Radial Gamma Scanning System for Irradiated Fuel Pin Sections

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1. Introduction

Gamma scanning is a vital PIE tool for characterizing irradiated fuels. The knowledge of the fission product distribution and their migration behaviour along the fuel column length and across the fuel pin cross section is crucial in understanding in-reactor fuel behaviour. The data obtained from radial gamma scanning (RGS) can be correlated with the corresponding microstructure which enables understanding of the fission product distribution and the fuel operating temperatures. A system has been established in the hot cells of Radio Metallurgy Laboratory (RML) at IGCAR for evaluating the radial distribution of fission products on irradiated fuel pin cross-sections. The newly established facility has been used to evaluate the radial profile of gamma emitting fission products on the cut sections of PFBR MOX test fuel pins irradiated in FBTR to a burnup of 112 GWd/t [1].

2. RGS system

The hot cells at Radiometallurgy laboratory has an inbuilt provision for axial gamma scanning of fuel pins. However, it does not have a dedicated port for carrying out RGS. For establishing RGS system, one of the existing dummy service plug in the hot cell wall was identified and modified to incorporate a collimator assembly.

RGS system comprises of (a) collimator assembly established by modifying an existing blank service plug in the hot cell wall, (b) a four-axis gamma scanning bench inside the hot cell for precise positioning of a sample prepared from cut sections of the irradiated fuel pin and (c) an HPGe based gamma spectroscopy system positioned in front of the collimator assembly in the operating area of the hot cell.

Collimator assembly is made up of five stainless steel cylindrical blocks of overall length 930 mm with outer diameter of around 45 mm. Two additional concentric SS tubes are inserted into above stainless steel block to obtain a final circular aperture of around 0.4 mm. The collimator blocks are assembled inside a SS sleeve with tight clearance for their proper alignment and its easy installation. The alignment of the collimator assembly was tested by a high intensity light source and also by passing a SS wire rope from one end to the other end of the aperture.

Lead rings were assembled in the annular gap between the collimator sleeve and the modified service plug to compensate for the loss of shielding due to removal of solid dummy plug. To prevent streaming through the annular gaps between the three stainless steel collimator blocks, a shielding disc made of high density alloy was placed on the operating side of hot cell. A lead shielding block was used to prevent the gamma streaming through the annular space between modified service plug and collimator sleeve. Fig.1 shows the sketch of the collimator assembly of RGS installed in the hot cells of PIED, IGCAR.

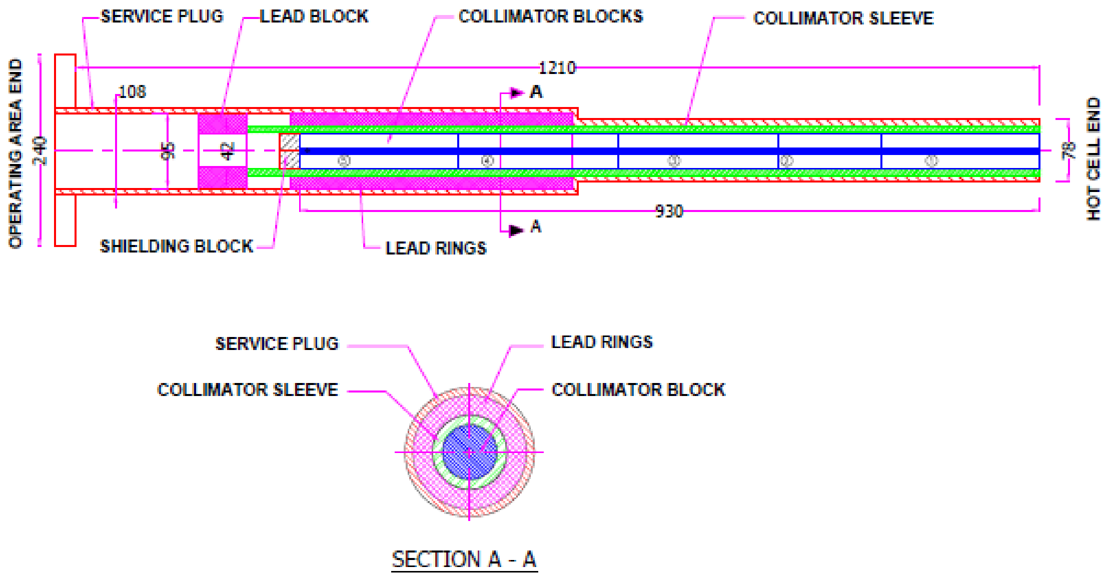

Figure 1. Sketch of collimator assembly with cross sectional view

Since the existing steel dummy service plug was modified, the dose rates in the operating area of the hot cell was computed using QAD-CGPIC [2] point kernel computer code to ensure the shielding adequacy of the new collimator assembly installed in the hot cell wall. ICRP-116 fluence to dose rate conversion factors has been used for computing the dose rates. Buildup factors have been considered in computing the dose rates at the cold side of the collimator aperture, when an irradiated fuel pin cut section is placed in front of the collimator at the hot side. The source term used for the computation corresponds to the activity of 10mm cut section of FBTR Mark I fuel pin irradiated to a peak burn up of 150 GWd/t after cooling time of 120 days.

The collimator inner tube dimensions have been optimized for allowable dose rates at the operating area and also for getting sufficient gamma counts in the HpGe detector based on the computation with respect to QAD-CGPIC code. Three different configurations were considered with different combinations of collimator apertures. Based on the optimisation, collimator aperture of 0.4 mm was chosen. The dose rates in the operating area were found to be within the acceptable limits for the selected collimator configuration.

The four axis gamma scanning bench incorporates automated PC based motion control system which is installed in the hot cell and is aligned with the collimator on the cell wall. The bench is designed in such a way that it can be accommodated in the limited space available in the hot cell in front of the collimator. It was designed modular in nature to facilitate assembling and dismantling of the individual modules remotely. The travel range of the axes was optimized for radial scanning and easy loading & unloading of the fuel cut sections from the bench. HPGe detector in the operating area enables gamma spectroscopy of the fuel pin sections. HPGe detector used for this work has a relative efficiency of 30% and energy resolution of 1.8 keV at 1332.5 keV. Fig. 2a shows the photograph of the collimator assembly installed on the hot cell wall and Fig. 2b shows the photograph of the four axis RGS bench installed in hot cell.

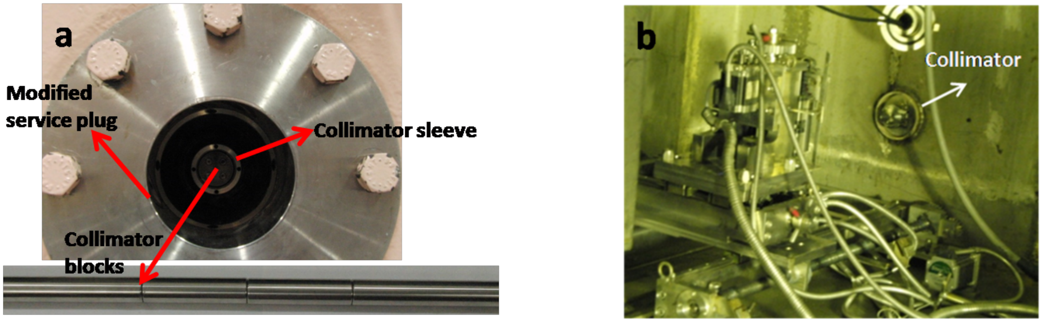

Figure 2. (a) Front view of the modified service plug with collimator assembly installed on the hot cell wall (b) Photograph of four axis gamma scanning bench installed inside the hot cell

The irradiated fuel pin sections are extracted in hot cells and were prepared for optical microscopy studies. The samples after optical microscopic examination were loaded in the sample holder of the RGS bench inside the hot cell facing the collimator for radial gamma scanning. To obtain the radial profile across the full diameter, the fuel pin cross section was precisely positioned in the RGS bench by monitoring the count rates from the fission products and clad activation products before radial gamma scanning.

3. Conclusions

Radial gamma scanning of MOX fuel pin sections have been carried out successfully using the above facility Fig. 3 shows a typical profile of 137Cs across the fuel pin diameter obtained from one of the irradiated MOX fuel sample.

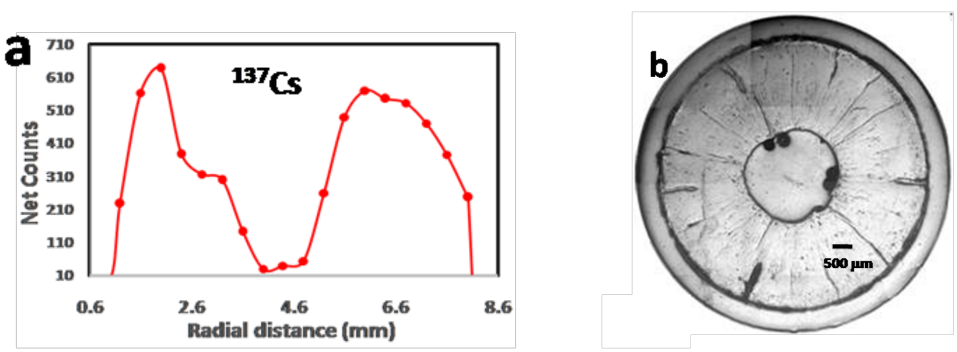

Figure 3. (a) Radial profile of ^{137}Cs across the fuel pin cross section (b) corresponding fuel micrograph

The profile clearly indicates the central hole region of the annular pellet, migration of ^{137}Cs from the hotter regions of the fuel (columnar grain growth region) to the relatively cooler fuel-clad gap. The observations from RGS could be correlated with the results of microstructural features.

References

1. Irradiation performance of PFBR MOX fuel after 112 GWd/t burn-up, C N Venkiteswaran et al, Journal of Nuclear materials 449 (2014) 31;

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