CHALLENGE:

Non-destructive inspection of redundant flasks

Sellafield Ltd is looking for solutions to identify the contents and internal activity levels of flasks that have been used to store or transport radioactive materials, without moving, opening or damaging the flasks.

Introduction

Sellafield is a large and complex site that has been at the heart of the UK's nuclear industry since 1947. The site is now undergoing decommissioning and Sellafield Ltd is responsible for the clean-up and disposal of its legacy of complex materials.

A precise understanding of the inventory on the Sellafield site supports waste management and decisions on the re-use, recycling or disposal of materials. Sellafield Ltd has a stock of over 200 legacy flasks, which are large metal structures with thick walls that shield radiation. Flasks have been used widely across the Sellafield site to store and transport radioactive materials. The flasks vary significantly in dimensions, mass, age and radioactivity levels. Although they are now redundant, it is possible some may still contain some debris, liquid or sludge. A precise understanding of the internal and external radioactivity levels of each flask is needed to conform to regulatory requirements before they can be processed in preparation to be transported off-site for re-use, recycling or disposal.

There is a flask maintenance facility on the Sellafield site, which is currently the only location equipped to remove the lids from flasks that potentially contain highly radioactive materials. However, this facility is already operating at full capacity with ongoing flask maintenance. The transfer of flasks to this facility is a hugely expensive and challenging process. Many of the areas where flasks reside no longer have the equipment required to lift them. In this challenge, Sellafield Ltd is looking for solutions that can verify the contents of each flask, including radiometric characterisation, without the flask being moved or damaged.

A non-invasive solution that can provide a confident assessment of internal radioactivity levels would be optimal. If that is not possible, an estimate of the activity levels obtained non-invasively is still useful, as that would support on-site flask management. If the levels of activity can be confidently shown to be low enough, then the lid can be removed from the flask locally, without being moved to the specialist flask maintenance facility.

This challenge applies to flasks located widely across the Sellafield site, but for the purpose of this challenge statement, the flask inventory at Calder Hall is used as an example as it is representative of the wider site.

Calder Hall

Around 40 heavily shielded flasks remain at Calder Hall, with the earliest dating from 1956. These flasks had been used to store or transport high-activity materials, such as fuel rods, control rods or graphite dust. Although the flasks are documented, due to their age and condition, it is not possible to be confident that there is no remaining liquid, sludge, dust or debris within the flasks. Within the next 2 years these flasks need to be removed from Calder Hall to be processed for disposal and, where possible, recycling. This will be challenging as the equipment needed to lift these flasks has been removed from Calder Hall.

The 40 flasks that remain at Calder Hall are highly individual so a solution that will work for any shape and size of flask is required. Such flexibility would enable the solution to be deployed on flasks across the rest of the Sellafield site. Each flask had been designed for a specific purpose, such as transporting control rods, graphite dust or fuel. The size and shape of these flasks reflect the original purpose. Other flasks were general purpose, although also designed to contain radioactive materials. As a result, most of the 40 flasks are unique, although all have a metal outer casing and thick shielding. They have been designed to act as an impenetrable barrier between their contents and the outside world. Example dimensions for similar flasks are presented in Table 1. In summary, differences include:

- Dimensions range from 400mm – 1550mm tall and 600mm – 7690mm wide
- Flasks may be a cube, cuboid or cylindrical
- Outer bodies may be stainless steel or mild steel
- Shielding material may be concrete, lead, plastics, balsa wood, stainless steel or mild steel
- The exterior of all flasks is painted, with lead-based paint used on some flasks but not all
- The flasks have been manufactured since the 1950s, with the bulk manufactured between the 1960s and 1980s
- Variable levels of rust and corrosion are present
- Wall thickness is not known for all flasks, but typically ranges between 75mm – 200mm

- Some flasks have additional features such as inspection ports and gamma gates (areas with removable shielding to measure activity levels)
- The lids of some flasks are welded in place, but not all

Flask used to contain / transport	Shape	Weight (Te)	Height (mm)	Width (mm)	Depth (mm)
Magnox fuel	Cylinder	11.2	1240	2210	
Irradiated non-fissile specimens	Cylinder	5.4	640	1590	
Control rods	Cylinder	27	860	5730	
Isotope cartridges	Cuboid	2	600	600	600
Intermediate Level Waste	Cuboid	3	1220	640	800
Intermediate Level Waste	Cuboid	6	1000	1000	1000

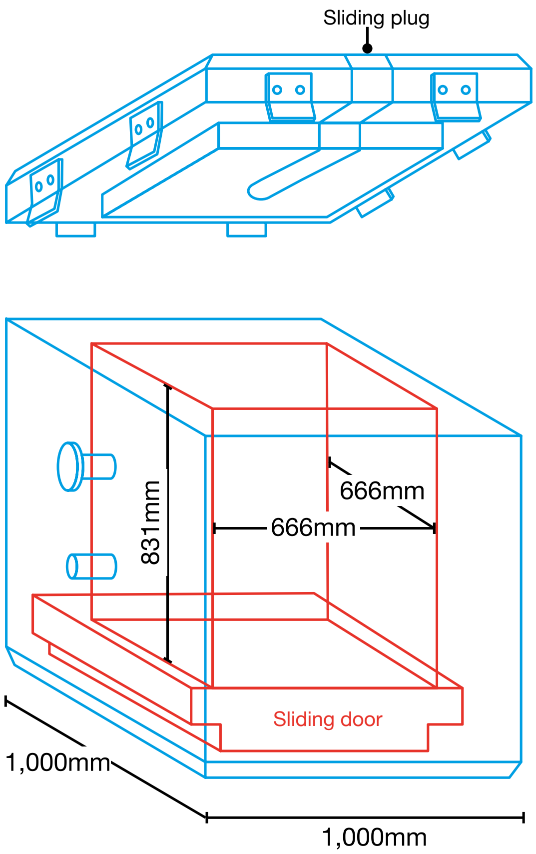

Figure 1: Dimensions of an example cuboid flask

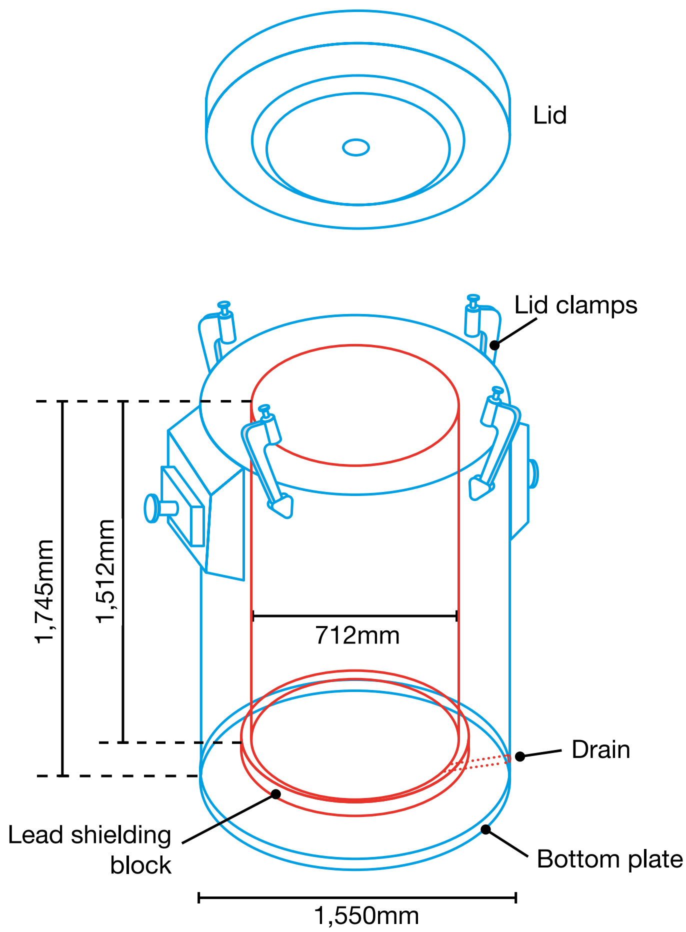

Figure 2: Dimensions of an example cylindrical flask

Figure 3: Control rod flask

Figure 4: General flask

Calder Hall is in the process of being cleared and access to the flasks is reasonably straightforward. Some flasks are stored outside under tarpaulin and the rest are in empty buildings with large entryways similar in size to domestic garage doors. Several flasks are on the first floor. These can be accessed using a lift large enough for a pallet (approximately 1200 x 1000mm, 2.5Te limit). All flasks are stacked or stored away from any walls, giving access to all sides and the top but not the base of the flasks. The buildings and external areas that the flasks are stored in require standard PPE such as hard hats and boots. It is expensive and impractical to move the flasks, so an in-situ inspection solution is required.

Any solutions to this challenge are intended for use across the Sellafield site, where there are around 200 additional flasks to be inspected. The flask inventory and accessibility described at Calder Hall are reflective of the rest of the site. Across the Nuclear Decommissioning Authority (NDA) estate there are sites with a similar inventory of redundant flasks. A solution that can work on a variety of flask types could be used widely across the UK and internationally.

Figure 5: Flask storage area containing standard flasks

Current Practice

It is not currently possible to identify the contents or internal radioactivity levels of redundant flasks without removing their lids. Opening and inspecting the flasks without knowledge of their internal radioactivity levels is hazardous, arduous and expensive.

The current practice when preparing to dispose of a flask is:

1. Consider flask history and determine whether it would be considered as a Surface Contaminated Object (SCO) or Low Specific Activity (LSA) under the regulatory guidance (IAEA SSR-6 section IV)
2. Operators open the flask to confirm the internal void is free from items and debris
3. Operators collect internal and external dosage information and contamination readings to support waste characterisation and for transport purposes
4. Activity levels are modelled, which can be very pessimistic
5. The activity is assessed against known fingerprints of radioactive species

Additional information on activity levels and location can be used to reduce the risk to operators and to provide more information for the modelling software to give a more realistic and less pessimistic view of flask activity.

Challenge Aims

Sellafield is looking for a solution that can provide the following information without the flasks being moved or damaged. There are two aspects:

Identify the flask contents:

(in order of priority)

1. Identify the presence of any remaining spent fuel/fuel debris
2. Identify the presence of any liquids/sludge
3. Identify the presence of any other solids (i.e. flask furniture)
4. Locate any solid, liquid or sludge within the flask
5. Quantify any solid, liquid or sludge within the flask

Radiometric characterisation:

(in order of priority)

1. Estimate the maximum dose rate expected if the flask lid was opened (the maximum dose rate criterion for R3 areas would normally be 100 μSv/h beta gamma)
2. Have limits of detection that enable the measurement of the internal loose surface contamination down to 40.0 Bq/cm^2 α or 400 Bq/cm2 β, and the airborne contamination down to 1.0 DAC (Derived Airbourne Concentration)
3. Confirm that the radioactive fingerprint is credible (if it aligns to a known fingerprint)
4. Determine total activity in Bq and specific activity in Bq/g (where the mass of the flask is known)
5. Indicate location of hotspots of radiation and contamination
6. Provide information on whether contamination is airborne, on the surface, or has penetrated the material

This is a complex challenge and Sellafield Ltd is interested in technologies that provide either whole or partial solutions. In addition, it is key that any proposed solutions:

- Are suitable for use with a wide variety of flask types, and not be limited to specific dimensions, materials or conditions
- Work in situ, without the flask being moved
- Work inside buildings or outside in the open
- Are transportable in a lift approximately 1200 x 1000mm, with a 2.5Te weight limit
- Only act on the outside of the flasks, which must not be opened during the inspection

The buildings that currently store the Calder flasks are due to be demolished in around 2 years. Sellafield Ltd is looking to support the development of a solution that can be used on-site within this timeframe.

Benefits to Sellafield

The ability to confidently determine the nature and radioactivity of the contents of the flasks without them having to be moved or opened would save a significant amount of money and time, whilst reducing operator exposure. This will support risk-reduction and enable Sellafield to satisfy regulator requirements.

If the activity levels are confirmed with confidence to be under the threshold required to be opened locally, the flasks can be opened and managed without being transported to the flask maintenance facility. This would result in a significant cost and efficiency saving. In addition to providing an enhanced understanding of a flask's contents, a suitable solution would further inform processing in line with the NDA's waste hierarchy.

There are around 40 flasks at Calder Hall and another 200 distributed across Sellafield site, as well as a similar inventory of flasks at Chapelcross in Dumfries and Galloway. There are potential opportunities across the whole of the NDA estate for successful solutions to this challenge.

Constraints

Any proposed solutions to this challenge will need to operate within the following constraining factors:

- Background radiation levels are in the region of 5 – 6 μSv/h
- Flasks are dispersed in a wide variety of locations, both indoors and outdoors and sometimes on the first floor of buildings. In these cases, there is lift access (approximately 1200 x 1000mm, 2.5Te limit)

- At Calder Hall, the top and sides of flasks are accessible as they are not stacked and do not butt up against walls, other obstacles, or each other. Access may be more restricted in other environments
- The environment in which all flasks reside is lit
- Where power is not available, use of a generator would be possible
- Standard PPE is required when working around the flasks, such as hard hats and boots. Dosimeters will be required for active areas
- Measurements can be taken from outside of the flask, including in contact with the flask
- Sections on the outside of flasks can be polished to remove rust or corrosion if required
- The flasks must not be opened or irreparably damaged. If the proposed solution does need to drill into the flask, then please be explicit about how this will be re-sealed in your Game Changers funding application
- Solutions that require radiation generators or sealed radioactive sources add practical complexities. Please ensure it is clear if this is what is proposed in your application

Functional Requirements

The technology needs to be able to:

- Identify the location of liquid (minimum 100ml pools), sludge or solid debris remaining within each flask
- Provide enough information to confirm, with confidence, that the external dose rate if opened is below 100 μSv/h beta gamma, the loose surface contamination below 40.0 Bq/cm^2 α or 400 Bq/cm2 β, and the airborne contamination is below 1.0 DAC
- Identify hotspots of radiation and infer whether the activity is airborne, surface contamination, or penetrated into the flask wall material
- Work indoors or outdoors

In addition, the operator can be present, there is no requirement for remote operation. If preferred, it can be a modular solution or something that inspects the flasks a section at a time. The solution can make contact with the outside of the flasks, or work from a distance.

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 2pm on Monday 26th February 2024.

Sellafield Ltd

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