Nuclear Spent Fuel Verification with Using of Miniature CdZnTe Detectors

V. Ivanov, L. Alekseeva, P. Dorogov, A. Loutchanski

ZRF RITEC SIA

23 Aizkraukles St. office 407, Riga, LV-1006, Latvia

Tel./Fax: +371-67543304, E-mail: ritec@ritec.lv

Introduction

Nuclear spent fuel verification techniques at working NPP should provide a true information about controlled objects in the volume necessary for their identification for short measuring time with minimal efforts.

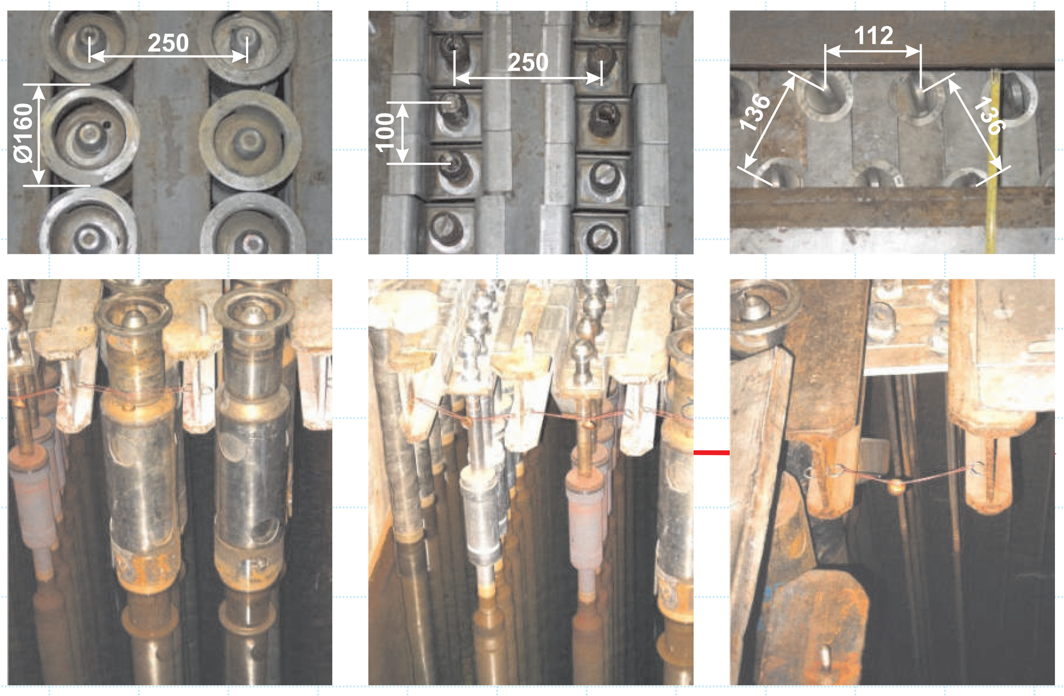
Large variety and quantity of controllable objects, various conditions of their storage in remote places demand application of small-sized universal devices allowing operation in heavy field conditions.

CZT detectors and devices on their basis due to high spectrometer characteristics, small dimensions, and stability to external influences find application for carrying out of such measurements.

Controllable objects

At the NPP under water in storage ponds can be stored both the irradiated nuclear fuel assemblies and other non-fuel irradiated objects such as process and instrument channels, absorbers, control and safety rods and etc. Irradiated fuel assemblies and other items are mainly stored in a suspension position without or inside of hermetic cases. Suspended fuel assemblies are arranged in slots closely to each other. May be few types of an arrangement differing by surface density. Also the cut bundles of spent fuel elements placed in baskets and other objects can be stored in the ponds.

Possible storage types of irradiated fuel assemblies



Fuel assemblies in cases | Fuel assemblies suspended on load-bearing rods | Fuel assemblies suspended on steel rods

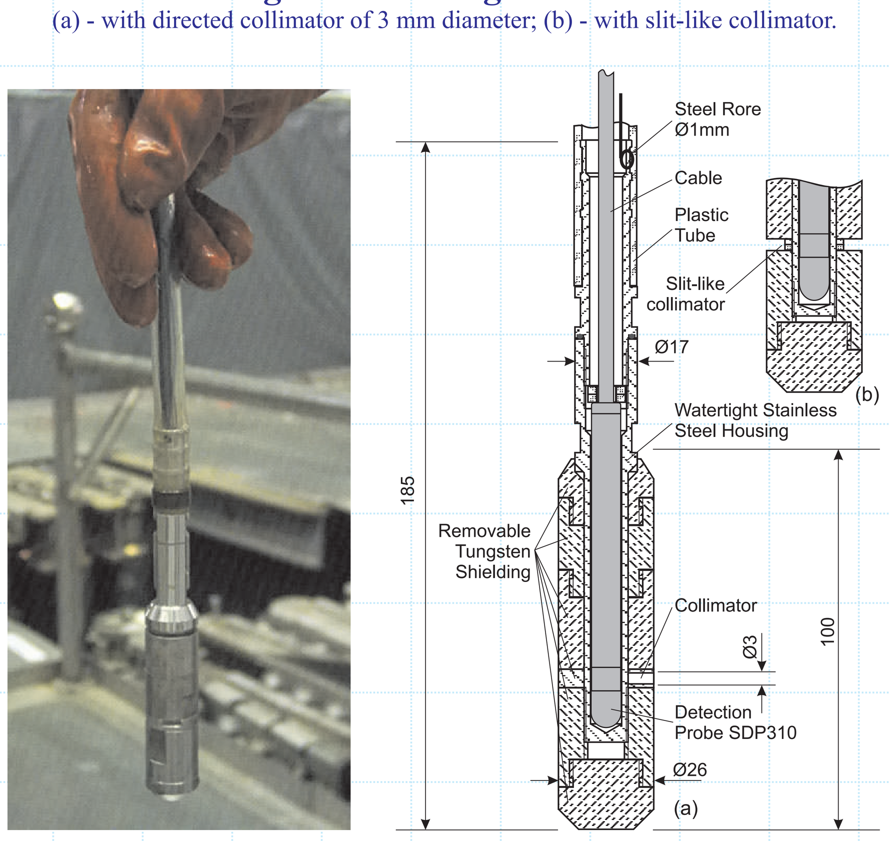
Measuring chambers

For underwater measurement a special waterproof measuring chamber with a low weight tungsten radiation shielding was used. For some measurements slit-like, hole or long air collimators can be arranged.

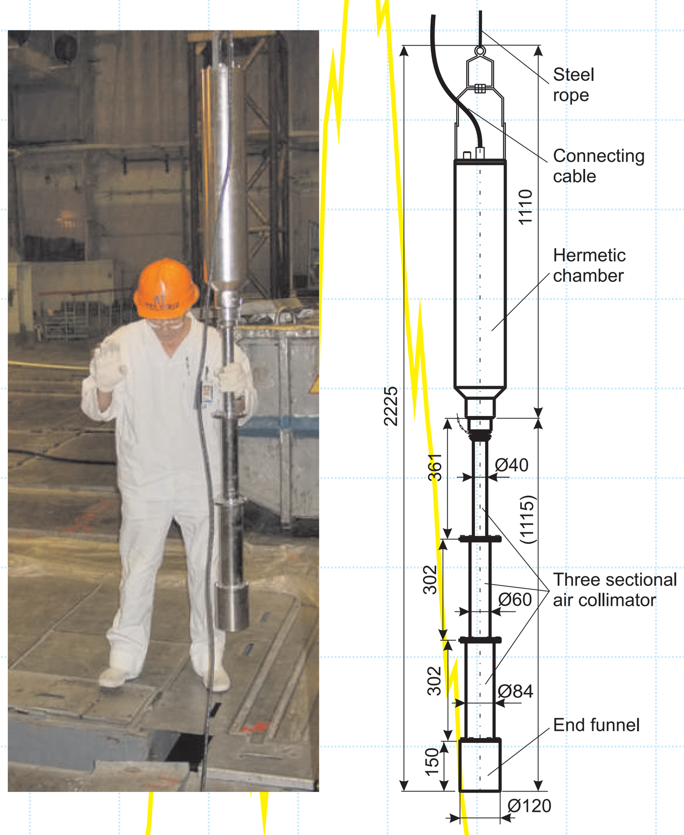
For cut bundles of spent fuel elements with long cooling time stored in baskets a special waterproof measuring chamber with funnel-shaped air collimator was used. Inside of the measuring chamber are placed the probe SDP500 with 500 mm^3 detector, radiation shielding and internal collimator.

Chamber for underwater measurements with tungsten shielding and collimators

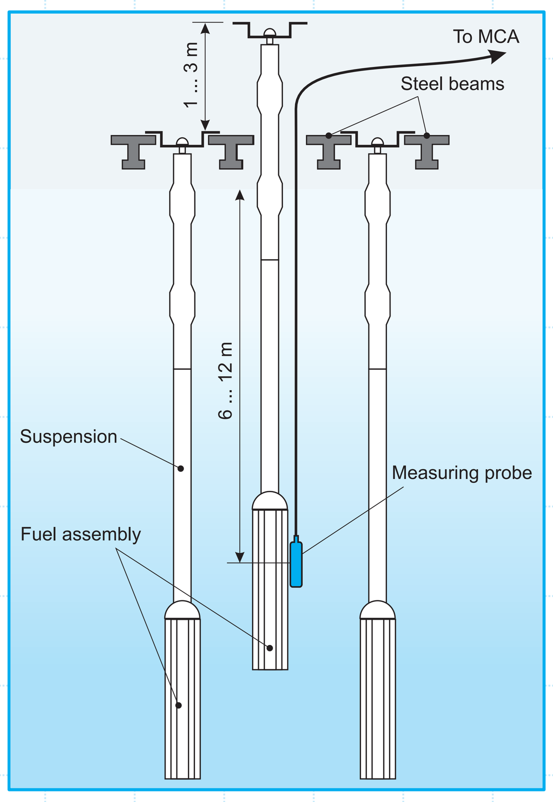
(a) - with directed collimator of 3 mm diameter; (b) - with slit-like collimator.



System for measurement of spent fuel bundles stored in baskets

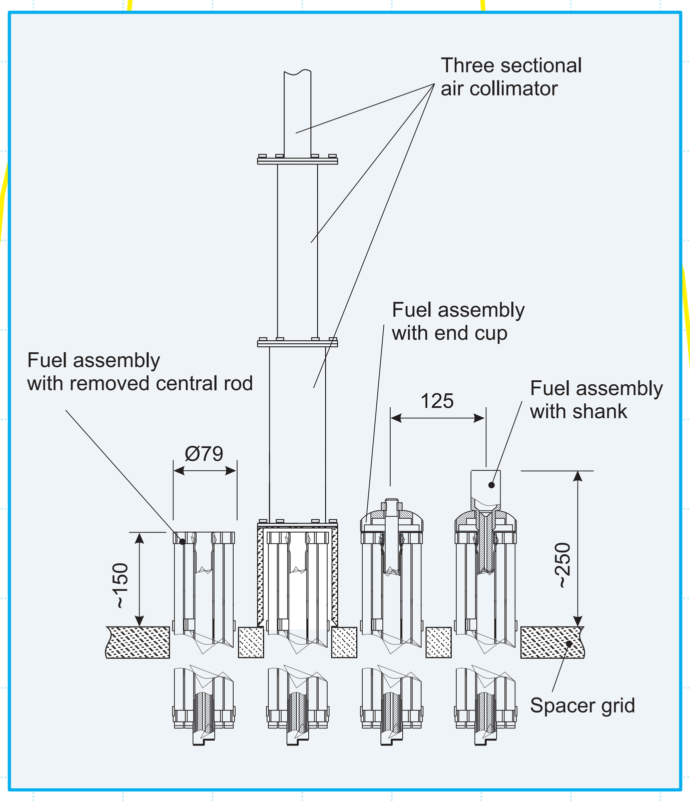


Measuring scheme of suspended irradiated fuel assemblies in storage pond



Places for measuring probe insertion

Measuring scheme of spent fuel bundles stored in baskets

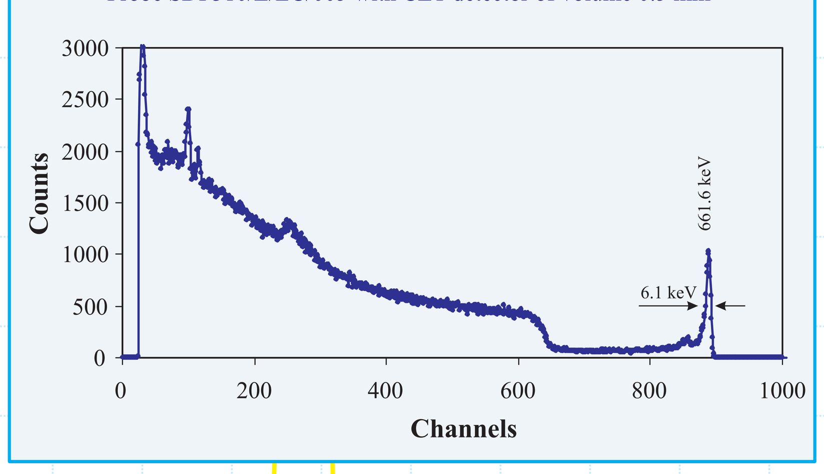


CZT detectors and probes

Spectrometric Detection Probes types SDP310 and SDP313 produced by RITEC with CZT detectors of volumes 0.5...20 mm^3 for high count rate measurements and probe type SDP500 with CZT detector of volume 500 mm^3 for low count rate measurements were used. All used probes consist the CZT quasi-hemispherical detector, charge sensitive preamplifier, watertight case and connecting cable. Typical energy resolutions (FWHM) of the used probes at a 662 keV line are of 10...15 keV. High-count rate measurements with calibrated irradiator with Cs^{137} source of high activity have been done.

Spectrum of Cs-137

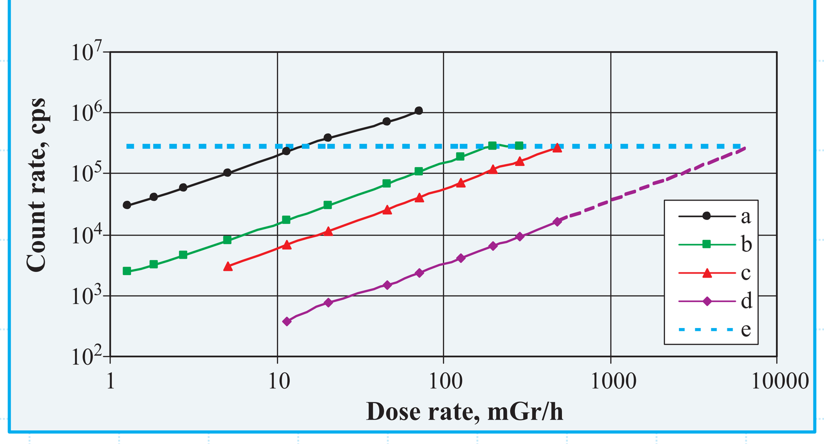
Probe SDP310/Z/LC/005 with CZT detector of volume 0.5 mm^3



Count rate vs. dose rate

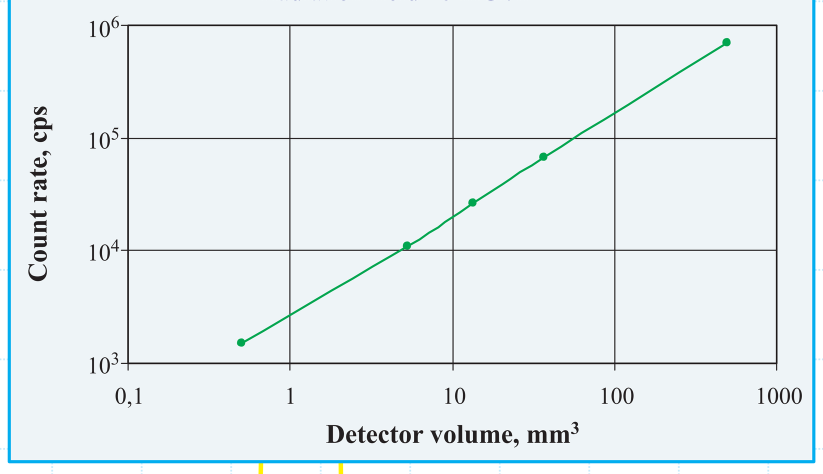
Detectors volumes: 500 mm^3 (a), 40 mm^3 (b), 14 mm^3 (c), 0.5 mm^3 (d)

Maximal count rate accessible with probes of SDP310 types (e)



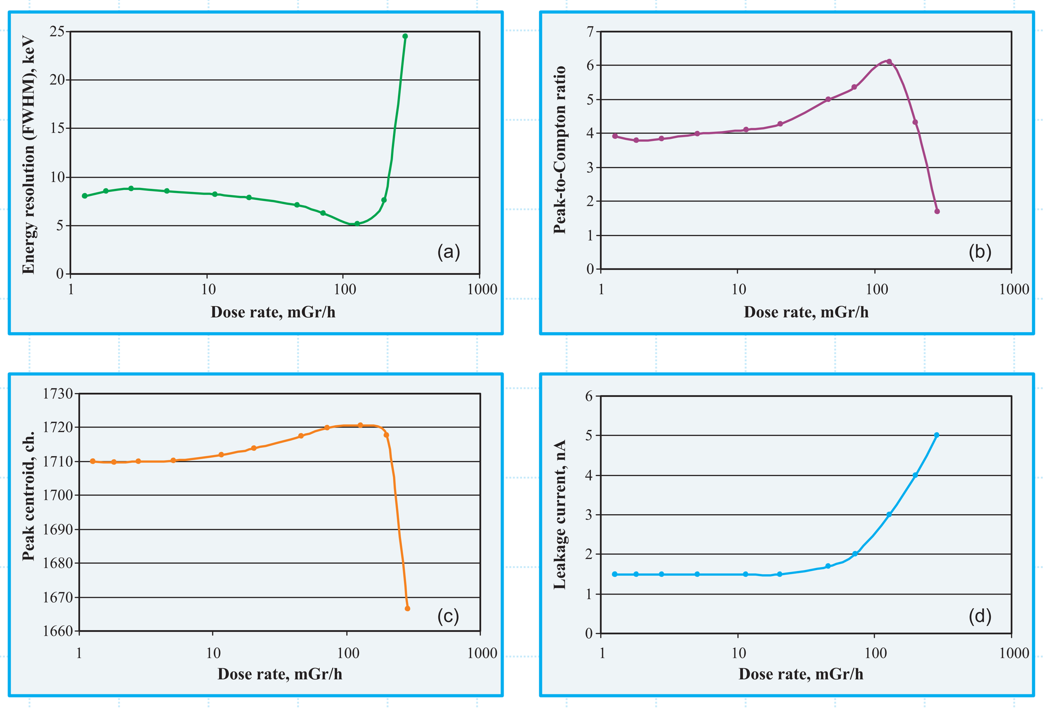
Count rate vs. detectors volume

Radiation field 46 mGr/h



Energy resolution (FWHM) at 662 keV (a), peak-to-Compton ratio (b), peak centroid (c) and leakage current (d) vs. dose rate

CZT probe SDP310, detector volume 40 mm^3



Spectrometric Detection Probes

Measurements and results of measurements

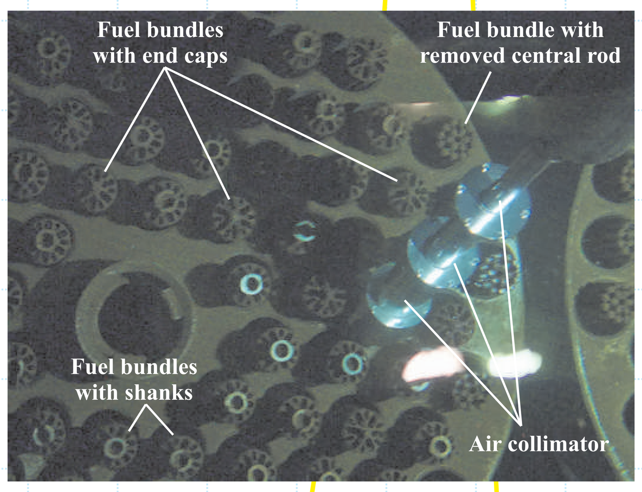
At inspection and verification of items stored in the storage ponds is necessary to obtain its specific features. Specific gamma spectra with typical lines of the irradiated items stored in the ponds can be used for this purpose. In a case of irradiated fuel it is the line of Cs^{137} with energy of 661.6 keV, the most typical line of irradiated nuclear fuel. In case of non-fuel irradiated items of stainless steel the typical lines are lines of Co^{60} with energies of 1173.2 keV and 1332.3 keV. For more exact identification of irradiated fuel, the lines of other isotopes such as Cs^{134} (604.6 keV, 795.8 keV) and Zr^{95} (724.2 keV, 756.7 keV) can be used. The presence in the recorded spectra lines of a short-lived isotope Zr^{95} may be used for the identification of items with short cooling time when identification of lines of other isotopes is hampered due to a very strong radiation field connected with a high level of short-lived activity. The line of U^{235} of 185.7 keV and/or groups of Uranium X-ray lines with average energy of 100.8 keV may be used for identification of fuel assemblies or very low burn-up. Energy resolution of used SDP310 probes in the most cases allows identification of these lines.

As usual in the storage ponds there are irradiated fuel assemblies with different cooling times from a very short to 15 and more years and with different burn-up. Closely located fuel assemblies with the high and low burn-up or/and fuel assemblies with long and short cooling times are the most complicated arrangement for measurements. Usual measuring procedure is carried out in an "ideal" arrangement of measurable items. Fuel assembly or other object is removed from the normal positions in a slot and positioned on the greatest possible distance from the others objects. In this case the most favorable conditions of the measurements are realized, but this requests a great volume of transportation.

We have used method without or with minimal volume of irradiated object transportation. For spectra measurements fuel assembly on suspension is slightly lifted up by the lifting crane at the height of 1...3 m. The created hole between the suspension and the slot beams is enough for insertion of the small size underwater measuring chamber. The measuring chamber with the probe was submerged in water at a depth of 6...12 m closely to measured assembly up to beginning of its fuel elements. Simple lifting up the fuel assembly reduces influence of the neighbor assemblies and makes possible qualitative spectra measurement of a selected fuel assembly.

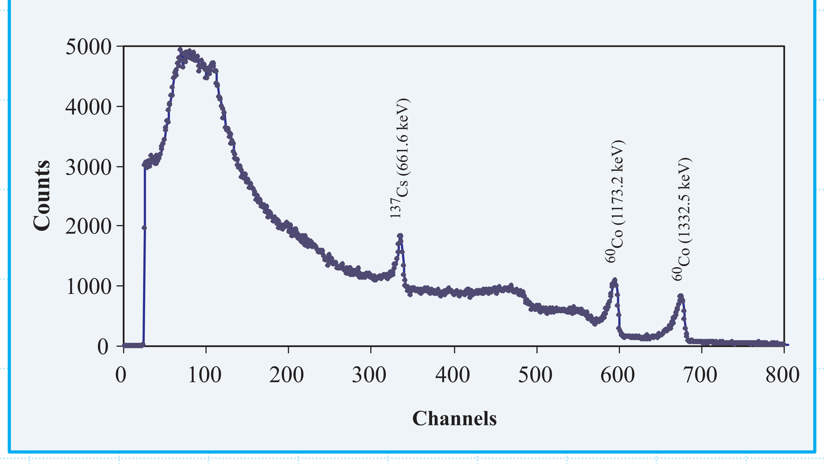
For measurements of the cut bundles stored in baskets the funnel-shaped air collimator of measuring chamber was placed above a top of verified bundle. Application of the long air collimator reduces influence of neighbor bundles, but intensity of radiation field in a place of the detector location is too low. For reduction of time of measurements the probe with a large volume detector of 500 mm^3 was used. Such measurement technique allows verification of spent fuel bundles with undeleted stainless steel: central rods, caps and shanks by presence of the peaks of Cs^{137} and Cs^{134} on an intense background of Co^{60}.

Basket with cut spent fuel bundles



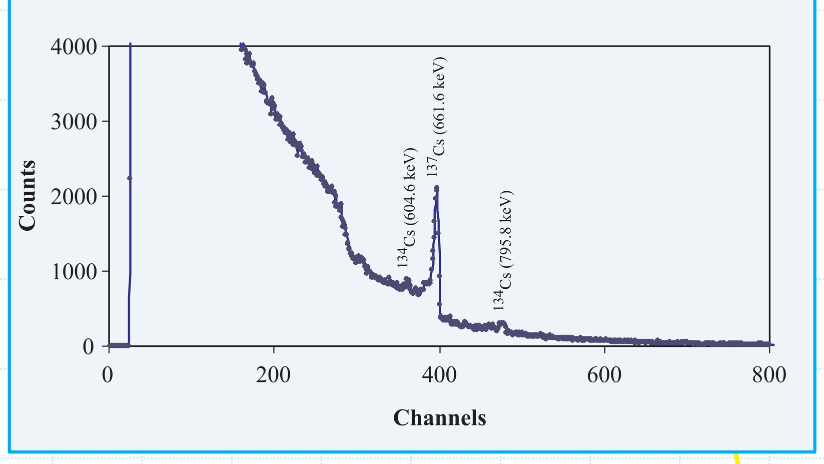
Spectrum of spent fuel bundle stored in basket with undeleted shank

Burn-up 1857 MWd/FA. Cooling time 149 months.



Spectrum of irradiated fuel assembly stored on suspension

Burn-up 180 MWd/FA. Cooling time 21 months.



Conclusion

The presented results show the possibilities of CZT detectors and probes on their base for operation in strong radiation fields of irradiated fuel assemblies. It was shown that the probes of SDP310 types can operate up to count rates of about 280 kcps. With CZT quasi–hemispherical detectors of volume 40...60 mm^3 it can operate in radiation fields of dose rate up to 200 mGr/h, with detectors of volume 10...15 mm^3 it can operate in radiation fields of dose rate up to 480 mGr/h. The detectors of volume 0.5 mm^3 basically could operate in very strong radiation fields of dose rate up to 5...7 Gr/h.

Measuring system with the CZT probes can be used for the high-level irradiated objects verification. Application of CZT detectors for underwater measurements in the NPP storage pond reduces the volume of transportation of irradiated object, time of measurements and the NPP operator's radiation exposure.