A γ-ray line with energy $E_\gamma = 11.3$ MeV was detected during an experiment, performed on a nuclear reactor, investigating the characteristics of the energy spectrum of γ-rays. The most likely source of this line is radiative capture of thermal neutrons by $^{59}$Ni nuclei, which accumulated in the corrosion-resistance steel as a result of the more than 20 years of irradiation in the reactor, via the reaction $^{58}$Ni(n,γ)$^{59}$Ni. It was found that for thermal-neutron fluence $10^{21}$ cm$^{-2}$ the $^{59}$Ni concentration is 0.47% of the $^{58}$Ni concentration.

A fundamental problem of the physics of nuclear fission is the characteristics of the energy spectrum of γ rays accompanying a fission process in the energy range >10 MeV. Experimental data on the energy spectrum of γ rays in the range 10–20 MeV have been obtained only for spontaneously fissioning nuclei $^{252}$Cf [1]. The spectra are characterized by the reciprocal slope $E_0 = 1.4$–2.2 MeV. The shapes of the spectra agree well with one another but they differ severalfold with respect to the intensity. The yield of γ rays in this energy range is explained by a highly excited state of the daughter nuclei, which arise in the fission process, and direct excitation of the giant dipole resonance. For energies above 20 MeV, the results of experiments and theoretical calculations are contradictory. In three experiments, no γ rays with such high energy were detected – only the upper limit was established [2]; in three other experiments, the energy spectrum was measured [3]. Theoretically, γ-ray emission in the range 20–80 MeV is attributed to coherent Bremsstrahlung of the products of fissioning of nuclei in a Coulomb field and depends on the fundamental characteristics of the nuclear fission process, such as the length of the neck of the fissioning nucleus, the mechanism of acceleration (instantaneous, purely Coulombic), and quantum-mechanical corrections to tunneling of fission products through the potential barrier. In different models, the computational results differ by a factor of 100. The discrepancy between the experimental and theoretical situations required that the investigations be continued since the detection of rare processes arising during fissioning of nuclei or the establishment of a stronger limit on the probability of such processes is important from the standpoint of expanding our knowledge on the structure of nuclear matter and the mechanism of nuclear fission. Consequently, the problem addressed in the present work was to investigate the spectrum of γ rays arising with induced fission of $^{235}$U nuclei by neutrons with energy >10 MeV.

The experiment was performed in the horizontal experimental channel of a nuclear reactor (Fig. 1). The energy spectrum was measured with a NaI(Tl) spectrometer with crystal diameter and length each 200 mm. To shield the detector from the neutron flux and decrease the γ-ray flux density to an acceptable level, a 300 cm long filter consisting of distilled water was placed between the spectrometer and the reactor core. The distance between the entrance and exit of the lead collimators was 150 cm. The diameter of the opening of both 15 cm long collimators is 2 cm. As a result, for reactor power 6 MW a γ-ray flux with intensity $I = 5 \times 10^4$ sec$^{-1}$ was incident on the detector.

Passive (lead, concrete) and active (scintillation detectors shielding surrounding the NaI spectrometer and operating in the anticoincidence regime) shielding was used as protection from the cosmic ray background. The signal from the anode...
A FÉU-49B device placed in optical contact with a NaI(Tl) crystal was fed into a charge-to-digital converter with integration time 300 nsec.

The lower part of the energy scale of the spectrometer was calibrated using $\gamma$-rays from a $^{60}$Co source. The gamma-ray lines due to the radiative capture of neutrons in aluminum and iron (7.72 and 7.64 MeV), contained in the plug of the horizontal channel and fuel assemblies [4], were used to calibrate the center of the energy scale. A monoenergetic secondary electron beam from the SIRIUS synchrotron was used for calibration in the energy range 30–100 MeV.

The resolution is $\delta = 11\%$ on the $^{60}$Co line ($E_\gamma = 1.33$ MeV) and $\delta = 7.7\%$ on the 7.72 MeV and 7.64 MeV lines (unresolved lines), after which it is slightly energy-dependent, remaining at the level ~8%. Calculations show that the $\gamma$-ray detection efficiency of the NaI spectrometer is 95% in the range 1–10 MeV and then remains at the 85% level [5].

![Fig. 1. Experimental arrangement in the horizontal experimental channel of a nuclear reactor: 1) horizontal experimental channel; 2) NaI(Tl) spectrometer; 3) system of scintillation counters connected in anticoincidence; 4, 5) lead collimator; 6) cadmium absorber; 7) core; 8) reactor shielding; 9) water filter; 10) water basin; 11) shielding box.](image)

![Fig. 2. Instrumental $\gamma$-ray energy spectrum.](image)