The Use of a Gamma Ray Imaging Device for In-Cell Assay – 8424

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ABSTRACT

Gamma ray imaging has become an established technique within the nuclear industry, especially within the field of decommissioning. The technique is most commonly used to identify the origins of radiation within contaminated environments in order to provide a level of characterisation that is not possible using conventional dosemeters. Gamma ray images demonstrate, in a clear, easy to understand format, where there are significant sources of gamma emitting radiation. These images are often used to help determine decontamination, decommissioning or clean-up strategies.

Recent developments at Sellafield, in the UK, have demonstrated how gamma ray imaging devices can be used to perform in-cell, quantitative, assay. A data collection and analysis procedure has been developed that can be used to produce activity values for gamma bearing items. The technique is of especial value as the items of interest can be located in cells with limited or no man access, either due to poor physical access or high dose rates. This quantitative assay technique can be used to segregate wastes in-situ, allowing only wastes meeting user-specified criteria to be selected. This paper describes two successful applications of this newly developed technique on the Sellafield site. The technique is covered by European Patent – EP1315004A1 and US Patent – US7095030B2 [1].

INTRODUCTION

Since the mid 1990s gamma ray imaging devices have become widely used within the nuclear industry, particularly within facilities undergoing decommissioning. These instruments provide images that indicate to plant owners and operators the distribution of gamma bearing contamination within a facility. This information is provided as a digital camera image overlaid with a colored contour map depicting radiation intensity. By using a gamma ray imager this information can be made available from locations where man access is limited, either because of high gamma dose rates, or due to poor physical access. Gamma ray imaging has been used extensively across the Sellafield reprocessing facility in the UK, usually through turn-key imaging surveys provided by instrument developers such as BIL Solutions.

Within the last two years, two separate applications on the Sellafield facility have arisen that have called for quantitative, in-cell, survey work. These facilities are the Caesium Extraction Plant and an early oxide fuel reprocessing facility. The Caesium Extraction Plant is a facility from the 1950s that produced 10s TBq / kilocurie Cs-137 sources for radiotherapy purposes. The facility is heavily contaminated with Cs-137, having had dose rates exceeding 1 Sv/hr; the decommissioning team have successfully decommissioned two of the four hot cells using innovative remote handling techniques. The end point of the current phase of decommissioning is the removal of all intermediate level radwaste (ILW) from each cell. A RadScan® gamma imager supported this work by measuring the distribution of Cs-137 contamination within the cell. This work allowed the decommissioning team to prioritise their strategy for removing items from the cell. Further work was undertaken, using recently developed analysis techniques, to measure the Cs-137 activities remaining in the second cell towards the end of the decommissioning phase. This work demonstrated which items fell into the ILW category and required further decontamination or removal, and, at the end of decommissioning operations was used to demonstrate that only low level radwaste (LLW) remained.

Similar analysis work has been carried out in the shielded cells of a now redundant nuclear fuel reprocessing facility at Sellafield, also of limited man access due to high dose rates. Gamma imaging measurements have been used to generate quantitative waste characterisation data. This data will be used to help develop the decommissioning strategy and more accurately define the quantities of waste within each high and medium active cell, which fall into each waste category. This work is ongoing and demonstrates the benefit which can be brought about by using appropriate radiometric characterisation tools at the planning stages of a decommissioning project.

The in-cell assay work described in this paper was carried out using the RadScan® gamma ray imager. This instrument is based on a small, tungsten-collimated NaI(Tl) based gamma spectrometer fitted to a pan and tilt unit. This imager can automatically scan a tightly collimated field-of-view over any scene of interest to produce colour overlays, examples of which are shown in Fig. 1. During an acquisition the system stores spectral and positional information which enables quantitative assay information to be produced in addition to the routine colour overlays.

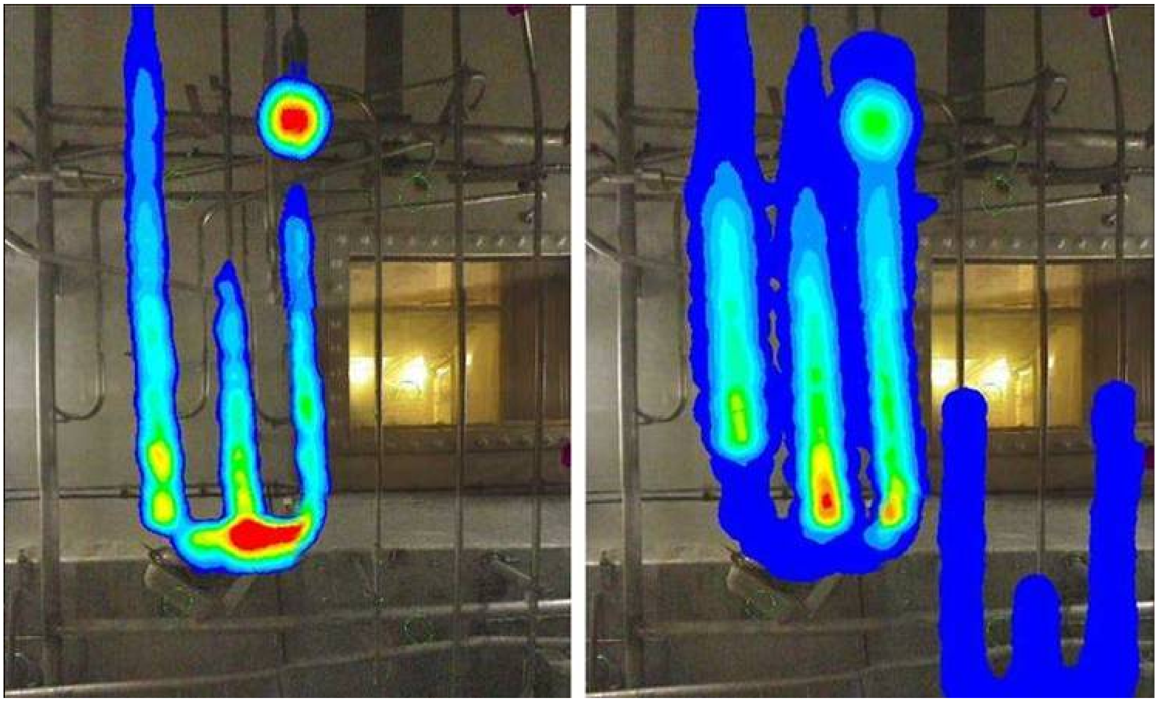

Fig. 1. Example images from the RadScan® gamma ray imaging device.

Fig. 1 shows the results of using the RadScan® 800 gamma ray imager in a cell containing residual plutonium hold-up. The left hand image shows the image relating to plutonium whilst the right hand image relates to Am-241. These images clearly show the locations and extent of the residual hold-up in this facility. This information was used not only to focus a series of neutron assay measurements but also to help develop the strategy for subsequent decommissioning of the cell.

HOW TO PERFORM ASSAY WITH A GAMMA RAY IMAGER

Quantitative, nuclide specific assay is achieved with RadScan® by following a straightforward imaging and analysis procedure. The gamma imager is positioned such that it has a direct line of sight to the item, or items, to be measured. These are then imaged using the automatic scan feature which collects all of the data needed for subsequent analysis. The scan comprises a series of discrete measurements each of which covers a small part of the total area to be scanned. The arrangement of the individual measurements ensures that the whole area is uniformly assayed. At each measurement point the system stores the co-ordinates of the measurement, a jpeg from the video camera, the range to the item (or portion of the item) in view as recorded by a rangefinder and an energy spectrum from the spectrometer. Spectrometry allows RadScan® to perform assay for one or more specific nuclides. This energy specificity produces a more accurate result than a measurement based upon dose or a non-spectrometric system as it enables the effects of scattered radiation, and of emissions from other isotopes, to be minimised. The individual count-rates measured by the system during the scan are corrected for the effect of range, integrated to give a total rate for the item of interest and then converted into an activity value by using a calibration factor. Calibration factors have been determined for a number of radioisotopes by making a series of laboratory based measurements of reference sources. An accuracy of 20% or better can be achieved using this technique, although this depends critically on knowledge of the physical details of the measured item.

Where there are appreciable levels of shielding the resulting attenuation can be accounted for using mathematical modelling techniques such as those offered by MicroShield [2] or MCNP [3]. Even when it is not possible to accurately determine the amount of shielding that is present it is still possible to produce quantitative data that is useful. Where, for example, the effects of shielding are ignored the resultant assay will indicate the minimum activity that can be present. This value can be used to positively identify where an item is above a classification limit.

For small items the automatic scans required to perform assay can be completed in as little as a few minutes. Monitoring a whole cell or a complete environment takes longer, however, as RadScan® is fully automated it may be left unattended, for example overnight, whilst a large area is systematically monitored.

Combination of the RadScan® assay result with the weight of the item allows a specific activity (activity per unit weight, e.g. GBq/te) to be determined and hence its waste category determined. In the UK waste with a specific activity of greater than 12 GBq/te beta-gamma or greater than 4 GBq/te alpha, but that does not required forced convection cooling, is classified as “Intermediate Level Waste”. Currently there is no final disposal route for ILW in the UK. Waste with a specific activity below these limits is classified as “Low Level Waste” and can be disposed of at the national shallow burial Low Level Waste Repository near Drigg. Although difficult to quantify the cost differential, it is significantly cheaper to dispose of LLW than to store and subsequently dispose of ILW, because of this projects can bring about significant savings by optimising their waste segregation.

APPLICATION IN THE CAESIUM EXTRACTION PLANT (CEP) AT SELLAFIELD

The Caesium Extraction Plant (CEP) is a facility from the 1950s, constructed in a building above a series of high activity liquor storage tanks. The CEP produced kilocurie Cs-137 sources for radiotherapy and contains four hot cells that are heavily contaminated with Cs-137, and exhibit dose rates exceeding 1 Sv/hr. These radiation these levels require decommissioning to be undertaken remotely. However, access to the rooftop facility is very limited due to space constraints imposed by adjacent plants and has to be co-ordinated with the ongoing operations on the storage tanks situated below the CEP. An 800te free standing mobile module has been constructed adjacent to the CEP which houses a remote access manipulator and ILW flasking facility. The project's objective was to remove all accessible ILW from the CEP.

The original strategy for decommissioning the facility was to export all of the waste to a sorting facility in which waste would be segregated into ILW or LLW as appropriate for disposal. Following the decommissioning of the first CEP cell, the strategy was changed to perform in-cell segregation of ILW and LLW. This strategy saved a significant quantity of money as it reduced the costs associated with the transport of ILW bearing flasks and reduced the costs associated with cell rental in the waste sorting facility. Furthermore, this strategy also meant that the project and its programme were not reliant on the availability of another facility, thus removing a risk from the project's delivery. A key aspect of this change of strategy was the ability of the project team to demonstrate best practice in executing this segregation. RadScan® formed an integral part of this improved strategy. In the early stages of cell decommissioning RadScan® images were used to identify the “cleaner” areas, that is where items were likely to be designated as LLW. The decommissioning team’s strategy saw the LLW items removed ahead of the ILW, thus reducing the scope for cross-contamination and potentially the generation of additional ILW through such cross-contamination. Having removed the LLW, the team then progressed to removing ILW from the cell. Towards the end of this campaign, RadScan® was used again to identify any remaining areas of ILW.

An example of where the assay capability proved particularly valuable was in the monitoring of a “Sample Cabinet”. Fig. 2 shows a gamma ray image of the cabinet carried out during the decommissioning.

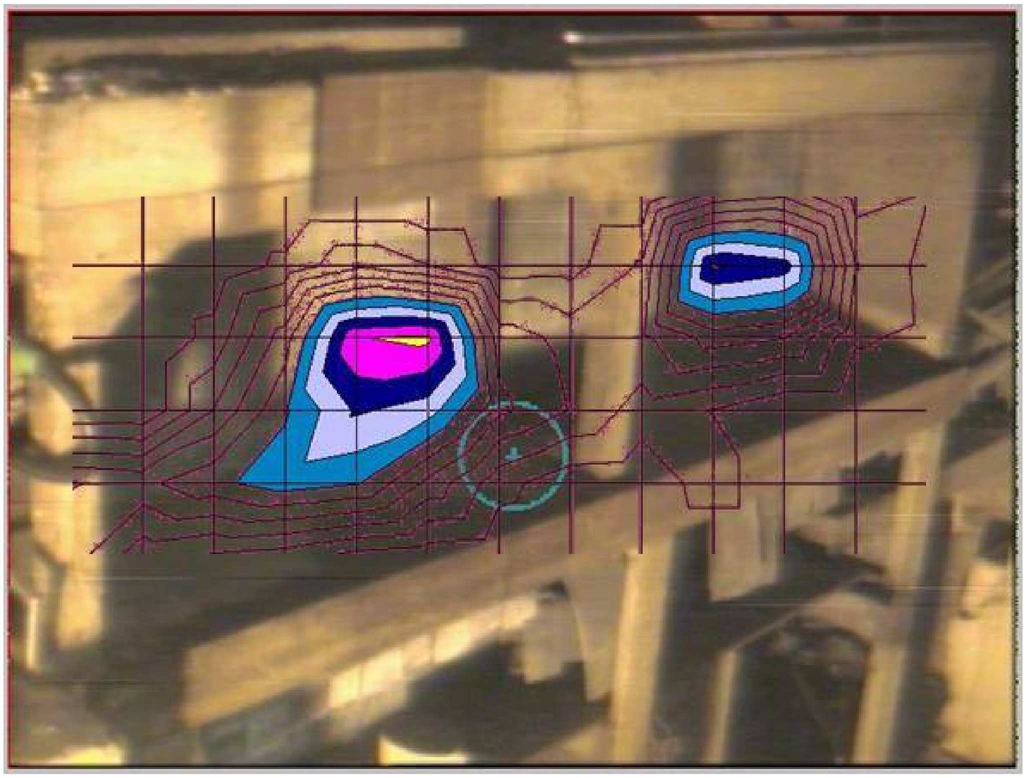

Fig. 2. Gamma Image Showing the Location of Contamination in the Sample Cabinet.

When RadScan® was first used to image the cabinet, analysis of the measurement data identified that the platform central to the cabinet had 33 GBq of Cs-137. Taking into account the weight of the item (approximately 850 kg or 1900 lbs) which was constructed from 10 cm (4 inches) thick steel, this categorised the item as ILW. The RadScan® images identified where the contamination was on this item and enabled the decommissioning team to decontaminate sufficiently for it to be classifiable as LLW, and therefore to be left it in-situ. Table I indicates the assay results achieved for this item. Removal of this item as ILW would have proved challenging for the remote decommissioning machine, and it is estimated that it would have added 6 to 8 weeks to the schedule of the decommissioning project for its size reduction and removal. In addition there would have been additional ILW disposal costs.

Table I. RadScan® assay results for the central platform of the cabinet.

Description	**RadScan® assay result (Cs-137)**	**Dispose as LLW?**
Cabinet as measured following initial decommissioning and decontamination	33 GBq	✘
Cabinet as measured following decontamination work addressing hotspots identified by RadScan®	12 GBq	✓

APPLICATION IN AN EARLY OXIDE FUEL REPROCESSING PLANT AT SELLAFIELD

Similar analysis work has been carried out in an early oxide fuel reprocessing facility at Sellafield containing a number of shielded cells. The access to these cells is limited both physically and by the presence of contamination and elevated gamma dose rate levels. RadScan® has been deployed within those cells where physical access allows in order to generate quantitative waste characterisation data. This data is being used to help develop the waste characterisation documentation and to provide information to help in the development of the decommissioning strategy. The quantitative assay capability helps to accurately define the quantities of waste that fall into each of the LLW and ILW waste categories. This process is achieved by combining assay results from RadScan® with plant information such as material type, thickness and dimensions, and assumed contamination dispersion for those specific items that RadScan® has identified as being contaminated.

Fig. 3 shows how the gamma ray images can be used to help segregate ILW from LLW, and be used, as appropriate, to guide decontamination work in an effort to reduce the amount of waste that needs to be disposed of as ILW. This image readily shows how the most active item within the cell, from this viewpoint, is a rod located within the metal tube pointing towards the camera. Effective segregation ensures that waste handling and waste disposal costs are kept to a minimum whilst demonstrating best practice.

Fig. 3. A gamma ray image of the contents of a cell

Fig. 4 shows a close-up image of the contaminated item shown in Fig. 3. This image also shows an active fuel 'hull' , to the left of the rod on the floor. The RadScan® assay capability determined that there was 2,600 GBq of Cs-137 associated with the rod and 120 GBq of Cs-137 associated with the fuel hull.

Fig. 4. A close up of a hull and a rod within a cell.

These examples show how RadScan® readily identifies and quantifies the most significant hotspots within an environment. The rod was identified as being the single most active item within the cell; prior to the RadScan® survey it was not known that this item was active. Taking account of their weights, both the hull and the rod fall well into the ILW category.

Gamma ray images allow such ILW to be identified and removed, leaving only LLW. Effective segregation and removal of the ILW can, by accelerated reduction of gamma dose rates, bring forward the time when man entry to the cell is possible; thus offering a more cost effective means of completing the decommissioning than remote techniques.

The work within this historic reprocessing plant is ongoing and demonstrates the benefit which can be brought about by using an effective, remote, non-destructive assay characterisation tool during the planning stages of high-rad decommissioning projects.

CONCLUSION

Quantitative, nuclide specific activities can be determined by analysis of the data gathered by RadScan®'s automatic, gamma imaging scans.

The knowledge gained from these projects demonstrates that an iterative use of gamma imaging can provide valuable activity and specific activity information to assist the decommissioning planning processes. In the first instance RadScan® can identify waste that is sufficiently active that decontamination may not be a feasible or cost effective means of waste recategorisation. Waste that is identified as falling close to a waste category boundary can be decontaminated to reduce the amount of waste falling into more expensive disposal routes.

ACKNOWLEDGMENTS

BIL Solutions Ltd would like to thank the decommissioning teams working on the CEP and the early oxide fuel reprocessing plant. In particular we would like to offer our thanks to Rhys Roberts, Sellafield

Ltd, CEP Decommissioning Team and Geoff Holland, Sellafield Ltd, Reprocessing Plant Decommissioning Team for their help and assistance with the production of this paper.

REFERENCES

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