EXPERIMENTAL RESEARCHES OF NUCLEAR REACTOR NEUTRON & GAMMA RADIATION SCATTERING INTO THE ATMOSPHERE

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ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ РАССЕЯНИЯ В ВОЗДУХЕ НЕЙТРОННОГО И ГАММА-ИЗЛУЧЕНИЙ ЯДЕРНОГО РЕАКТОРА

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Radiation situation around different nuclear-technical facilities in some cases is determined by radiation scattering in the air. This is known as "skyshine"-radiation. Reliable experimental data are required to verify calculation methods and to formulate specific recommendations for designing the nuclear facilities shielding.

The authors have suggested and realized the "skyshine" experiment, using the RA and IVG.1M specialized research reactors as the radiation sources, which permit emitting intensive radiation fluxes upward. The reactors are sited near Semipalatinsk (Republic of Kazakhstan) in a desolate steppe region at ~290 m altitude above sea-level, with the altitude difference never in excess of ±5 m. The distance from the nearest residential settlement is at least 60 km.

Spatial distributions of radiation on the site were measured in the southern direction from the reactors, which is not built up. Four series of the reactor startups were performed in the period of October 1996 - October 1997. Radiation levels were measured at distances of 50, 100, 200, 300, 400, 500, 600, 800 and 1000 m from the reactor axis, the detectors being fixed at a 1 m height from the ground surface. A wide range of detectors, including dosimetric, radiometric and spectrometric instruments, was used in the experiment.

Besides, for studying characteristics of the reactors as radiation sources, radiation fields directly above the reactors were considered in greater detail. Distributions of fast neutron and thermal neutron fluxes and gamma radiation dose rate in the radial direction at three heights from the reactor cap were measured. The activation detectors and thermoluminescent glasses were used for the purpose. Neutron spectra in wide energy range were measured with the help of 18 threshold and resonance detectors.

In the report there are results of measuring radiation distribution on the caps of RA and IWG.1M reactors. Comparative analysis of the results is also in the report. There are neutron spectra in the interval of energies from 10^{-9} to 13 MeV above RA and IWG.1M reactors. The spectra were measured with a set of activation detectors. Measurements were calculated to a nominal rate: for RA reactor – 300 kW, for IWG.1M – 7 MW.

Neutron and gamma radiation scattered in the air was measured at a distance from 50 to 1000 m from the reactors in different calendar periods, hence, the weather conditions differed essentially:

- summer (June) - the air temperature was 35-40°C, atmospheric pressure was 720-730 mm Hg, relative air humidity was 20-30%;
- autumn (November) - the air temperature was minus 10-15°C, atmospheric pressure was 760-770 mm Hg, relative air humidity was 60-70%.

There were obtained results of measurements of neutron dose rate D_n, intermediate and fast neutron fluxes Φ_{int+f}, thermal neutron flux Φ_{th}, gamma radiation dose rate D_γ at different distances from the RA and IVG.1M reactors. The error of the dosimetric and radiometric measurements does not exceed 10-20% as a rule. The IVG.1M radiation measurements at great distances, where the error reaches 25-30%, are the only exception.

The influence of the weather conditions on radiation levels, especially at great distances, are clearly traceable.

The data obtained in the first approximation may be presented as a simple ratio:

$$D_{n,\gamma}(r) = D_{n,\gamma}(r_0) \times \left(\frac{r_0}{r}\right) \times \exp(-\frac{r - r_0}{\lambda_{n,r}}),$$

where:

$D_{n,\gamma}(r)$ - dose rate at a distance of r, μSv/h;
$D_{n,\gamma}(r_0)$ - dose rate at a distance of r_0, μSv/h;
r - distance from the reactor, m;
$r_0 = 50$ m;
$\lambda_{n,\gamma}$ - the value of relaxation length for neutron and gamma quanta dose rates, m;

The table contains values for relaxation lengths λ_n and λ_γ derived from the ratio for the RA reactor. Evidently, the relaxation lengths for neutron and gamma quanta dose rates vary within 10-20% depending on the weather conditions. For the IVG.1M reactor the values of relaxation lengths within measurement error of ±5% coincide with the data obtained for the RA reactor.

VALUES OF RELAXATION LENGTHS FOR NEUTRON (λ_N) AND GAMMA QUANTA (λ_γ) DOSES

Distance, m	λ_n, m		λ_γ, m	
	autumn	summer	autumn	summer
50-200	100	110	105	105
200-500	113	131	112	147
500-800	125	145	177	189

In the report there are also energy distributions of neutrons in the energy range from 30 keV to 8 MeV for the RA reactor have been measured by H spectrometer, ^{3}He spectrometer and fast neutron spectrometer with a stilbene crystal, the results are presented in Fig. 10. The error of measurements in the energy range $E_n < 0.5$ MeV does not exceed 10-15%, in the range of 0.5 MeV - 2 MeV - 15-20%, and in the range $E_n > 2$ MeV - 20-30%.

It follows from the data provided that the spectrum shape changes but slightly with increase in the distance from 100 to 400 m and it is similar to the 1/E form in the intermediate energy range. A peak in neutron spectra for the fast energy range $E_n \approx 5$-6 MeV is noteworthy, moreover, the peak increases with the distance. It stems from irregularities in nitrogen and oxygen cross sections in the energy range mentioned.

In the course of reactor experiments there were performed measurements of the on-site gamma quanta energy distributions at distances varying from 100 to 400 m from the RA reactor obtained using spectrometer with a stilbene crystal. Data have been processed using the FERDO code. Statistical error of the measurements does not exceed 10 % and total error is 10-15 %. As to their shape the spectra are very "hard" and vary but slightly with the distance increase up to 1000 m. For energies above 1 MeV the spectra are determined entirely by secondary gamma radiation, mainly as a result of neutron capture on nitrogen and oxygen nuclei. In the spectra the peaks of capture gamma-radiation of nytrogen in the range of 3.5 – 3.7 MeV; 5.2 – 5.4 MeV; 5.8 – 6.0 MeV; 7.2 – 7.6 MeV; 8.2 – 6.5 MeV.

Thus, vast experimental information relating to distribution of the RA and IVG.1M reactor gamma and neutron radiation scattered in the air for distances varying from 50 to 1000 m from the reactors has become available. The data obtained will be used to verify the calculation codes and to validate the group nuclear constants.

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