Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

CHALLENGE:
Identifying Deformities in 500L Drums

Sellafield Ltd would like to explore techniques and technology which will enable them to accurately measure the dimensions of waste drums used for long-term storage, and identify any deformities.

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Introduction

Sellafield Ltd are responsible for the safe, long-term storage of highly radioactive waste materials that contain magnesium and **uranium**. This material has been produced by the reprocessing of Magnox fuel. Sellafield Ltd must provide secure containment of this waste for around 100 years of interim storage, that is until the waste is disposed of in a Geological Disposal Facility (GDF). This challenge is focused on 500L stainless steel drums in which uranium containing waste is stored.

A method is required for accurately measuring all dimensions of the waste drums and identifying any deformities. The drums are contained within stillages, and Sellafield Ltd would prefer to be able to obtain drum measurements whilst they remain in their stillage. It is also preferred that any proposed solutions are radiation tolerant and able to fit within the confined space available within an inspection facility. Alternatively, solutions would need to be deployed through a multi-layered, lead glass shield window.

The ability to conduct accurate drum inspections will give Sellafield Ltd greater confidence in their understanding of the evolution of the stored waste. This will reduce how frequently future inspections and interventions are required.

Magnox 500L Drums

There are currently around 23,000 Magnox waste containing drums stored in Sellafield's **Encapsulated Product Stores (EPS)**. Within the stores, the drums are contained in stillages with four drums per stillage in a 2 x 2 formation, see Figure 1. Depending on the precise layout of the store, between 9 and 18 stillages can be stacked on top of one another. The drum contents are encapsulated in grout and highly radioactive with no shielding provided by the stainless steel structure of the drum. The specification of the drums is as follows:

- 316L stainless steel
- Water bead blasted to give a uniform featureless finish
- There is a filter in the centre of the drum lid that allows gas venting
- Unique identifier markings are on the flange and body of each drum
- The drums are 1230mm tall and 800mm in diameter, see Figure 2
- Drum wall thickness 3mm
- Internal payload capacity 0.47m^3

Full specification for the drums and stillages can be found at:

WPSGD no. WPS/605/01 - Geological Disposal: Specification for stillage for the transport and disposal of 500 litre drum waste packages (publishing.service.gov.uk)

The Office for Nuclear Regulation (ONR) requires Sellafield Ltd to demonstrate that the drums will maintain their integrity during the period of interim storage. Sellafield Ltd must also understand, and therefore be able to predict, the evolution of the contents of the drums during this period. The majority of drums in the EPS are benign, but some are known to have expanded. This is due to the expansive corrosion of the uranium, resulting from its reaction with water in the high pH grout.

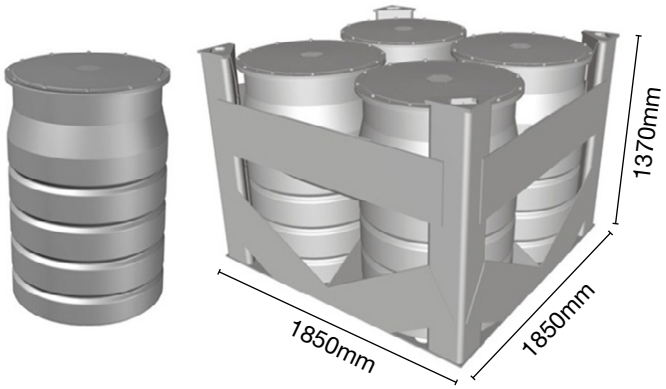


Figure 1 – Image of an individual 500L drum (LHS) and four drums in a stillage (RHS)

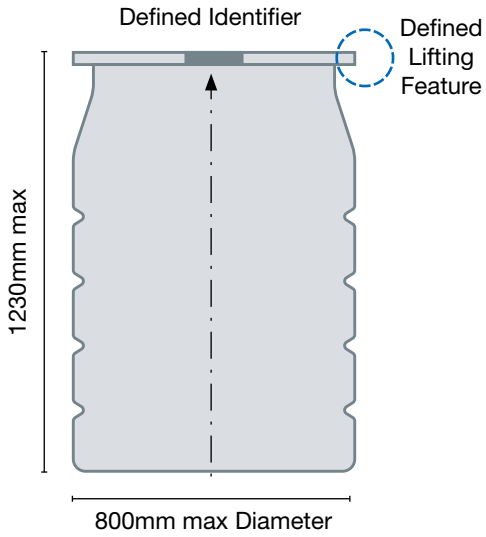


Figure 2 – Dimensions of a 500L Drum

Magnox Encapsulation Plant

Operations to encapsulate waste in 500L drums are undertaken in the **Magnox Encapsulation Plant (MEP)**. For the purpose of this challenge statement, a simplified version of these operations is provided as follows:

- The whole contents of a transport flask are tipped into a single 500L drum
- An anti-floatation plate (AFP) is placed in the drum at a fixed position above the waste, this prevents waste from floating to the top of the drum during the grouting process
- The waste in the drums is dewatered
- Grout is poured over the waste to just above the level of the AFP
- In early operations, the drum was vibrated whilst the grout was still in a liquid phase to remove air bubbles, but this procedure is no longer undertaken
- Once the grout has set, capping grout is added to seal the grout surface and fill the ullage in the drum
- Once the second batch of grout has set, the drum is sealed with a lid that is bolted in place
- The exterior of the drum is decontaminated by a high-pressure washing regime
- The drums are placed into a stillage and transferred to the EPS via a transfer tunnel

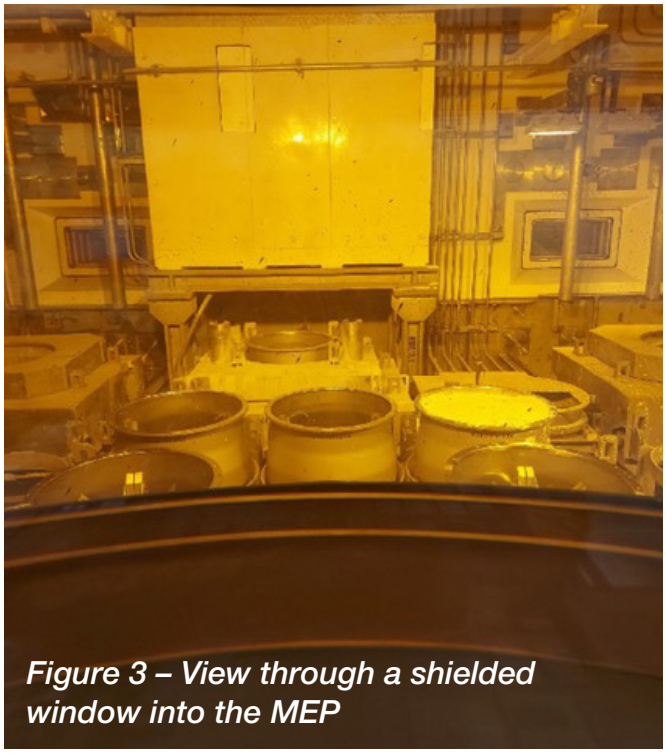


Figure 3 – View through a shielded window into the MEP

Figure 4 – Cut away of a replica 500L drum showing waste material encapsulated in grout. It should be noted that in this example the waste is evenly distributed within the grout, whereas normally the waste tends to settle towards the bottom of the drum

Figure 3 shows the inside of the MEP as seen through the shielded viewing window and Figure 4 depicts a cut-away dummy 500L drum that has been filled with encapsulated waste.

During the grouting process, uranium containing waste materials settle in the lower section of the drum. It is therefore reasonable to expect that deformities due to corrosive expansion are more likely to develop in the lower section of the drums.

Drum Inspection Facilities

In order to satisfy ONR requirements, the Magnox drums must be inspected for signs of evolution, such as expansion or corrosion. Due to the highly radioactive nature of the drum contents and lack of shielding provided by the thin-walled stainless steel drum, any inspections must be undertaken within a **drum inspection facility**.

Drum inspection facilities vary in their layout, but have the following features in common:

- A gamma gated transfer tunnel to the EPS
- Overhead cranes providing translational and vertical movement of drums and stillages, but with no rotational capability
- Overhead cranes have a safeguarding boundary of 1500mm from the walls of the inspection facility
- Between one and five stillage park positions, with the number depending on the facility
- A rotating inspection platform
- At least one viewing window (Figure 5)

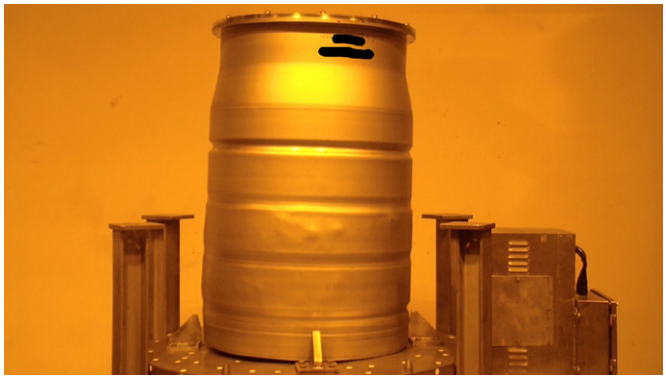


Figure 5 – View through a shielded window into an inspection facility with a deformed 500L drum mounted on a rotating inspection platform

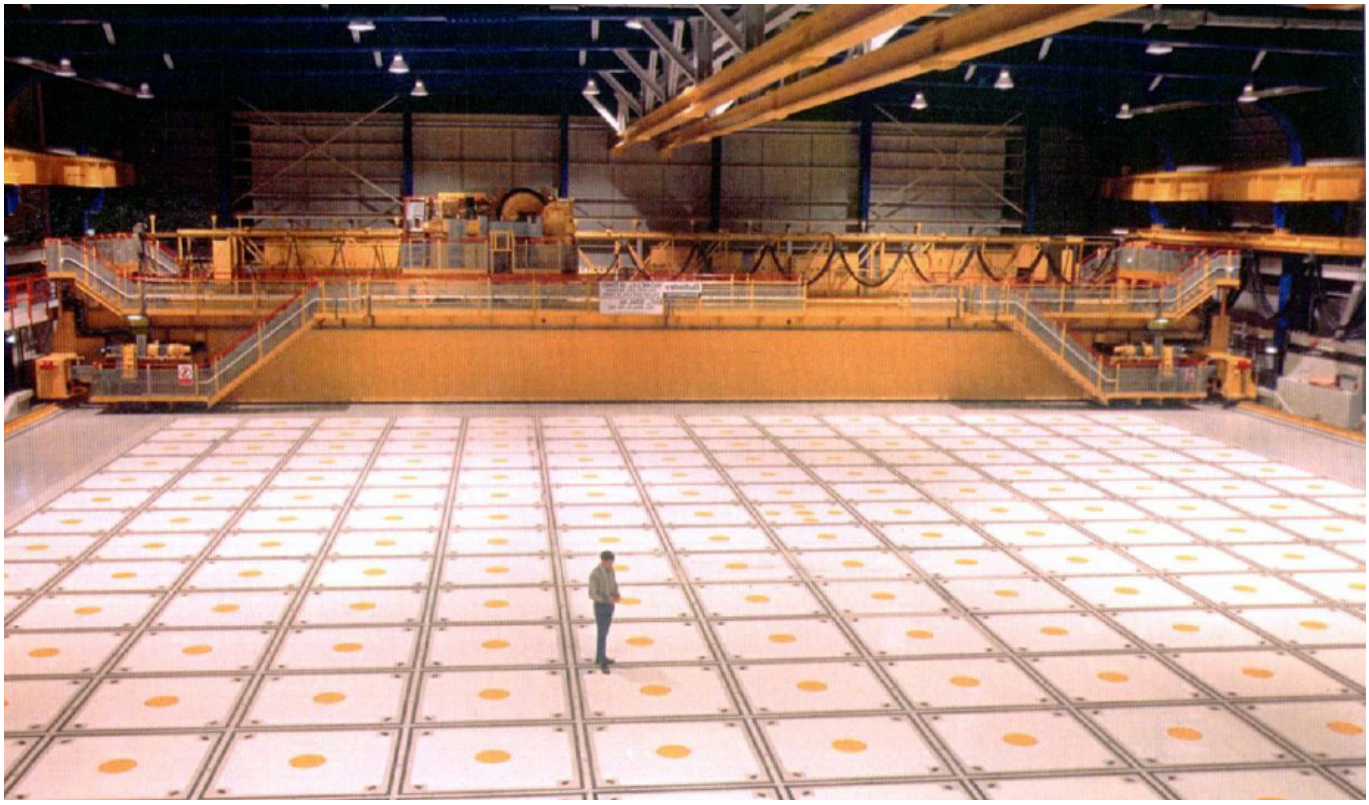
Manned access to inspection facilities is only possible when they are devoid of waste drums.

Within an inspection facility it is possible to remove drums from their stillage for placement on the rotating inspection platform. The base of the drum can be inspected whilst the drum is suspended in transit from its stillage to the rotating platform. There is a risk in performing this operation, as any drum that has expanded may be difficult or even impossible to replace back into the stillage.

In one EPS, stillages are removed for drum inspection by the EPS Charge Machine (Figure 6). This enormous piece of complex machinery can remove and replace a maximum of two stillages per 12 hour shift. The time available for Condition Monitoring and Inspection (CM&I) within an EPS is restricted by operational constraints whilst a store is being populated with waste drums. Once a store is full to capacity, this time restriction is less of an issue.

Sellafield Ltd need to ascertain whether the 500L drums stored in the EPS conform to their original shape and size and this is the essence of this challenge.

Figure 6 – EPS charge hall with the charge machine towards the rear of the image



Current Practice

The current method for identifying drum deformities is human visual inspection backed up with video camera footage for image capture. Around a decade ago, attempts at detecting deformities were made using infra-red and white light scanning with image stitching, but this was without success. These inspections were undertaken inside the EPS using an inspection bogie that can rotate a single drum through 360 degrees.

Sellafield Ltd have also considered installing high-definition video cameras, positioned above the stillage to give a view of the top and sides of the four drums within. However, this camera position restricted the view to around 20% of the total drum, which is insufficient to confidently ascertain whether drums have expanded or deformed in any other way.

Other techniques that have been considered and discarded include:

- Laser scanning for precise measurement of any drum surface deformities whilst in the stillage. This would require multiple scanners or a means to move scanners around a stillage. Analysis of the vertical walls of the drum would be severely hampered by the structure of the stillage
- Thermal imaging as an indicator of damage to the drum surface as well as the radiogenic heat output of the drum contents. This approach was thus rejected because of a lack of radiation hardness of the hardware
- Additional specialist cameras within the inspection facilities, rejected due to size and lack of radiation hardening of costly hardware

Challenge Aims

Any method of identifying expansion of drums prior to their removal from their stillage would be highly desirable. This would provide confidence that drums would fit back into the stillage following their removal for inspection.

Sellafield Ltd are open to solutions that are deployed from either within or through the window of a drum inspection facility, although preference would be for a solution deployed within the inspection facility. The components of a solution that would be deployed within an inspection facility must be extremely radiation tolerant (see constraints).

- Any proposed solution should identify any distortions and be capable of measuring the following dimensions of a drum:
    - Vertical height
    - Circumference
    - Width from the vertical centre line

Sellafield Ltd are seeking solutions that can:

- Assess around 10 stillages (40 drums) within a 2-week window
- Complete a single drum inspection within an hour
- Ideally demonstrate a prototype to Sellafield Ltd within 3 months from the closing date of this challenge
- Be capable of active deployment within 12 - 18 months

Benefits to Sellafield

Sellafield Ltd need to demonstrate that they are creating waste packages that will be suitable for final disposal. Should that requirement not be satisfied, the cost of re-working the waste drums would run into billions of pounds.

A method for accurately measuring all dimensions of the waste drums that is radiation tolerant and able to fit within the confined space available within an inspection facility would be highly desirable. This would enable Sellafield Ltd to confidently satisfy the requirements of the ONR.

If the method can provide this assessment whilst the drums are still in their stillage that would have the greatest benefit, as it avoids the risk of removing a drum from a stillage that then can't be returned, which then blocks man-access to the inspection facility.

Better inspections will give higher confidence in the understanding of the evolution of the waste and therefore reduce frequency of need for future inspections or intervention.

Constraints

Any proposed solution to this challenge must be able to operate within the following constraints:

- Any equipment deployed within an inspection facility must be able to tolerate radiation levels in the region of 10Sv/hr. There is little or no radioactive contamination on the exterior surface of the drums
- Any solution deployed from the outside of an inspection facility will need to work through a shielded window, which is 900mm to 1500mm thick and made from multiple layers of lead glass
- Inspection facilities are highly congested areas with limited zones of potential space for additional equipment
- Delivery of equipment to inspection areas is likely to involve flights of stairs and man access doors, so large items of equipment would preferably be implemented as a modular system with individual units being no more than 25kg in weight
- Inspection area rotating inspection platforms rotate at a fixed speed of around 1rpm; precise speeds may vary between different inspection areas
- The rotating platforms within some inspection facilities have a guide for centrally locating a drum; however, precise central placement of a drum on the rotating inspection platform is difficult, if not impossible, to achieve
- Stillages cannot be placed on the rotating inspection platform
- There is a low but possible risk of damaging the drums every time they are moved in or out of their stillage, so this operation is preferably kept to a minimum

Functional Requirements

Any proposed solutions to this challenge must:

- Provide measurements of drum dimensions to an accuracy of +/- 0.5mm without the need to add markers or any other additional features to the drum
- Provide both vertical and circumferential measurements of a drum
- Not require physical contact with the surface of the drum being inspected
- Operate in temperatures ranging between 15°C and 40°C
- Capture and store data for future analysis
- Confirmation of the dimensions of a drum could be provided as an image or any other form of data

Find out more

Game Changers are hosting a workshop for this challenge where delegates will have the opportunity to meet challenge owners. Details are available on the Game Changers website www.gamechangers.technology.

If you have new ideas or innovations which can be applied to address this challenge, we invite you to join us. If you'd like more information about the funding available through the Game Changers programme, please visit Our Funding Process (gamechangers.technology).

The deadline for applications for this challenge is 12 noon on Thursday 28th September 2023.

Sellafield Ltd

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