Nuclear Spent Fuel Verification with Using of Miniature CdZnTe Detectors

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**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.

**Controlled 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 press-coils, instrument channels, absorbers, control and safety rods, 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 in 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 suspended in the ponds.
- Fuel assemblies suspended on the steel rods.
- Fuel assemblies suspended in the basket.
- Fuel assemblies suspended on the steel rods and in the basket.

**Measuring chambers**

For underwater measurement a special waterproof measuring chamber with a low weight and tungsten radiation shielding was used. For some measurements silt-like, bulky 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 is placed the probe SDP500 with 500 mm 3 CZT detector, radiation shielding and internal collimator.

**Chamber for underwater measurements with tungsten shielding and collimators**

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

**System for measurement of spent fuel bundles stored in baskets**

- Measuring probe with directed collimator and associated electronics.
- Measuring probe with tungsten shielding and collimator.

**Spectrometric Detection Probes**

Spectrometric Detection Probes types SDP310 and SDP113 produced by RITEC with CZT detectors of volumes 1–20 mm 3 for high count rate measurements and probe type SDP109 with CZT detector of volume 500 mm 3 for low count rate measurements were used. All used probes consist of the CZT quasi-hemispherical detector, charge sensitive preamplifier, windowless casing 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.

- Measuring chambers for underwater measurements with funnel-shaped air collimator.
- Measuring chambers for underwater measurements with directed collimator and associated electronics.

**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 cases of irradiated fuel it is the line of the 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 Cs 137 with energies of 1732.3 keV and 1332.5 keV. For more exact identification of irradiated fuel, the lines of other isotopes such as Cs 133(604.6 keV), 795.8 keV and Cs 134(724.2 keV), 736.7 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 objects is hampered due to a very strong radiation fields connected with a high level of short-lived activity. The line of Fe 55(55) of 60.6 keV and of Uranium X-ray lines with average energy of 100.6 keV may be used for identification of fuel assemblies or very low burn-up. Energy resolution of used SDP310 probes in 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 3 and more years and with different burn-up. Closely located fuel assemblies with the high and low burn-up or and fuel assemblies with low and short cooling times are the most complicated arrangement for measurements. Usual measuring procedure is carried out in an "idiot" 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 other objects. In these cases the most favorable conditions of the measurements are realized, but this requires a great volume of transportation.

We have used method without or with minimal volume of irradiated object transportation. For spectra measurements fuel assembly in 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 bottom 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 of the probe with a large volume detector of 500 mm 3 was used. Such measurement technique allows verification of spent fuel bundles with irradiated stainless steel central rods and tanks by presence of the peaks of Cs 137 and Cs 134 on an intense background of Cs 137.

**Conclusion**

The presented results show the possibility 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 SDP110 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 400 mGr/h. The detectors of volume 5,5 mm 3 basically could operate in very strong radiation fields of dose rate up to 5...7 Gr/h.

The SDP310 probe 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 objects, times of measurements and the NPP operator's radiation exposure.