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Irradiated Low-Enriched Uranium Fuel Measurements with a Gamma-Ray Scanning System

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Background

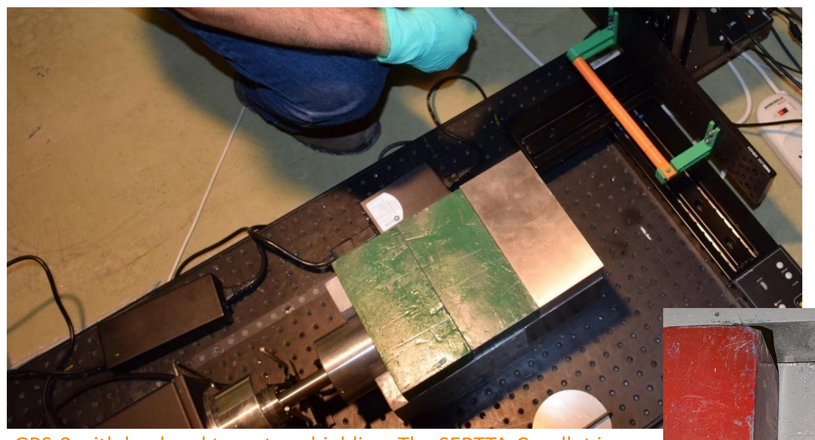
A gamma-ray scanning system was designed to perform post-irradiation measurements of nuclear fuel at INL.

The gamma-ray scanning system version 0 (GRS-0) is composed of:

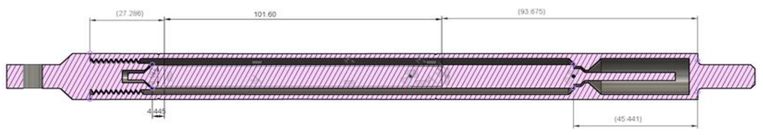
- A coaxial high-purity germanium (HPGe) detector manufactured by ORTEC
- An adjustable collimators assembly
- Three high-precision mechanical positioning stages that translate the fuel sample across the front of the collimator

The Static Environment Rodlet Transient Test Apparatus (SERTTA) testing campaign took place in the Transient Reactor Test Facility (TREAT) to test fuels in an environment that simulates a Reactivity Initiated Accident.

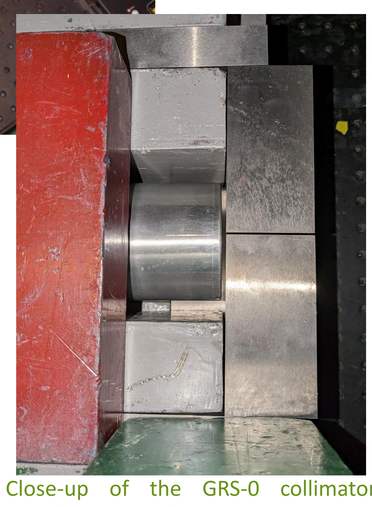
The SERTTA-C rodlet is composed of eight uranium oxide (UO_2) pellets with 0.74wt% uranium enrichment in zirconium alloy. After undergoing a transient at TREAT, the SERTTA-C rodlet was extracted for post irradiation examination where a gamma measurement was performed using the GRS-0.



GRS-0 with lead and tungsten shielding. The SERTTA-C rodlet is inside the plastic holder and mounted to the translation stages.



Rendered image of the holder to illustrate the design of the rodlet. The fuel is shown in the inner rectangle towards the middle.



Close-up of the GRS-0 collimator showing the 4-inch tungsten blocks with a 1-mm slit

Measurements & Number of Fissions Calculations

The distance from the face of the detector to the outer diameter of the holder was 12.9 cm. The scanning was completed in 1-mm increments between the mounting brackets. At each increment, data was recorded for 1300 seconds.

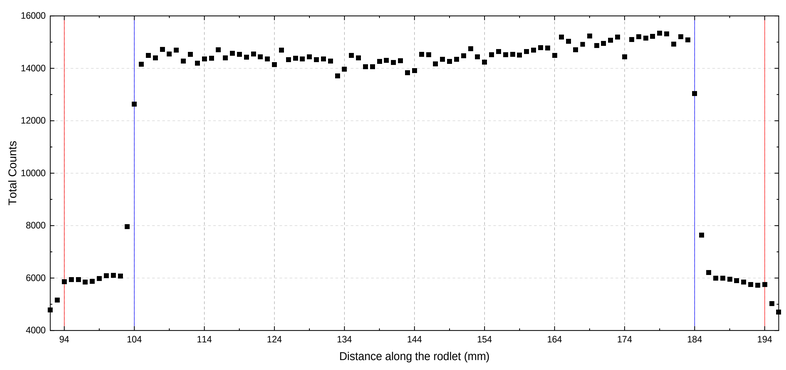
The measured gamma-ray spectrum highlights the prominent isotope peaks that can be used for these calculations:

- 497.08 keV (^{103}Ru)
- 661.66 keV (^{137}Cs)
- 724.20 & 756.73 keV (^{95}Zr)

The nuclear data for the isotopes of interest was taken from ENDFVIII. The number of fissions was calculated using the equation below with the parameters defined in the tables.

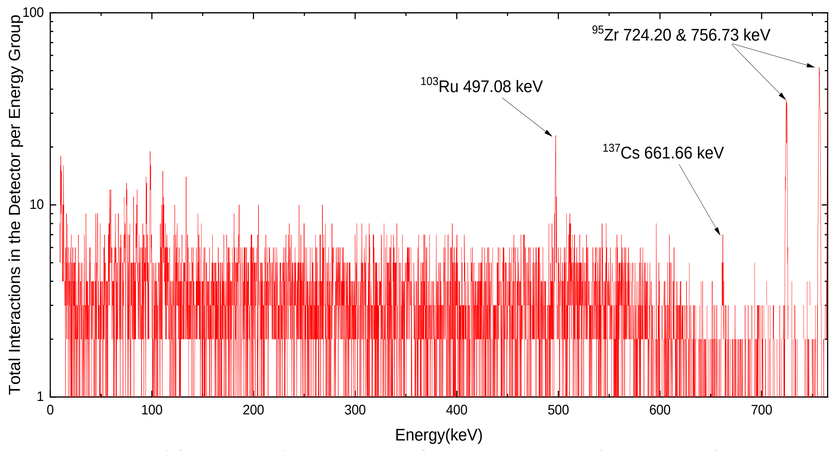
$$N = \frac{Ae^{\lambda t_d}}{C\eta\varepsilon mg\left(1-e^{-\lambda t_r}\right)}$$

Quantity	Value
Counting Live Time per millimeter step (s)	1300
Counting Real Time per millimeter step (s)	1304.4
Decay Time (s)	20167200
Standoff Distance (cm)	12.9

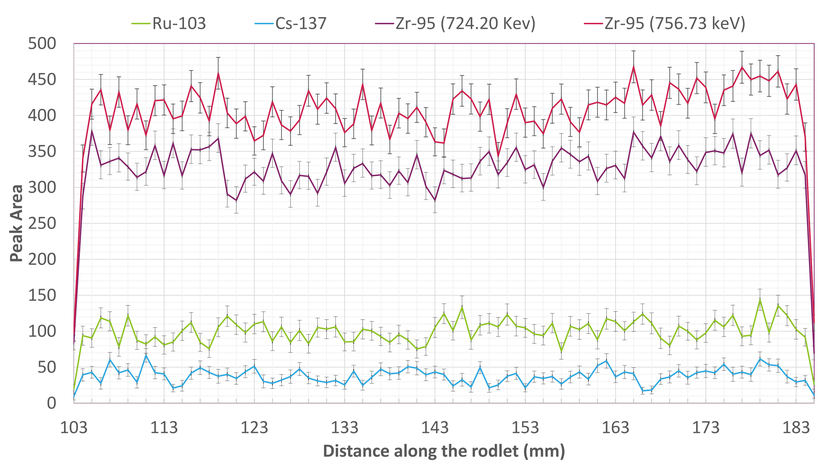


Total counts for the rodlet region only. The blue lines illustrate the approximate beginning and end of the fuel pellet region. The red lines before and after the fuel region help identify the location of the insulator pellets.

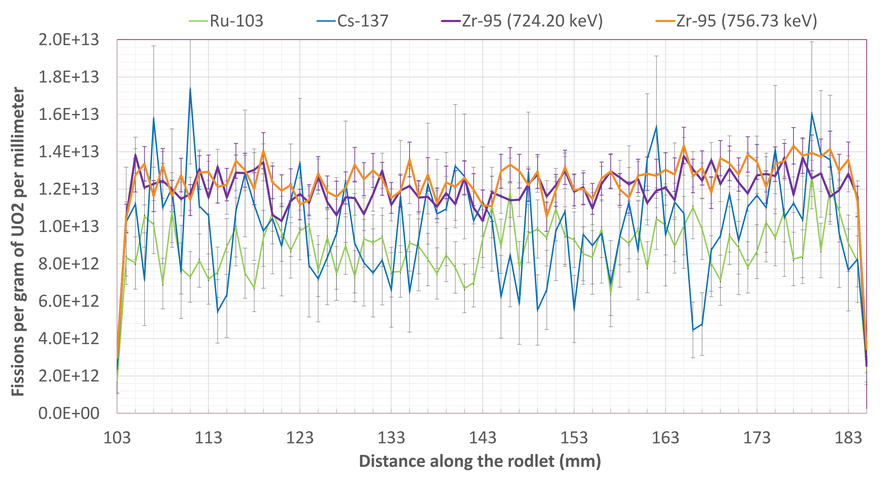
Variable	MCNP Necessary	Description
N	No	Number of fissions per gram of fissile isotope
A	No	Area of photopeak that corresponds to gamma of interest (counts)
t_r	No	Real time of measurement by detector (s)
t_d	No	Time between beginning of irradiation to beginning of detector measurement (s)
η	No	Quantum yield of gamma ray per disintegration
ε	Yes, for geometric correction	Absolute efficiency at desired energy
g	Yes	Self-shielding factor
λ	No	Decay constant (s^{-1})
C	No	Cumulative fission yield
m	No	Mass of parent isotope in sample (g)



Measured fission product spectrum for MSERTTA-C at the 145-mm location



Peak area along the length of the rodlet for the isotopes of interest



Fissions per gram of UO_2 per millimeter for the rodlet.

Conclusions

The irradiation of the SERTTA-C rodlet produced fission products that may be used to estimate the total number of fissions that occurred in the rodlet. The measured gamma-ray spectrum provided the isotope peaks that can be used for these calculations. The number of fissions was then calculated per gram along the axial length of the SERTTA-C rodlet.

Acknowledgements

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