Sellafield Ltd

GAMECHANGERS
DELIVERING NUCLEAR INNOVATION

# CHALLENGE: Analytical Services: Measurement of evolved gases from radioactive samples

Sellafield Ltd would like to explore new technologies or techniques for the measurement of impurities from solid or mixed matrix radioactive samples to improve upon current practices.

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## Introduction

As the UK's largest nuclear site, Sellafield has played a central role in the history of the nuclear industry in the UK. Operations at Sellafield initially involved supporting national defence. This was followed by energy production and spent fuel management through to the present-day challenges of nuclear waste management and the development of safe treatment and storage options. Today, Sellafield Ltd is using its unrivalled nuclear expertise to create a clean and safe environment for a sustainable future. Throughout all operational phases, Sellafield Ltd's Analytical Services teams have provided essential support to safe operations, waste processing, and hazard/risk reduction activities.

Analytical Services operate in a 70-year-old facility using many analytical protocols, some of which were developed 30 to 40 years ago. The facility houses 90 separate laboratories analysing approximately 100,000 samples annually. These samples range from effluents to plutonium products, and complex wastes. The analysis involves the use of a range of specialised equipment, and may be undertaken on benches, in fume hoods, in glove boxes, or in active cells. Most of the current protocols are designed for homogenous samples of known matrix. However, future samples may be heterogeneous and of uncertain matrix.

Operations in these laboratories are currently being phased out and much of the future work will be performed in the National Nuclear Laboratory Central Lab (NNLCL), a facility that is being substantially re-fitted to meet this demand. The move to the NNLCL creates a great opportunity for new and innovative technologies and techniques to be introduced into the analytical work to improve the efficiency, safety and quality of the analysis.

It is vital Analytical Services assess, understand and support the development of new technologies to ensure the potential benefits of the move to updated facilities are achieved.

A particular challenge that could benefit from innovation is the measurement of impurities from solid or mixed matrix radioactive samples. Sellafield Ltd would like to explore new technologies or techniques to improve upon current practices.

## Current Practice

The quantification of impurities in solid or mixed matrix radioactive materials is often achieved by volatilising analytes at a high temperature in a gaseous stream and measuring the evolved gases. A sample is placed into the glove box and into a furnace, where it is then heated, analysed, allowed to cool and removed.

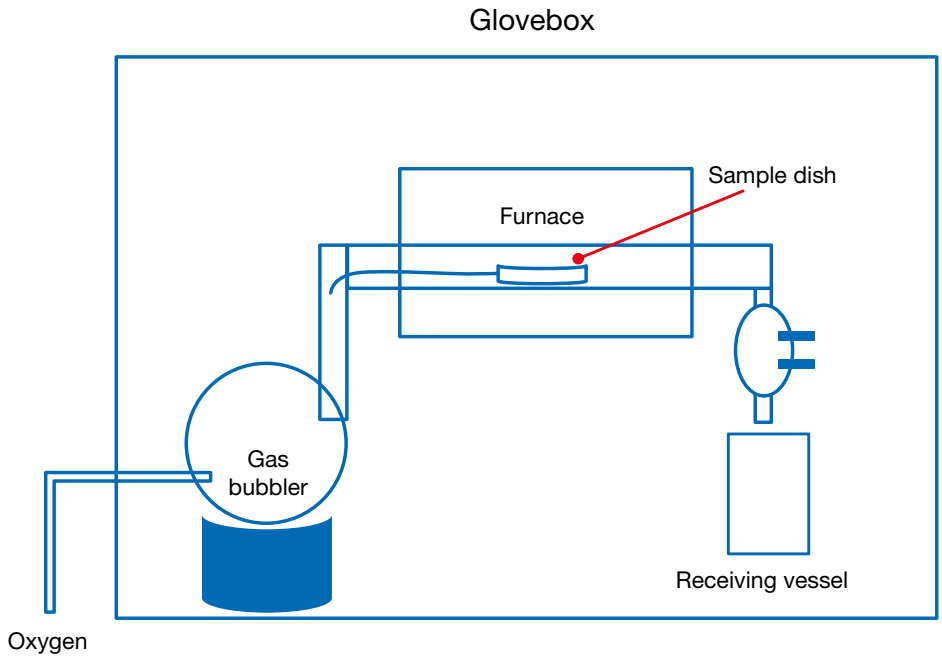


*Figure 1 – Current arrangement for the pyrolysis-based technique within containment.*

Samples analysed for impurities in this way include plutonium and uranium oxides. Sellafield typically carry out this process within a glove box in strict containment, but the measurement equipment may be outside the box, e.g. in a fume hood. Evolved species requiring measurement using this approach include water, chlorine and other halides, carbon (as either CO and $CO_2$), tritium, and carbon-14. Other impurities could be present within the samples.

Gases collected by this process are captured by the current flue stack system. Charcoal samples are sometimes taken from within the stack to monitor release through the stack. Moisture content may be measured using silica gel pre- and post-heating – an increase in mass of the silica gel suggests an uptake of moisture emanating from the sample.

## Challenge Aims

Sellafield Ltd wishes to adopt more accurate, efficient and effective techniques and technologies to identify impurities in the samples. Typical samples, often in powder form, include plutonium and uranium oxide, with small quantities of impurities-less than 400µg per gram. The evolved species to be measured and quantified where they exist in the sample include water, chlorine and other halides, carbon (as CO and $CO_2$), tritium, carbon-14 and other species most likely to be in solid form. Any solution must be robust and maintainable and should avoid techniques that create radioactive waste. Ideally solutions should be able to measure more than one sample in a run. The measurement technology may be deployed directly or could be placed outside containment.

## Benefits to Sellafield

It is expected that a new robust and maintainable method of measuring impurities from evolved gases will improve efficiency for Analytical Services, whilst also reducing any potential risks to the operator analysing the samples. The solution may also have other potential applications in areas across the site. Techniques and technologies that could be retrofitted to existing glove boxes may bring advantages to Sellafield Ltd, considering the high number of existing glove boxes.

Alternatively, creating the new labs, a significant investment, provides an opportunity to develop cutting-edge techniques to improve operational efficiency, safety and accuracy. Approximately 1/3 of the new labs will have a role to play in such sample analysis and 50% of the techniques would involve a furnace leading to this area of analytical services to benefit from significant investment.

## Constraints

- The solution should not involve techniques that create radioactive waste – the sample should be preserved as much as possible
- Radiation hardness of proposed solutions should be considered
- Proposed solutions should ideally not involve the use of oxygen as a carrier/reactant gas
- Species analysed are volatile
- Whilst the glove boxes may limit access and be a physically constraining environment, it may be possible to take gas stream outside of the glove box
- Might be limited in the use of exotic gases in the lab areas
- Solution must be resistant to a high-temperature environment – sample currently heated close to 1000°C

## Functional Requirements

- The solution should be maintainable and robust
- Equipment can be sacrificial (i.e. single use) but radioactive waste generation should be minimised
- Techniques must be capable of detecting ppm levels with respect to the sample
- The technology may be deployed directly in a glove box or could be placed outside containment dependent on the function
- Species can either be measured directly or captured for later measurement. The gas is currently measured as it comes off the sample and captured in a container (e.g. through a bubbler)

- Sample excitation currently uses heat – other methods to excite the material to release gases for analysis would be considered, e.g. electrical, chemical etc.
- Sensor technology of interest – may need to compound data over half an hour
- Resolution of detection (impurities may be in the region of 400mg per gram of sample)
- Techniques that can measure more than one sample within a process run and therefore provide some efficiency of scale may be of interest

## 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 Tuesday 24th October 2023.**

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