INVESTIGATION OF $\beta$-EMISSION METHODS OF MONITORING COOLANT WATER LEVEL IN NUCLEAR POWER PLANTS

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This investigation was performed on a vessel heat-engineering bench. The working medium was water under pressure up to 20.5 MPa and temperature from 20 (cold) to 350°C (hot). The controllers were a $\beta$-emission sensor of level and a Sapfir-22DD differential manometer as the standard. The objective was to determine the characteristics of a $\beta$-emission sensor under the conditions of the working medium. Analysis of the experimental data showed that the indications of the $\beta$-emission sensor and differential manometer were identical and linear as a function of the level of both the cold and hot water. The characteristics of the $\beta$-emission sensor are: minimal response time and measurement error, very small dimensions, serviceability at pressures to 20.5 MPa and temperature to 350°C, at least 10 years life, and energy independence of the primary converter.

The operational reliability and safety of water-cooled nuclear power plants can largely be secured by monitoring the state of the coolant by means of in-reactor level sensors. This can be achieved in the normal operating regime as well as during excursions from it. In-reactor level sensors must possess minimal dimensions, minimal response time, structural simplicity, and adequate life [1]. In terms of the principle of operation, coolant level sensors can be classified as visual, mechanical, hydrostatic, electrical, acoustic, electromagnetic, nuclear-physical (radio isotopic), and others [1–8].

In this article, we present the results of investigations of $\beta$-emission coolant level sensors based on $\beta$-emission as a variant of the nuclear-physical principle.

The principle of operation of $\beta$-emission level sensors is based on the detection of $\beta$-particles after their passage from the emitter ($\beta$-emitting isotope) up to the sensitive element through a layer of coolant. Analysis showed that the average energy of the $\beta$-particles for use as an emitter must be at least 0.8 MeV and the half-life of the parent isotope must be at least 10 yr [6, 7]. For this reason, $^{90}$Y (short-lived, daughter isotope relative to $^{90}$Sr), emitting $\beta$-particles with maximum energy 2.26 MeV and half-life of parent isotope 29 yr, is recognized as being most effective [9].

Direct-charge sensors and $\beta$-emission neutron detectors, which are used to detect neutron radiation and whose sources of $\beta$-particles are short-lived $^{104}$Rh and $^{108}$Ag, $^{110}$Ag as products of neutron activation of stable $^{103}$Rh and $^{107}$Ag, $^{109}$Ag, can be considered as certain analogs of a $\beta$-emission level sensor [6, 7]. The principle of generation and detection of the signal of a $\beta$-emission level sensor is similar to that in a direct-charge sensor or $\beta$-emission neutron detector. Experiments performed in a research reactor have shown that the sensitivity of a sensor to neutron and gamma radiation of an operating reactor is,
respectively, $3 \times 10^{-22} \text{ (A/m)/(sec}^{-1}\text{.cm}^{-2})$ and $0.88 \times 10^{-16} \text{ (A/m)/(R/h)}$. Therefore, for neutron flux density $10^7 \text{ sec}^{-1}\text{.cm}^{-2}$ and $\gamma$-ray dose rate $10^4 \text{ R/h}$ at a possible location for a $\beta$-emission level sensor, the background signal generated by, respectively, neutron and gamma radiation of the reactor will be $3 \times 10^{-6}$ and $0.88 \times 10^{-3} \text{ nA/m}$, which is negligibly less than the sensor signal (to 3 nA/m).

The computational part of these investigations of the characteristics of $\beta$-emission level sensor, which entail evaluation of the passage of $\beta$-particles through matter, was performed using the MCNP-4A software [6, 10].