Thus an analysis of the experimental results allows us to draw the following conclusions:

there is reliable reproducibility and a steady tendency towards decrease in the random error of measurement results when the amplitude of movement of the weighted control rod is increased within the range from 20 to 320 mm;

within the range of shim rod movement of 120 mm on the linear portion of its characteristic which is allowed to be used at full power, the random error of measurements using the relative weighting method is ∿3%;

satisfactory agreement has been shown between the shim rod effectiveness distributions obtained by the rod removal and relative weighting methods;

the method can be used for monitoring BN-600 physical characteristics at all power levels;

the relative weighting method makes it possible to compare the relative shim rod effectiveness distributions for different core temperature conditions.

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INVESTIGATION OF THE AGING OF SCINTILLATION DETECTORS

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Scintillation detectors based on alkali-halide crystals with activating admixtures have been widely used in equipment recording various types of ionizing radiation. Stationary operation under various conditions is expected from this equipment which is often subjected to increased mechanical and climatic loads. Since the techniques of purifying the initial material have been improved, new scintillators are employed, the working of the crystals has been improved, and since the purity of the packing has been increased, the number of random processes which lead to a deterioration of the scintillation characteristics could be reduced.

When a detector is produced, the surface of the crystal is covered with a diffuse reflecting layer of a previously dried powder of an oxide of magnesium, titanium, aluminum, etc. It was noted in some of the first papers on the scintillation technique [1] that aluminum oxide should be preferred in the case of NaI(Tl) crystals because magnesium oxide enters into a chemical reaction with this crystal. Abroad one has rejected magnesium oxide for the preparation of scintillation detectors. But the use of aluminum oxide complicates the design and the assembly of the detector because a special system fixing the scintillator in the housing must be created, especially in the case of shock- and heat-resistant samples [2].

Studies of the reflection of light [3] and also determinations of the technical feasibility involving parameters such as the degree of electric charging, compressibility, dehydration upon heating, have shown that on a whole, magnesium is to be preferred. This has been confirmed in the testing of a large number of detectors of various types with dimensions ranging from 10 × 10 to 100 × (100-200) mm; these detectors were subjected to mechanical loads, namely vibrations of up to 2.5×10^3 Hz at accelerations of up to 15 g, impact loads

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of up to 200 g, etc. MgO is compressed in the detectors to an extent such that it does not leak out under the polished exit face of the crystal.

Thus, to date no alternative solution to a housing which is diffuse reflecting by virtue of its production has been found. We studied in our work the deterioration of the characteristics due to the penetration of water vapor into a detector with a reflector of magnesium oxide powder when the detector is stored for a long time (up to 15 years).

There are two ways for the water vapor to enter into the container. The first is related to the absorptive capacity of the detector elements. The second is caused by irreversible disturbances (fissures and transverse defects) in the glued seams and the structural elements. This mechanism becomes effective during the natural aging of hermetically sealed detector materials. The mechanism manifests itself as the so-called "moisturizing" of the scintillator when sections with yellow-green spots appear on the surface and indicate that irreversible hydrolysis occurs on the surface: $NaI(Tl)\ n\ H_2O \rightarrow NaOH + NaI + TlI$. Since the solubility constants of NaI and TlI differ considerably, the latter precipitates in the form of its solid phase (development of an opaque, specifically colored layer on the scintillator surface).

The aging of the detectors can be studied in two ways. Firstly, the aging of each of the materials and of each of the structural elements can be studied and then the system can be synthetized. Secondly, the process can be explored by long-storage testing under normal climatic conditions and also by using more rigorous load conditions (simulating the conditions of operation).

The outside of the detector is visually inspected and the scintillation parameters are monitored until breakdown occurs, i.e., until the detector no longer works properly. The operational capability of detectors is defined as the confirmation of the scintillation parameters within the confidence interval of the initial measurements when the detector is periodically checked. It is not acceptable that the scintillators become moist.

We adopted the second way of studying the aging of detectors. The detectors were divided into related lots (of 5-10 samples each). The observation time of a lot was assumed to be the experimentally determined detector survival time at a certain probability of storage without breakdown: $P_x = 1\ d(\tau)/N$, where $d(\tau)$ denotes the number of breakdowns during the storage time of the lot; and N denotes the volume of the lot. Obviously, the longer the storage without breakdown, the shorter the remaining survival period.

The testing of a lost of 10 x-ray detectors with scintillators made of 30 × 63 mm NaI(Tl) single crystals was started in 1973 and is continued to the present time. July 1989 was the last time when scintillation parameters (relative resolution and light yield) were monitored.

During the test period, the detectors were 11 times irradiated with γ-quanta of ^{137}Cs; in the first three irradiations, the absorbed dose rate was $(5.5 \pm 0.5)10^{-1}$ G/h, and this accelerated the aging of the scintillators as far as the parameter "reaction to irradiation" is concerned. In the initial stage of the experiment, reaction to irradiation of the detector was understood as the difference between the background counting rates ($\leq$500 pulses/sec) obtained in two measurements, namely before the irradiation and 10 min after irradiation with the γ-quanta of ^{137}Cs (absorbed dose: $(5.5 \pm 0.5)10^{-1}$ G/h). Later on, the difference between the background counting rates ($\geq$500 pulses/sec) was calculated from measurements made before, and 5 min after, a 30 min long irradiation at an absorbed dose rate of $(5.5 \pm 0.5)10^{-2}$ G/h).

The results of the tests have shown that the scintillation-detector parameters measured before and after irradiation in the course of 16 years satisfy the technical specifications of the detector; the changes to the scintillation parameters of the detectors were during 13 years within the error limits of the measurements (10%). After 16 years, the light yield of only two detectors had deteriorated by 25%, and the reduced resolution had maintained — within the error limits of the measurements — the previous values in all detectors. Visual inspection of the detectors' appearance has shown that small sections with a hardly recognizable bright green spot had formed after 8-10 years on the scintillator surface of two detectors, namely on the side of the sealing epoxy cement of the entry window. The size of the color spots had increased after 16 years and such spots appeared also on other detectors. This state of the detectors did not result in a critical deterioration of the scintillation parameters. The color spots are associated with the aging of the material of the cement seam and the entry of moisture through the seam. Similar defects were not observed on the other surfaces of the scintillator.

The probability of defect-free storage of this lot of detectors during 16 years is equal to 1. The above results show that it is possible to use magnesium oxide powder in NaI(Tl) scintillation detectors, though magnesium oxide is a catalyst of the hydrolysis which occurs when water vapor is incident on the detector, yet does not interact with the scintillator.

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ESTIMATE OF THE RADIATIVE NEUTRON-CAPTURE CROSS SECTIONS OF 0.5 MeV NEUTRONS FOR ELEMENTS WITH A NATURAL ISOTOPE ABUNDANCE

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To calculate the radiative neutron-capture cross section of an element in a natural mixture of isotopes, it is necessary to know the cross sections of all of its stable isotopes. The evaluation of cross sections for many elements has not been conducted, because of the incompleteness of such information at the present time. If one makes use of the isotopic and isotonic systematics of the radiative neutron-capture cross sections of nuclei established by the author of the present work, then complete and reliable experimental data are not necessary, providing that the isotopic structure of the element is known. The abundance of isotopes in the earth's crust is constant, as a rule, except for several notable exceptions.

Isotopic and isotonic relationships, discovered as a result of the data analysis of radiative neutron-capture cross sections for 0.5-2 MeV neutrons by nuclei of 54 stable isotopes of several elements [1-3], have the form:

$$\sigma = \sigma_0 \exp\left[-K(N-Z)/A\right], \tag{1}$$

where σ_0 and K are constants, N, Z are the number of neutrons and protons of the nucleus, and A is the mass number. On a semilog plot, dependence (1) has the form of a straight line:

$$\ln \sigma = \ln \sigma_0 - K(N-Z)/A. \tag{2}$$

Estimating the cross sections, or determining the position of the straight line in spatial coordinates ln σ and (N − Z)/A can be determined by two methods:

from the known radiative capture cross sections of two reference isotopes or isotones (in the case of an isotonic dependence);

from the known radiative capture cross section of one reference isotope or isotone and the angle of the slope of the straight line (2), which can be determined by analogy with the slope of the straight line for corresponding groups of even nuclei that are neighboring in Z (or N in the case of an isotonic dependence.)

The procedure for evaluating the cross sections was executed in the following steps:

the choice of reference (one or several) experimental data on the radiative neutron-capture cross section was made separately for even—even and even—odd nuclei (by Z or N of the nucleus);

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