Applications of the TRU-D Portable Package Monitor for rapid gram estimation of plutonium bearing waste packages at the point of origin.

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ABSTRACT

BNFL Instruments' TRU-D Portable Package monitor (PPM) was developed in response to a market need for a simple, highly maneuverable, accurate, reliable and inexpensive packet monitor. The instrument plays a major role at nuclear sites in performing a wide variety of plutonium measurement tasks, but is primarily being used as a portable instrument for criticality safety measurements of the fissile content of waste packages at the point of origin.

Traditional packet monitoring methods used in operations and decommissioning have relied on methods such as gross gamma counting, which are subject to considerable variation, due to differences in the attenuation properties of waste matrix and source. The TRU-D Portable Package Monitor uses the total neutron counting method, which is far less sensitive to such biases. The system has been designed for rapid set-up and simple push button operation and can accept packages up to 30 cm in diameter and 50 cm in length with a maximum weight of 25 kg. The minimum detectable activity (MDA) is of the order of 0.1 - 1g Pu for a 10 minute measurement. Total measurement uncertainty (TMU) is typically less than +/- 40% at the 95% confidence level.

Three applications are described in this paper, which demonstrate the versatility of this instrument. At nuclear sites in the United Kingdom, more than a dozen PPMs have been deployed in various waste management applications including provision of a "Threshold" indication of Pu content for criticality safety control. In the USA at the Rocky Flats Environmental Technology Site (RFETS) a PPM is in use, also for criticality safety controls, for cumulative waste container loading estimates. The qualification work at RFETS established a PPM upper range limit of 500g for Weapons Grade (WG) Pu Oxide. In the third application, Advanced Mixed Waste Treatment Plant (AMWTP) in Idaho, the instrument was upgraded with gamma spectroscopy to provide sensitivity to fissile uranium isotopes as well as plutonium. This system has been built to meet AMWTP's needs for fissile content tracking and control of material entering or leaving the Special Case Waste (SCW) gloveboxes.

INTRODUCTION

Portable Packet Monitors (known as TRU-D PPMs) are used to measure plutonium bearing material using the total neutron counting technique. Each instrument consists of a measurement chamber, encompassing four He3 detectors, and signal-processing electronics all mounted on a mobile "trolley" platform. Small packets of waste up to 35 liters can be monitored in the cylindrical measuring chamber. The system uses just two buttons 'Start/Standardise' and 'Stop/Accept/Print' to control the instrument and a Liquid Crystal Display (LCD) to display the results.

OVERVIEW OF THE TECHNIQUE

Traditional packet monitoring methods used in operations and decommissioning have relied on methods such as gross gamma counting which are subject to considerable variation due to differences in the attenuation properties of waste matrix and source. The TRU-D PPM uses the total neutron counting method, which is far less susceptible to such biases.

Fig. 1 TRU-D Portable Package Monitor.

Figure 1 shows the general arrangement of the TRU-D PPM. The system has been designed for rapid set-up and simple push button operation and can accept packages up to 30 cm in diameter and 50 cm in length with a maximum weight of 25 kg.

The four He3 detector outputs are combined, amplified and fed to the counting/processing electronics mounted inside the instrument. The Start, Stop and Lid Open switches feed into the processing electronics and the LCD display and printer are controlled by the processing electronics.

The Pu mass is calculated as follows:

$$M_{Pu} = \frac{K \times T}{\varepsilon \times 473 \times \nu_{s(1)} \times M \times (1+\alpha)}$$

where:

M_{Pu} = Pu mass / g;

T = Totals count rate after segment rejection, deadtime correction and background subtraction / s^{-1};

K = Pu/^{240}Pu$_{eff}$ mass conversion factor;

ε = Detection efficiency;

$\nu_{s(1)}$ = First moment of spontaneous fission for ^{240}Pu;

M = Source self multiplication;

α = source (α, n) ratio.

Upper and lower limits for the Pu mass are calculated as follows:

$$M_{Pu(+)} = \frac{K \times T_{(+)}}{\varepsilon_{(-)} \times 473 \times \nu_{s(1)} \times M_{(-)} \times (1+\alpha_{(-)})}$$

$$M_{Pu(-)} = \frac{K \times T_{(-)}}{\varepsilon_{(+)} \times 473 \times \nu_{s(1)} \times M_{(+)} \times (1+\alpha_{(+)})}$$

where:

$T_{(+)} = T + k_c \cdot \sigma T$ = Upper net total count rate /s^{-1}

$T_{(-)} = T - k_c \cdot \sigma T$ = Lower net total count rate /s^{-1}

k_c=Confidence level (i.e. no. sigma)

$M_{Pu(+)}, M_{Pu(-)}$ = Upper and lower Pu mass / g;

$\varepsilon_{(+)}, \varepsilon_{(-)}$ = Upper and lower detection efficiency;

$M_{(+)}, M_{(-)}$ = Upper and lower source self multiplication;

$\alpha_{(+)}, \alpha_{(-)}$ = Upper and lower source (α, n) ratio.

Thus, the total Pu mass of a package is determined from the measured total neutron count rate using a fixed Pu isotopic composition, an assumed chemical composition and a calibration which is set for the worst-case spatial distribution of Pu and matrix within the measurement chamber. This ensures a measurement result which is appropriate for criticality control. For criticality safety, the upper limit on the Pu mass is reported by the instrument on the LCD screen. A warning is provided for packages whose content is beyond the calibrated mass limit.

System constants (efficiency, M, K, α etc.) are stored on the hard-drive and may be modified (e.g for a change of waste stream) by attaching a keyboard and monitor to the hard drive or by connecting to a lap-top computer through an ethernet terminal.

To ensure the validity of the system's calibration, a regular standardization check is performed. A standard neutron check source is placed in a holder at the bottom of the measurement chamber and the standardization check is initiated by a prolonged press of the Start button. The LCD display indicates that a standardization check is underway and confirms afterwards the monitor is within specification.

APPLICATIONS

At nuclear sites in the UK, more than a dozen TRU-D PPMs have been deployed in various waste management applications including provision of a "Threshold" indication of Pu content for criticality safety control. These systems are currently in operation at the Sellafield and Dounreay sites.

At the Sellafield Mixed Oxide (MOX) Demonstration Facility in Cumbria, England, a system has been deployed to allow Pu measurement of cans containing MOX material. The system meets nuclear safety requirements to allow the cans to be transferred to storage. This particular application demonstrates the ease with which materials from glove boxes and loaded into cans can be assayed using PPM technology. The real time assay results are based on "worst case" isotopics are therefore conservative estimates. To improve the accuracy, off-line analysis may be performed to yield a result that is suitable for accountancy and safeguards. This involves a correction for the isotopic composition of individual cans. In addition, at the Sellafield MOX Plant, four TRU-D PPMs are currently in use for the measurement of plutonium contaminated waste packets.

For waste retrievals at Sellafield the TRU-D PPM is to be used in conjunction with an HPGe system to monitor Pu contents . This waste typically has very low Pu contamination levels, and therefore the total measurement time (including background) can be as short as 3 minutes. Such rapid assays enable the operators to maintain high throughput and accelerate the remediation process.

At the Sellafield Waste Treatment Complex (WTC), the TRU-D PPM is used to assay bottles of liquid, arising from the compaction of drums (known as squeezants). The system assays two liter plastic bottles in plastic containment. Unlike the AMWTP application (described below), these systems do not require a High Purity Germanium (HPGe) system for uranium measurements, because the feedstock streams have negligible U235 content.

A TRU-D PPM is currently being commissioned for deployment at the Dounreay nuclear site in Scotland. The system will support the decommissioning of the Fast Reactor Fuel Reprocessing plant where packages of plutonium contaminated material will be measured prior to drum filling. The deployment of the TRU-D PPM is aimed at improving the operational efficiency of decommissioning activities. Waste packages are currently assayed with a hand-held total neutron counting device with the Pu mass being determined by a manual calculation. This method had several weaknesses: (i) the hand-held monitor currently deployed is proving to be difficult to maintain through obsolescence of components, (ii) the method was subject to large systematic geometric errors as package were not measured in a reproducible geometry, (iii) the short fixed measurement time used by the device was subject to large statistical errors, (iv) lack of background shielding resulted in a high MDA, (v) the manual calculation method was labor intensive and subject to human error in the data recording and data entry processes.

In the USA at RFETS, a TRU-D PPM is in use for criticality safety controls, providing cumulative waste container loading estimates. The qualification work at RFETS established a TRU-D PPM upper range limit of 500g for Weapons Grade Pu Oxide. The operational efficiencies gained by the use of this instrument will help RFETS achieve its accelerated site closure deadline.

In the final application, which we shall explore in depth in this paper, the instrument has been deployed at the Advanced Mixed Waste Treatment Plant in Idaho. The instrument was upgraded with gamma spectroscopy to provide sensitivity to fissile uranium isotopes as well as plutonium. This system has been built to meet AMWTP's needs for fissile content tracking and control of material entering or leaving the Special Case Waste (SCW) gloveboxes.

CASE STUDY: USE OF THE TRU-D PPM AT AMWTP, IDAHO

The SCW Packet Assay Monitor (SCW PAM) is a combined Packet Gamma Energy Analysis System (PGEAS) and TRU-D PPM system for the assay of FGE (Fissile Gram Equivalent) of packages. The former system performs an isotopic analysis of the waste packet; the latter system measures the total plutonium content via total neutron counting. The assay station is shown in Figure 2.

The PGEAS system incorporates a single Ortec HPGe LoAx detector. An Ortec DSPEC unit provides the signal amplification, high voltage, multi-channel analysis (MCA) functions. Master control of the system is via the PGEAS computer.

The combined system is able to quantitatively measure Pu240 effective mass and the relative ratios of U233 and U235 to Pu239 for a variety of packages with a maximum outer diameter of 30cm.. This information is combined with Pu isotopics, to yield the total FGE content and its respective TMU for each packet.

Surrogate waste packages loaded with plutonium, uranium and Cf252 standards were used in calibration and validation activities. A full list of containers and matrices is given in Table I. The packages are shown in Figure 3.

Fig. 2 AMWTP SCW Packet Assay Monitor.

Fig. 3 Surrogate Waste Packages.

Table I. Matrices used in calibration and validation of AMWTP Packet Assay Monitor

Jar Label	Nominal Container Vol (ml)	Matrix	Actual Diam. (mm)	Actual Height (mm)
JAR101	20	Silica Sand	27	60
JAR102	40	Soil	27	100
JAR103	125	Silica Sand	47	97
JAR104	1000	Salt	122	140
JAR105	4000	4 parts Cat Litter, 1 part water	186	258
JAR106	4000	Shredded Paper	186	258
JAR107	2075	Aerosol Can - Empty	102	254
JAR108	19000	Polyethylene beads	260	413
JAR109	19000	Vermiculite	260	413
JAR110	4000	Polyethylene beads	186	258

The combined assay system's performance criteria are as follows:

1. Range of Measurement: The PAM is required to assay packets with up to 200g FGE (Weapons Grade Pu isotopics).

2. MDA: For all matrix conditions, the PAM is required to have a MDA of 2g FGE.

3. TMU: The target TMU for a 10g FGE matrix is +40%, -100% at the 95% confidence level.

4. For matrices at or above 10g FGE, the probability of measured FGE plus TMU being less than 50 % of the true value shall be less than 1 in 10,000.

For routine assay, once system performance checks have been completed, the operator initiates a TRU-D PPM background assay, loads the packet into the TRU-D PPM chamber, performs a packet assay, removes the packet and performs a replicate background assay. The operator then transfers the packet to the PGEAS station. Various filter options are available to the operator to reduce the count rate at the HPGe detector to specified acceptable levels. An assay is initiated and the operator scans in the packet barcode. The TRU-D neutron result is automatically uploaded from the TRU-D to the PGEAS computer via an ethernet connection. The operator inputs the appropriate matrix and filter type and proceeds with the gamma measurement. A final report is produced with the combined neutron and gamma results. The software incorporates a set of automated data quality checks to verify that the assay is within acceptable bounds (e.g. checks on gamma spectrum, isotopics and valid measurement range). For assays where the data quality flags are within specified tolerances, the data from the final report is uploaded to the site's data management system. Off-line expert review is required to investigate and resolve any non-conforming assays (i.e. where data quality flags are outside of specified tolerances).

For all measurements, the gamma assay time is 60 seconds, and the PPM assay (which includes two background assays bracketing the packet assay) takes a total of 840 seconds. Thus each packet is assayed in a total of 15 minutes.

Detection Efficiency

The chamber efficiency was determined by positioning (i) a 15.04g Pu standard vertically in the bottom center of the TRU-D chamber and within surrogate waste packages (ii) a Cf252 source (B2-722) inside the empty chamber and within surrogate waste packages. For each configuration three replicates were performed.

The total neutron emission rate of the Pu standards is subject to relatively large uncertainty, because the α [the ratio of (α,n) emissions to spontaneous neutron emissions] is not well known for the Pu standards. For this reason the Pu measurements were used as calibration confirmation rather than to actually determine the calibration efficiency. Note that Cf252 has a known total neutron emission rate but neutrons are emitted with a different energy spectrum than the spectrum characteristic of plutonium oxide. Thus the Pu calibration confirmation provides confidence in the calibration and TMU factors.

The Cf252 calibration is summarized in Table II. The nominal efficiency was set to 0.018. This is an arbitrary value selected to represent a typical AMWTP special case waste package. The minimum detection efficiency (0.0134) was determined from the penultimate column, which is the lower tail of the 95% confidence level of the minimum observed efficiency across the set of Cf252 calibration measurements. Maximum detection efficiency (0.0267) is likewise calculated from the maximum value in the final column (upper tail of 95% confidence interval).

Table II. Calibration Summary

Container ID / Source Position	Matrix	Container	Source	Efficiency	% Uncertainty in Eff (1 sigma)	Efficency at Lower Tail of 95% CI	Efficency at Upper Tail of 95% CI
Empty - Bottom	Empty	None	Cf-252 Ser# B2-722	0.0189	1.3%	0.0184	0.0194
Jar106 - Bottom	Paper	4 Liter	Cf-252 Ser# B2-722	0.0230	1.3%	0.0224	0.0236
Jar108 - Bottom	Poly	19 Liter	Cf-252 Ser# B2-722	0.0137	1.3%	0.0134	0.0141
Empty - Middle	Empty	None	Cf-252 Ser# B2-722	0.0200	1.3%	0.0195	0.0205
Jar108 - Middle	Poly	19 Liter	Cf-252 Ser# B2-722	0.0153	1.3%	0.0149	0.0157
Empty - Top	Empty	None	Cf-252 Ser# B2-722	0.0182	1.3%	0.0178	0.0187
Jar106 - Top	Paper	4 Liter	Cf-252 Ser# B2-722	0.0260	1.3%	0.0254	0.0267
Jar108 - Top	Poly	19 Liter	Cf-252 Ser# B2-722	0.0189	1.3%	0.0184	0.0194
			Nominal Efficency	***0.0180***			
			Min Efficiency (min value at lower tail of 95% CI)			***0.0134***	
			Max Efficency (max value at upper tail of 95% CI)				***0.0267***

Calibration confirmation with Pu is summarized in **Table III**. It can be seen that the Pu efficiencies fall within the minimum and maximum efficiencies determined in **Table II** with Cf252 standards.

Table III. Calibration Confirmation Summary

Container ID / Source Position	Matrix	Container	Efficiency	% Uncertainty in Eff (1 sigma)
None - Bottom	Empty	None	0.0192	10.0%
Jar106 - Bottom	Paper	4 Liter	0.0213	10.0%
Jar108 - Bottom	Poly	19 Liter	0.0160	10.0%

Total Measurement Uncertainty

TMU is calculated for each assay by combining the statistical uncertainty of each measurement (i.e. propagated from the square root of total counts) with applicable systematic components. The systematic components of TMU are:

- Uncertainty in the neutron emission rates of the calibration standards,
- Statistical components in the calibration measurements,
- Self-shielding and/or multiplication effects in the FGE materials in the waste,
- Matrix effects,
- Source distribution effects,
- Uncertainty associated with the (α,n) emission rate of the waste,
- Uncertainty associated with the isotopic composition of the waste.

The TRU-D PPM uses a universal efficiency, to calculate the Pu mass value from the net neutron count. The system also uses minimum and maximum efficiencies to determine upper and lower bounds on the Pu mass. The lower tail of the statistical uncertainty at the 95% confidence level is combined with the minimum efficiency to give the upper bound on the WG Pu mass. Similarly, the lower bound of the Pu mass is established from the maximum efficiency.

Thus the minimum and maximum efficiency parameters essentially represent the upper and lower bounds of the combined uncertainty effects arising from matrix, source distribution and calibration (statistical and neutron emission).

Measurement uncertainty due to variations in α have been calculated based on a study of typical isotopics grade inputs to the SCW. The best estimate of α for these waste streams is 0.863.

The value of K, is based on the most conservative (highest) value of the three streams, (i.e. K =17.180 for 1988 AMWTP). No measurement uncertainty term is included in the TMU from isotopic variation, because the worst case condition is constant. Significant underestimates in the FGE upper limit can only arise when "Super A Grade" Pu is present (i.e. Pu240eff/Pu content less than 0.06). The HPGe software has internal flags to detect a Pu240/Pu239 gamma line mass average ratio of less than 0.04 (an indication of "Super A Grade" Pu). When this flag is raised, the data will be dispositioned for off-line analysis (expert review) to assess the impact upon the FGE and TMU.

Overestimates in FGE caused by the presence of high Pu238 mass fractions (e.g. from Heat Source Pu) are detected by the Pu238/Pu239 gamma line mass average ratio. The flag is set when the ratio exceeds 0.01.

Significant measurement uncertainty arising from self-shielding or multiplication in the passive neutron count is not expected.

The system's final TMU was estimated to be +/- 38% for a 10 g loading. Which is within the required range of +40%, -100%.

Validation

In order to validate the instrument over its calibrated range, 29 measurements were performed with a diverse range of jars and known Pu and U mass loadings using the standard operating procedures. The results are given in Table IV. These results validate the calibration up to 198.24 g FGE (just short of the required upper range of 200g FGE) and also demonstrate the system's ability to detect and flag the presence of small quantities of U235 (3.67 g FGE) in the absence of Pu. This capability is critical to the plant safety case as it ensures that packages that have no measurable neutron emission but have high FGE content due to fissile uranium will be flagged for off-line review.

Note that the measured FGE is, in most cases, significantly higher than the actual FGE because the Pu standards that were used for validation had a high (α,n) emission rate.

Table IV. Validation of the AMWTP Packet Assay Monitor

Container	Fissile Content	Actual FGE Mass (g)	Measured FGE Mass +TMU (g)	Data Quality Message	Meets Over-estimate Criteria? (Measured + TMU > Actual)	Meets U235 flag criteria?
JAR102	WG Pu Oxide	0.85	2.29	Data OK	Yes	N/A
JAR102	WG Pu Oxide	0.85	2.51	Data OK	Yes	N/A
JAR102	WG Pu Oxide	0.85	2.36	Data OK	Yes	N/A
JAR102	WG Pu Oxide	0.85	2.33	Data OK	Yes	N/A
JAR102	WG Pu Oxide	0.85	2.39	Data OK	Yes	N/A
JAR102	WG Pu Oxide	24.52	43.58	Data OK	Yes	N/A
JAR102	Uranium (0.19% U235)	3.67	1.32	U235 detected in absence of Pu239	N/A	Yes
JAR102	WG Pu + 3.67 g of U235	28.19	44.32	Data OK	Yes	N/A
JAR104	WG Pu Oxide	0.85	2.57	Data OK	Yes	N/A
JAR104	WG Pu Oxide	0.85	2.62	Data OK	Yes	N/A
JAR104	WG Pu Oxide	24.52	45.20	Data OK	Yes	N/A
JAR104	WG Pu with high Am241 (0.5%)	46.86	193.80	Data OK	Yes	N/A
JAR104	WG Pu Oxide + Metal	198.24	521.20	Data OK	Yes	N/A
JAR104	WG Pu Oxide + Metal	198.24	520.40	Data OK	Yes	N/A
JAR104	Uranium (0.19% U235)	3.67	1.25	U235 detected in absence of Pu239	N/A	Yes
JAR104	WG Pu + 3.67 g of U235	28.19	45.91	Data OK	Yes	N/A
JAR105	WG Pu Oxide	0.85	2.57	Data OK	Yes	N/A
JAR105	WG Pu Oxide	0.85	2.73	Data OK	Yes	N/A
JAR105	WG Pu Oxide	24.52	51.71	Data OK	Yes	N/A
JAR105	WG Pu with high Am241 (0.5%)	46.86	221.30	Data OK	Yes	N/A
JAR105	WG Pu Oxide + Metal	198.24	556.00	Data OK	Yes	N/A
JAR105	WG Pu Oxide + Metal	198.24	557.40	Data OK	Yes	N/A
JAR105	Uranium (0.19% U235)	3.67	1.26	U235 detected in absence of Pu239	N/A	Yes
JAR105	WG Pu + 3.67 g of U235	28.19	47.46	Data OK	Yes	N/A
JAR109	WG Pu Oxide	0.85	2.80	Data OK	Yes	N/A
JAR109	WG Pu Oxide	0.85	2.81	Data OK	Yes	N/A
JAR109	WG Pu Oxide	24.52	52.69	Data OK	Yes	N/A
JAR109	WG Pu with high Am241 (0.5%)	46.86	228.60	Data OK	Yes	N/A
JAR109	WG Pu Oxide + Metal	198.24	606.50	Data OK	Yes	N/A
JAR109	WG Pu Oxide + Metal	198.24	606.30	Data OK	Yes	N/A
JAR109	Uranium (0.19% U235)	3.67	1.25	U235 detected in absence of Pu239	N/A	Yes
JAR109	WG Pu + 3.67 g of U235	28.19	52.52	Data OK	Yes	N/A

A Monte Carlo simulation in Microsoft Excel was conducted, in order to verify that, for matrices at or above 10g FGE, the probability of the measured FGE plus TMU being less than 50% of the true value is less than 1 in 10,000. The parameters α, K and efficiency were allowed to vary randomly based on a Normal distribution with the mean and sigma based on expected plant variations. For each parameter, the upper and lower tails were restricted by any applicable physical limitations (e.g. α may not be less than zero). For a tag FGE of 10g, the system's predicted upper FGE value was calculated (i.e. FGE + TMU) incorporating an assumed 0.5% statistical error. The value was compared to 5g (50% of tag) and a PASS recorded where the value is above or equal to 5g. This was repeated for 1,000,000 random test cases. It was found that 23 failures occurred. This represents a failure rate of 0.23 in 10,000, which meets the required criteria of <1 in 10,000.

Minimum Detectable Activity

The MDA is dependent on the radiation background, characteristics of the waste type being measured, and other factors. The MDA is defined here as that mass of FGE which, if present, yields a measured value greater than the critical level with 95% probability, where the critical level is defined as that value which measurements of the background will exceed with 5% probability.

MDA was determined by performing 8 replicate measurements on four surrogate packets representative of the waste feed envelope with a matrix containing no added activity. The detection limit equations defined by Currie [1] were used to calculate the MDA (taking into account the fact that for each assay the combined bracketed background assay time is twice the time of the packet assay). The measured variance of background for each matrix is used, together with the calibration constants determined in this report. Chamber efficiencies have been selected based on the chamber position-averaged efficiency for the most similar matrix. The resulting MDAs for the system were found to be between 0.1 and 1.0 g FGE depending on the matrix. All MDAs were less than the required value of 2g FGE.

CONCLUSION

The TRU-D PPM has been deployed at various nuclear sites in the UK and USA. This mobile push-button device uses total neutron counting to provide a "threshold" indication of Pu content in waste packages of various sizes up 35 liters. The system offers significant cost savings in waste management by enabling efficient packaging of waste in large containers (e.g. drums, crates or boxes) with a low overall cost per assay due to the operational simplicity of the system.

At Sellafield and Dounreay in the UK and at RFETS in the USA, the device is used in a simple standalone configuration for waste management and criticality control. The results are used for cumulative waste container loading estimates.

The TRU-D PPM has also been deployed at AMWTP in Idaho. The device has been integrated with a gamma spectroscopy sub-system to provide sensitivity to fissile uranium isotopes as well as plutonium. The combined system provides control of material entering or leaving the Special Case Waste (SCW) gloveboxes. The system's software combines the TRU-D PPM result with the measured isotopic ratios and provides automated data quality checking in order to minimize the number of packages requiring off-line expert review. Measurement results are automatically uploaded to the site's data management network to provide real time tracking of fissile material.

The TRU-D PPM provides many advantages over traditional "semi-quantitative" methods of assay by hand held gamma or neutron detectors:

- The total neutron counting method provides a rugged "gram estimator" method that is ideal for plant safety related applications with low susceptibility to self attenuation. Packets up to 35 liters with a maximum weight of 25 kg can be measured with a measurement uncertainty typically less than +/- 40% at the 95% confidence level.
- The packets are measured in a shielded well that reduces the background interference resulting in a relatively low MDA (of the order of 1 gram WG Pu). The assay time is configurable enabling operators to achieve high throughput by selecting short assays (3 minutes) for lightly contaminated waste or conversely, to select longer assay times for problematic packages.
- The fixed assay geometry means that the monitor is less subject to the systematic geometric errors that can occur for hand-held measurements.
- The standardized assay software and hardware based on off-the-shelf detectors and electronics enables easy maintenance and provides sites with a regulatory defensible measurement.

- The automated background measurements and standardization checks have been designed to minimize sources of bias that can often be encountered in an operational plant environment e.g. background variation, amplifier gain drifts etc.
- The mobile platform and simple two button operation provides easy set-up and deployment. Minimal operator training is required and the automated calculation eliminates the potential for human error that can occur in traditional hand calculations.

REFERENCES

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