Gamma spectrometric measurement of burn-up

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1. Introduction

The gamma spectrometric measurement of burn-up is based on measurement of activity Cs134 and Cs137. The ratio activity Cs134/activity Cs137 is linear in dependence on burn-up.

Fuel assemblies VVER-440 were in ISFSF Jaslovske Bohunice measured. The analyzed assembly has radial profile of enrichment, average enrichment is 3.82%. The assembly is hexagonal

The measurement of burn-up has several steps:

1. Measurement of activity Cs134 and Cs137 -
   a) spectrum acquisition on specific positions
   b) Analysis and quantification activity of Cs134 and Cs137 from spectrums of specific “cuts” of fuel assembly
2. Calculation ratio activity Cs134/activity Cs137 in dependence on burn-up
   Determine ratio activity Cs134/activity Cs137 by the SCALE 5.1 code system
3. Determine experimental burn-up according measured activity Cs134 and Cs137
4. Comparison experimental and calculated (3D pinwise PERMAK-3D code) burn-up

2. Measurement of activity Cs134 and Cs137

Gamma spectrometric measurement of burn-up has been carried out in inspection stand SVYP-440 in ISFSF Jaslovske Bohunice. Measurement of ^{134,137}Cs was performed by HPGe GC2018 detector. Scheme of measurement is shown in Fig. 2.1. Positioning of fuel rod in front of collimator was performed by manipulator MAPP-440.

Spectroscopic software Genie2000 was used for acquirement and analysis of spectra. Photon energy interval from 20 to 2000 keV was recorded. Dead time of measurement varied from 5 up to 25 % according to measurement point (count rate 9 000 - 48 000 cps). Example of the spectrum is shown in Fig.2.1.

2. Measurement of activity Cs134 and Cs137

Each position (radial and axial) of fuel rod was measured via 1.5 m thick steel rectangular collimator. Position of measurement was controlled by particular device with appropriate software. This position was recorded to the spectrum description to meet QA requirements (e.g. traceability). Time of measurement was set up according to the aim of the measurement from 20 s up to 3600 s. Efficiency calibration of HPGe detector was done by ISOCS software (generic characterization). For efficiency calculation some simplifications were accepted like homogeneous material of fuel rod.

2. Measurement of activity Cs134 and Cs137

After measurement device was calibrated, there were measured more than 200 spectrums in various positions. It was necessary to decrease the dead time because of high input count rate. The original project included the measurement of construction properties like spacer grid position (and its comparison with documentation). For declaration of spacer grid position, 20 seconds measurements were sufficient. Activities of ^{137}Cs round 3rd spacer grid are in Tab.2.1 and Fig.2.3

Fig.2.1Scheme of measurement

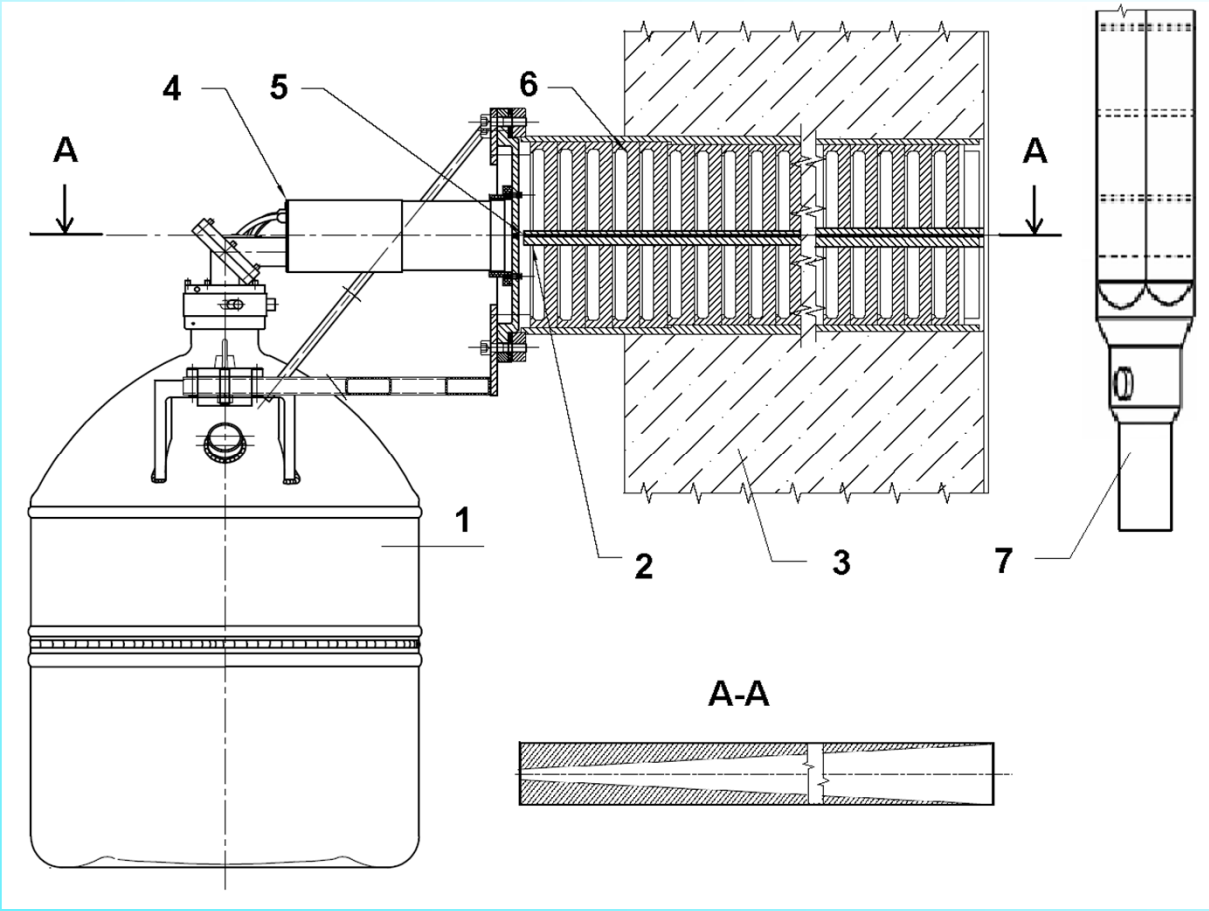


Fig.2.2 Example of measurement spectrum

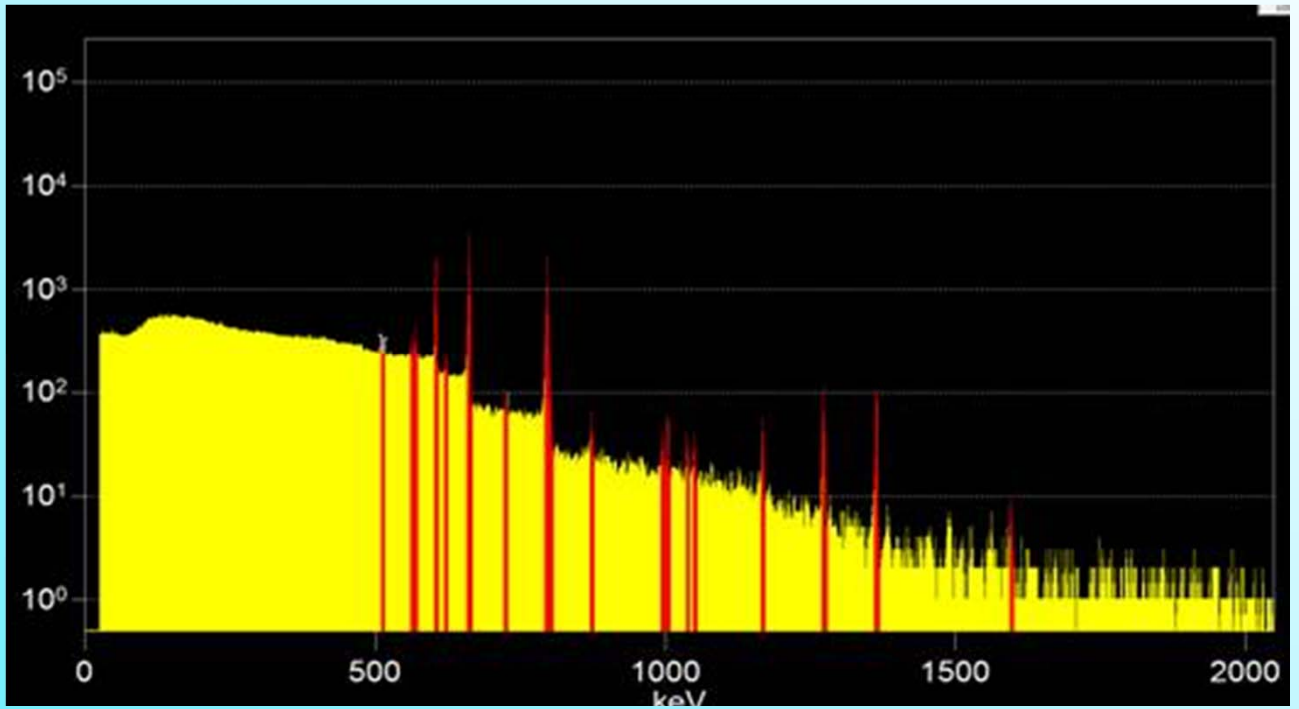
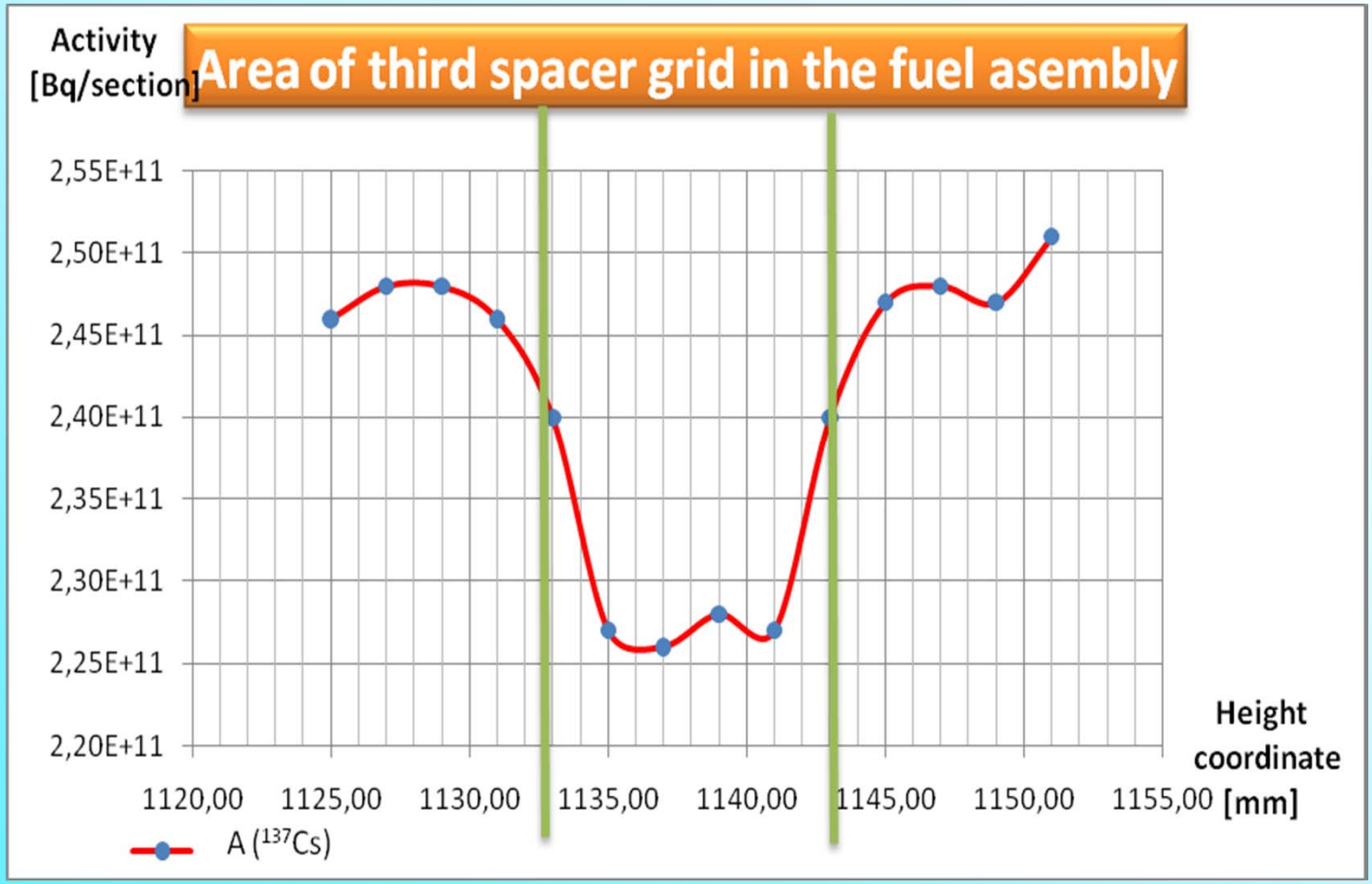


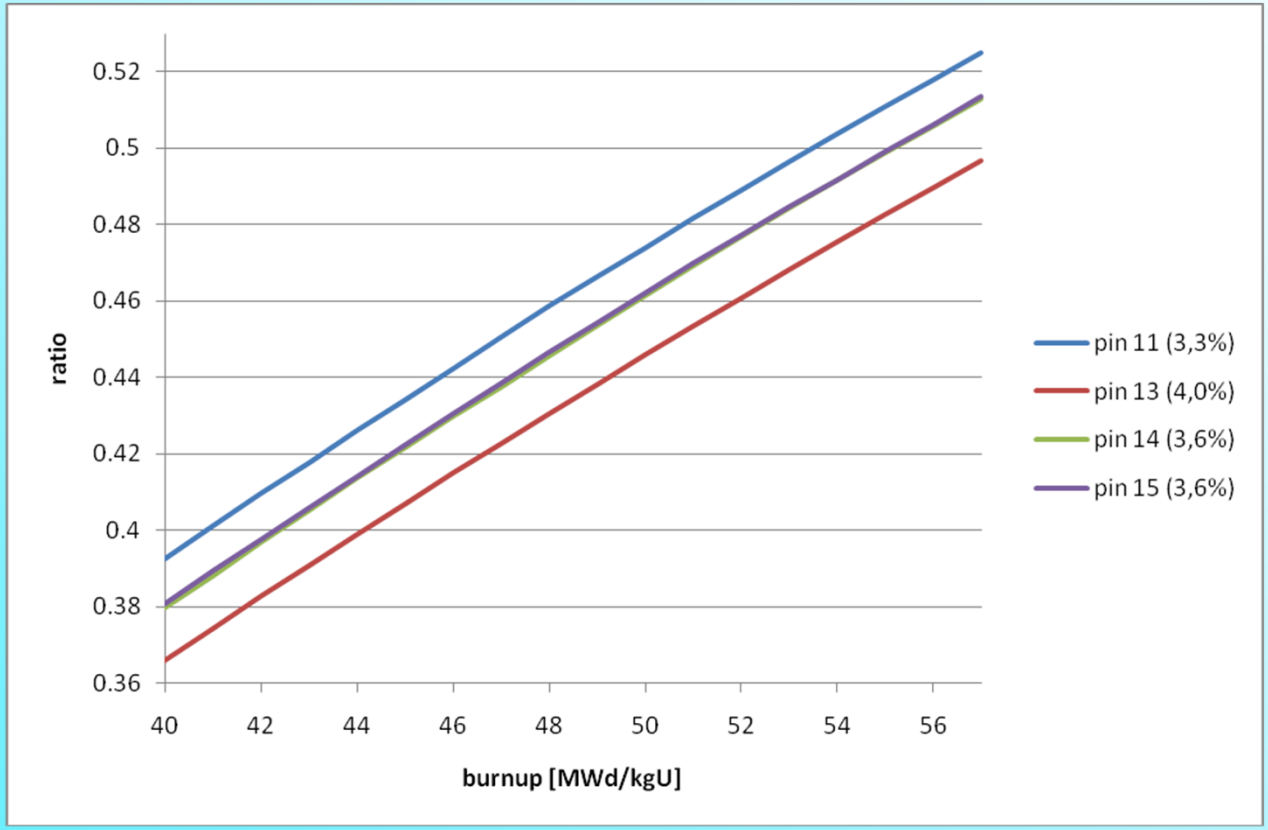
Fig. 2.3 Spacer grid in the fuel assembly



3. Calculation ratio activity Cs134/activity Cs137 in dependence on burn-up

The measured assembly 138 62894 has profiled enrichment, average enrichment is 3.82%. The average burn-up is 46 206 MWd/tU. The cooling time was 1328 days. The ratio activity Cs134/activity Cs137 was calculated with the TRITON module (the SCALE 5.1 system). By the shroud are pins with enrichment 3.3% and 3.6%, inside with 4.0%.

Fig.3.1 Assembly 138 62894, ratio activity Cs134/activity Cs137 calculated with the TRITON module for different pins



4. Determine experimental burn-up according measured activity Cs134 and Cs137

For calibration measurement we have:

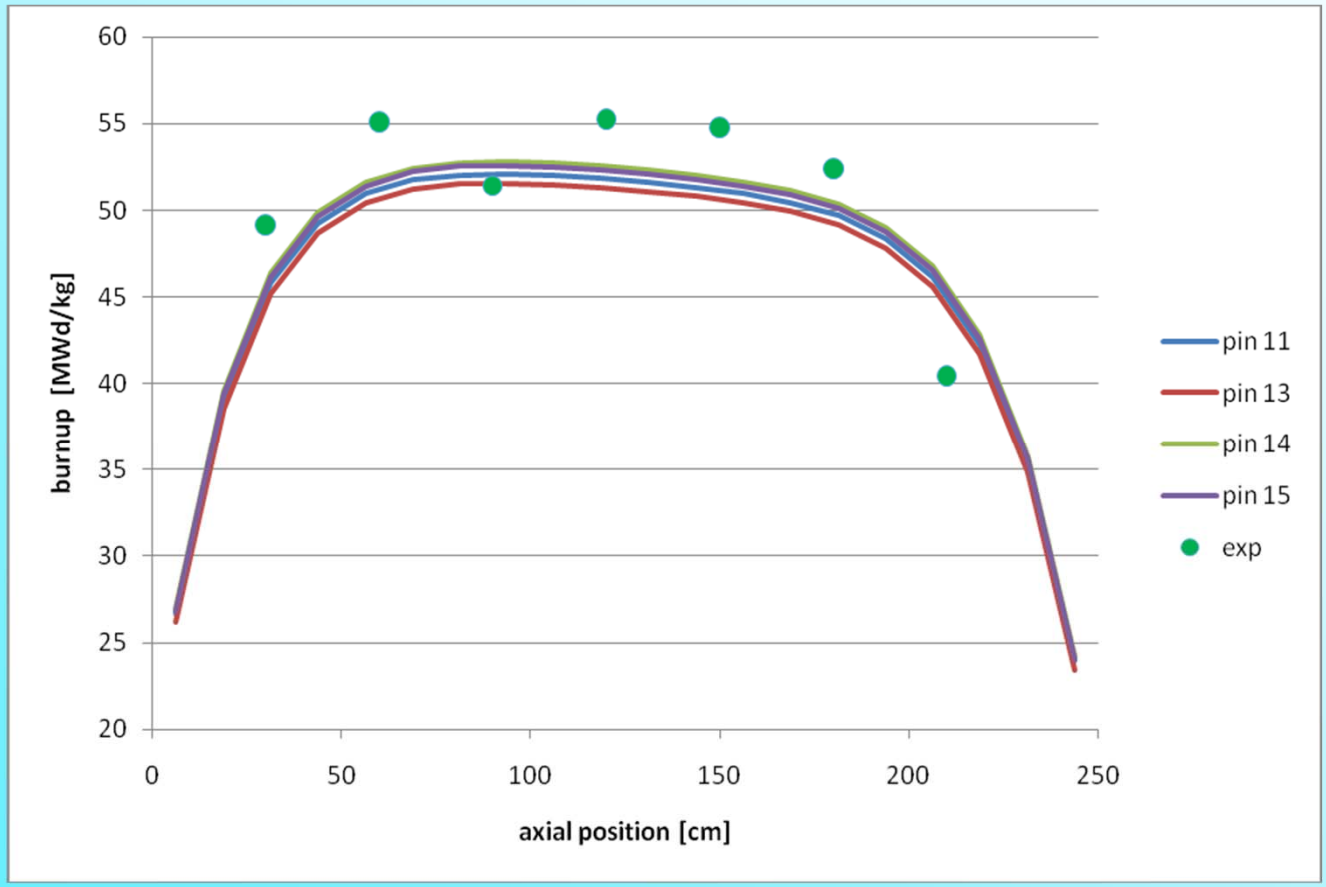
- **ratio measured activity Cs134/measured activity Cs137**
- **ratio calculated activity Cs134/calculated activity Cs137 for burn-up (calculation TRITON)**

For measured activity Cs137 we have “measured” burn-up: B = k * activity Cs137

5. Comparison experimental and calculated (3D pinwise PERMAK-3D code) burn-up

The PERMAK-3D code is diffusion, 4- group and 3-dimensional pinwise code.

Fig.5.1 Assembly 138 62894, axial profile of burn-up for different pins. Calculated value is from thePERMAK-3D code.



Tab.5.1 Assembly 138 62894, radial profile of burn-up (relative value), Z = 120 cm

Angle	0°	60°	120°	180°	240°	300°
PERMAK-3D	0.99	0.98	0.99	1.01	1.02	1.00
Measurement	0.97	0.95	0.99	1.03	1.04	1.02

6. Conclusion

Gamma spectrometric measurement has wide utilization by checking of spent fuel assemblies:

- **to find top and bottom of fuel pin**
- **to find space grid**
- **to measure burn-up**

The half time of Cs134 is $T_{1/2}$ = 2.065 y, therefore the cooling time between end of irradiation in reactor and measurement should be not longer than 4 years.