Development of an Integrated Optical Microscopy Facility for the Examination of Irradiated fuel and other materials at Windscale

M S Stucke and N Penny

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by

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Summary

This paper describes the development of a new metallographic facility in the Post Irradiation Examination Facilities at Windscale for the examination of irradiated fuel and components. It has been constructed within the main PIE facilities providing full integration of the main activities including fuel receipt, non-destructive and destructive examination and active waste handling and disposal.

The paper describes the facility and provides details of the development of new low cost optical microscopes and macrosopes for the examination of the metallographic samples.

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AEA Technology
Windscale
Sellafield
Seascale
Cumbria
CA20 1PF
United Kingdom

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1.0 Introduction

Two years ago a review was carried out by AEA Technology of its Post Irradiation Examination (PIE) facilities at Windscale. These facilities were concentrated in two main buildings. Building 13 was primarily concerned with non-destructive examination and testing of irradiated fuel and components and consists of 13 heavily shielded concrete caves. The majority of destructive testing was undertaken in Building 14 in four lines of lead shielded cells and numerous other lead and steel cells for mechanical testing and other operations.

In the preceding year the management, safety and operation of both plants had been extensively reviewed as part of the licensing of AEA Technology's nuclear facilities by the UK Regulatory Authority, the Nuclear Installation's Inspectorate. This review highlighted several significant shortcomings in the lead cell lines in Building 14, illustrated in Figure 1, which although did not jeopardise short term operation, certainly did preclude long term operation (more than five years) without major modifications. These modifications would have been very expensive, required a long shut-down of the facilities (two to three years) and led to significant dose uptake by the workforce.

The two sets of facilities in Buildings 13 and 14 meant that there was a large number of transfers of materials between the buildings in shielded flasks. These movements were labour intensive and also led to significant dose uptake by the workforce. In addition the multiplicity of cell lines and individual cells within Building 14 also led to large numbers of transfers of radioactive materials in flasks within Building 14 itself. These factors, together with the requirements for modification of the cells led to the conclusion that the metallographic facilities in Building 14 were no longer viable and that alternatives were required.

Various options were considered but finally it was decided to utilise two of the concrete shielded caves in Building 13. There were several reasons for this decision, primarily:

- The cost of modification was lower than other options considered.
- The dose uptake during modification was minimal, one cave was 'clean' (it had never been used for active work) and the other was easily decontaminated.
- The caves are located within the main Building 13 PIE facilities and connected to the internal active material transfer system eliminating the need for flasking.

The transfer of the main metallographic facilities into Building 13 has led to the complete integration of the main PIE functions at Windscale into a single
building. These facilities are illustrated in Figure 2 and these include:

- Fuel receipt and flask handling.
- Fuel and component cutting.
- Optical metallography.
- Scanning electron microscopy.
- Waste handling and processing.
- Fuel despatch.

A limited amount of work is carried in other facilities located close to Building 13; principally mechanical testing, electron microscopy and specialised fuel property measurements [eg density, thermal diffusivity and specific heat].

The concrete shielded caves in Building 13, with 1.4 m thick walls, precluded the use of existing remote optical microscopes and a new approach to the design and construction of the instruments had to be taken. Details of these developments are given later in the paper following an overview of the new metallographic facility.

### 2.0 Metallographic Specimen Preparation Cave

The new metallographic facility has been constructed in two adjacent caves in Building 13 and is illustrated in Figure 3. The metallographic specimen preparation facility consists of a cave with five working stations, each with a zinc bromide viewing window and a pair of Master Slave Manipulators [MSMs]. The operating face and consoles are shown in Figure 4.

The consoles have the controls for the in-cave cutting, grinding and polishing machines. These machines are the same as those used in the lead cell lines in Building 14 for many years. New jigs have had to be constructed to facilitate the mounting of samples in resin and the electropolishing of samples.

In the old facilities liquids arising from the metallographic specimen preparation process were discharged into the Site active drain system. This is not now possible and techniques had to be developed to eliminate liquid discharges completely. Liquids are introduced into the cave in small measured quantities [for criticality control purposes] via tundishes on the cave face [see Figure 4]. The liquids are evaporated after use, in the cave, in small stainless steel vessels, which also act as disposal containers for the solid residues.

The cave is currently equipped to prepare about 100-150 samples per year, although its ultimate capacity is much greater than this with adequate space to duplicate the preparation processes. It can accept uranium metal and oxide fuel samples, the full range of cladding materials [Magnox, stainless steel,
zircaloy] and other samples from irradiated components [mainly stainless steel and nimonic alloys].

Small samples of irradiated cladding are also required for examination in the scanning electron microscopes. These are prepared in the cave by fine cutting from the bulk material. Removal of these samples from the cave will utilise a shielded glove box and gamma interlocked posting system to be located on the roof of the cave. This will permit samples to be removed from the cave, transferred into clean containers and placed within small hand flasks for transfer to the SEM facility.

The prepared metallographic samples are transferred to the adjacent examination cell via an air operated transfer system. The samples are loaded into a small capsule which is placed in the shielded transfer tube. The capsule is pushed along the tube by compressed air. The shielded doors at each end of the transfer tube are interlocked so that only one can be opened at any time, providing full shielding between the preparation cave and examination cell at all times.

3.0 Metallographic Examination Cell

The metallographic examination cell is located in the adjacent cave and contains two remotely operated microscopes and a low magnification macroscope providing magnifications from about x5 up to x2000.

The cell utilises two of the five operating stations of the cave. The cell is separated from the rest of the cave by a steel shield wall fitted with a door for access to the cell to allow maintenance of the optical instruments. The two operating stations have zinc bromide viewing windows and each has a pair of Master Slave Manipulators. The cell is illustrated in Figure 3 and the operating face is shown in Figure 5.

3.1 MICROSCOPE DEVELOPMENT

It has been mentioned earlier that the remotely operated microscopes used in the lead cells in Building 14 were not suitable for use in the new facility. The conventional remote microscopes used in hot cells are highly specialised instruments and extremely expensive. A decision was taken to replace these with cheaper commercially available instruments modified for remote operation. The basis for this development is the Leitz 'Ergolux' microscope, which is a medium priced bench microscope widely used in the semiconductor industry and designed to be used in 'clean rooms' either semi or fully remotely. The microscope is fitted with a good X, Y stage and a selection of viewing adaptors. The stage is fully motorised with about 150 mm of movement in both directions. Movement is controlled by stepper motors which allow positional accuracy of 0.5 micron. The stage can therefore be used for direct measurement.
The microscopes were modified for in-cave use in several areas:

- The lens change mechanism: the microscope is fitted with a motor driven lens turret which can be fitted with up to five objective lenses. This turret was controlled by an optical encoder which was highly susceptible to radiation damage; it was replaced by microswitches.

- The focus controls: the manual coarse and fine focus controls were fitted with motor drives and position feedback potentiometers for each.

- Lamp housing: this was modified to allow remote replacement of the bulb using Master Slave Manipulators.

- Rotary superstage: sample rotation on the microscope is a requirement and this was accomplished by fitting a rotary 'superstage' to sit on top of the X, Y stage. The stage is driven by a stepping motor similar to that of the X, Y stage to allow it to be controlled by an X, Y, Z controller.

- Motorised polariser: for some applications, polarised light is used and a means of remotely rotating one of the polarising filters was required. A miniature geared motor driving the polarising filter is fitted into the housing, which replaces a standard filter housing in the microscope light path.

- Zoom lens: Leitz provide a zoom lens for this microscope and this was modified to allow a motor drive to be fitted.

- Remote control unit: all controls for the various electrical drives to the instrument were built into a remote control unit to be used by the operator on the cell face. This control unit includes automatic control of the stage height during lens changing operations to prevent lens damage.

- Remote image viewing: two systems have been developed for image viewing. One microscope is equipped with a closed circuit television [CCTV] directly located above the zoom lens and this relays the image to a TV monitor on the cell face. The CCTV is a high quality, high resolution camera. This gives very adequate images for viewing but as yet it has not been able to record images and obtain hard copies of adequate quality. The second microscope has been fitted with a through-wall optic transfer tube which allows the optical image to be transmitted through the cave wall to a console on the cave face [as shown in Figure 5]. This console allows direct viewing of the image via a microscope eyepiece, CCTV and photographic recording on 35 mm film or 125 x 100 mm polaroid film.

The optical systems within the microscope have not been modified, quite deliberately, to retain the very high quality optical performance of the as
purchased microscope. Components in the optic path, including objective lenses are not therefore radiation stabilised and will deteriorate with use. They are, however, all easily replaced and relatively inexpensive. Dose rates to the sensitive optical components have been minimised to prolong their life by:

- Only allowing one specimen to be exposed in the cell at a time [a shielded storage block is provided].
- Minimising specimen time on the microscope stage.
- Using long working distance objective lenses.

Local shielding can be fitted to protect the CCTV camera and other optical components, but this does introduce operability problems, so far it has not been found to be necessary.

Initial experience with the microscopes is that they are very easy to use, reliable and produce very good image quality. The microscopes are shown in Figure 6 together with the optic transfer tube and CCTV camera. Figure 8 shows typical micrographs and illustrates the high quality of images produced by the microscopes.

3.2 MACROSCOPE DEVELOPMENT

The examination cell is also equipped with a low magnification macroscope, also developed by AEA Technology at Windscale. This is shown in Figure 7 and consists of a simple sample stage and light source in-cave. The image is transferred to the cave face via an optic transfer tube. The cave face console is equipped with a zoom lens to vary magnification between x5 to x20. The image is viewed normally by a CCTV camera and monitor or directly with a monocular eyepiece. Examples of the images produced by the macroscope are shown in Figure 8.

3.3 FUTURE DEVELOPMENTS

The use of very high resolution CCTV cameras and digital image recording systems is being investigated with the aim of eliminating photographic recording and reproduction of images. TV cameras are now available with resolution better than 3000 x 2000 pixels. Computer storage of images at these high resolutions is now possible using the latest personal computer technology and high resolution laser printers can now produce hard copies of images of photographic quality. These systems provide very powerful archiving capabilities and the use of high resolution computer graphics techniques can improve the quality of images and their presentation.
Figure 1. Lead cell line in building 14.
Figure 3. New metallographic facility in building 13.

1. Preparation cave.
2. Examination Cell.
3. Shield wall and access door.
4. Operating station.
5. Microscope/macroscope control desk.
7. Microscope maintenance area.
8. Padirac flask port shutter.
9. Cave/cell ventilation extract system.
Figure 4a. Metallographic preparation facility operating face

Figure 4b. Polishing and grinding machines.
Figure 6. Microscopes in examination cell.
Figure 7. Macroscopic in examination cell.
Macros of dummy AGR fuel.

Micro of magnox cladding.

Figure 8. Typical photographs from macroscope and microscopes.
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