Experiments on the neutralization of radioactivity and the processing of their results

Execution of experiments

With the purpose to practically verify the possibility of the neutralization of a radioactive substance inside a solid body due to the initiation of a self-developing collapse in it, about 100 experiments named "Experiments on the neutralization of radioactivity" were carried out on targets made of radioactive materials at the Laboratory "Proton-21" (positioned on the leased territory of the Institute of Nuclear Research of the NANU).

In the experiments, we used targets containing partially activated cobalt or silver. A target was positioned at the center of a specially manufactured hermetic body (a chamber) which excluded the leakage of a radioactive substance.

The high-energy action of the electron beam on a target resulted in its explosion, and then its fragments were deposited on the internal surface of the body.

The measurements of radioactivity were performed prior to and after the experiment at a distance of 770 mm for various positions of the body (see Fig. 1) by using a Ge-Li gamma-detector DGDK-100 V-3 on the basic spectral lines of the target substance. A change of the position was realized by a turn of the body around its symmetry axis by 90 degrees. In such a way, we performed in 10 measurements (positions 1–10) prior to and after the experiment. The conclusions on the amount of the residual radioactivity were drawn by comparing the results of measurements prior to and after the experiments.

Methods of estimation of the residual radioactivity and the arisen problems

Upon the determination of a residual radioactivity, the main problem is to estimate the partial or complete distribution of a target substance over the body's walls. Due to a sufficiently complex form of the body, the redistribution of the radioactive substance changes significantly the character of the absorption of radiation by details of the chamber. The change of the absorption should be taken into account upon the comparison of the results of measurements of radioactivity prior to and after the experiment. This circumstance becomes especially important in connection with the fact that, at present time, the degree of neutralization does not exceed 10% in most experiments. In this case, the opponents can always call into question the running of the process of neutralization, by explaining the decrease of the counting rate of a detector by the increase of the absorption of gamma-quanta after the redistribution of a radioactive substance in the body.

Thus, in order to strictly prove the presence of the process of neutralization in the experiments executed at the Laboratory "Proton-21", it is necessary to take into account all the circumstances, including even the insignificant factors, in the determination of a neutralization degree.

To estimate the influence of the absorption of radiation by elements of the body after the redistribution of a radioactive substance in the volume of the hermetic chamber, we may use a number of indirect methods:

1) To place the calibrated sources of radioactivity at various points of the body's internal surface and, by performing the measurements, to obtain some averaged value of the absorption of radiation;
2) Since the radiation absorption coefficient depends on the energy of quanta, we can use the ratio of the readings of a spectrometer for different spectral lines for the estimation of the attenuation of radiation in details of the chamber;
3) It is logical to assume that the main tendencies of the distribution of a radioactive substance in the volume of the body are repeated from experiment to experiment; then,

by successively washing away the sprayed radioactive substance from different areas of the internal surface of the chamber, we can estimate its distribution.

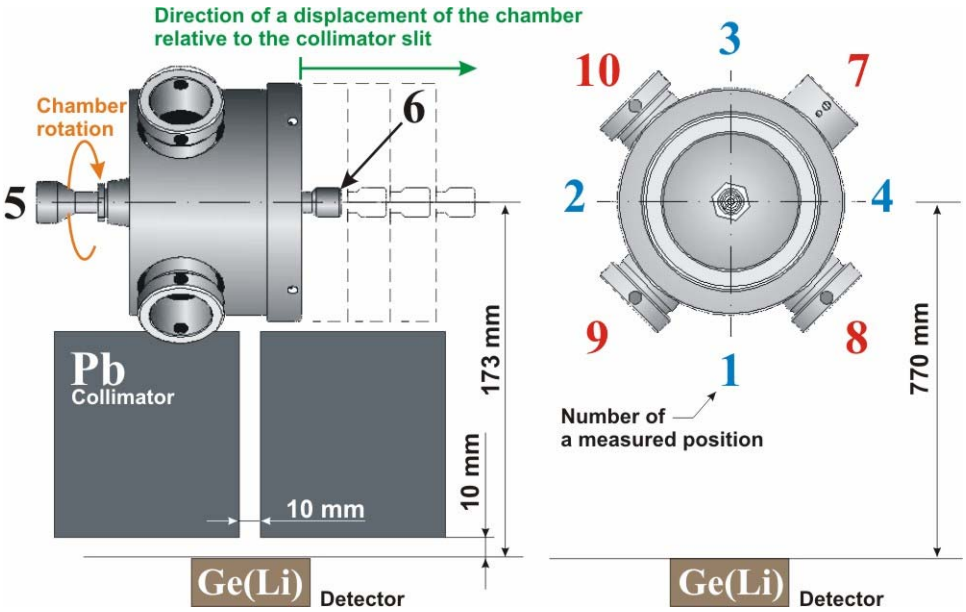


Fig. 1. Scheme of measurements of the distribution of radioactivity in the chamber with a collimator (a) and without it (b).

By calculating a change of the readings of a spectrometer and by introducing the correction on a change in the absorption, we can estimate the amount of a residual radioactive substance.

A drawback of such approaches consists in the following. In the first case, one uses, to various extents, the assumptions about the distribution of radioactivity in the body after the experiment. In the second and third cases, the results can be used only as estimating ones. Moreover, the great difficulties arise in the calculation of errors of the derived results.

A direct exact method for the determination of the amount of radioactivity

The procedure of calculations which would raise no doubts must be based only on the results of measurements of radiation and give both the maximally and minimally possible amounts of a radioactive substance in the body. Such an approach leads to the classical problem of mathematical programming: to find such a distribution function for the substance of an exploded target in the body which meets all the performed measurements as restrictions and maximizes (minimizes) the total amount of a radioactive substance.

The necessity to solve this specific problem has led us to the development of a sufficiently universal method used to calculate the amount of a radioactive substance in an assembled structure. In this case, we took into account that the components of the object have a complicated, but known, topology and are made of different materials. Moreover, the studied object itself cannot be dismounted. That is, one can carry out only the integral measurements of radioactivity under conditions of the complicated character of the absorption of radiation by the object components without any reliable information on the distribution of a radioactive substance in the object.

We succeeded to reduce the problem of mathematical programming to the well-studied problem of linear programming, which allowed us to quite efficiently solve it on available computers. In view of the three-dimensional geometric model of the body corresponding to its actual sizes with accuracy better than 0.01 cm, we constructed a network on its internal surface. The amount of a radioactive substance at each node of the network covering the possible places of accumulation of radioactivity was described by a separate independent variable. Based on the

body's model, we calculated the radiation attenuation coefficient for the paths from each point of the internal surface of the body to a spectrometer and presented its readings in the form of a linear equation for the unknown masses of the substance at nodes of the network. Taking into account the fact that the measurements are carried out with some errors, we associated each equation with two inequalities. These inequalities constructed for all the performed measurements compose a system of restrictions for the posed problem of linear programming. As a target function, we take the total amount of the substance at all nodes of the network. Finding the minimum and maximum, the given problem was solved.

It is obvious that the real amount of a radioactive substance in the body is between the determined values of the minimum and maximum. The difference between them decreases as the number of measurements increases.

For one of the bodies used in the experiments on neutralization, we have carried out additionally 64 measurements (in positions 1–4) with a slit collimator made of Pb (Fig. 1a), which allows us to determine the amount of the radioactive substance with an error of about 1%. Its amount was (90.06 – 91.81)% of the initial value.

By transforming the equalities into inequalities, we took into account the statistical error of the readings of a spectrometer (± 2.5%) and the error of the mathematical model (±0.3%) which was obtained by the run of the method on the *a priori* known data. The total error was ±2.8%.

We note that, within this method, the result was obtained only on the basis of the measurements without the use of any assumptions. Such an approach allowed us to consider all the sources of possible errors. The obtained results of calculations have proved convincingly and strictly the fact of the neutralization of at least 8% of the radioactive isotope ^{60}Co in a given experiment, whose atoms were supposedly distributed uniformly in the target volume after its irradiation with neutrons from a nuclear reactor.

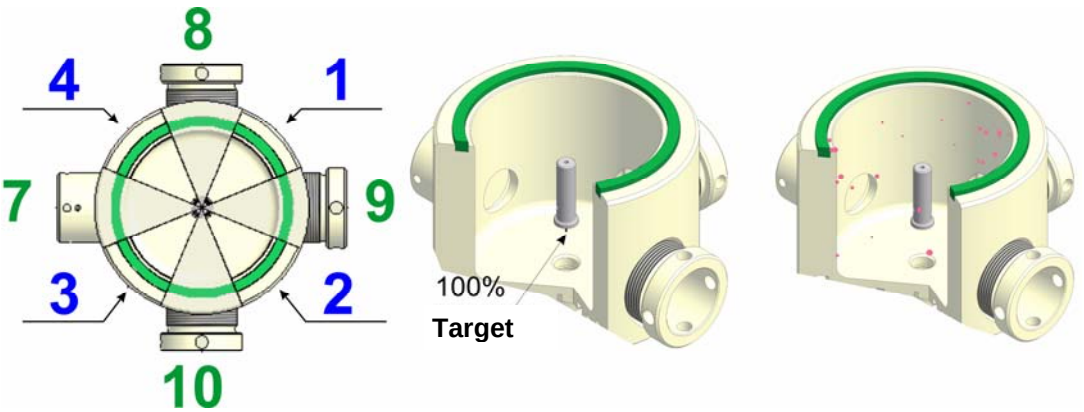
As a result of the solution of the above-indicated problem, we have determined some distribution of the radioactive substance at nodes of the network. We note that the used method does not allow one to find the real distribution of radioactivity over the internal surface of the body with high accuracy, but it indicates the positions of areas of the internal surface with enhanced concentration of a radioactive substance (Figs. 2–3). In Fig. 2, we show schematically the top view of the chamber with the indicated numbers of positions under the measurement and the chamber cuts (without the lid) prior to and after the experiment. Fig. 3 displays the chamber which is cut into sectors corresponding to the numbers of positions.

Conclusions

The developed method is based only on the results of measurements, uses no assumptions, and allows one:

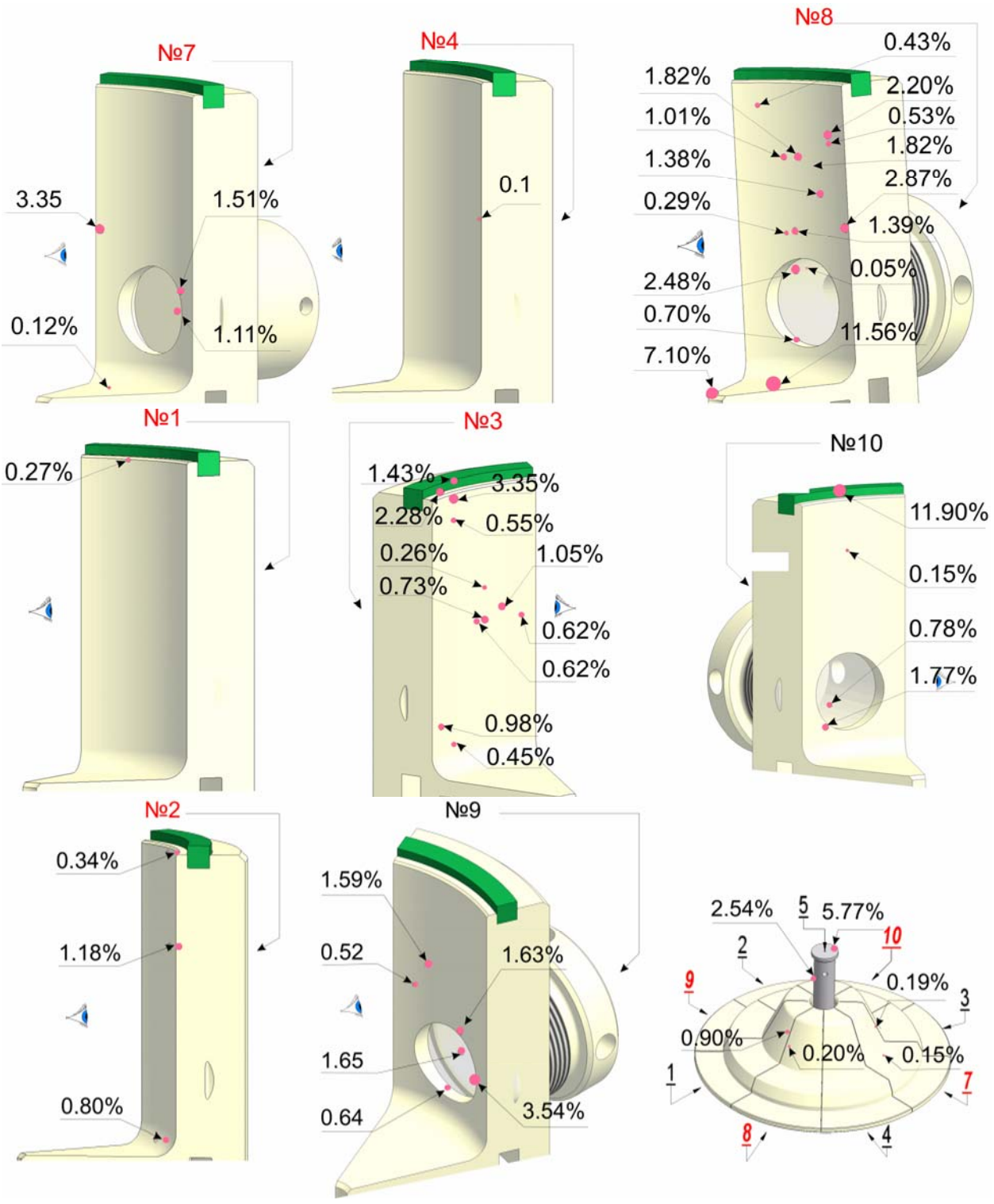
1. To determine the total amount of radioactivity in an inaccessible closed object with necessary accuracy.
2. To localize, with sufficient reliability, the «spots» where radioactivity is concentrated.
3. To utilize an inexpensive commonly available measuring equipment for the execution of measurements.
4. To apply a commonly used computational hardware in calculations (the summary time of computations for one measurement was about 7 min on a computer with the Intel Pentium III processor)

The decrease in the total radioactivity inside the hermetic chamber cannot occur without the running of nuclear reactions. Hence, the used method has once more confirmed the fact of the running of nuclear reactions in the setup of the Laboratory «Proton-21» in the course of experiments on the impact compression of a substance.



a b c

Fig. 2. Scheme of the body:
a – top view;
b – a cut of the body prior to the experiment (without the lid);
c – a cut of the body after the experiment (without the lid)



● – a network node with the possible concentration of radioactivity; the circle diameter is proportional to the calculated amount of the residual radioactivity at the node and in its vicinity

7.10% – the amount of the residual radioactivity in % of the initial one

Fig. 3. Scheme of the body's sectors with the indication of the calculated relative amount of the residual radioactivity