ACCESSING THE INACCESSIBLE; AN INNOVATIVE APPROACH TO THE RADIOLOGICAL SURVEYING OF METAL WASTE.

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ABSTRACT

Decommissioning and Decontamination (D&D) operations often results in the production of large volumes of scrap metal waste with little or no radioactive contamination. Proving that the waste is clean can be costly and time consuming, as the shape and size of the metallic waste items often means that it is difficult or impossible to monitor all surfaces using conventional hand-held survey meters. This is a particular problem for alpha contamination measurement.

A survey system, IonSens®, has been developed by BIL (formerly BNFL Instruments Ltd) which allows rapid surveying of scrap metal for alpha contamination at very low levels. The system comprises a large chamber into which scrap metal is placed with a door sealing the chamber while a measurement is carried out.

A challenge to traditional radiological surveying techniques was faced by the decommissioning team at the Springfields Oxide Fuel Complex in the UK, where a number of reject fuel pin tubes from the fabrication of Advance Gas cooled Reactor (AGR) fuel assemblies had accumulated over a period. These tubes were approximately 80cm long with an inner diameter of 14mm, making surveying by traditional methods impractical. However, the Long Range Alpha Detection (LRAD) technique remotely detects and measures secondary ionization created in air by alpha particle interactions, allowing extremely low levels of alpha contamination to be measured. The LRAD technique is an original invention from the Los Alamos National Laboratory, and through a successful collaboration, has been developed into the commercial waste monitoring family of systems known as IonSens®.

The LRAD technique has proved to be an effective survey method, as large numbers of tubes could be surveyed simultaneously. More importantly, pre-processing of the metal is not required to allow surfaces to be accessed by a hand held survey meter, for example by cutting the tubes open.

INTRODUCTION

The Oxide Fuel Complex at Springfields, operated by Westinghouse Nuclear Fuel, was presented with an acute radiological surveying challenge through the accumulation over time of rejected fuel pin tubes from the fabrication of AGR fuel assemblies. These tubes were approximately 80cm long and have a very small inner diameter (14mm), making radiological surveying by traditional methods impractical. The Long Range Alpha Detection system however allowed bundles of the tubes to be quickly surveyed to unrestricted release levels in batches of 36.

This surveying challenge has now been addressed using the innovative Long Range Alpha Detection (LRAD) Technique, developed at the Los Alamos National Laboratory (LANL). The technique has allowed the interiors of the tubes to be surveyed, for extremely low level of alpha contamination without any additional mechanical processing of the material.

The LRAD technique was applied within a robust industrialized survey system termed IonSens™. The system uses the technique to ensure that scrap metal contamination levels are sufficiently low to allow the material to be released from regulatory control. The system comprises a large chamber into which scrap metal is placed and a door which is closed to seal the chamber while a measurement is carried out. The system is operated from a PC based workstation and automatically stores all measurement data for quality assurance purposes.

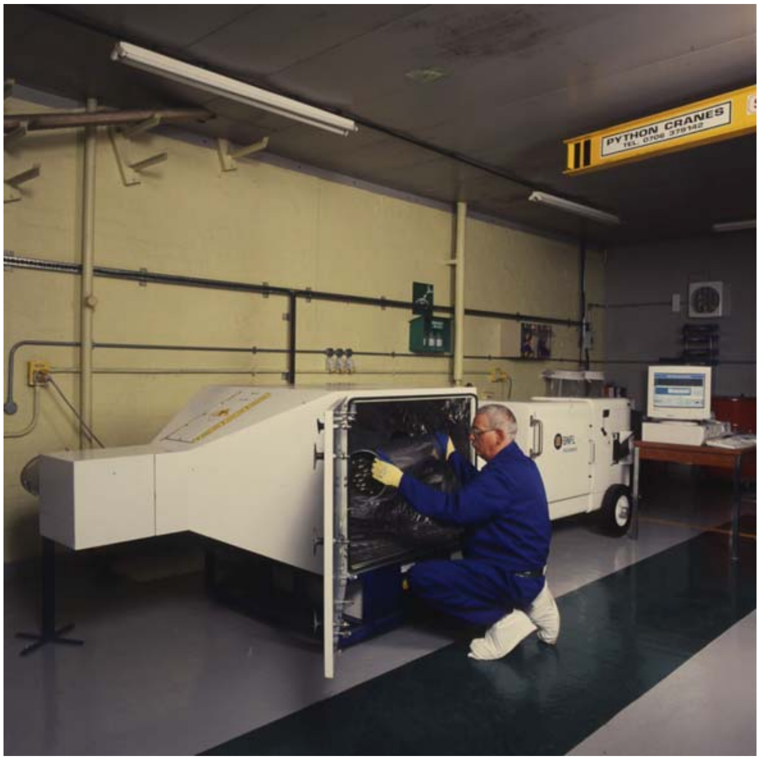

Fig. 1. The system in operation at the UK Springfields Oxide Fuels Complex.

This method of radiological surveying has proved to be highly cost effective, as a large number of items can be surveyed simultaneously and more importantly no pre-processing of the metal, to expose all surfaces, is required to facilitate a survey using hand held instruments. The most cost effective use of the LRAD technique is gained where either large number of metallic items are required to be surveyed, or mechanical processing (e.g. cutting open) of the metal items would be required to access interior surfaces

The Long Range Alpha Detection (LRAD) Technique

The detection of alpha particles emitted from contaminated surfaces can be challenging because of the very short range of the particles in air. Alpha particles emitted by typical contaminants found in nuclear facilities have a range of around 4 to 5cms, depending upon the alpha emitter. Hand held detectors commonly used for the detection of alpha contamination must therefore be placed within around 2cms of the contaminated surface to ensure that the contamination is detected.

The LRAD technique was originally invented in the 1980s by Dr Duncan Macarthur at the Los Alamos National Laboratory in New Mexico. The technique has since been used for a wide number of applications where conventional survey methods are challenged by the limited range of alpha particles. Examples of the deployment of the LRAD technique have included ground surveying, personnel monitoring and liquids monitoring.

The LRAD principle is based upon the detection and measurement of ionization occurring in air as a result of alpha particle emission from a surface.

There are 3 basic steps to the LRAD process, these being as follows:

1. **Ion Creation**. Alpha particles traveling through air loose energy and create a large number of ionized air molecules, typically of the order of 150,000, for a single ~5MeV alpha particle. Instead of immediately loosing this ionization through recombination, these ions remain present as a cloud of ionized air for many seconds. Therefore, if the presence of ionized air can be detected and measured, the presence of alpha particle emissions can be inferred
2. **Ion Transportation.** To allow the ionization to be detected the cloud of ionized air must be moved from the point at with it was created to a means of detecting the ionization in the air. In the system this is achieved by drawing air through a chamber containing the potentially contaminated item so as an air flow passes over any potentially contaminated surfaces. This is carried out by a conventional fan which draws air from outside the chamber in through a filter which ensures that any ionization present in the ambient air is removed.
3. **Ion Detection**. Detection of ionization within the air is achieved by drawing the air through a stack of electrically separated copper plates with each alternative plate maintained at a potential difference to its adjacent plates by a DC battery. With no ionization present in the air between the plates, no current will flow in the circuit. However if ionized air is present between the plates an extremely small (but readily measurable) current, typically of the order of 10^{-15} amps will flow.

Limitations of Alpha Survey Techniques

The capabilities and limitations of the LRAD technique are largely identical to those of the traditional frisk probe surveys, only the LRAD technique has the capability of detecting alpha contamination in locations which are difficult to manually access, with conventional alpha frisk probes.

The major limitations of any form of alpha survey technique arises from both the short range of alpha particle in air and also the ease with which alpha particles are stopped by a thin coverings such as dirt, paint or moisture. The LRAD technique therefore mitigates the first alpha particle measurement limitation by effectively, extending the range at which alpha particles can be measured.

The Development of the Alpha Survey System

Following the initial invention of the LRAD technique at the Los Alamos National Laboratory BIL entered into a Corporate Research and Development Agreement (CRADA) with the laboratory to further develop the technology.

The development program was based around three stages of prototype system. The first prototype was a small bench-top device with which the LRAD technique could be investigated when applied to the surveying of pipework. The second prototype phase involved the construction and testing of a proof-of-principle device. This had a similar layout to an industrial system but was constructed to a standard designed to validate the physics of the pipework measurements. The third development system built was the pre-production prototype, designed to the build standard of a production device but with the purpose of extensive testing. The minor modifications which were identified through trials with the pre-production prototype were fed into the design of the production unit.

Two basic configurations of the system have been developed, these are described below:-

Pipe Monitoring Configuration

The pipework surveying configuration comprises a series of 2m long narrow chambers into which pipes of up to 15cm outer diameter can be placed. With three of these chambers connected in series the system is capable of surveying a 6m long scaffold pole.

A fan draws air through the middle, and over the outer surface of the pipe this air then passing between a stack of ionization detector plates. Ionization created by alpha contamination inside or outside the pipe is swept through the detector plates by the airflow, allowing ionization levels to be detected and therefore contamination levels to be measured. A valve mechanism incorporated in the system allows the airflow to be either directed over both the outer and inner surfaces of the pipe, or the inner surface only.

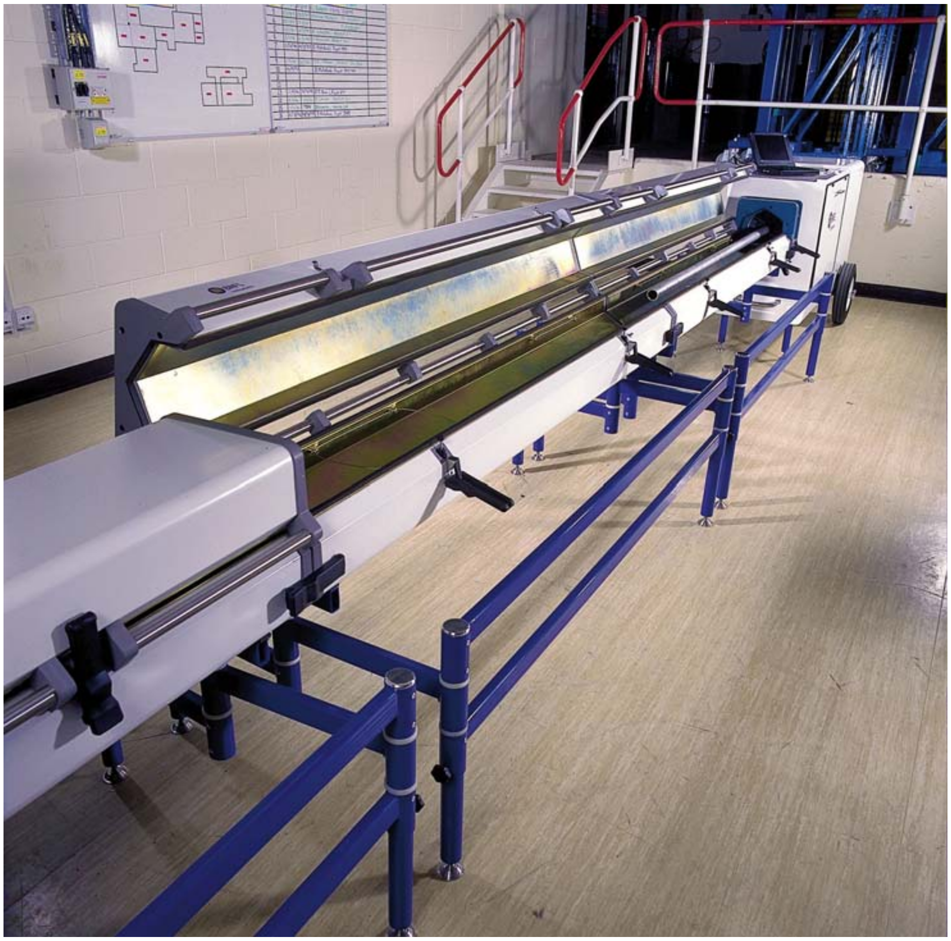

Fig. 2. Pipe monitor at the BNFL Sellafield Nuclear Facility

Large Items Monitoring Configuration

The “Large Item Monitoring” configuration (as deployed at the Springfields, Oxide Fuels Complex) comprises an identical ionization detector arrangement to the Pipe Monitor although with this system a large volume chamber measuring, 1m long by 1m wide by 0.8m high accommodates either large individual items or multiple small items requiring to by surveyed. A turntable is located on the base of the chamber to ensure that all surface of an object are exposed to a flow of air.

The LRAD technique can be incorporated with a number of different chamber dimensions which can be built to specific requirements. As in the two examples above, the ionization detector arrangement will remain the same, however, it is possible to interchange various chamber units, depending on the size of items to be monitored. This allows for adaptability in future operations.

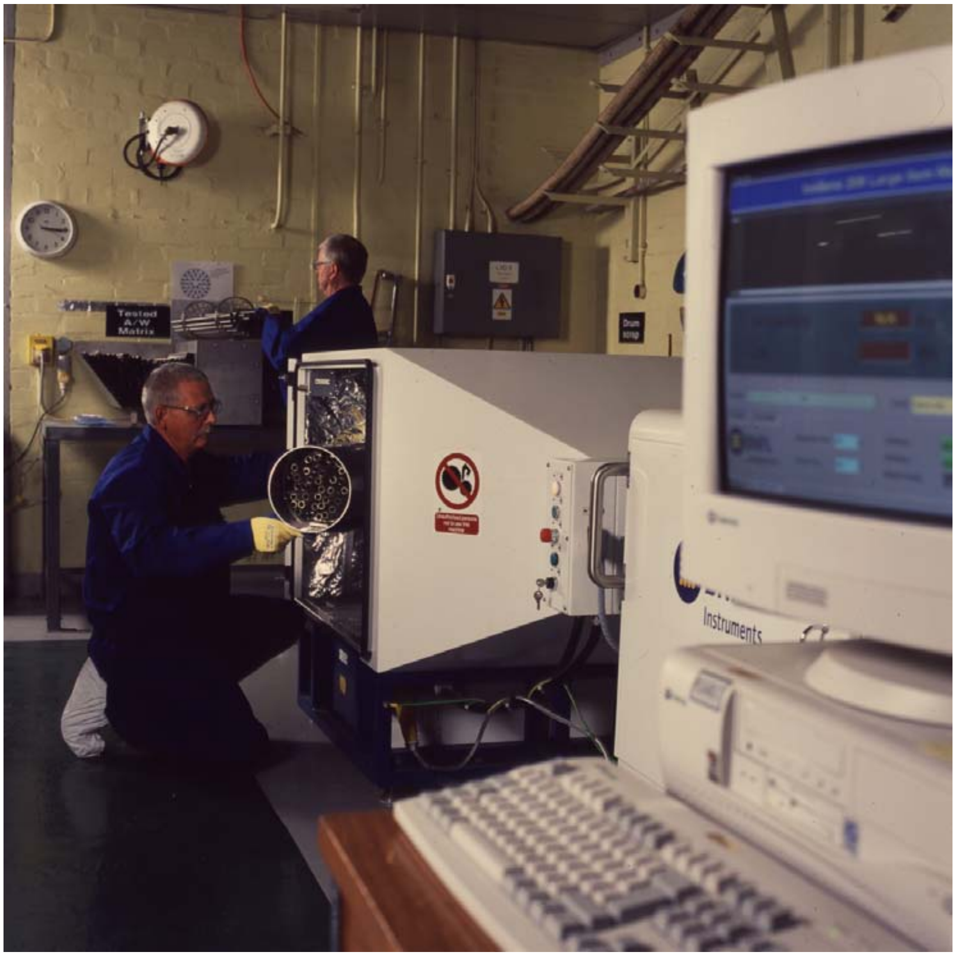

Fig. 3. System control workstation adjacent to survey chamber module.

Testing of the System

An extensive series of tests on the system were carried out by the United States Department of Energy (DoE) at Savannah River. As well as looking into the technical functionality of the system, these trials also reviewed the commercial aspects to deploying the system. Areas such as the cost effectiveness of deploying the system were reviewed and also how its operation compared with current baseline technology, in this case traditional frisk probe surveys. The results from these trial are summarized in a DoE produced Innovative Technology Summary Report (ITSR) (Ref.1) available on the DoE website. The ITSR concludes that the initially high cost of deploying this technique (compared with an alpha frisk probe) is offset (reaches a breakeven point) after approximately 400 items have been surveyed after which the use of the Long Range Alpha Detection technique becomes a more cost effective survey method.

Prior to the deployment of the system at Springfields, independent 3rd party accreditation of the suitability of the technique for measuring alpha contamination was sought from the UK National Radiological Protection Board (NRPB). An extensive series of trials were carried out on the system under the direction of the NRPB, establishing the boundaries of operation of the system. Some minor modifications to the system design were carried out on the recommendation of the

NRPB and a favorable report was issued describing the functionality and operating envelope of the system.

Deployment of the System at Springfields

UK Legislation on the Disposal of Wastes

The principle legislation governing the disposal of radioactive wastes in the UK is the Radioactive Substances Act 1993 (RSA 93). Disposals are regulated by the Environment Agency (EA) or the Scottish Environmental Protection Agency (SEPA). The Radioactive Substances Act, (Substances of Low Activity (SOLA)) Exemption Order (EO) No 1002, 1986 specifies that solid radioactive material is exempt from regulatory requirements provided that its activity does not exceed 0.4 Bq/g. However, when applying the SOLA EO to uranium, the specified element limit in Schedule 1 of RSA93 allows exemption from disposal authorization where the activity is less than 11.1 Bq/g.

Survey Method and Calibration

One of the key issues in ensuring that the measurements would comply with the UK legislation, was the definition of an operating envelope, specific to the range of items which are required to be surveyed. As the system is required to measure alpha contamination on a range of item shapes and sizes, it must be calibrated assuming that any contamination may be located on the item at the position which exhibits the lowest sensitivity for a measurement. In the case of a tube, this will be a small patch of contamination located inside the pipe at the end furthest away from the ionization detector. A result of calibrating the system for the position of least sensitivity is that if alpha contamination is present at any other position, then its activity level will be overestimated. For most applications, the function of the system will be the confirmation that waste having a high probability of being uncontaminated, is indeed uncontaminated.

On site commissioning and calibration of the system was carried out using new, unused AGR fuel cans suspended in a framework (retaining 36 cans) while ensuring that an air gap was maintained around each can. The air gap is necessary so that alpha particles emitted from the outside surface of the AGR fuel can, would have a sufficiently long path length through the air to produce suitable level of ionization. In effect, the surrounding air is acting as the detection medium in a similar manner to a traditional air ionization chamber.

An extensive series of trials were carried out to determine the response of the system to a well characterized alpha source believed to be representative of the alpha emitting species encountered at the Oxide Fuel Complex. The alpha source was placed both on the outside and inside of AGR fuel cans in a wide range of locations throughout the array of 36 cans.

Fig. 4. Measurement chamber being loaded with a batch of AGR fuel cans

The criteria for deciding whether the scrap AGR Fuel Cans were clean or not was based on the activity level per unit mass of can material. Using the upper specification limit of 11.1 Becquerel's per gram plus an additional safety margin, a total activity limit for a full bundle of 36 cans was derived. Assuming that in the worst case all of this activity is located on one can, the total activity limit was divided by 36 to ensure that no individual can was released with an activity higher than the specification. Even with a series of worst case calibration assumptions in place the working limit for the system was calculated to be 0.2 Becquerel's per gram i.e. one fiftieth of the RSA schedule 1 limit for uranium and one half of the general SOLA EO limit.

CONCLUSIONS

Industrialization of the LRAD technique was possible through collaboration between the Los Alamos National Laboratory and BIL. This collaboration has allowed the development of an innovative technology into an industrial system.

Testing of the system by the US Department of Energy (DoE), the UK National Radiological Protection Board (NRPB) and the Westinghouse Nuclear Fuels, Radiological Protection Group, has provided third party accreditation of the technique, both in terms of radiometric sensitivity and cost. Feedback from the testing has allowed refinements of the design to be carried out which have improved its usability in an industrial environment.

The first large scale deployment at of the Long Range Alpha Detection system at the Springfields Oxide Fuel Complex in the UK, has allowed the project to realize significant time and cost savings when compared with current baseline technology. This would have involved cutting open each individual tube and surveying the exposed surfaces using a standard frisk probe survey.

Use of the LRAD technique has opened up a wide range of radiological surveying applications which are impractical to address by traditional means. These now include the surveying of items such as flanged pipe sections, valves, and “T” pieces.

Additional trials for further applications of the system are currently progressing at both the Sellafield and Winfrith nuclear sites in the UK.

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