TARGET UNIT FOR RADIATION TEST OF MATERIALS UNDER BREMSSTRAHLUNG OF ELECTRON ACCELERATOR

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There is a necessity to provide an immobilization of the long-lived radioactive waste into radiation-resistant structure (a cement matrix, container capsule, geological disposal environment and so on) for it safely disposal. The material of the every of these barriers should have resistance corresponding to the absorbed dose value up to 10^8 Gy for the period of time up to 1000 years. The method of imitation exposure of the materials under bremsstrahlung of the high-current Linac was developed for prediction behavior and material selection. For realization of this method in a wide range of exposure conditions (by temperature, humidity, rate and amount of the doze) the special target unit was designed. It has a modular construction and includes two chambers for samples (one for exposure in liquid and another one – in the atmosphere) that are placed along the irradiation axis and integrated together spatially. Also, the target unit has plane-parallel ionization chamber for continuous monitoring of the photon flux intensity and absorbed doze. The copper thermistor is used as a temperature probe. The structure and characteristics of measurement channels are described as well.
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1 INTRODUCTION

The main goal of imitation exposure of the materials that are used for the immobilization of radionuclides is a creation of absorbed doze up to 10^8 Gy in investigated samples during acceptable period of the time (no more than 1 year) at monitoring parameters of radiation effect. These parameters in the first instance are an absorbed doze rate and a temperature of the samples. Namely these parameters define the annealing rate of the radiation defects, and thus, representability of the results obtained. It is easy to make sure that the radiation heating of samples is no more than ~10° under absorbed doze rate noted above, i.e. contribution of the temperature to annealing of defects in the process of imitation exposure can be ignored. However, the specified parameters and also spectral characteristics of radiation are basic objects of metrological accompaniment of the imitation exposure.

The gamma-ray unit with radionuclide sources (basically, Co-60) is a traditional radiation source for testing in doze range up to 10^8 Gy. The advantage of such tests is stability of influence conditions to the sample. Therewith, the setup with activity up to 1 MCi is needed to provide the absorbed doze rate (ADR) about 10 Gy/s [2]. The electron accelerator can provide the same conditions with converting its beam to bremsstrahlung (BR) [3]. The value of the BR ADR in a sample of about 10 Gy/s for electrons with the energy 10 MeV is reached by converting a beam with the power 10 kW, that corresponds to parameters of modern industrial accelerators (see, for example, [4]). A possibility of the electron energy and flux control provides an expansion of range of the influence parameters to the sample during its test.

The results of development of the special target unit for sample exposure under bremsstruhlung of high-current electron accelerator are presented in this report.

2 TARGET UNIT COMPONENTS

2.1. The target unit (TU) has a parallelepiped shape and consists of three chambers (Fig. 1).

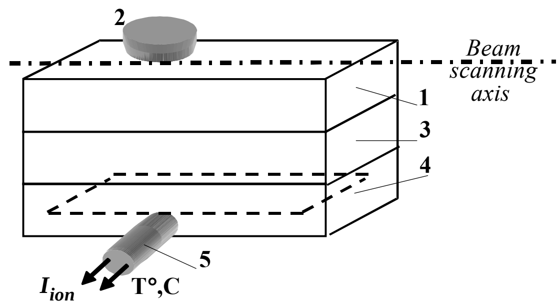

Fig. 1. TU components.

Upper hermetically sealed chamber **1** is designed for placement of samples, being irradiated in liquid (throat **2** is made to pass samples in liquid), and central chamber **3** – in air. The free-air ionization chamber (IC-1) is placed in volume **4** for continuously monitoring of photon stream through the samples. The passage with tube **5** for the ionization chamber feed and signal cables is made in ceramic insulator.

2.2. The linear sweep of the electron beam within limits of the output accelerator window is performed by the electromagnet **EM** (see Fig. 2).

The scanned beam is directed to the converter of bremsstruhlung **C**, that is a plate from material with a high atomic number (tantalum, tungsten) and placed into a tank being cooled by the running water. The thickness of the water layer under the plate is chosen so that the part of accelerated electrons passed through the plate is absorbed in this layer. The **TU** is placed under the bottom of the tank symmetrically to the line of the beam scan. An irregularity of the photon flow density on a surface of the TU is defined by distribution of the electron flow density on a surface C, and also by the width of TU and typically is less than ±5%.

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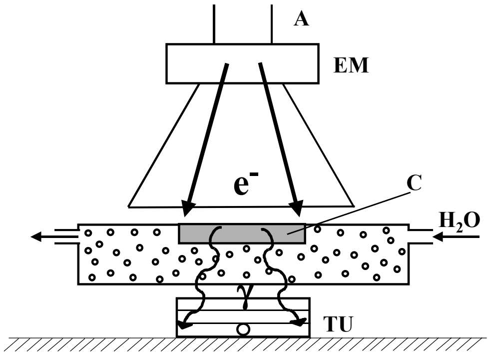

Fig. 2. TU geometry placement.

3 COMPUTER SIMULATION

As known, granite is the promising geological environment for radioactive waste disposal [4]. Therefore, the samples from granite (that consists of more than 70% of SiO_2) was chosen as one from objects to study. The preliminary calculations showed that replacement of the real matrix from granite to pure SiO_2 when simulating the radiation effect gives the results varied no more than 3%, but the calculation time is reduced considerably in this case. Version of the TU analyzed with a method of the computer simulation is presented in Fig. 3.

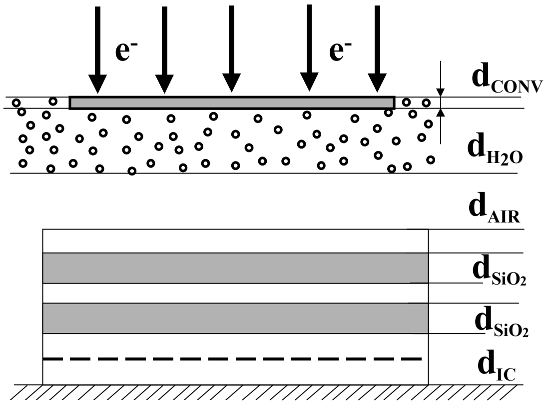

Fig. 3. Geometry and parameters of simulation.

d_{conv},cm	d_{H_2O},cm	d_{air},cm	d_{SiO_2},cm	d_{IC},cm
2	15	5	2	2

The calculations were made for three values of the accelerated electron energy: 10, 15 and 20 MeV with the average beam current 1mA (see Table 1). Analysis of the data obtained shows that the version of the TU under consideration provided an irradiation of the samples by "pure" braking photon flow in all the range of the accelerated electron energy.

Table 1. Simulation results

	Electron energy, MeV		
	10	**15**	**20**
Electron energy flux, kW	10	15	20
Number of absorbed electrons, % in converter in water filter	99.5 -	92.79 6.92	49.07 50.73
Photon energy flux at TU, kW	1.07	2.76	5.08
Average energy of photons, MeV	0.82	1.12	1.44
Absorbed power P of photon radiation in SiO_2, W	16.32	50.18	110.8
Ionization current *I* in IC, μA	60	191	419
k=*I*/P, μA/W	3.64	3.80	3.78

The average photon energy $\overline{E}_\gamma$ by spectrum occurs near the values for such representative components of the radioactive waste as Cs-137 (E_γ=0.662 MeV) and Co-60 (E_γ=1.25 MeV), and ADR in SiO_2 is ≥10 Gy/s, that satisfy the conditions of the imitation exposure.

Close linear dependence of ionization current on absorbed power of the braking photon radiation in SiO_2 is observed in the investigated energy range of accelerated electrons. That can be explained by realization of the electron balance conditions for the given relation of electron energy and also the thickness of the water filter and irradiated samples [5]. This result gives a reason to carry out continuous nondestructive monitoring of the absorbed doze in irradiated samples from ionization charge in IC.

4 MEASUREMENT CHANNEL

4.1. In the context of the results noted above the measurement channel for the TU (Fig. 4.) was developed and designed for on-line monitoring of absorbed doze and ADR of the photon radiation and also for measuring the temperature of samples under irradiation. The channel provides measurements both in the standalone mode and in the remote mode controlling by computer using RS-232 interface.

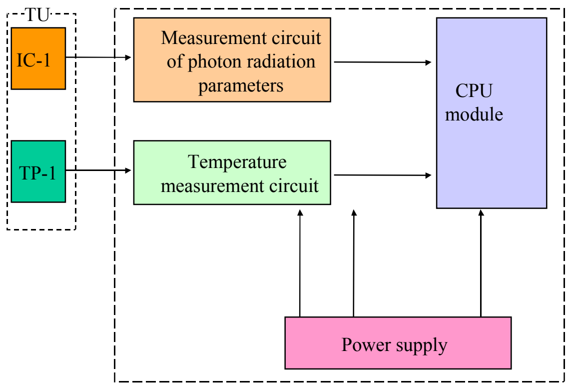

Fig. 4. Block-diagram of measurement channel.

The channel includes two measurement circuits. The free-air ionization chamber IC-1 is used as a primary sensor in the measurement circuit of the braking radiation parameters. The thermal probe TP-1 is used in the measurement circuit of the sample temperature.

4.2 Technical data

The measurement channel of photon radiation:

- current range of the IC-1, μA - 5…5000
- relative measurement error of the IC-1 current, % - ≤ 3

The measurement channel of the sample temperature:

- temperature range, °C - 0…80
- relative measurement error, % - ≤ 3

The power supply produces a stabilized DC voltage +/-15 V to feed the measurement circuits and +5 V to feed the central-processing unit (CPU) module.

4.3 The measurement circuit of the photon radiation parameters

A signal from the ionization chamber IC-1 (Fig. 5) directs to the input of the current-to-voltage converter (CVC). The voltage with the amplitude proportional to the input current is produced at the output of the CVC. Then a signal through the optoisolation and amplifier goes to the input 1 of the analog-to-digital converter (ADC). The CVC is made on a base of the operational amplifier (OA) type AD711. The resistors of type C2-29OC ±0.5% are used to increase the time and temperature stability.

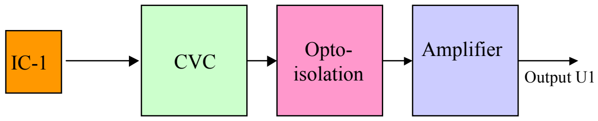

Fig. 5. Block-diagram of measurement circuit of ionization current.

4.4 The temperature measurement circuit

The thermal probe TP-1 (Fig. 6.) is feed from the stable current generator with a magnitude of 1 mA. A signal from the thermistor TP-1 is going to the input of the thermostable differential amplifier (DA). The input of the DA has the filter for suppression of an HF noise. The DA is made on a base of OA type AD623 with the resistors C2-29.

The CVC, the stable current generator and DA are placed into the thermostat from the foam plastic.

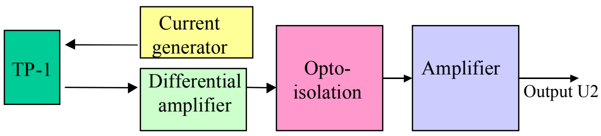

Fig. 6. Block-diagram of temperature measurement circuit.

4.5 CPU module

The CPU module (Fig. 7) consists of the following components:

- ADC;
- CPU;
- data memory (RAM);
- program memory(ROM);
- indication module (IM);
- control keypad (CK);
- level translator of the serial interface (LT).

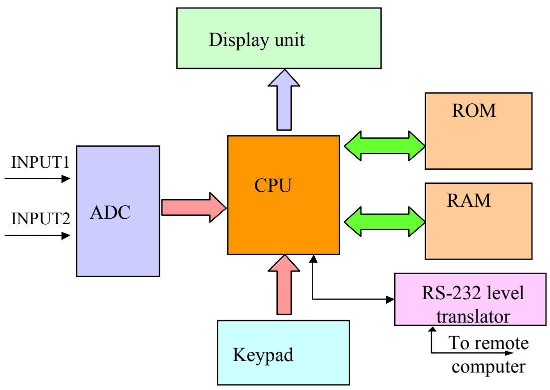

Fig. 7. Block-diagram of the CPU module.

The basic functions performed by the CPU module are:

- conversion of analogue signals from the measurement circuit to the digital code by the ADC;
- storing the results of the measurements and converting them to physical units;
- measurement data display; control of the operation mode by using the keypad;
- data exchange between the CPU module and remote computer using a serial interface RS-232.

4.6 Measurement procedure

After starting a measurement the CPU produces the control signals for the ADC during 10 ms with 1 s period. The scan rate of ADC is 10 kHz. The values of analogue signals converted to the digital code from one of the measurement circuits are stored into the data memory RAM. Then these data are averaged, converted to physical units and output to the display unit. Every second the measurement circuit is switched to another one. One time per second the increment of the measurement values are calculated and stored. The timer is started from the begining of measurement process for calculation of measurement time. The measurement process is stopped after a corresponded key has been pressed on the keypad.

There are two mode of the CPU module operation: from the keypad control (stand-alone mode) and under control from the remote computer using a serial interface RS-232. In last case the data transfer to the remote computer.

5 CONCLUSION

The special target unit to provide radiation tests of the material samples in bremsstrahlung field of the electron accelerator has been developed with the follow parameters range:

- absorbed doze rate of photon radiation, Gy/s - 1…100;
- absorbed doze, Gy - 10^3...10^{10};
- average photon energy , MeV - 0.8…1.4;
- samples temperature, T°C - 0...80.

The device has the measurement channel linked to the remote computer that provides on-line monitoring of the photon radiation parameters and temperature of the samples.

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REFERENCES

1. N.P.Dikiy, S.Yu.Sayenko, V.L.Uvarov, E.P.Shevyakova. Application of Nuclear-Physics Methods for Studying the Radionuclide Transport in Granite Rocks // *Voprosy atomnij Nauki i Tekhniki. Seriya: "Yaderno-Fizicheskiye issledovaniya"* (36). 2000, № 2, p. 54-57.
2. A.K.Krasin et al. Powerful gamma-setup UGU-200 // *Atomnaya Ehnergiya*. 1971, v. 31, N. 3, p. 205-207.
3. V.V.Kluyev et al. *Nondistructive Control with the High-Energy Sources*. Moscow: Energoatomizdat, 1989, 176 p. (in Russian).
4. Z.M.Deconik et al. Investigation of Possibility of Radioactive Waste Disposal in Deep Geological Formation // *Bulletin of Ecological State of Chernobyl Zone*. 1999, v. 13, p. 64-66 (in Ukrainian).
5. V.Vexler et al. *Ionization Methods for Investigation of Radiations*. Moscow: GITTL, 1949, 424 p.