Characteristics of detectors for prevention of nuclear radiation terrorism

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Abstract. There is description of one type of detectors in use for the task of nuclear terrorism cases prevention to determine the direction to the radioactive source and geometrical structure of radiation field. This type is a modular detector with anisotropic sensitivity. The principle of work of a modular detecting device is the simultaneous operation of several detecting modules with anisotropic sensitivity to gamma radiation.

1. Introduction
The problem of counteractions to nuclear terrorism threat is particularly relevant at the present time, not only in Russia, but also worldwide. This highlights two ways of solving the problem. The first is to search for nuclear and radioactive materials (NRM), the second - the identification of detected and legally transported radioactive materials.

Detection and identification of NRM takes place on such parameters as type of radiation, its intensity, the energy distribution of gamma or neutron radiation. When using active methods of detection parameters added to the secondary gamma or neutron radiation.

2. Radiation parameters used for the detection and identification of nuclear and radioactive materials.
2.1. The intensity and type of radiation
For the purposes of efficient search NRM usually two types of radiation are used: gamma and neutron radiation, which have a high penetrating power. In addition, the presence of neutron radiation is a witness to the presence of nuclear materials in the composition of the substance.

The radiation intensity is very significant effect not only on the speed and range of detection NRM, but also on the time needed to identify the dangerous substance [1].

2.2. Spectral analysis of gamma radiation
Analysis of the spectral composition of gamma radiation is used for the identification of NRM. This method has a high accuracy in determining the presence of a substance and its concentration. The disadvantage of this method is the time required to gather the necessary information [1].

The formation of individual energy windows and the use of special techniques to increase the signal / background in these windows are applicable to reduce time to collect information. However, in this case, the method becomes selectively responsive only for certain substance [1].
2.3. An analysis of the energy distribution of neutron radiation
An analysis of the energy distribution of the neutron flux is quite a time-consuming task, since today there is no compact devices that are relatively quickly and with high precision could determine the energy of the neutrons.

Energy spectrum is separated into the several groups and ratio of neutron radiation intensities in these groups is monitored for the purposes of rapid analysis of neutron. This approach gives an indication of the type of source of neutron radiation. A more precise identification of the substance is only possible by means of the spectrum analysis of gamma-radiation [1, 2].

2.4. Secondary gamma and neutron radiation
Secondary gamma and (or) neutron radiation is generated if the test object is exposed to external radiation. This is a fairly aggressive approach to the analysis of the substance, but it allows obtaining maximum information about the object. The most well known method for analyzing a substance this manner is the method of labeled neutrons. It allows not only to identify the substance, but also to determine the location of the substance in the container [1].

2.5. The spatial distribution of the radiation flux
The spatial distribution of radiation flux studies are needed to determine the location of the source on the ground, its geometrical parameters, identify weaknesses protection for more accurate identification of NRM. A separate task analysis of irradiance distribution - is the task of analyzing the rapidly changing field of radiation. This type of problems is connected with the search for sources of radiation over large areas, where the search engine is located on the mobile device (car, helicopter, quadrocopter, etc.) [1].

3. Examples of detection equipment and identification of NRM
3.1. A multi-detection device (MMDU)
For the detection and location of radioactive substances frequently uses multi-module detection system. Some of them found their way back to the lab NRNU MEPhI. The first modification MMDU was developed in the early 90s of the 20th century. The NRNU MEPhI device exists in 2 versions: MMDU MMDU-4 and-6 that contain 4 and 6 detection units [3].

One of the most important characteristics of MMDU is the angular dependence of the sensitivity of the recording modules. Figure 1 shows the results of the experiment to determine the angular dependence of the sensitivity MMDU modules. Similar relationships with corresponding axial shift change angle $\phi$, and prepared for recording other modules. The obtained dependence in within the error well approximated by a cosine functions, so you can determine the gradient of the field of gamma radiation virtually in real time.

3.2. Examples of operating systems
Existing examples of multi-module or multi-layer detectors with improved capabilities for detection of NM and RS are shown in figures 2 and 3.

Figure 2 shows the device placed on the vehicle and adapted to detect the operational detection of gamma-ray sources, the measurement of the dose rate and the dose of gamma radiation, the measurement of differential flows and the determination of the angular distribution of gamma radiation. The instrument used multi modular principle of the detection units combined into a single information network. This provides a high accuracy for determining the direction of the gamma source, and the angular distribution of gamma radiation.

Figure 3 shows an improved version of the complex cell search and detecting radiation sources of gamma radiation. The complex provides the search and disclosure of local sources of gamma radiation from the air and ground-based facilities with the construction of cards dose fields and refer to them the source location, as well as the definition of the energy spectrum and identify the source of the nuclide composition.
Figure 1. The dependence of the ratio of the number of photons detected by one module to the total number of photons detected by all modules together (relative count rate) on the angle - the direction of the source of γ-radiation. The numbers on the curves indicate the numbers of the module. The model with 4 modules.

The complex also implemented the principle of building a multi-modular detection units, it contains 4 spectrometric gamma radiation detection units.

There are examples of complexes repeatedly tested in practice, they have shown high efficiency of NRM detection.

References
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[2] Kolesnikov S et al. 2009 (in Russian) Recovering energy neutron flux distribution using an artificial neural network Engineer. Phys. 5 22 (Original Russian title: Inzhenernaya fizika)
[3] Ryabeva E, Kadilin V and Dedenko G 2016 Modular detecting device to find direction to the gamma-ray source Lecture Notes in Engineering and Computer Science 2 727
Figure 2. Measurer of dose rate and differential fluxes of gamma - radiation.

Figure 3. Mobile complex equipment for remote search and detection of gamma-ray sources.