STANDARDIZATION FOR IONIZING RADIATION*

V. A. Kut’kov, V. F. Demin, and V. Ya. Golikov

By January 1, 2000, all organizations in the Russian Federation should have implemented the new Russian standards for radiation safety NRB-96 [1]. They were adopted in 1996 to replace the former USSR standards for radiation safety NRB-76/87 [2], which in fact had existed in almost unchanged form for more than 30 years. Developments in radiation safety standards represent a history of improving systems for monitoring and managing ionizing radiation sources. Up-to-date radiation safety standards in this country require the rethinking of purposes, tasks, and methods in providing radiation safety and radiation shielding for staff and populations.

**Radiation Safety.** Radiation safety and protection require a system of measures including the following:

1) procedures and equipment for keeping the radiation doses to individuals and the risks of serious consequences below set limits and the lowest possible level actually attainable;

2) means of protecting individuals from ionizing radiation and ensuring safety; and

3) procedures and equipment for preventing accidents or for alleviating their consequences if they occur.

The purposes of radiation safety measures consist in protecting the health of individuals from the harmful effects of ionizing radiation by observing basic principles and standards subject to unsound constraints on useful activities in the use of ionizing-radiation sources. On current ideas, the main content of radiation safety consists in managing the sources at all stages in their life cycles to provide safe states. It is possible to manage various forms of ionizing-radiation source (natural, man-made, and medical ones) and the corresponding forms of radiation in various ways. By irradiation is meant the exposure of people to ionizing radiation. A measure of the effect is provided by the radiation dose, whose determination is dependent on the effect considered as the result of the action. Real hazards to human health are represented only by sources that have escaped from monitoring, since under normal conditions the controlled use means that the radiation doses to staff and the population are small. Under these conditions, the total irradiation dose to a person from all types of sources acting on him is not regulated, and the irradiation by sources of various forms is regulated separately by the use of various approaches. The purposes of radiation safety measures are attained primarily by monitoring and managing ionizing-radiation sources. There are several forms of irradiation as regards the source management periods:

1) completed irradiation, namely irradiation that has occurred in the past. Its value is already formed, and it cannot be controlled at present;

2) current irradiation: part of the irradiation occurring at present time. The radiation safety system should include methods and means of managing the dose of that irradiation; and

3) potential irradiation: irradiation that may occur in the near future, over a certain period of time, or in the remote future. The potential irradiation dose is a stochastic quantity, and it can be predicted only with a certain probability on the basis of experience in handling the sources.

In radiation protection, there are two forms of radiation to be managed: current and potential. The current irradiation dose reflects how well the source is operated and how well the operations correspond to the radiation safety requirements, with individual dose monitoring acting as one of the means of feedback between the source and the controller of it. On the whole, radiation monitoring is a tool in forecasting the potential dose and in evaluating the stability of operations with the source insofar as it is well controlled.

---

*Journal form of a report to the 7th Russian conference on protection from ionizing radiations at nuclear engineering plants (Obninsk, GNTs RF-FEI im. A. I. Leipunskii, September, 1998).
Standardization Development. The scientific basis for radiation safety is provided by observations over many years on groups of irradiated people. The purpose of the long-term observation is to identify regularities in the effects of ionizing radiation at low doses such as are characteristic of normal source working conditions. Irradiation causes two classes of effect: stochastic and deterministic. The stochastic effects include radiation-induced cancer (malignant tumors and leukemias) and serious inherited diseases. All the other effects usually are deterministic. The most important parameters characterizing those effects for radiation safety purposes are as follows:

1) the latent period (period separating the action of the ionizing radiation from the occurrence of effects in the form of diagnosable diseases). The latent period for stochastic effects is comparable with human lifetimes. As a rule, deterministic effects have much shorter latent periods;

2) a reduced probability of realizing an effect: the probability of realizing an effect of radiation is dependent on the dose and the time after irradiation. This probability is close to zero from times much less than the latent period. In irradiation safety, one usually considers the probability referred to the entire expected lifetime for reduced probability. The reduced probabilities of effects leading to death are usually called the probabilities of premature death. The dose dependence of the reduced probability for a deterministic effect has a threshold in the region of high doses, below which the occurrence of the effect is unlikely. When the threshold is exceeded, the probability approaches one rapidly. In the low-dose range, one assumes a linear dependence of the reduced probability for stochastic effects;

3) the severity of the effect: the number of years of life lost as a result of premature death or disease caused by the radiation. The severity of a deterministic effect increases with the dose above the threshold. The severity of a stochastic effect is usually independent of dose.

The largest contribution to radiation safety has come from research on effects in people who have received high doses from radiation accidents and victims of the military use of atomic weapons: those who survived the nuclear bombadiments of Hiroshima and Nagasaki in 1945. Analysis of the stochastic effects from ionizing radiation in the Japanese cohorts is extremely important for the development of radiation safety. Figure 1 shows the time distribution of the probability of death from radiation-induced cancer for the Japanese cohort. These data [3] illustrate the trends in the effects in the cohort, which includes persons aged from 0 to 18 at the time of irradiation and who received external γ-ray doses of about 1 Gy. Other levels for the effects with a similar time course are to be expected for cohorts of such ages who received other doses, where there are two waves: the first is premature death from leukemia and the second is from solid cancers.

The data from the Japanese studies form the principal basis of the recommendations of the International Commission on Radiation Protection ICRP, which is an independent and highly authoritative scientific organization dealing with radiation safety and protection. The ICRP recommendations of 1959 [4] were published after the data had been surveyed on the realization of deterministic effects and realization of the first wave of stochastic effects, which were revised in 1967 and 1969 [5, 6]. The ICRP recommendations formulated the concept of the critical organ, which was used in radiation safety principles in the USSR. The purpose of the concept was to restrict the probability of deterministic effects on human irradiation. It largely reflected the health approach to safety in handling dangerous chemical substances. This concluded the first major stage in researching the consequences of nuclear strikes at Hiroshima and Nagasaki.

At the start of the 1970s, developments in nuclear power required an effective tool for the optimum radiation protection of large groups of staff and the general population. The critical organ concept was unsuitable here. A solution was