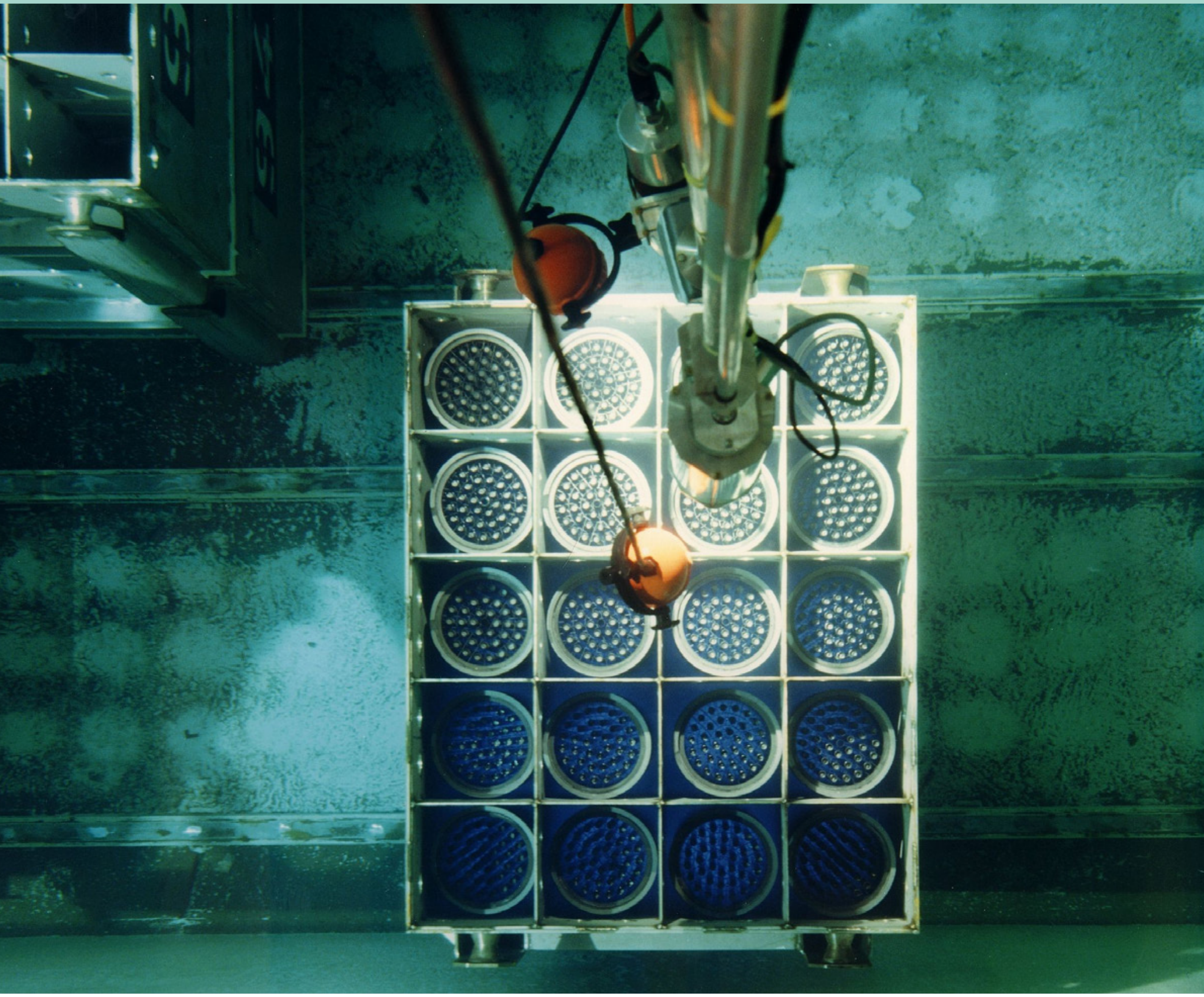
NATIONAL NUCLEAR LABORATORY

GAME CHANGERS .technology



CHALLENGE: Fuel pin remote sampling tool

NNL are seeking an innovative sampling tool to collect carbonaceous deposits from the cladding of Advanced Gas-cooled Reactor (AGR) fuel pins which are situated in cooling ponds.

The sampling tool may work in conjunction with endoscopic equipment currently used by NNL for visual inspections of the fuel pins, or it may be a standalone device.

Solutions to this challenge must be deployable within 12 – 24 months.

FIS360 innovation to revenue

Introduction

Carbonaceous deposit on Advanced Gas-cooled Reactor (AGR) fuel pins affects the efficient operation of fuel in nuclear reactors. Post Irradiation Evaluation (PIE) is performed to provide assurance that fuel condition remains within the expectations for reactor operation.

For AGR fuel, a key function of PIE is to monitor the growth of carbonaceous deposit that forms on fuel pin surfaces during operation. Fuel pins consist of uranium dioxide pellets clad in stainless steel. The carbonaceous deposit affects transfer of heat from the fuel to the coolant, which in turn affects fuel temperature. Knowledge of both the deposit thickness and its structure allows an assessment of the impact of deposit on fuel temperature.

NNL has vast knowledge and an array of techniques it relies upon to assess carbonaceous deposit. The initial technique for fuel PIE is underwater visual inspection of spent fuel in cooling ponds at AGR power stations. These inspections provide a broad assessment of a large throughput of recently discharged fuel from a wide range of positions in the reactor. After in-pond assessment, there is a down selection of fuel elements for endoscope validation and general condition monitoring. Additional in-depth analysis of the selected elements is conducted at NNL's Active Handling Facility (AHF).

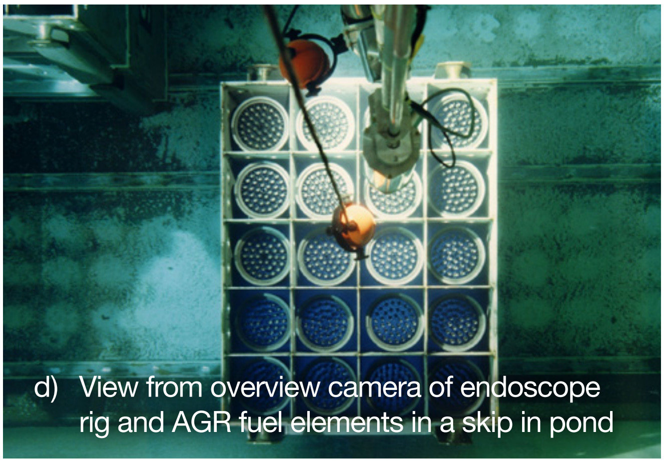
Additional analysis at the AHF gives a far more accurate assessment of carbon deposit. One of the most precise techniques used for this is Scanning Electron Microscopy (SEM), which involves studying flakes of carbon deposit under a microscope. However, the drawback with this process is that it is typically at least one to two years after the fuel has been discharged from the reactor before samples are received at the AHF for SEM analysis. Therefore, the challenge is to reduce the time it takes to get accurate measurements of carbon deposit, by sampling deposit flakes during in-pond inspections. This will not only reduce the time taken to obtain flake samples suitable for SEM, but also allow for a larger range of samples to be taken.

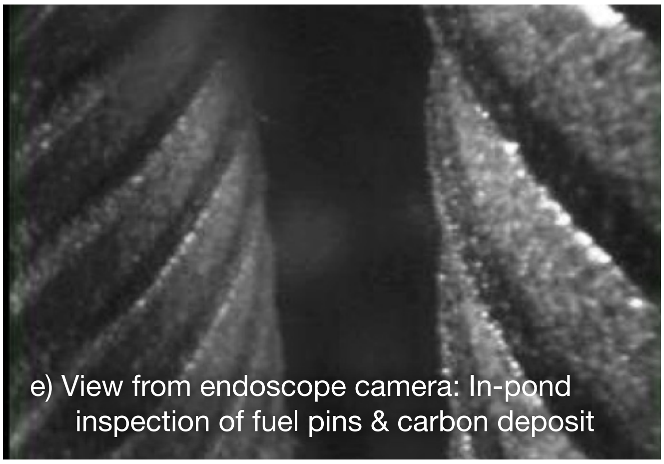
There are approximately 10 regular in-pond inspection surveys per year, therefore NNL are seeking equipment which is robust and easy to operate to allow the retrieval of samples on a regular basis. It is hoped that the introduction of new sampling equipment will facilitate the in-depth analysis of a higher number of fuel elements. Any techniques developed to address this challenge may also have applicability in sampling crud and other surface deposits from fuel discharged from Light Water Reactors (LWR), which are the more widely used commercial reactor type worldwide.

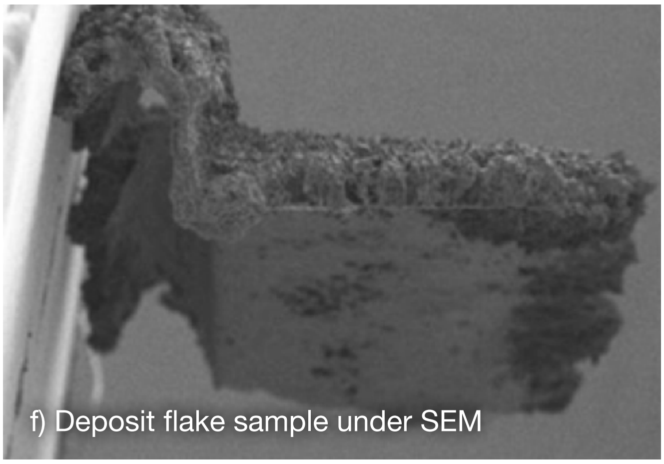

a) Hartlepool AGR Power Station

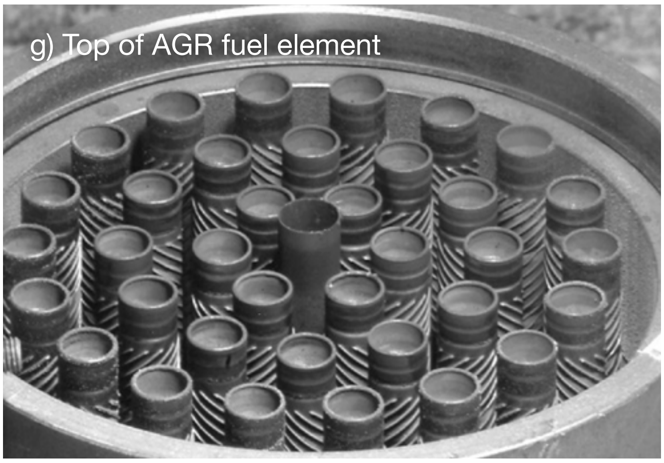

b) Dungeness B AGR power Station

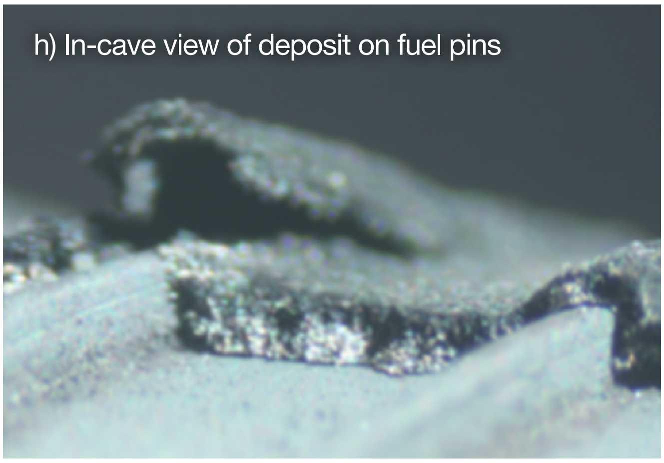

c) Typical setup of endoscopy team operating equipment in a cooling pond.


d) View from overview camera of endoscope rig and AGR fuel elements in a skip in pond


e) View from endoscope camera: In-pond inspection of fuel pins & carbon deposit


f) Deposit flake sample under SEM


g) Top of AGR fuel element


h) In-cave view of deposit on fuel pins

Current Practice

NNL's specialist endoscopy team uses radiation hardened underwater video rigs to perform visual inspections of in-pond fuel for seven AGRs across the UK. The rigs are inserted into AGR fuel elements to assess carbonaceous deposit. Visual inspection is a limited technique as it is an estimation rather than a measurement of deposit thickness. However, the benefit of endoscopy is the ability to view a wide range of fuel from across the reactor in a short time frame after discharge.

There are approximately 10 regular in-pond inspection surveys per year across the AGR fleet, with two-week time windows to operate and inspect a minimum of several tens of fuel elements.

More detailed PIE analysis of carbonaceous deposits at the AHF results in a lower throughput and obtaining deposit flakes requires a full dismantle of a fuel element. Compared to the breadth of fuel examined by endoscope, a relatively small number of deposit flakes are retrieved per year. The AHF technique to obtain flake samples involves scraping adhered deposit away from the pin surface using remote manipulators. However, the manipulators are far too large to be applied to intact fuel elements in-pond.

Previously in the 1990s a brush and suction device to collect flake samples was trialed in-pond at Torness Nuclear Power Station. This technique was successful at retrieving loose deposit samples. However, identifying the location of samples was only accurate to within three pins, retrieval was fairly time consuming and the device was unable to sample well-adhered deposits.

Challenge Aims

NNL are seeking a game changing solution to sample deposits in-pond. A modified sample collection process brings significant advantage in terms of the time reduction to get accurate measurements of carbonaceous deposit and also introduces the potential to analyse in detail a larger number of fuel pins.

Sampling deposits in-pond is an immediate challenge and the solution needs to be at a sufficiently high TRL such that it can be deployed within the next 12-24 months. An adapted off the shelf solution may offer the quickest route, but fast-tracked development of a lower TRL solution could also achieve this.

There is also an opportunity for a collaborative partnership to develop future in-pond PIE techniques. As well as sampling from AGR fuel elements there is interest in sampling crud from LWR type fuel in the future.

Benefits to NNL

Sampling deposit flakes in-pond offers huge benefits in time reduction in obtaining samples and generating crucial data which is of greater accuracy and collected from a greater range of fuel locations.

The opportunity to provide a solution for game changing in-pond PIE techniques is critical for the continued safe operation of the UK's AGR fleet of reactors. Over the next decade, in-pond PIE techniques will become increasingly important and NNL are keen to collaborate to develop new techniques that offer time and cost saving efficiencies. Beyond AGRs there is interest in PIE in-pond techniques for other reactor types such as LWR.

Constraints

Power station cooling ponds and their surrounding work environment are by design Radiation/Contamination controlled areas as they handle spent fuel discharged from the reactor. Solution providers will be given support by NNL if necessary, to ensure that their equipment is suitable to be used in this environment.

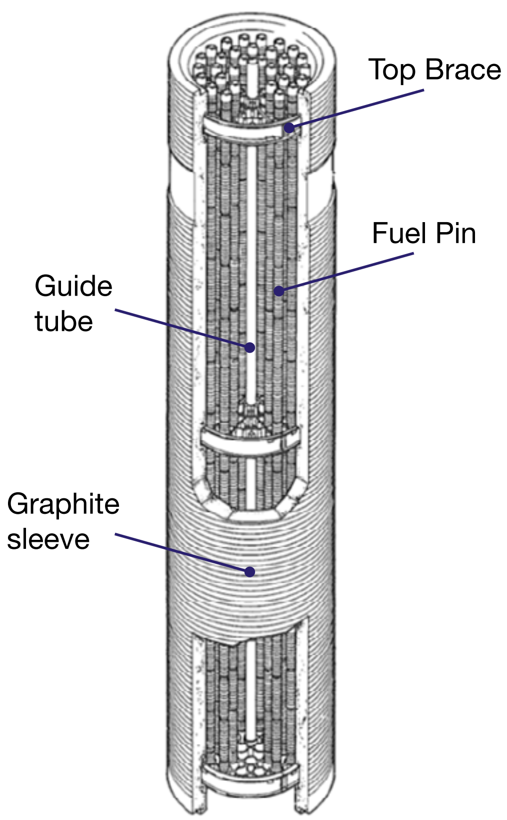
Image I shows a schematic of an AGR fuel element: 36 fuel pins (uranium dioxide pellets clad in stainless steel), held in place by metal braces and encased in a graphite sleeve.

Further constraints are as follows.

The sampling equipment must:

- Be submersible up to 10 meters in boronated water
- Present no risk to pond infrastructure; it is particularly important that no damage is caused to fuel pins or their cladding
- Be highly radiation tolerant
- Operate with a pond temperature range of 15 – 50 °C

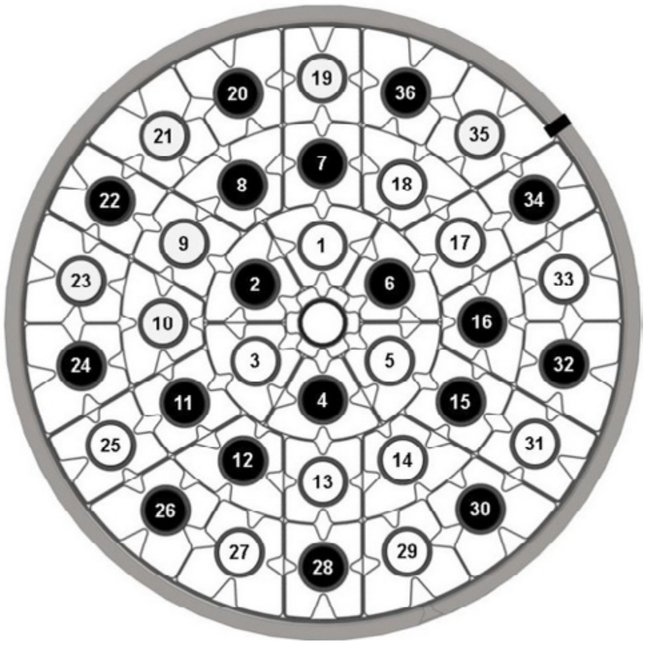
- Fit through the top brace of an AGR fuel element with an operating envelope between fuel pins of <10mm gap
- Be practical to be deployed in-pond by operators above the surface
- Weigh no more than around 125 kg in order to comply with existing lifting equipment above the pond.
- Be robust enough to retrieve 10's of samples in the standard two-week survey window
- Be able to locate and retrieve a sample in less than 30 minutes. Flake sample dimensions are up to 3mm x 4mm and 0.5mm thick
- Be retrievable in the event of equipment failure



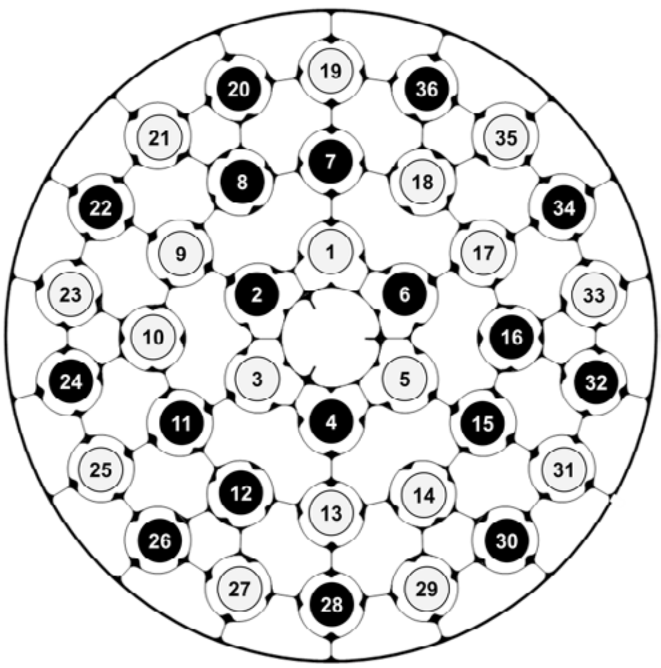
I) Fuel element schematic

Any sampling equipment may need to work in conjunction with current endoscopy equipment in order to provide a visual guide for operators. The endoscope insertion points are provided below, to give a rough guide.

Fuel Element Diagrams J & K show types of brace holding fuel pins in position. Note the machined brace (newer type) offers larger gaps for insertion. It may be acceptable if any solution were to only retrieve from machined brace fuel given the time frame and current phase out of fabricated brace fuel.



J) Fabricated brace diagram (old type)



K) Machined brace diagram (new type)

Functional Requirements

The key functional requirements of any in-pond sampling solution are to:

1. Collect carbonaceous deposit samples suitable for SEM
2. Be easy to use, time efficient, and collect deposit in such a way as to not be a contamination problem for the operator (i.e. the deposit can be placed into a sealed container with no direct handling by the operator)
3. Introduce no damage to pins/elements, other than very minor scrape marks
4. Allow identification of sample location to within a length of circa 10cm and a rotational position of +/- 90 degrees
5. Allow sampling of deposit that is attached to the fuel pin, not just deposit that is significantly lifted (visibly above the pin surface, as seen in fig 1h)
6. Be at sufficient TRL to deploy within the next 12-24 months

What Next?

Game Changers are hosting an online briefing webinar for this challenge. Details of the webinar will be 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 www.gamechangers.technology/ourprocess.