UDC 531:535

D.Sci. Tech., prof. **Banzak O.V.** (SUITC)
D.Sci. Tech. **Sieliykov O.V.** (KNUCA)
Dr. Sci. Tech., prof. **Yefimenko N.A.** (ChNU)
Konovalenko O.I. (m/u A 3814)

DOI: https://doi.org/10.17721/2519-481X/2021/71-01

DEVELOPMENT OF A COMPLEX FOR INDIVIDUAL DOSIMETRIC CONTROL

At present, practically all branches of industry, many branches of science use sources of ionizing radiation (IR). Nuclear power plants, gamma plants of various capacities, flaw detectors, counters and many other equipment are widely used in the defense complex, medicine, agriculture. However, the most important sector of the use of IR in Ukraine after the elimination of nuclear combat potential is nuclear power. The country has five nuclear power plants (NPP) with reactors of two types, which generate about 40% of the country's total electricity.

In this regard, the problems of dosimetry, which today have become an independent scientific and technical area of nuclear physics, are acquiring ever increasing importance. Dosimetry, in its essence, solves the problem of linking physical quantities with the expected radiation effects of the use of IR.

When standardizing radiation doses for personnel in accordance with international recommendations and rules, the issue of reducing the dose costs of personnel, and, first of all, repair costs, arose sharply, since the main contribution to the collective radiation dose of NPP personnel is made by maintenance and repair work. At the initial stage, it was possible to reduce the radiation doses mainly due to the implementation of organizational measures of administrative increase in the requirements for the quality of preparation and performance of work in the controlled access area. Further reduction of personnel dose loads can be ensured by introducing ALARA principle into the NPP operation practice. To do this, it is necessary to create a system for monitoring the radiation situation and personal dosimetry, which could ensure the identification of areas with increased radioactivity and measure the full set of their parameters (at least, dose, dose rate, coordinates, time point, personal dosimeter number) in real time. without the participation of the wearer of a personal dosimeter, that is, within the framework of his normal life and without his knowledge, if the dose rate does not exceed the maximum permissible level. When this level is exceeded, the wearer of a personal dosimeter must be warned of the impending danger in order to take part in actions to overcome it, but not as an intermediary in the process of the above measurements.

On the basis of this concept, a complex of individual dosimetric control is proposed in this work.

Keywords: nuclear power, personnel exposure dose, radiation monitoring, radiation dose rate, personal dosimeter

Introduction. The main task of dosimetry – identification of sources ionizing radiation (IR) that pose a threat to the environment and humans – today is solved using a variety of technical registration tools with varying degrees of efficiency. In addition, the existing variety of terms and values in this industry requires some clarification in order to convey the reliability of the presented research results. Nowadays, almost all industries, many branches of science use IR. Nuclear power plants, gamma plants of various capacities, flaw detectors, counters and many other equipment are widely used in the defense complex, medicine, agriculture [1-3]. However, the most important sector of the use of IR in Ukraine after the elimination of nuclear combat potential is nuclear power [4]. The country has five nuclear power plants (NPP) with reactors of two types, which generate about 40% of the country's total electricity [5, 6].

In this regard, the problems of dosimetry, which today have become an independent scientific and technical area of nuclear physics, are acquiring ever-increasing importance. Dosimetry, in its essence, solves the problem of linking physical quantities with the expected radiation effects of the use of IR. The main task of dosimetry – identification of sources radiation, posing a threat to the environment and humans – today is solved using a variety of technical registration tools with varying degrees of efficiency. A comparative analysis of such means and methods of their application for registration and dosimetry is presented in this section [7, 8]. In addition, the existing variety of terms and values in this industry requires some clarification in order to ensure the reliability of presented research results.

Formation of the problem. The development of nuclear energy, the spread of nuclear technologies have put forward new requirements for the control and metrology of ionizing radiation. The modern level of nuclear instrumentation cannot fully satisfy them. The solution to this problem can be provided by the development of: methods for choosing the optimal type of semiconductor materials and controlling their properties to create uncooled detectors; sensors with higher resolution; electronics with less noise; computer methods and information processing programs with lower estimated costs; control systems for nuclear materials and the state of NPP protective barriers that meet the requirements of existing automatic control of radiation safety (CRS).

Analysis of previous studies. The level of development and application of radiation technologies is largely determined by the state of nuclear instrumentation. In a relatively short period of time, this industry has gone through several stages of development, and each of them was marked by the emergence of various devices that register and measure the parameters of ionizing radiation: gas-discharge counters, scintillators, semiconductor detectors, and others. Their appearance and further widespread use was provided in the past by works from Crookes, Rutherford, Geiger and Müller to the works of A.B. Dmitriev, S.N. Perelman, V.G. Tchaikovsky, and V.G. Baranov, which are closer to us in time. I., Golbek G.R., Nemirovsky B.V., Yakubovich A.L. and many others. The basis for the progress of nuclear instrumentation was the simultaneous development of two directions - nuclear physics research and electronics. However, both directions at that time developed independently, without proper mutual connection.

The advent of modern semiconductor sensors for the first time linked nuclear instrumentation and electronics into a single complex – a semiconductor detector. It combines semiconductor primary converter of ionizing radiation (sensor), secondary converter of information from the sensor (electronics) and software for processing this information, interconnected in terms of the problem being solved and parameters. The possibility of the appearance of such a complex is provided in materials science by the works of Vavilov V.S., Baransky P.I., in applied nuclear physics research by M.V. Maksimov, O.V. Maslova. and others. In these works, a technique was shown for the selection of semiconductor materials and a design of sensors was proposed, directions for the creation of electronics and computer programs for detectors were determined. This ensured the creation and effective use of semiconductor detectors in dosimetry, radiation control of materials and technological processes of nuclear power plants.

Main part. In this work, a complex is proposed, which consists of a main unit – an individual electronic direct-display dosimeter (ID) and an expansion unit – "cassette boxes" with individual dosimeters nested in the compartments-cells. The multiplicity of the ID connection in the cassette holder is 256 ID. The total number of serviced cassettes is limited only by the capacity of the battery charging module for personal dosimeters (Fig. 1).

The development of modern detecting units designed to monitor the state of protective barriers by measuring the dose rate of gamma radiation in the air as part of the radiation monitoring systems of nuclear power plants is an important and urgent task. The detecting units of AKRB-03 system currently in operation have exhausted their resource (AKRB – radiation safety monitoring equipment) [9 - 11]. The system itself, developed more than 20 years ago, has not only exhausted its resource, but is also morally outdated [12, 13]. It is obvious that new detecting units should have higher metrological and operational parameters. A significant improvement in the metrological and operational characteristics of detectors, as shown above, can be obtained only through the use of new materials, in particular, wide-gap semiconductors such as CdZnTe [14].

The functions of the main unit are as follows:

– presentation of the interface to an individual dosimeter;

– receiving information from an individual dosimeter (personnel number, route, dose, time, errors, temperature, etc.);

– recording of service information into an individual dosimeter (time, dose limit);

– recharging the battery of personal dosimeter while it is in the cell.

Expansion unit (EU) – "cassette holder" serves as an intermediate link between the control computer and the individual dosimeter. All records are stored and processed in a computer. EU presents a computer interface for communication with a dosimeter. The control computer interacts with EU via RS-232 or RS-485 serial interface.

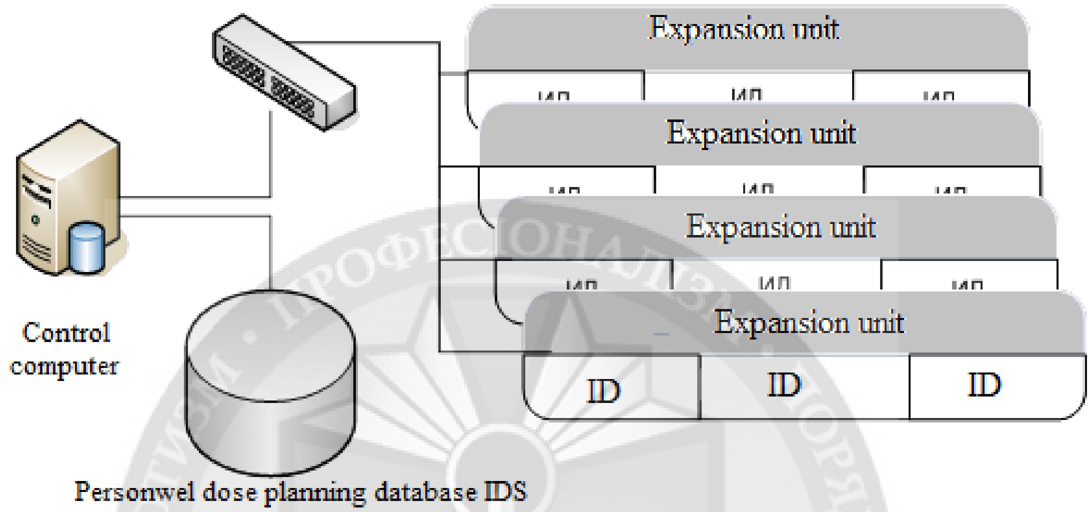

Figure 1 – Block diagram of the individual dosimetric control complex

The individual electronic dosimeter is made in accordance with the requirements of the "Unified requirements for individual dosimetric control ET IDK" and other regulatory documents, since works on the basis of BDMG-CZT detection unit.

The sensitive element of the dosimeter is made on basis of CdZnTe crystal and is a complete element of the detector. The dosimeter uses the algorithm for software correction of the “stiffness course” of the recorded radiation, which was considered earlier.

Functionally, an individual dosimeter consists of the following units (Fig. 2):

– detection (detector, preamplifier, pulse normalizer);

– detector power supply (programmable voltage supply to the detector);

– temperature measurement (dose measurement correction is implemented on DS18B20);

– real time clock (for calculating the dose rate DS1302);

– indications and notifications (indication of time, ambient temperature, dose rate, dose, thresholds for setting dose load, battery discharge, etc., indicator from NOKIA telephone);

– log memory (to save intermediate dose measurement results on the way of personnel and at the workplace AT24C512);

– wireless interface (to receive access control labels for certain zones, as well as presence at the workplace);

– single-wire interface (for data transmission through the main unit to a computer);

– power control (to control battery charging);

– microcontroller (for general organization of operation ATMEGA8 device control).

The design of the dosimeter is a standard miniature plastic case from Bopla for hand-held devices, BOPLA-Arteb 335 series in shockproof dust and moisture resistant design. Its three-dimensional model is shown in Fig. 3.

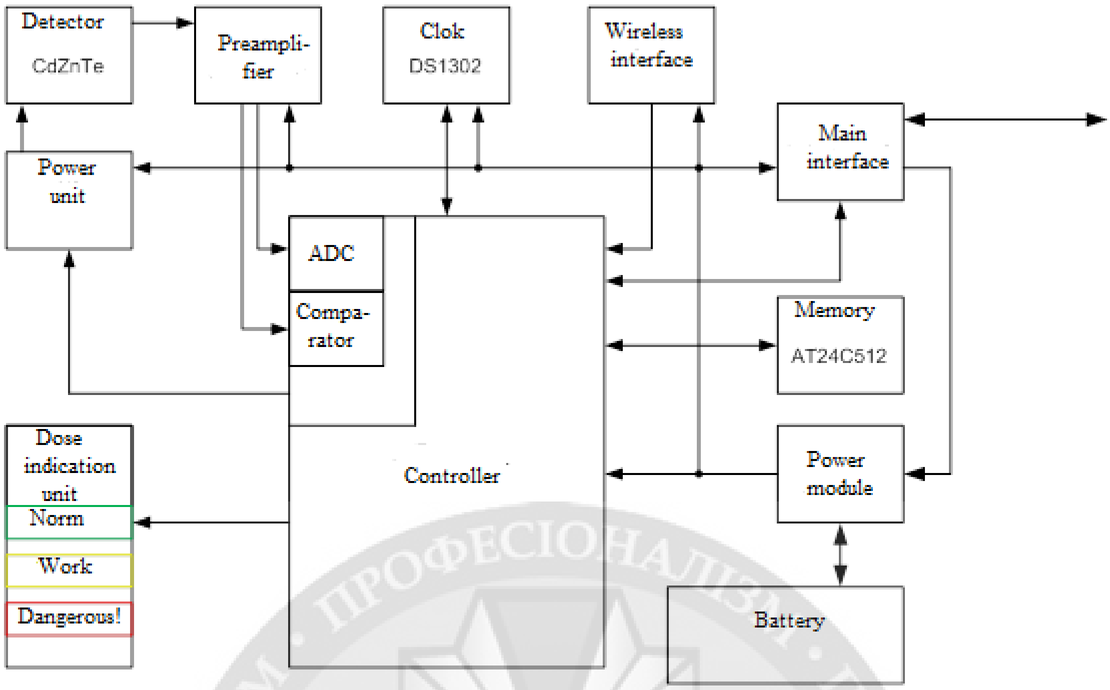

Figure 1 – Block diagram of an individual dosimeter (functions of blocks in text)

For the first time, a complex of individual dosimetric control has been developed. The complex consists of an individual electronic direct display dosimeter (ID) and an expansion unit (EU) with ID located in the cells.

The use of such a complex will allow for the first time to create a system for monitoring the radiation situation and personal dosimetry capable of detecting areas with increased radioactivity, measuring a full set of their parameters in real time, the radiation dose of ID carrier, etc. and will ensure the introduction of ALARA principle into the practice of NPP.

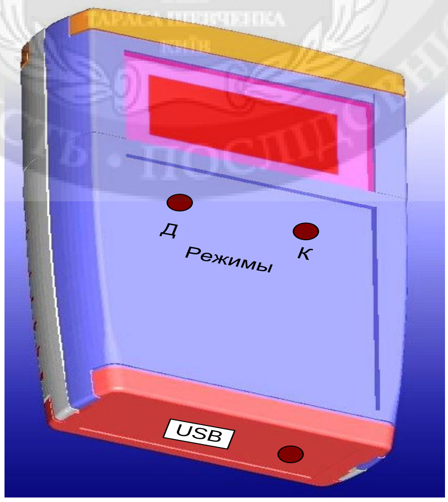

Figure 1 – Appearance of an individual dosimeter: D - dose indication;
K - indication of control dose levels

Conclusions. For the first time, a complex of individual dosimetric control has been developed. The complex consists of an individual electronic direct display dosimeter (ID) and an expansion unit (EU) with ID located in the cells.

The use of such a complex will allow for the first time to create a system for monitoring the radiation situation and personal dosimetry capable of detecting areas with increased radioactivity, measuring a full set of their parameters in real time, the radiation dose of ID carrier, etc. and will ensure the introduction of ALARA principle into the practice of NPP.

REFERENCES:

1. Vavilov V.S. Effect of radiation on semiconductors / V.S. Vavilov, N.P. Kekelidze, L.S. Smirnov. - Moscow: Nauka, 1988. -192 p.

2. Lenkov S.V. Physical and technical foundations of radiation technology of semiconductors / S.V. Lenkov, V.A. Mokritsky, D.A. Peregudov, G.T. Tarielashvili. - Monograph. - Odessa: Astroprint, 2002. 297 p.

3. Garkavenko A.S. Radiation modification of the physical properties of wide-gap semiconductors and the creation of high-power lasers on their basis / Lvov: ZUKTs, 2012. - 258 p.

4. Banzak OV New generation semiconductor detectors for radiation monitoring and dosimetry of ionizing radiation / O.V. Banzak, O.V. Maslov, V.A. Mokritsky: Ed. V.A. Mokritsky, O.V. Maslov. - Monograph. - Odessa, 2013. - Publishing house "VMV". - 220 p.

5. Bouchet J.M. PWR primary flow masurements by correlation analysis of nitrogen-16 fluctuations / J.M. Bouchet, et al. – Progress in Nuclear Energy. – 1982. – Vol. 9.

6. Awadalla S.A. Characterization of detector-grade CdZnTe crystals grown by traveling heater method (THM) / S.A. Awadalla, J. Mackenzie, H. Chen, eds. // Journal of Crystal Growth. – Vol. 312, issue 4. – 2010. – 507-513c.

7. Grybos P. Front-end Electronics for Multichannel Semiconductor Detector Systems; EuCARD Editorial Series on Accelerator Science and Technology, Vol.08 / Institute of Electronic Systems Warsaw University of Technology. – Warsaw: 2010. – 201 p.

8. Dumitrescu A. Comparison of a digital and an analogical gamma spectrometer at low count rates / A. Dumitrescu // U.P.B. Sci. Bull., Series A. – Vol. 73. – Iss. 4, 2011. – P. 127-138.

9. Maslov O. Passive Computer Gamma- Tomography of Nuclear Fuel / O. Maslov, V. Mokritsky, O. Banzak, // ANIMMA. Third International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications – Marseille, June 23-27, 2013. – Book of Abstracts – P. 51.

10. Maslov O.V. The Improved CdZnTe Dose Rate Probe / O.V. Maslov, M.V. Maksimov, L.L. Kalnev // 2008 IEEE Nuclear Science Symposium, Medical Imaging Conference and 16th Room Temperature Semiconductor Detector Workshop – Dresden: 19–25 Oct. 2008. – P. 12-87.

11. Maslov O. Multiple energies passive computer tomography of nuclear fuel / O. Maslov // Proceedings of the International Ukrainian-Japanese Conference on Scientific and Industrial Cooperation – Odesa 24 – 25 October 2013. – P. 114-116.

12. Masuruk K. Dopant incorporation during liquid phase epitaxy / K. Masuruk, T.Bryskewicz // J. Appl. Phys., 1981. – V. 52. – N3. – part 1. – P. 1347–1350.

13. Mokritsky V.A., Maslov O.V., Bansak O.V. Methods and means controls of nuclear materials and state of protective barriers at nuclear power plants // Collection of scientific works of the Military Institute of the Taras Shevchenko National University of Kyiv. - К .: MIKNU, 2019. - № 63. – P. 66 – 72.

14. Mokritskij V.A., Maslov O.V., Banzak O.V. The detector on basis of CdZnTe-gauge for systems radiating-technological control // Collection of scientific works of the Military Institute of the Taras Shevchenko National University of Kyiv. - К.: MIKNU, 2018. - № 58. - P. 68 - 73.

д.т.н., проф. Банзак О.В., д.т.н., с.н.с. Сєлюков О.В.,
д.т.н., проф. Єфименко Н.А., Коноваленко О.І.

РОЗРОБКА КОМПЛЕКСУ ІНДИВІДУАЛЬНОГО ДОЗИМЕТРИЧНОГО КОНТРОЛЮ

У даний час практично всі галузі промисловості, багато галузей науки застосовують джерела іонізуючих випромінювань (ІІ). Широко використовуються в оборонному комплексі, медицині, сільському господарстві ядерні енергетичні установки, гамма-установки різної потужності, дефектоскопи, лічильники і багато іншої апаратури. Однак найбільш важливою галуззю використання ІІ на Україні після ліквідації бойового ядерного потенціалу є атомна енергетика. У країні працює п'ять атомних електростанцій (АЕС) з реакторами двох типів, які виробляють близько 40% всієї електроенергії країни.

У зв'язку з цим все більшого значення набувають проблеми дозиметрії, яка сьогодні стала самостійним науково-технічним напрямком ядерної фізики. Дозиметрія за своєю суттю вирішує завдання зв'язку фізичних величин з очікуваними радіаційними ефектами застосування ІІ.

При нормуванні доз опромінення персоналу відповідно до міжнародних рекомендацій і правил гостро постало питання щодо зниження дозових витрат персоналу, і, в першу чергу, ремонтного, так як основний внесок в колективну дозу опромінення персоналу АЕС вносять роботи з технічного обслуговування і ремонту. На початковому етапі знижувати дози опромінення вдавалося, в основному, за рахунок виконання організаційних заходів адміністративного підвищення вимог до якості підготовки та проведення робіт в зоні контрольованого доступу. Подальше зниження дозових навантажень персоналу може бути забезпечено за рахунок впровадження в практику експлуатації АЕС принципу ALARA [3]. Для цього необхідне створення такої системи контролю радіаційної обстановки та персональної дозиметрії, яка могла б забезпечити виявлення ділянок з підвищеною радіоактивністю і вимірювати повний набір їх параметрів (як мінімум, дозу, потужність дози, координати, момент часу, номер персонального дозиметра) в реальному масштабі часу без участі носія персонального дозиметра, т. е. в рамках його нормальної життєдіяльності і без його відома, якщо потужність дози не перевищує гранично допустимого рівня. При перевищенні цього рівня носій персонального дозиметра повинен попереджуваться проте, що йому загрожує небезпека, щоб взяти участь в діях по її подоланню, але не в якості посередника в процесі вищезазначених вимірювань.

На основі такої концепції в даній роботі запропоновано комплекс індивідуального дозиметричного контролю.

Ключові слова: атомна енергетика, доза опромінення персоналу, контроль радіаційної обстановки, потужність дози опромінення, персональний дозиметр.