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AN AUTOMATED NON-DESTRUCTIVE ASSAY SYSTEM FOR THE MEASUREMENT AND CHARACTERIZATION OF RADIOACTIVE WASTE

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ABSTRACT

The paper describes an automated non-destructive assay (NDA) system for the measurement and characterization of radioactive waste. The Waste Characterisation System (WCS) can be adapted to measure a variety of drum sizes: 60, 220 (55 gallon) and 440 liter, the latter with a maximum weight of 1500 kg (1.5 tonnes). The NDA system includes a Tomographic Segmented Gamma Scanner (TSGS) and an active/passive neutron Differential Die-away (DDA or DDT). The system can assay a wide variety of waste types in a range of waste matrices. The assay stations are linked by a heavy duty roller conveyor which incorporates a 20 drum buffer store, a load cell (built into the conveyor), bar code readers and a dose rate measurement station.

The Tomographic Segmented Gamma Scanner (TSGS) combines conventional high resolution gamma spectrometry and a transmission source to interrogate a waste drum in vertical slices (segments) as for Segmented Gamma Scanner (SGS) measurements. However, in the case of the TSGS, while the drum is rotated, it is also moved in the horizontal direction leading to an enhanced ability to correct the gamma ray energies, from the nuclides of interest, for the attenuation of the matrix. The TSGS can also be operated as a conventional SGS for the measurement of homogeneous waste drums.

The DDA is a very sensitive active neutron interrogation method that uses thermalised neutrons from a pulsed source within the chamber to irradiate a waste drum. Prompt neutrons from fissile material present in the waste (e.g. ^{239}Pu , ^{235}U) are detected and provide a measure of the fissile content in the drum. In passive mode, the DDA determines the even Pu nuclides exhibiting significant spontaneous fission (e.g. ^{240}Pu). Measurement accuracy depends on correction algorithms to compensate for self-shielding and matrix effects in waste

drums containing hydrogenous materials. In addition, the DDA will be provided with the Fission-Fission Neutron Correlation Analysis System (FFnC) which is an absolute technique eliminating the need for matrix dependent mass calibrations, and allowing separate U and Pu determination using delayed neutron counting. The FFnC technique will be tested for the first time on the WCS.

The NDA system incorporates integrated stations to determine the weight and dose rate of each drum, the former built into the conveyor the latter as part of the TSGS. Six Geiger Muller tubes measure the surface dose at three positions on the drum side, one at 1 metre from the drum and one each measuring the surface dose of the top and bottom of the drum.

The assay instruments are linked to a heavy duty conveyor system onto which up to 20 waste drums can be loaded for delivery to the various measurement stations, thus permitting unattended, automated operation. Once measured, the drums remain on the conveyer in a holding system waiting to be unloaded. Automation is provided using a programmable logic controller (PLC) and associated computers. A central computer and associated software is used for data acquisition and management.

INTRODUCTION

This paper describes the characteristics of a Combined Technology Automated Waste Characterisation System (CTA-WCS) which is designed for the measurement of radioactive waste in a variety of container sizes. These include 60, 220 and 440 litre drums, the latter with a maximum weight of 1500 kg. The assay technologies include a Tomographic Segmented Gamma Scanner (TSGS) and an active and passive neutron Differential Die-away (DDA) system.

The system is designed to perform radiometric measurements of fission products, activation products and other radionuclides as well as determine the quantity of U and Pu in contact handleable waste drums. A variety of waste matrices can be measured including homogeneous, heterogeneous, hard, soft, decommissioning waste and legacy waste from nuclear fuel processing. In addition the system has a non-destructive

examination (NDE) capability, and can determine both the weight and surface dose of the drums.

The assay stations are linked by a heavy-duty roller conveyor which incorporates a 20 drum buffer store to permit automatic, batch operation. The conveyor is controlled by a PLC and in conjunction with the computer controlled assay stations allows the assay of up to 20 drums. In addition to the assay stations the system includes a load cell (built into the conveyor), bar code readers and a surface dose rate measurement station.

A waste characterisation system, with characteristics similar to the system described in this paper is being supplied by ANTECH to the Waste Management Unit, at the Joint Research Centre, Ispra. JRC Ispra is a laboratory of the European Commission located in northern Italy. Three nuclear reactors have operated on the site. In addition nuclear fuel processing has also been carried out. The system is designed to assay the wide variety of waste types in a range of waste matrices. An outline of the system is shown in Figure 1 below:

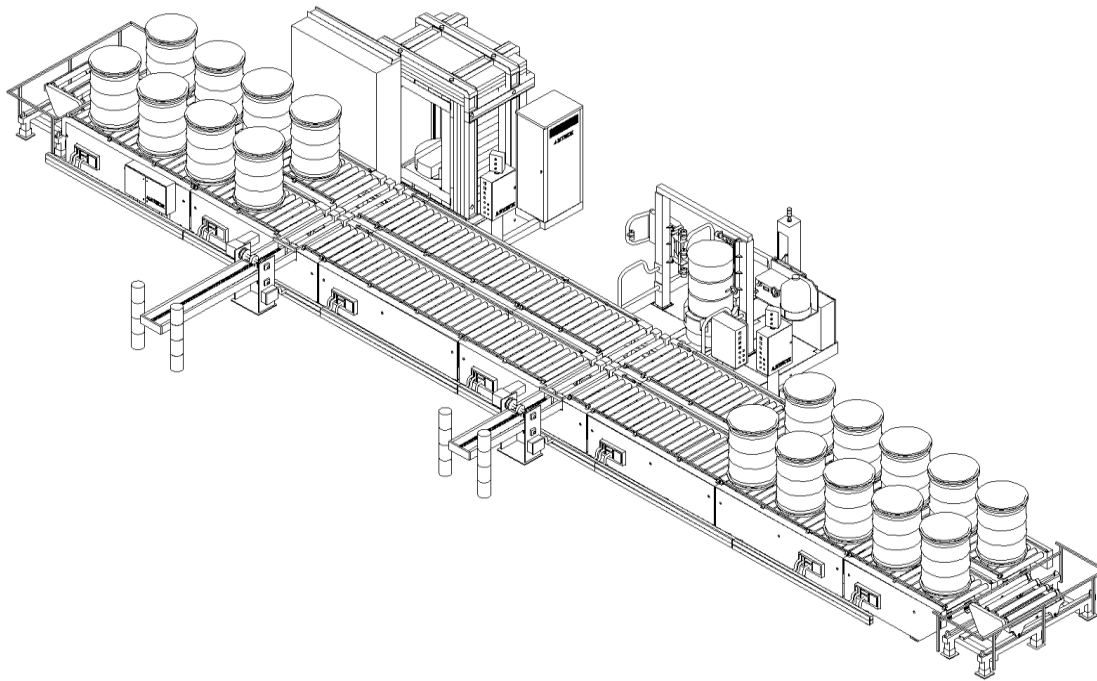


Figure 1 – Combined Technology Automated Waste Characterisation System

TOMOGRAPHIC SEGMENTED GAMMA SCANNER

The Combined Technology Automated Waste Characterisation System incorporates a Tomographic Segmented Gamma Scanner (TSGS) designed to measure drums of up to 440 litre capacity. The TSGS is the NDA instrument depicted measuring a waste drum, shown in the foreground of Figure 1 above. The TSGS design is based on the ANTECH model

3800-440, but modified to incorporate a dose rate station and coupled to a conveyor. It employs analysis software developed at the Los Alamos National Laboratory (LANL). In addition to tomographic measurements, the TSGS is also designed to operate as a Segmented Gamma Scanner (SGS). This dual mode of operation permits the choice of the most appropriate technique. Where waste drums are known to be homogeneous, the SGS mode can be selected to achieve higher throughput.

SEGMENTED GAMMA SCANNING

The drum is rotated about its vertical axis and simultaneously scanned, segment-by-segment along the vertical axis. This method of scanning reduces the effects of non-uniformity in waste density and nuclide distribution. Corrections are made for count dependent losses from pulse pile-up and analyser dead time, as these are monitored during the measurement process.

The detector is shielded in such a manner so as to allow the waste drum to be scanned in segments (typically 10 to 16 segments for a 220 litre waste drum). For each vertical segment of the drum the average linear attenuation coefficient is calculated by measuring the transmitted intensity of an external gamma-ray transmission source. The source is mounted directly opposite the gamma-ray detector on the far side of the drum. The system normally operates in a two-pass mode (measurements made with the transmission source shutter closed, then opened, at each vertical segment).

The SGS makes the assumption that the waste has a uniform density within each horizontal segment. The energy of the transmission source is selected to match that of the gamma-ray line(s) being measured. ^{75}Se is typically used for the measurement of ^{239}Pu , while isotopes such as ^{152}Eu or ^{154}Eu , which have longer half lives and many more gamma ray lines, extend the SGS measurement to the determination of U, Co, & Cs isotopes. State-of-the-art digital counting electronics, the DSPEC digital multi channel analyser is provided by ORTEC, an alliance partner of ANTECH, allow high dynamic counting rate ranges. Dead time corrections are measured with a second small, low-energy source positioned near the detector (^{109}Cd).

At the completion of the measurement of all segments, count rates are summed, and mass values for the nuclides of interest in the entire container are calculated based on comparisons to previously measured, appropriate physical standards. Counting precision data calculated for individual segments are propagated to obtain the estimated precision of the analysis based on counting statistics. This data is analysed, incorporating systematic biases, to arrive at a total measurement uncertainty.

TOMOGRAPHIC GAMMA SCANNING

Tomographic Gamma Scanning (TGS) measurements involve measuring drums in segments as for Segmented Gamma Scanner (SGS) measurements. However, in the case of TGS, while the drum is rotated, it is also moved in the horizontal direction (translated). Also, instead of taking a single large spectrum for each segment, 150 separate spectra are taken as the drum rotates and is translated. These 150 spectra are obtained both for transmission and for emission measurements. The 150 spectra taken for transmission constitute a set of data that can be solved to yield the distribution, or map of attenuation coefficients throughout the segment of the sample or drum. The measurement equations are over specified and the solution uses a maximum likelihood analysis. This results

in the determination of a map (after a geometric transformation) of attenuation coefficients in a rectangular grid suitably superimposed on each segment. The attenuation map enables the operator to 'visualise' the variation of the density (governed by the collimator size and voxel resolution) in regions of the drum. This serves a non-destructive examination (NDE) function similar to 'real time radiography' but with three dimensional information at reduced resolution.

For the analysis of the emission data, the additional information obtained from the transmission data allows the emission data to be corrected for attenuation. This attenuation correction is the essential and important characteristic of TGS measurements not present in other gamma-ray measurement systems. For the first time, in the case of the TGS, the map of attenuation is used to correct the measured source distribution in the matrix (segment by segment). The TGS extends the range of gamma-ray measurement technology, as it is able to correctly determine the attenuation corrected radionuclide inventory in heterogeneous matrices where previous techniques such as the SGS are only applicable to homogeneous matrices. In the case of the SGS large errors can occur if incorrect assumptions concerning homogeneity are made. For the TGS, a single calibration based on a non-interfering or empty matrix is made and then corrections relating back to this non-interfering matrix are made using the attenuation information determined from the transmission scan.

TGS uses transmission-corrected, single-photon emission, computerized tomography (SPECT) to determine the spatial distribution and quantity of radionuclides within a waste drum. High-resolution gamma-ray spectroscopy (HRGS) is used to make accurate measurements of individual gamma rays in complex spectra. Transmission computerized tomography is used to develop a three-dimensional spatial map of the attenuation coefficient of the sample. By using a radioisotope such as ^{75}Se or ^{152}Eu for the transmission source, gamma-ray transmission can be measured accurately at several energies. By interpolating the transmission data, spatial maps of the attenuation coefficient can be obtained at any energy.

Once the attenuation map has been determined, emission tomography is used to determine the distribution of selected radioisotopes within the waste drum. The waste drum is scanned with the transmission source shuttered off and net counts are recorded for regions of interest (ROI) about peaks corresponding to gamma rays emitted by the target isotope. For plutonium assays, ROIs are typically established for four well-resolved gamma rays: 129-, 203-, 345-, and 414-keV. Each of these gamma rays is used to develop an independent estimate of the distribution and amount of ^{239}Pu within the waste drum.

As the waste drum rotates and translates relative to the detector, the net count rate varies. The magnitude of the net count rate depends on the distance of the gamma-ray source from the detector and the intervening attenuating material. Since the attenuation map is known for the gamma ray of interest, the net count rate can be calculated for trial distributions of the emitting material for each detector location. The calculation requires knowledge of the detector spatial response function, which is determined by Monte Carlo simulations.

Reconstruction of the spatial distribution of emitting material is accomplished by adjusting the trial distribution until the estimated net counts match the measurements.

By integrating the emission distribution over the volume of the waste drum, a number proportional to the amount of the selected isotope within the waste drum is obtained. Because bias caused by variations in the source position and matrix attenuation has been reduced, a single calibration constant can be used to determine the mass of the selected isotope for a much wider range of material and matrix types that was previously possible. For example, it is reasonable to use the same calibration constant for combustibles and cemented sludge. Before the advent of TGS, in attempting to make SGS work, count room operators would develop separate calibration constants for a large number of waste drum categories, with the hope that the variation in bias within each category would be small enough to meet accuracy requirements. Needless to say, this practice was costly and time consuming and required a valid reference technique. By eliminating the need for item categorization, TGS reduces the effort required for calibration.

In a TGS scan, the waste drum is divided typically into 10 to 16 axial sections (or layers), depending on the height of the waste drum. Within each layer, the waste drum is rotated and translated continuously. ROI data are acquired in uniform time intervals. The scan of a layer is broken into 150 such intervals, each associated with a narrow set of displacements and angles. Transmission and emission ROI data are stored for each interval and are later used to reconstruct the attenuation coefficient image and emission distribution. The length of each interval is typically short, no more than 0.6 s. Consequently, the entire waste drum can be covered in less than 30 minutes. Assuming two passes are made, one for transmission and one for emission, the total data acquisition time is less than 1 hour. With this scan protocol, each layer can be represented by a coarse image with approximately 100 image elements.

The accuracy of TGS is almost always better than 10% root-mean-square (RMS) difference between measured and reference values. However, the accuracy that can be achieved depends on the density of the contents and the distance gamma rays must travel to escape the sample. For assays of plutonium in 220 litre drums containing cement (~2 g/cm³ bulk density), it has been found that the scan protocol described here yields better than 20% RMS difference. Note that for such samples, it has been found SGS to be in error by more than a factor of 5.

Because accuracy depends on waste drum size, we usually quote accuracy in terms of areal density. For example, as a rule-of-thumb we expect TGS measurements of ²³⁹Pu using the 414-keV gamma ray to have better than 10% accuracy for waste drums with areal density less than 90 g/cm². The bulk density is derived by dividing the areal density by the diameter of the waste drum. Assays of 220 litre drums containing metal scrap are typically accurate to within 10%. We also note that increasing the resolution of the scan, along with the scan time, can improve accuracy. So, in principle, the accuracy of TGS is limited only by how long the operator is willing to wait.

The precision that can be achieved by TGS varies from waste drum to waste drum and depends on the placement of the source, the distribution of attenuating material, and collimator parameters. Precision also depends on the isotope being measured. For 220 litre drums, as little as 0.5 g ²³⁹Pu in low-density matrices with <1-hour acquisition time can be measured. With a typical collimator setting, a 1-hour TGS scan will produce the same precision as a 20 to 30 minute SGS scan. The minor loss in precision is not noticed for waste drums >10 g ²³⁹Pu, and is a penalty that must be paid for increased accuracy.

Although the TGS technique extends the envelope of the range of measurements which are possible, it has some limitations. The precision of the TGS technique depends on the degree of attenuation of the matrix. Although compensation is made for attenuation, the presence of materials with densities higher than 2000 kg/m³ lead to reductions in measurement precision because signal is lost as a result of the large attenuation. The technique does, however, identify situations where a measurement cannot be made. For example, if a tungsten container were placed in the center of the drum, the SGS technique would fail to identify the black absorber in a drum and simply report an average attenuation for the drum segment as a whole. An SGS would not see a Pu sample placed in such a tungsten container inside a drum and reports an erroneous result. The TGS, in contrast, will report a region of opaque voxels.

The TSGS serves four functions as part of the overall assay system. The first is to screen drums in order to determine the most appropriate assay technology. The second is to perform NDE by providing three-dimensional images of the attenuation coefficient distribution of the matrix and the radioactive source distribution within the matrix. The third function of the TSGS, (applicable if Pu is present) is to determine the Pu isotopic ratios using the LANL analysis code, PC/FRAM. Finally the fourth function, depending on the outcome of the screening, is to provide the assay result using the TSGS measurement method. The TSGS is also able to provide the assay result using the SGS method.

DIFFERENTIAL DIE-AWAY (DDA)

Active and passive neutron measurements are performed by an advanced, graphite lined Differential Die-away (DDA) system. The DDA is an active and passive neutron measurement device for determining the fissile content of waste drums. A pulsed neutron generator is employed in active interrogation mode to determine the ²³⁵U and ²³⁹Pu content of waste drums by induced fission using total neutron counting. With appropriate matrix calibration and flux normalisation it is possible to infer the total fissile mass at low levels contained in the waste drum from the total neutron count rate as measured in fast neutron detectors. The design of the ANTECH model 4100-440 DDT is based on an optimisation of the well-characterised Combined Thermal Epithermal Neutron (CTEN) DDA design developed at LANL. Monte Carlo neutron modelling (benchmarked to CTEN) has been employed to enhance the design and to extend the thermal neutron die-away time to greater than 550 microseconds (μs) and to increase the fast neutron detection efficiency to greater

than 10%. The thermal neutron die-away time of the Model 4100-440 DDA is $\sim 1000\mu\text{s}$ (1ms).

In conventional DDA totals mode, pulses of neutrons are used to interrogate a waste drum placed in the measurement chamber. A neutron generator placed in one corner of the chamber is pulsed at 100 Hz producing 14 MeV neutrons. The neutrons are slowed down in the graphite providing a source of thermal neutrons that cause induced fission in the ^{235}U and ^{239}Pu in the waste. Each pulse, of approximately $20\mu\text{s}$ duration, generates approximately 1×10^6 neutrons and typically 30,000 pulses are generated per assay. Cadmium shielded, polyethylene moderated ^3He detector packages are used to measure the prompt induced fission neutrons after a time period ($\sim 800\mu\text{s}$) when neutrons from the initial generator burst have been cleared from the fast detector packages. Additional ^3He flux monitors are placed in the measurement chamber and provided a measure of the interrogating neutron intensity and its die away characteristics. A later time period is used to determine the background due to delayed neutron production from fission products and from any spontaneous fission nuclides present. The fissile mass is proportional to the net fissile signal normalized to the interrogating flux. The system is calibrated for uranium and plutonium mass using representative matrices.

In passive neutron mode the DDA operates as a conventional passive neutron coincidence counter for measuring Pu using neutron pairs and neutron total count rates. The passive mode operation uses conventional neutron counting of the correlated neutrons arising from spontaneous fission of the even Pu nuclides, principally ^{240}Pu . The measured isotopic ratios (from PC/FRAM (TSGS)) are used by the software in order to convert $^{240}\text{Pu}_{\text{effective}}$ to total Pu mass.

A third (active) mode of operation implements Fission Fission-Neutron Correlation (FFnC), an absolute technique employing active neutron coincidence counting. FFnC (based on extensions to the theory of passive neutron multiplicity counting developed by W.Hage) has the potential to eliminate the need for matrix dependent mass calibrations. In a manner analogous to the use of neutron multiplicity counting for the passive assay of plutonium, FFnC uses an equivalent theoretical model to analyse active neutron pair correlation. Using neutron totals and correlated neutron pairs it is possible to solve two equations for two unknowns and thus perform an absolute assay of fissile Pu or U by determining the induced fission rate. The second parameter, which is determined by FFnC, is the detection probability (efficiency) which characterises the matrix. Although the FFnC technique requires a normalisation measurement to determine a scaling factor for the hydrogen content and interrogation source strength (to determine the penetration of the matrix), matrix dependent mass calibrations are not required.

It is anticipated that FFnC will permit the direct characterisation of the waste by determining both the fissile mass and the detection probability for fast neutrons arising in the matrix being measured. The use of delayed neutron counting allows separate U and Pu mass determination. The

performance of the FFnC method will be comprehensively tested during the commissioning of the WCS.

THEORY OF OPERATION

The ANTECH Active Totals Counting Differential Die-away (DDA or DDT) Model 4100-440 is an active neutron non-destructive assay measurement station to measure alpha emitting radionuclides by neutron integration. The DDA is an NDA station forming part of the Waste Characterisation System. The station is optimised for 220 litre drums but is capable of measuring up to 440 litre drums with a maximum weight of 1500 kg. The measurement is very sensitive to the presence of U & Pu and it can measure these nuclides in a wide variety of waste types and matrices. Operating in active mode, the DDA can measure the isotopes ^{235}U , ^{239}Pu . The system is capable of passive neutron measurement to determine the ^{240}Pu (effective) mass in the waste based on measuring spontaneous fission neutrons. Correction is made for (α , n) reactions, which produce single uncorrelated neutrons.

The waste drum to be assayed is loaded into the DDA measurement chamber cavity using a cantilever beam arrangement. A pulsed neutron generator is used as the source of interrogating neutrons. Prompt induced fission neutrons and delayed neutrons are measured in the fast neutron detector modules, ^3He tubes embedded in high density polyethylene, which are built into the measurement chamber. The fast detector packages are adjacent to the inner surface of the graphite moderator. A neutron burst frequency of 100 Hz is employed and the active neutron waste assay measurement of a drum normally takes ~ 5 minutes.

The principle of an active neutron totals counting differential die-away measurement is as follows: a burst of fast neutrons is produced by the pulsed neutron generator located in the measurement cavity next to the waste drum. A fraction of these neutrons are slowed-down (moderated) by repeated scattering in the graphite cavity walls and sample materials. The cavity walls are made of graphite which has good neutron moderating properties yet, unlike hydrogen, is not an absorber of neutrons. The average energy of the neutron pulse from the generator decreases continuously until thermal equilibrium is reached with the graphite moderator. Graphite is chosen for good neutron economy. Some of the thermalised neutrons induce fission in the fissile material of the waste, resulting in the production of prompt and delayed neutrons. A number of the fission neutrons will penetrate the cavity walls and be detected in the surrounding detectors. The number of detected prompt and delayed neutrons and the time distribution of neutron detection are important measurement quantities to be used in the data analysis. Many repeated bursts of source neutrons are necessary in order to achieve a good statistical determination of the measured quantities.

DDA MEASUREMENT CHAMBER

The DDA has a rectangular chamber. The DDA loads waste drums for measurement using a novel, although well proven, cantilever mechanism to load the drum (or aluminium puck on

which smaller drums are placed) into the measurement chamber. The loading mechanism eliminates the need for steel components to be permanently placed inside the measurement chamber.

The fast neutron detector packages are located external to the graphite moderator, adjacent to the inner face of the graphite. The thermal neutron die away time (the thermal neutron lifetime in the complete system, including the graphite moderator), as determined by Monte Carlo modelling (MCNP4B), is in excess of 1 ms. With the graphite moderators, the detection efficiency (to ^{252}Cf neutrons) of the system is $\sim 10\%$.

The neutron generator tube is installed within the measurement cavity in the left rear corner of the measurement cavity. An on-barrel flux monitor (shielded flux monitor) is also deployed in the cavity in the right hand rear corner. An external flux monitor is located behind the graphite moderator.

DDA DETECTOR SUBSYSTEM

The detector modules consist of a number of ^3He tubes of 25.4 mm diameter embedded in high-density polyethylene (HDPE) with cadmium cladding. The detector modules are arranged around the periphery of the graphite moderator in a '4 π ' configuration. There are 3 detector packages in each of the six sides of the cube. In the four walls and roof of the DDA chamber, each package contains a number of ^3He tubes. In order to accommodate structural requirement of passing the drum weight onto the DDA plinth, there are 3 detector packages in the floor of the DDA chamber. These packages contain an uneven number of ^3He tubes. The active lengths of the tubes are 1250 mm for all four sides and 850 mm for the floor and roof. The ^3He gas pressure is 6.5 atmospheres for each tube and contains between 2.5 and 3% carbon dioxide quench gas. The walls of the tube are constructed of stainless steel.

ANTECH designed preamplifier/amplifier/discriminator circuitry is based on the LANL design employing the A-111 charge sensitive preamplifier. Each junction box with associated amplifier and ^3He detector tubes provides a TTL signal output which is fed to an ANTECH de-randomising buffer mixer circuit. Gain and discriminator threshold adjustments are provided by the head amplifier circuit.

DDT PULSE NEUTRON GENERATOR

The Differential Die-away instrument uses the model A-211 Zetatron tube supplied by MF Physics, a company based in Colorado Springs in the USA. The MF Physics model A-211 Zetatron tubes are well proven in DDA applications and the Model A-211 allows both pulsing of the ion source voltage and the accelerator voltage.

DRUM WEIGHT AND DOSE RATE MEASUREMENT

In addition to the radiometric assay, the Combined Technology Automated Waste Characterisation System (CTA-WCS)

measures other characteristics of the waste drums. Incorporated into the conveyor system is an accurate load cell to determine drum weight. The data from the load cell is recorded as part of the drum data and used as part of the drum matrix assessment.

A drum surface dose rate measurement station is included in the CTA-WCS. It is incorporated into the TSGS in order to make effective use of the drum rotation platform. There are a total of six shielded Geiger tube detectors that measure the surface dose at the drum side (one each measuring the surface dose of the upper, middle and lower sections of the drum), the top and bottom of the drum and one at 1 metre from the drum. The side surface and 1-metre detectors are mounted on a support frame with adjustable positions in order to accommodate the different drum sizes. The top detector is similarly deployed; the bottom detector is fixed.

BUFFER CONVEYOR SYSTEM

The TSGS and DDA assay instruments are coupled to a heavy-duty roller conveyor system Model 440-1500 onto which up to 20 waste drums can be loaded. The system will automatically deliver the drums to the various measurement stations, thus permitting unattended, automated operation of the WCS. Once the drums have been measured, they remain on the conveyer in holding positions waiting to be unloaded.

A programmable logic controller (PLC) and associated computer form the basis for controlling the automation of the conveyor and the measurement stations of the WCS. A central computer and associated automation software are used to link all of the components of the WCS and control data acquisition, data management, data archiving and the man-machine interface.

PLANT AUTOMATION SYSTEM

The WCS is entirely operated from within a shielded control room. Drum loading and unloading is semi-automatic. An overhead gantry crane is used to transfer drums from their transport pallet to the loading station of the conveyor, with final placement supervised by an operating using joy-stick control assisted by local CCTV.

The WCS Plant Automation System Software permits batch measurement, from 1 to 20 drums to be planned with all necessary set-up conditions and data archiving requirements to be specified.

During operation, the status of both the mechanical handling system and the nuclear measurement machines are displayed, graphically, so that the progression through the batch sequence can be monitored, if required, by the operator.

WCS Plant Automation is implemented as a distributed control system which combines dedicated instrumentation, industrial control equipment and data and display computers using Fieldbus and Ethernet communication technologies. This both reduces the volume of plant wiring and permits the transfer of

larger amounts of monitoring and status information than would be practical using wholly hardwired techniques.

The WCS Plant Automation System is structured in a hierarchical manner, allowing individual sub-systems, such as the weighing station to be independently operated and commissioned. A fully hardware based emergency stop and interlock system is incorporated to enable compliance with EC machinery norms. This approach is key to maintaining operational reliability and maintainability, as the effect of equipment failure can be partitioned and the consequence controlled.

CONCLUSION

The Combined Technology Automated Waste Characterisation System is a fully automated state-of-the-art assay system capable of measuring a wide variety of waste types in a range of matrices arising from nuclear fuel and nuclear materials processing, reactor operations and military wastes. A combination of non-destructive assay techniques is deployed to achieve the measurement of a wide range of nuclear waste materials.

The Tomographic Segmented Gamma Scanner (TSGS) is the most comprehensive gamma-ray measurement solution for the assay of a broad range of waste types and combines conventional high resolution gamma spectrometry, segmented gamma scanning and three-dimensional tomographic imaging and NDE capabilities in one complete system.

The Differential Die-away (DDA) is the most sensitive assay technique for the measurement of low levels of fissile material in waste and combined with Fission Fission-Neutron Correlation, delivers an absolute technique, eliminating the need for matrix calibration, and allowing the separate determination of U and Pu mass.

Linking the two measurement stations is an automated mechanical handling system with a 20-drum capacity storage conveyor, drum weight measurement station and surface dose measurement station. Once loaded, the system is designed to perform automatic assay and return drums to the buffer.

The Waste Characterisation System described in this paper is the most comprehensive waste assay solution for the measurement of contact handled and remote handled waste. Its range can be extended to the measurement of Low Level Waste by substituting the TSGS model 3800 described above with an ANTECH model 3900 shielded TSGS.

The Waste Characterisation System is the first of its type oriented to the high throughput measurement and remedial examination of waste materials for future long-term storage.

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