Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

CHALLENGE: Nuclear Materials Stores Inspection – Corrosion

Sellafield's mission to create a safe environment for future generations requires the secure storage of Special Nuclear Materials (SNM) within a purpose-built store for a duration of approximately 100 years. The Sellafield site is in a coastal location so the air surrounding the store is humid and salt-laden. Store ventilation is provided by the natural convection of unfiltered air and it is known that the moisture and salt in the air are causing corrosion of steel and aluminium structures within the store. Sellafield are seeking solutions that will improve their understanding of the in-store corrosion situation, including physical and chemical analysis of corrosion and reproducible sampling in this difficult to access environment.

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Introduction

The **Sellafield Product and Residue Store (SPRS)**, houses **special nuclear materials (SNM)** that have resulted from nuclear fuel reprocessing activities over the last 60 years. SPRS will play a key role in delivering Sellafield's mission to create a safe environment for future generations. The SNM are packaged into containers for safe and secure storage within the SPRS facility for a duration lasting until 2120.

The Sellafield site is in a coastal location so the air surrounding the SPRS is humid and salt-laden. The SPRS is ventilated by the natural convection of unfiltered air and it is known that the moisture and salt in the air are causing corrosion of steel and aluminium structures within the SPRS.

Sellafield are exploring a variety of avenues to improve their understanding of the corrosion occurring within the SPRS and that is the essence of this challenge.

Housing of SNM within the SPRS

Prior to storage, SNM are packaged into stainless steel canisters, such as the one illustrated in Figure 1. The SPRS can hold a maximum of 9,600 SNM canisters.

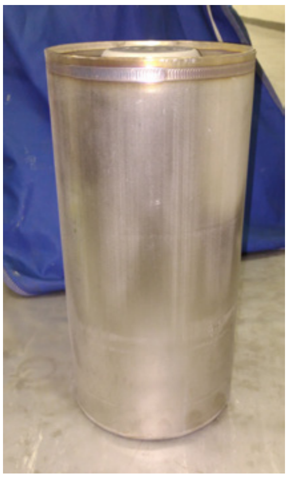

Figure 1: Image of a typical SNM container

The cylindrical SNM canisters are housed within aluminium alloy channels that consist of 8 mm thick aluminium 6063 extrusions. A cross-section of the structure of the aluminium extrusion is shown in Figure 2. The aluminium extrusions provide secondary nuclear containment, with the stainless-steel canister being the primary nuclear containment.

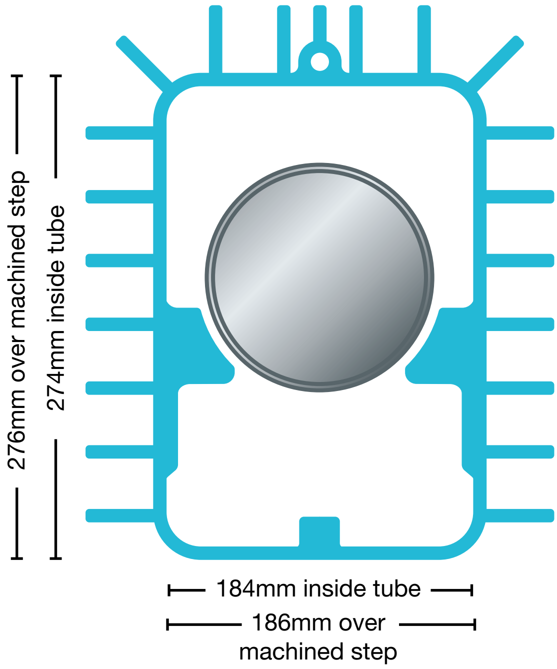

Figure 2: Cross section illustrating the positioning of an SNM canister within an aluminium 6063 extrusion

An illustration of the longitudinal arrangement of SNM canisters within an aluminium extrusion is shown in Figure 3. The SNM canisters are entirely surrounded by the aluminium extrusion and are, therefore, not visible once they are located in the SPRS.

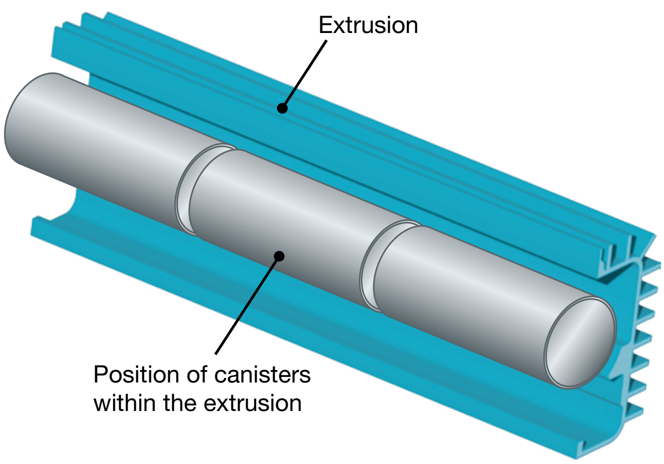

Figure 3: Section of an aluminium extrusion containing SNM canisters

The SPRS contains 16 cells, the structural arrangement within cells, illustrated in Figures 4 and 5, is as follows:

- Each cell contains 40 aluminium alloy channels (extrusions) of 6.3m in length
- There are 20 channels in the upper cell and 20 in the lower cell, these are highlighted blue in figure 4
- The channels are arranged in a horizontal parallel formation with centre-to-centre spacings of 750 mm
- The aluminium alloy channels are supported by a steel support structure highlighted red in Figure 4
- The vertical distance between levels of aluminium channels is approximately 450 mm
- The horizontal gap between adjacent extrusions is approximately 550 mm

The cross section of a structural stainless steel box section is shown in Figure 6, including the welds which are the areas most susceptible to corrosion.

The only regular access to each cell and the corroding surface of the aluminium extrusions is via two inspection ports located in the ceiling of the cell. Each port is circular, with a 140mm diameter and approximate length of 2 metres. The distance between the ports in the floor above the cell and the upper most level of aluminium channels is approximately 3 metres and the distance to the floor of the cell is approximately 16 metres.

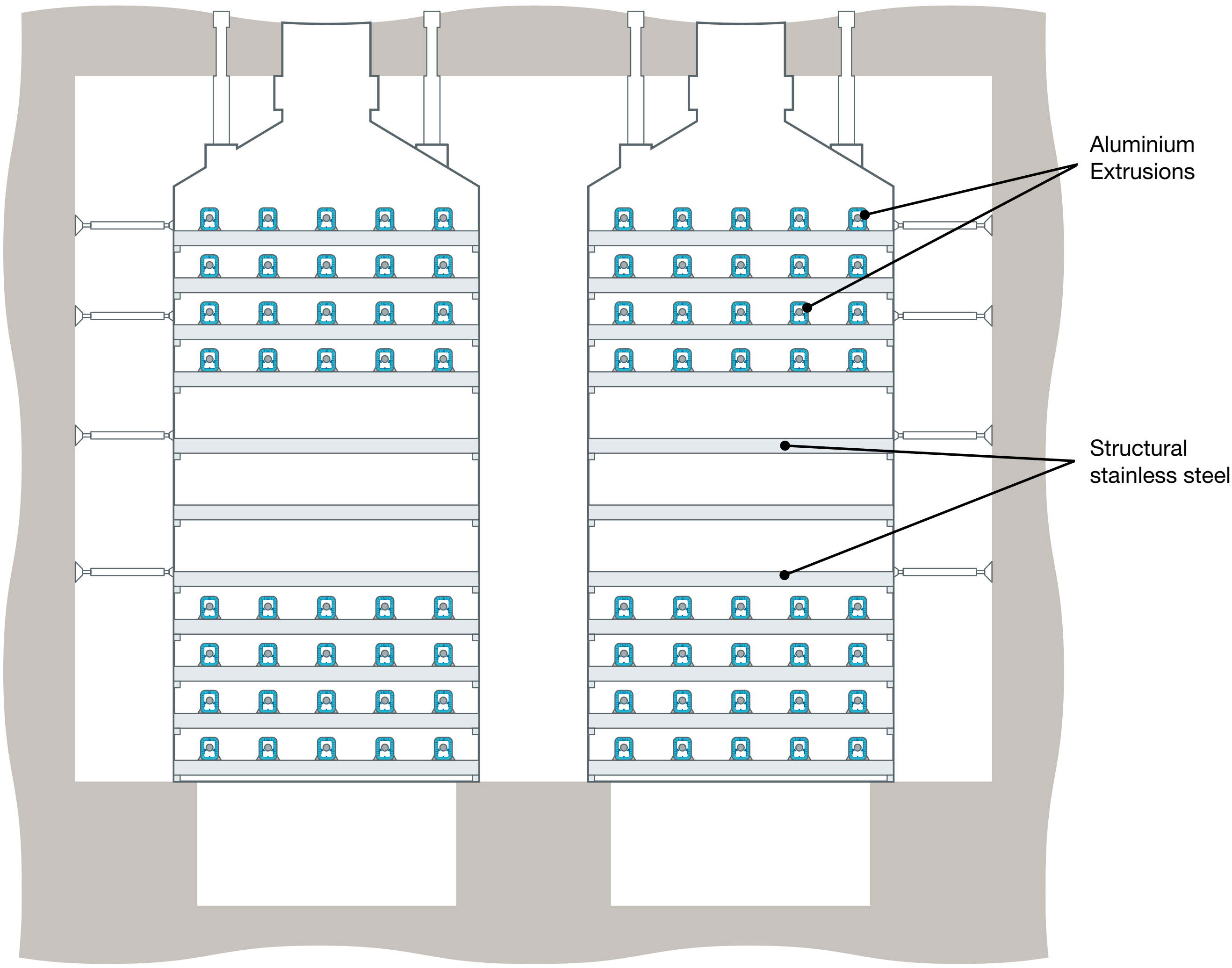

Fig 4: Schematic of the interior of an SPRS cell

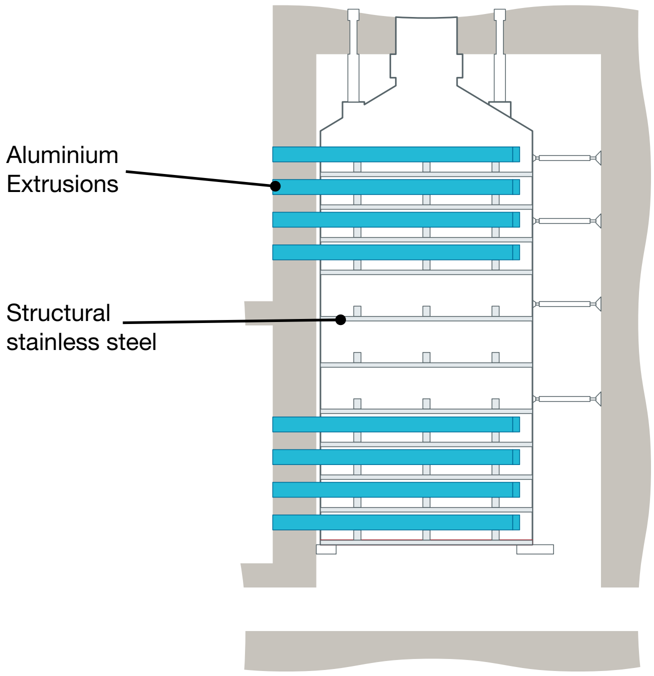

Figure 5: Schematic drawing of the cross section of a storage cell as viewed from the side with the aluminium extrusions highlighted in blue and steelwork highlighted in red.

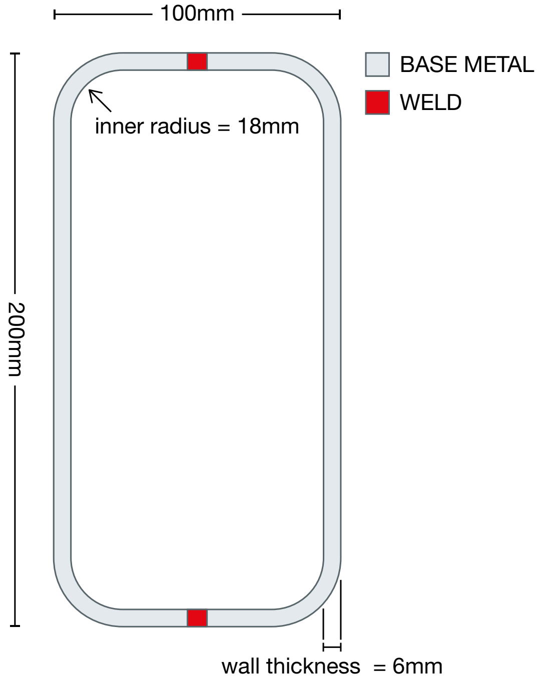

Figure 6: Schematic of the cross section of a stainless-steel box section. The inner radius is 18mm and the wall thickness is 6mm.

The corrosion situation

Within the SPRS, the supporting steel framework has started to corrode and appears to be dripping corrosion products onto the aluminium extrusions as shown in figures 7a-c. This is corroding the aluminium, however it is not possible to see to what extent the corrosion is occurring or what corrosion products are forming. If the wall of the extrusions is breached, they can no longer serve their secondary nuclear containment purpose. Sellafield needs to understand whether the observed corrosion is going to be limiting to the forecast 100-year lifetime of the SPRS store.

Figure 7a: Corrosion is seen forming here, predominantly on the central weld of an LDX 2101 stainless steel box-section. Corrosion product is visibly dripping down onto the underlying (finned) aluminium extrusion.

Fig 7b: Green/brown corrosion products from the LDX 2101 supports can be seen on the surface of the aluminium extrusion.

Fig 7c: Salt can be seen forming on the aluminium extrusion. These extrusions are shown supported and strapped to the structural stainless-steel box-section.

Aluminium corrosion coupons from the SPRS environment have shown aggressive pitting and intergranular corrosion due to the high levels of chloride salt deposition as shown in Figure 8a. It will be important to support the measurements from coupon samples with real measurements of corrosion depth to the extrusions within the store.

The results of laboratory-based experiments are shown in Figure 8b, where the interaction between stainless steel corrosion products (e.g. iron and chromium chlorides) and aluminium 6063 is seen to be highly aggressive. Therefore, it is important to identify the quantity and chemical composition of the corrosion products from LDX 2101 which are falling onto the aluminium extrusions in SPRS.

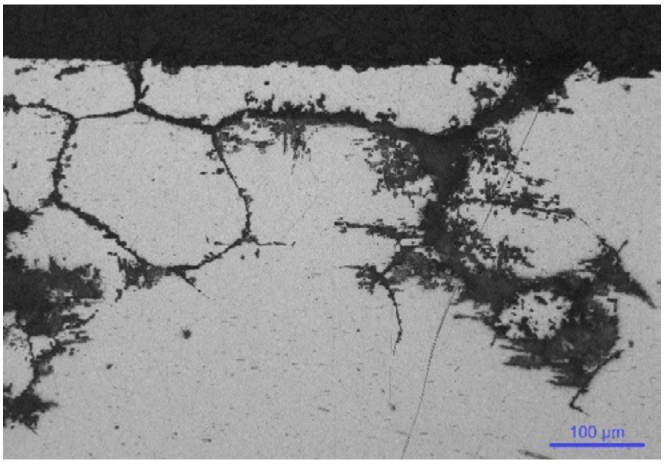

Figure 8a – Pitting and intergranular corrosion of corrosion coupons as observed by optical microscopy following destructive sectioning

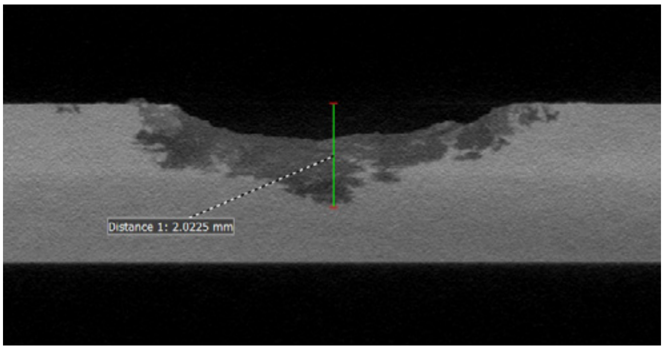

Figure 8b – Corrosion attack to aluminium following application of simulated stainless steel corrosion products in a laboratory environment imaged by X-ray Computed Tomography

Current Practice

Detailed inspection of the corrosion situation is very difficult as human access to the SPRS is rarely (if at all) possible. Samples of corrosion products from structures within the SPRS were last taken during a store entry in 2016. The samples were analysed ex-situ. Silicone impressions were also taken to measure depth of corrosion to stainless steel and aluminium components.

Entry into the cells may require movement of the SNM inventory to reduce the dose to the inspectors and the human residence time within filled cells is limited, potentially to minutes. This becomes more difficult as the store inventory increases over time. Eventually, the only means of seeing inside an SPRS cell will be to lower a camera on the end of a pole through the inspection ports at the top of the store. This visual inspection data enables monitoring of the progress of corrosion but does not give any chemical information or allow for assessment of the depth of corrosion.

Challenge Aims

Sellafield are seeking innovative solutions that provide:

- Non-Destructive Evaluation to establish the depth of pitting into the surface of structures caused by corrosion
- In-situ chemical analysis of corrosion products on both aluminium and stainless steel structures
- Measurement of the depth of corrosion in aluminium and stainless steel structures using a technique that does not require extensive surface preparation
- The means to remove solid samples from corrosion deposits for later analysis. In some cases, the location of the deposits is already known. It would be helpful to know the precise location from which any samples are taken
- Sampling of salt deposits on structures within the SPRS cells
- Sampling of dripping liquors and measurement of drip rate within the cells of the SPRS
- Measurement of temperature of the aluminium channels and surrounding air

- Measurement of humidity of the air local to the aluminium channels

Sellafield are seeking solutions that can be rapidly deployed via the inspection ports at the top of the store once Proof of Concept has been established.

Benefits to Sellafield

Achieving the above sampling and analysis aims will provide Sellafield with a clearer picture of the corrosion processes ongoing within the SPRS. As a result, Sellafield will better understand rates of corrosion and have improved confidence in lifetime predictions for the store. This will drive future planning decisions with regard to storage of SNM, helping to ensure operational safety and underpinning operational assumptions.

The current store has a capacity of 9600 SNM packages. The current strategy requires that this capacity is available until 2120, so if store capacity is limited by corrosion issues, either remediation of the affected cells or alternative storage will need to be provided. It is essential to fully understand the extent of the current corrosion situation in order to make these decisions as soon as possible.

The current modern storage facilities at Sellafield will be expanded. Understanding the extent of corrosion in the SPRS will inform the design of future storage facilities.

Constraints

Any solutions to this challenge will need to factor in the following aspects:

- The configuration of an SPRS cell as detailed in this document
- Extremely limited access to the interior of the cells within the SPRS. This is via two 140mm inspection ports at the top of each cell. These ports are approximately 2 metres long and require the removal of the shield plug to enable access
- Access to the structural steelwork and aluminium extrusions, particularly in the lower part of the cells, is extremely difficult
- There is no lighting within the SPRS cells
- There is no power supply within the SPRS cells
- Relative humidity within the SPRS cells is around 70-80%
- Temperatures within the SPRS cells can reach as high as 50°C
- Radiation levels within the SPRS cells are approximately 2 mSv/hr gamma and 2 mSv/hr neutron, although levels may be higher than this in localised regions of some stores
- Equipment or contamination should not be left within any SPRS cell

Functional Requirements

Solutions to this challenge must be agile, remote deployment techniques that are feasible within the constraints of the SPRS cell.

Solutions to this challenge must be able to achieve at least one of the following:

- Non-destructive measurement of the depth of corrosive attack on the exterior of the aluminium extrusions
- Characterisation of the chemical nature of aluminium and stainless-steel corrosion products in-situ
- Acquisition of physical samples of corrosion deposits on both aluminium and stainless-steel surfaces and their removal from the SPRS for analysis

Solutions to this challenge should be able to:

- Log the precise location from where any samples are taken
- Repeat location specific measurements/ sampling at intervals of several years

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 Thursday 24th November at 12 noon.

Sellafield Ltd

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