Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

CHALLENGE: Salt concentration measurement

Sellafield Ltd would like to explore techniques and technologies to allow the remote measurement of salt concentrations within a hazardous environment with constrained access.

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Introduction

At Sellafield, the birthplace of the UK's nuclear industry, there are a diverse range of buildings and structures located on a complex site with an area of six square kilometers. Many of these buildings are ageing and effective monitoring and maintenance is fundamental to operating both safely and cost-effectively.

The Vitrified Product Store (VPS) was built to store containers of vitrified waste. It is a passively cooled store, using the heat generated by the store contents to draw a cold air stream into the store through a set of cooling air ducts. Sellafield is in a coastal location, so the air surrounding the VPS is humid and salt-laden. The drawn-in air is not conditioned, and therefore the moisture and salt content have the potential to cause corrosion inside the store.

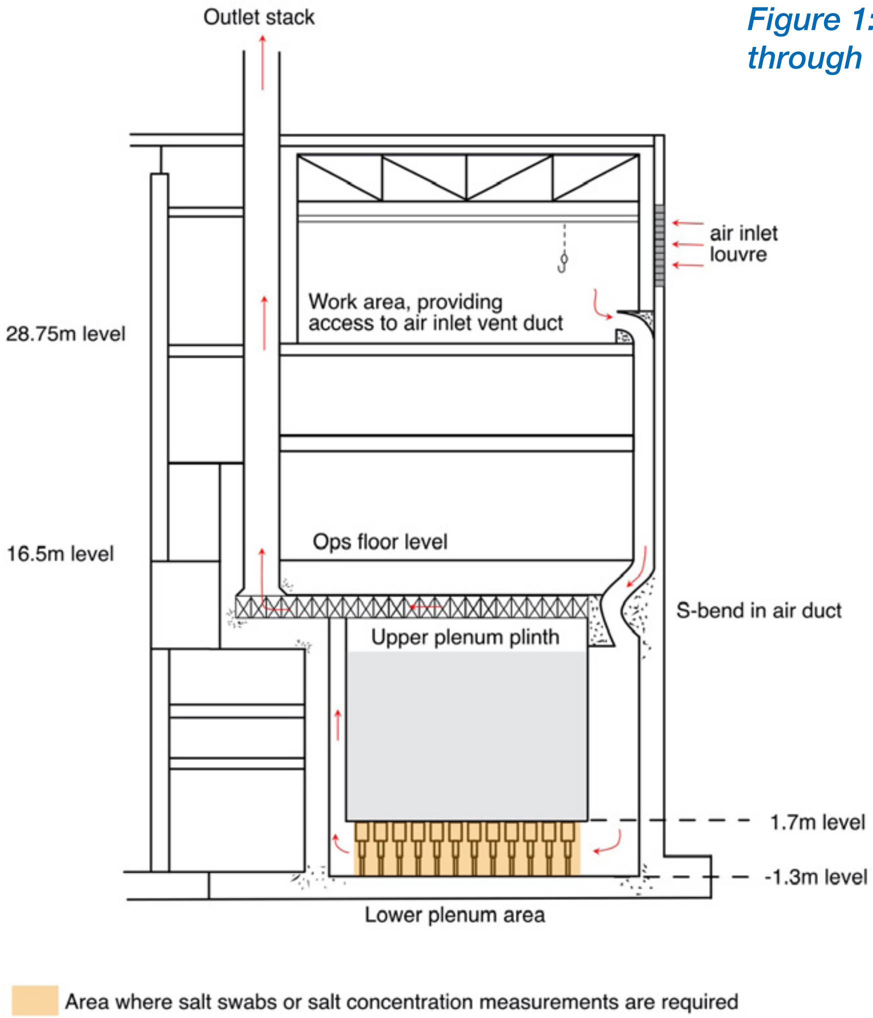
The VPS contains a mild steel and stainless steel structure referred to as the Tube Module Assembly (TMA). Man access in the proximity of the TMA is not possible, therefore Sellafield would like to explore different techniques and technologies to allow the remote measurement of salt concentrations on the TMA. This will help to develop an understanding of the corrosion occurring inside the VPS and to inform the design of future storage facilities.

Current Practice

The VPS contains a number of floors. The structure of the building is illustrated in Figure 1. Four vaults are located in the lower plenum of the building. Each of the vaults houses a number of mild steel storage tubes (known as thimble tubes), held vertically within the TMA. The TMA structure is held on 'corbels', which are cast into the surrounding vault walls. The thimble tubes rest on the vault floor with a shock absorber arrangement.

Each vault has three off-parallel air inlets located on the 28.75m level floor of the building (Figure 1). These air inlets provide the only access to the vaults, with each of the inlets covered by a grille (Figure 2).

Figure 1: Cross-section through VPS vault



Detailed inspection of the corrosion situation is very difficult as human access to the vaults in the lower plenum is not possible. Previous remote visual inspection, temperature and humidity measurements have provided no evidence of general or significant corrosion.

Challenge Aims

Sellafield are seeking innovative solutions that will enable the measurement of salt concentration on the TMA support structure in the lower plenum. Solutions must be capable of deployment into the vaults via vertical air ducts which contain a series of bends (Figures 3 and 4).

Solutions should be capable of deployment once Proof of Concept has been established within the next 18 – 24 months. Proposals for solutions which address part or all of this challenge are invited. Applications solely describing salt measurement technology are welcome, as are applications solely describing potential deployment solutions.

Benefits to Sellafield

The current cost estimate to replace VPS with VPS2 is in the order of hundreds of millions of pounds, with lifetime costs estimated to be in excess of £1bn. Achieving the challenge aims will lead to greater understanding of the level of corrosion and the corrosion processes ongoing within the current building. As a result, Sellafield will have improved confidence in lifetime predictions for the store. This could potentially save millions of pounds and drive future planning decisions for VPS2.

The ability to accurately determine the salt concentrations deposited on other hard to reach structures in hazardous environments could have additional benefits across the wider UK Nuclear Decommissioning Authority estate and internationally. This challenge therefore represents a global opportunity across the nuclear industry and in many other industrial sectors.

Constraints

Several constraints need to be considered when developing potential solutions, including:

Environment

- Temperature gradient ranges from 10°C to 25°C
- Humidity < 35%
- The lower plenum is in darkness (no natural light or artificial lighting)
- This is a highly active environment; the solution should be able to tolerate dose rates up to a maximum of 250Gy/hr and should be able to withstand a total cumulative dose of at least 375 Gy
- The floor of the lower plenum appears to be dusty but does not contain other debris forms
- Any device placed inside the lower plenum should not include cooling fans and should otherwise minimise the potential for loose activity to be drawn into the device

Reliability:

- Solutions must be capable of operating in the environment for at least 2hrs
- Must be maintainable at the work face
- Minimal maintenance regimes are required
- Integration of proven technology may be beneficial

Access:

- Potential solutions will need to include a lifting or deployment system. From previous camera deployments, Sellafield (via its partners) may be able to offer a deployment system
- Solutions should minimise the potential for direct dose upon retrieval by being designed to minimise potential pick-up of activity/ contamination (the engineered structure of the VPS building should already protect the operator from the cell shine paths)
- The cooling air ducts must not be damaged by any solutions deployed through them
- All equipment should be within manual handling limits. This will involve carrying the equipment 12.25m from the operational level via 6 sets of half flight stairs
- Components can be assembled near the air ducts before deployment, if required

Retrieval:

- To prevent damage to plant in the event of catastrophic failure of equipment (i.e. the equipment becomes stuck in the vault), the materials used in the solution should not contain halides
- The solution shall provide means of manual recovery if a powered deployment system fails

Functional Requirements

The solution must be deployable and retrievable through the existing air duct structures without any modification to the structures.

The vertical air duct with an inlet at the 28.75m floor level has a series of bends to provide shielding from radiation emanating from the store below, whilst maintaining cooling flow. The air inlet access is 1000mm wide by 535mm high. This is depicted in Figures 2, 3 and 4. Once through the duct inlet area, the duct bend turns 90 degrees to point downwards. The duct has an inner radius of 500mm and an outer radius of 1500mm at this point (Figure 3). The duct continues vertically for approximately 12m before reaching a swan neck (or S bend), with a 1000mm inner and 2000mm outer radius (Figure 4). Once through the swan neck and having moved in a vertical direction past the bottom of the air duct, the equipment will be within the vault and experiencing the highest radiation field.

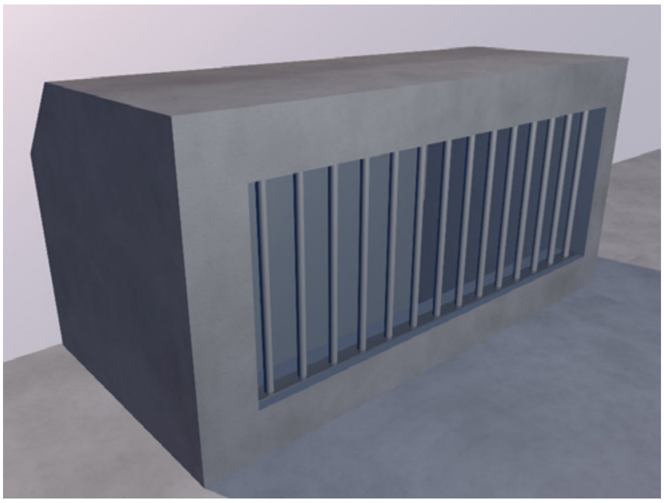


Figure 2: Typical inlet duct (note mesh has been removed)

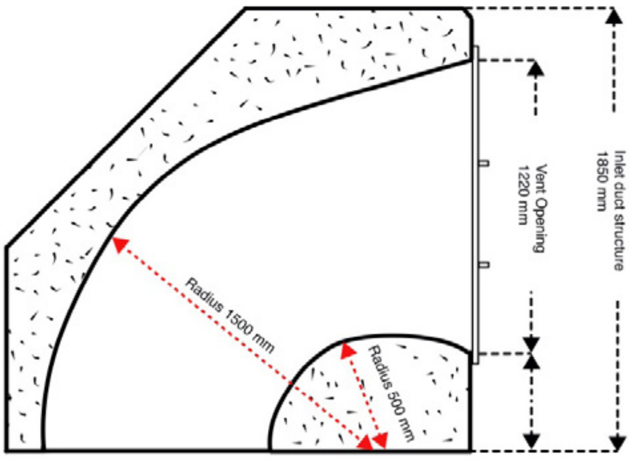


Figure 3: Duct inlet 28.75m level

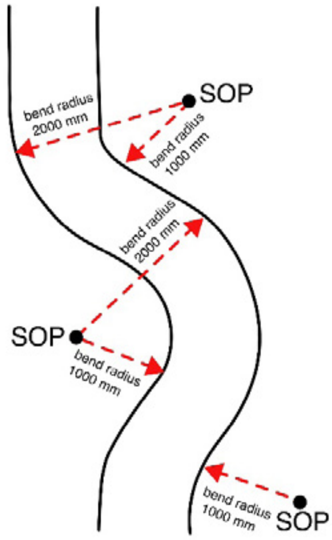


Figure 4: S-bend in duct.
SOP = Setting Out Point

Other functional requirements include:

- An ability to measure the concentration of salt on coated and uncoated steel structures. Steel structures in the lower vaults are coated with a 200µm aluminium oxide coating
- Measurements must be taken at multiple locations per vault
- The minimum area analysed per vault will be dependent on the technique proposed
- Capable of transmitting the salt concentration data or collecting and transporting physical samples which can be analysed by operators

- Capable of differentiating between a variety of salt compounds [desirable]
- Data format should be compatible with standard ‘office’ equipment e.g. videos in MP4 format, position/instrument data in CSV format
- A need to have real-time, live viewing functionality. This will necessitate taking into account the levels of radiation in the VPS
- A modular system to enable replacement of consumable items and improved on-board equipment. Modular items must be maintainable and replaceable via hands on maintenance by members of the inspection team
- Minimisation of contamination potential during operation
- Capable of decontamination i.e. the solution should make use of smooth surfaces and sealed units with no openings (although the environment is regarded as a low contamination environment)
- Illumination will need to be included in the proposed design. Guidance will be provided in relation to illumination for projects which are successfully awarded feasibility funding
- Capable of transmitting location data when deployed in the lower plenum, within a tolerance of ±0.25m [desirable]
- An operator interface within 10m of the air duct introduction location is required, comprising the necessary control, monitoring and recoding management
- Ability to be scaled for alternative use-cases [desirable]

The device does not need to measure humidity or temperature (unless another aspect of the proposed solution relies on humidity or temperature measurements). UKCA marking will be required for any commercially deployed solutions but is not necessary for a prototype active deployment demonstrator.

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 **12:00 noon on Friday 25th November 2022**.

Sellafield Ltd

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