Radial gamma scanning system for irradiated fuel pin sections

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Outline

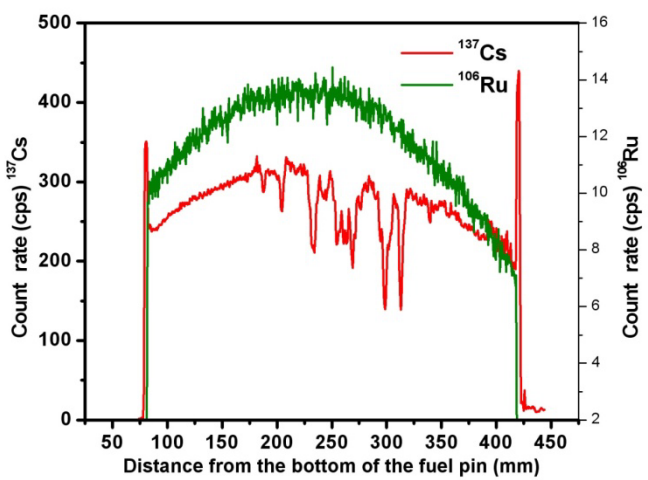
- Introduction
- Radial Gamma Scanning system- Components
- Radial Gamma Scanning
- Conclusions

INTRODUCTION

- The knowledge of axial and radial distribution of fission product and their migration behaviour is crucial in understanding the in-reactor behaviour of fuels
- Gamma Scanning is an important tool for non- destructive examination of irradiated fuel pins
- RML hot cells has an in-built provision for axial gamma scanning of fuel pins
- Axial gamma scanning has given valuable data on the axial FP distribution in mixed carbide and mixed oxide fuels irradiated in FBTR

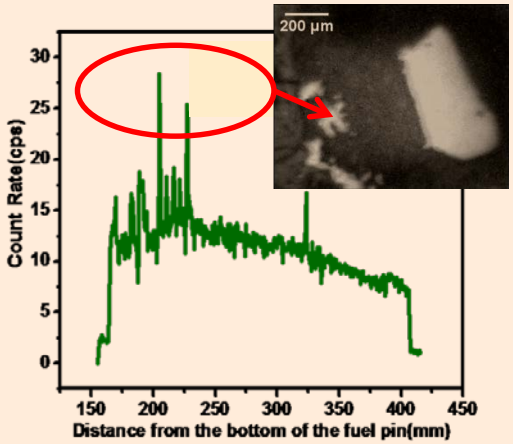
INTRODUCTION

Typical results from axial gamma scanning of irradiated fuels



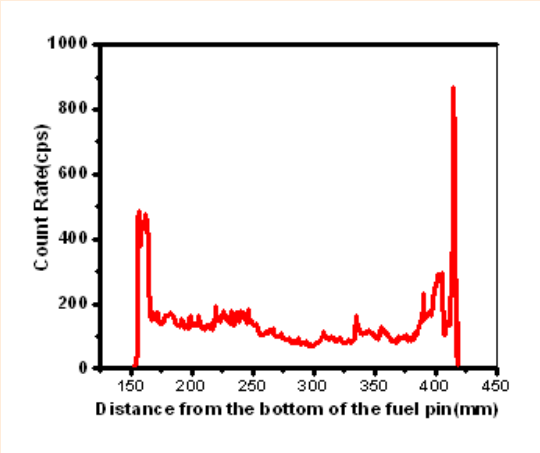
Axial profile of ^{137}Cs and ^{106}Ru in carbide fuel

Extensive migration & redistribution of Cesium isotopes



Axial profile of ^{106}Ru in MOX fuel

Localized Ru peaks corresponds to metallic precipitates



Axial profile of ^{137}Cs in MOX fuel

Segregation Cesium at fuel column ends

Radial Gamma Scanning System

- **Hot cells of RML does not have in-built provision for carrying out Radial Gamma Scanning of fuel pin sections**

- **A RGS system has been installed by modifying one of the existing dummy service plug in the hot cell wall to incorporate a collimator assembly**

- **RGS system comprises of**

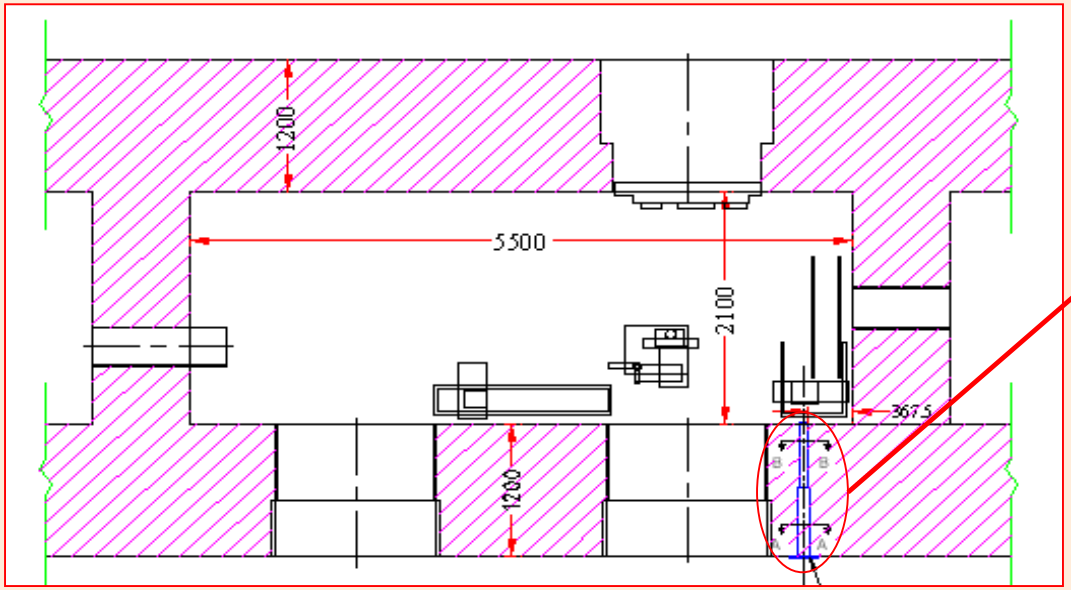
  (a) collimator assembly

  (b) A four-axis gamma scanning bench inside the hot cell for precise positioning of a sample

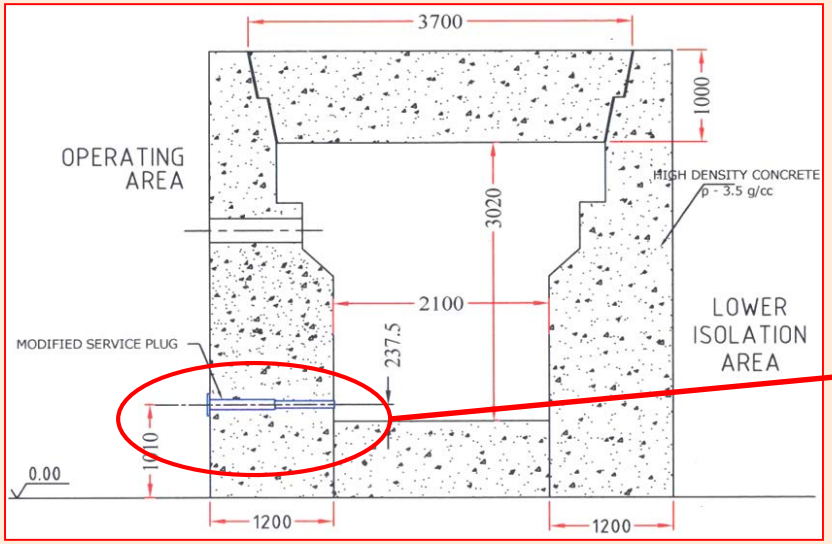
  (c) HPGe based gamma spectroscopy system positioned in front of the collimator assembly in the operating area of the hot cell.

Hot Cell View

Plan view of hot cell



Collimator Assembly



Cross sectional view of hot cell

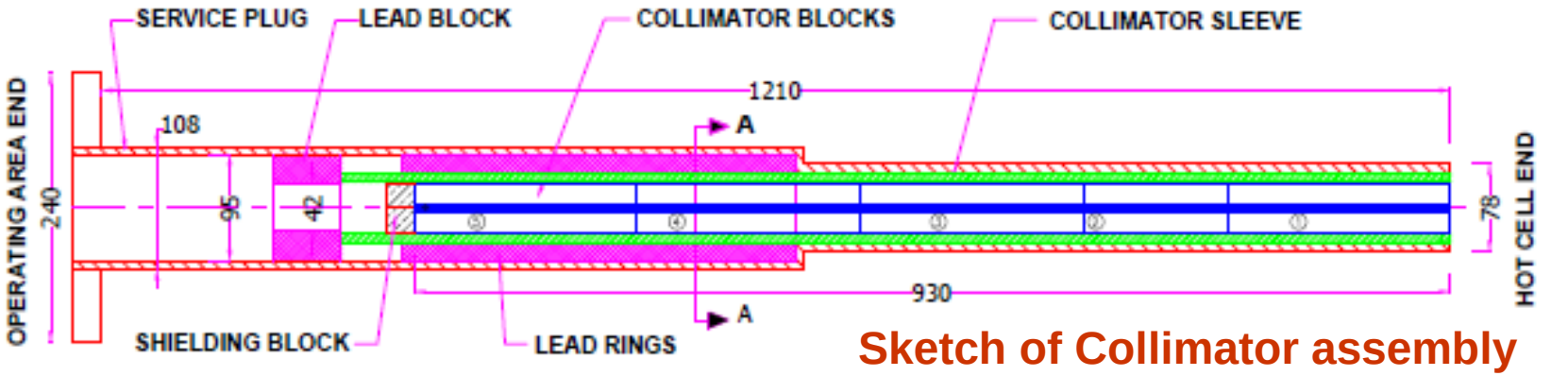
Collimator Assembly

Collimator assembly

- ✓ Made up of five SS cylindrical blocks of overall length 930 mm with outer diameter of around 45 mm
- ✓ Concentric SS tubes (2 Nos) are inserted into above stainless steel blocks to obtain a final circular aperture of around 0.4 mm
- ✓ Collimator blocks are assembled inside a SS sleeve with tight clearance for their proper alignment and its easy installation
- ✓ The alignment was tested prior to installation

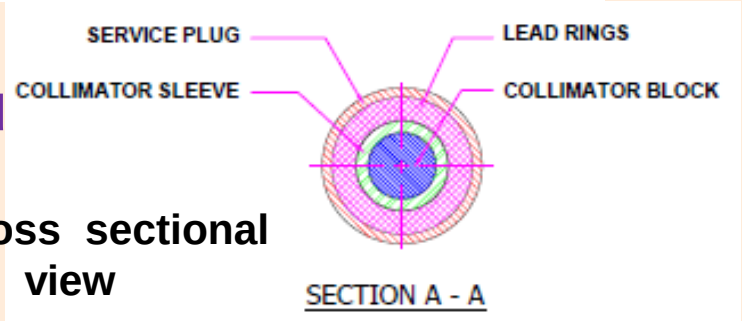
Collimator blocks

Radial Gamma Scanning System



Sketch of Collimator assembly

- ✓ SS sleeve with collimator blocks are placed inside the modified service plug



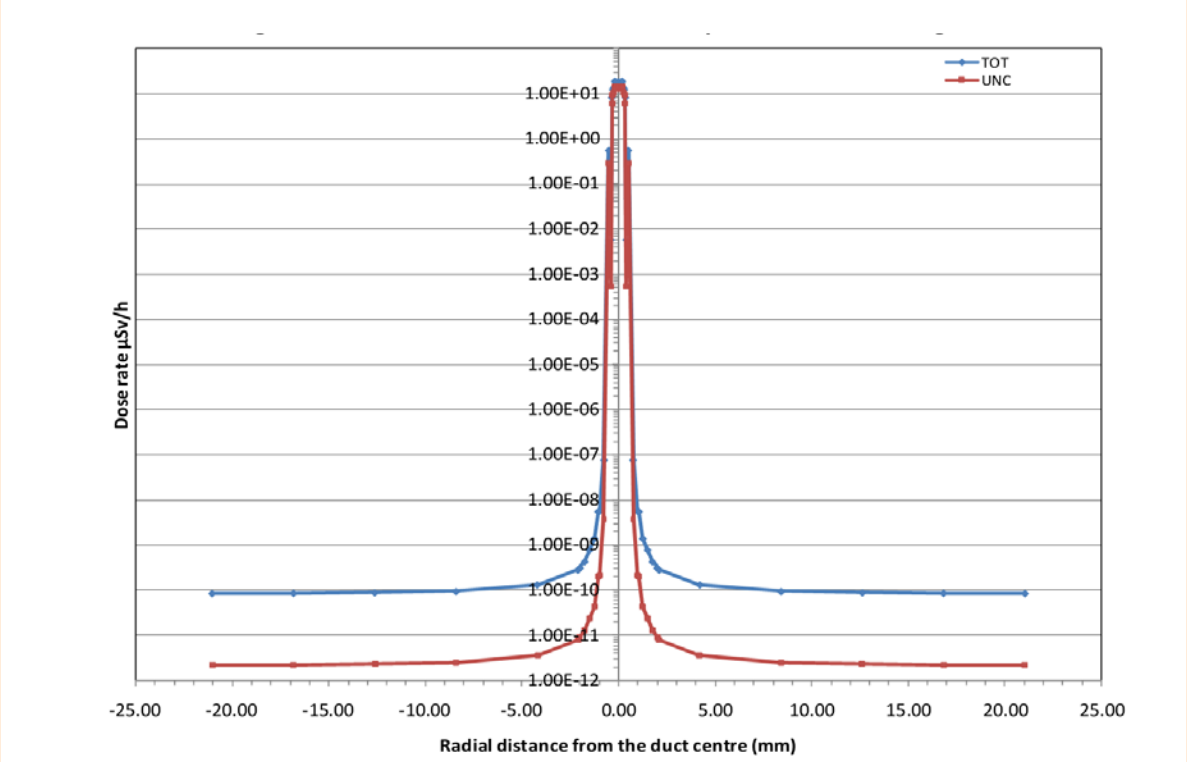
Cross sectional view

- ✓Lead shielding blocks are provided between the collimator sleeve and the service plug inner diameter to compensate for the loss of shielding due to removal of solid dummy plug
- ✓ To prevent streaming through the annular gaps high density alloy was placed at the exit of the collimator in operating area side

Dose rate computation

- ✓ Dose rates in the operating area of the hot cell was computed using QAD-CGPIC point kernel computer code to ensure the shielding adequacy of the RGS
- ✓ Source term used for computation - 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
- ✓ Collimator inner tube dimensions were optimized based on the computation such that dose rates at the operating area are within acceptable limits while ensuring adequate gamma counts in the detector detector
- ✓ Collimator aperture of 0.4 mm was chosen based on the optimization

Dose rate computation



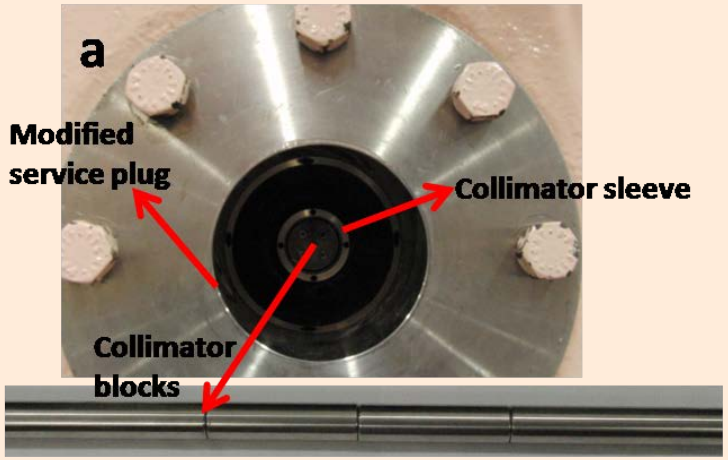
Dose rate distribution across the collimator

Maximum computed dose rate at the centre of the collimator aperture is 10 µSv/h

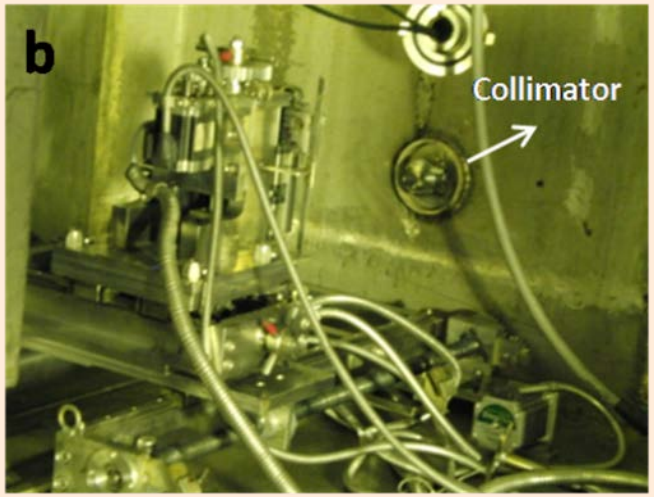
Radial Gamma Scanning System

Four-axis gamma scanning bench

- Four axis automated gamma scanning bench has been designed for precise positioning of sample inside the hot cell
- Bench has been designed in modular nature to facilitate assembling and dismantling of the individual modules remotely
- Bench was installed and aligned with the new collimator assembly in the cell wall



Front view of the modified service plug with collimator assembly



Four axis gamma scanning bench installed inside the hot cell

HPGe based gamma spectroscopy system

- ✓ **HPGe detector in the operating area in front of collimator enables gamma spectroscopy of the fuel pin sections**

- ✓ **HPGe detector used - Relative efficiency of 30%**
  Energy resolution of 1.8 keV at 1332.5 keV

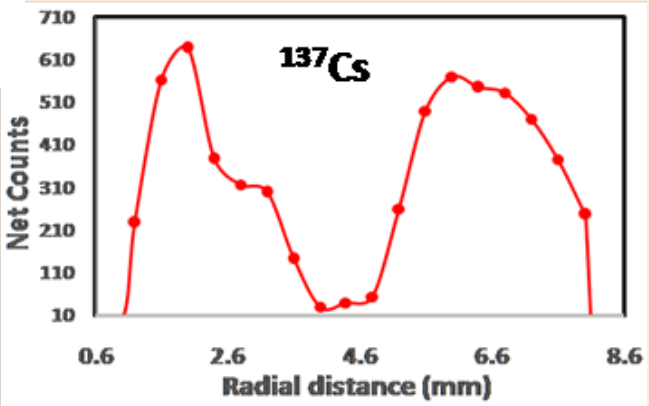
Radial Gamma Scanning

- Radial Gamma scanning was carried out on fuel pin section of MOX test pin with PFBR fuel composition irradiated in FBTR
- Irradiated fuel pin sections were extracted in hot cells and prepared for optical microscopy studies
- After optical microscopic examination samples were loaded in the sample holder of the RGS bench inside the hot cell
- Fuel pin cross section was precisely positioned in the RGS bench by monitoring the count rates from the fission products and clad activation products
- Gamma spectrums were collected at interval of 0.4 mm across the radius of the fuel pin cross section

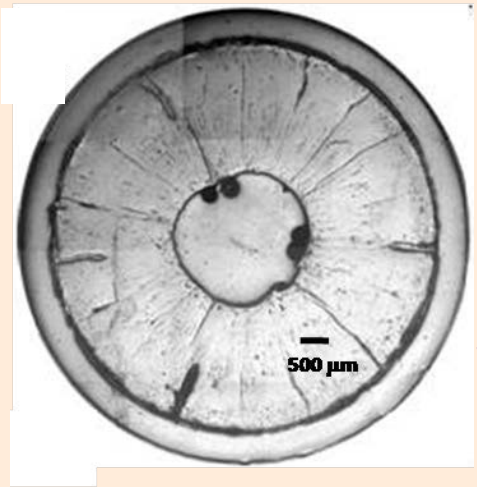
Radial Gamma Scanning

- Radial profile of ^{137}Cs across the fuel pin cross section 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



Profile of ^{137} Cs



Cross sectional micrograph of the fuel pin section taken for radial gamma scanning

PFBR MOX test assembly fuel pin section

29±1% PuO_2 Rest UO_2 with 53.5% ^{233} U

CONCLUSIONS

- ✓ **A new Radial Gamma Scanning system has been established in the hot cells by retrofitting one of the service plugs**
- ✓ **Radial gamma scanning of MOX fuel pin sections have been carried out successfully using the new facility**
- ✓ **Examination of other fuel samples are in progress**

Thank You