll Free 1-800-243-4422 FAX: (203) 235-1347 <http://www.canberra.com>



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