DEVELOPMENT OF A DESIGN OF A RADIOISOTOPE SWITCHABLE NEUTRON SOURCE AND NEW PORTABLE DETECTOR OF SMUGGLING

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Physical features of interaction of neutrons with material have initially defined special and considerable area of their application in instrument making - from geophysics to purposes of a military-industrial complex. Importance of fields of implementation of neutron methods of control devices defined scale R&D and technical realisation. In such conditions, questions of strengthening safety at times faded into the background. In due course, in process of strengthening of norms of radiating safety, application of neutron methods was rather limited, as for safe storage and transportations of an isotope source of neutrons with an yield $10^5-10^7$ n/s it is necessary to place it in the protective container in weight in tens kilogram. Now similar devices are applied seldom, only in special cases.

It is desirable to have opportunity to “switch off” equipment using isotope neutron sources for the time when the device does not work. It is especially important to have such source as a part of portable equipment.

Among neutron control devices, neutron indicators of level for application in thick-walled tanks, pipelines of the oil-extracting and petrochemical industry use again high requirement.

Also, special potential of use in the field of the boundary and customs control shall be mentioned, in particular, in prevention of an illegal turnover of explosives, radioactive and fissile materials.

Besides, compact and mobile devices are still widely used as auxiliary and additional control equipment. Thus they can be used as the basic control devices in the poorly equipped customs points and internal lines of developing countries. For compact and mobile devices of the specified types, use of sources of neutrons with an exit $10^4-10^6$ in a second is sufficient.

Manufacture and application such low-activity neutron switched off sources can solve or is essential simplify a problem of radiating safety during time –

- storage
- transportation
• assembly and engineering setup.

Directly in the course of work radiating safety is ensured through distance from the operator to a source (sensor control) provided by the telescopic handle of the device.

Such approach in maintenance of radiating safety through application of law activity SNS may provide a basis for development of new generation of neutron devices of wide application.

Usually neutrons obtain in \((\alpha, n)\) reactions on nucleus of light elements. At present Am-241 \((T_{1/2}=432\) years, specific activity of \(1.27 \times 10^{11}\) Bk/g) or Pu-238 \((T_{1/2}=87\) years, specific activity of \(6.3 \times 10^{11}\) Bk/g) are mostly used as \(\alpha\) – radiators. As energy of \(\alpha\) - particles Pu-238 and Am-241 differ poorly; the data shown in the table quite precisely characterizes an yield of neutrons from specified radioactive nuclide for different targets.

<table>
<thead>
<tr>
<th>Nuclide-target</th>
<th>The maximum energy of neutrons</th>
<th>Average energy of neutrons, MeV.</th>
<th>Yield of neutrons on (10^6) alpha particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be-9</td>
<td>13</td>
<td>4.7</td>
<td>80</td>
</tr>
<tr>
<td>B-11</td>
<td>7.3</td>
<td>3.2</td>
<td>26</td>
</tr>
<tr>
<td>B-10</td>
<td>8.1</td>
<td>3.4</td>
<td>13</td>
</tr>
<tr>
<td>O-18</td>
<td></td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>F-19</td>
<td>2.5</td>
<td>1.4</td>
<td>12</td>
</tr>
<tr>
<td>Li-7</td>
<td>1.2</td>
<td>0.45</td>
<td>2.6</td>
</tr>
<tr>
<td>Mg-25</td>
<td>10.15</td>
<td>3.6</td>
<td>6.1</td>
</tr>
</tbody>
</table>

The first patent materials about SNS have appeared in the end of 60 in the USA and Japan:


The principle of SNS action is the following: for switching on the source it is necessary to pull together \(\alpha\)-radiator with a target so that in switched off position it would be possible to separate them again, without pollution one with another(fig1.).

![Fig.1 Principle of operation of SNS.](image)
Besides, the source design should provide the minimum dimensional sizes and hermiticity.

The yield of neutrons of a source depends on the area of overlapping of the target and the source and, certainly, from specific surface activity of \( \alpha \) - radiator. Since, as a rule, the thickness of a sputtering makes submicron, at small specific activity of radioactive nuclide, for reception of the big yield of neutrons it is necessary to increase the sputtering area. So, for a source on the basis of Pu-Be with an yield \( 1 \times 10^6 \) n/c the area of an active surface of a layer of metal plutonium should be 200 sm\(^2\), and for the same source on the basis of Am-241 - about 1000 sm\(^2\). However if sources with the yield to \( 2 \times 10^5 \) n/c are used, their sizes are quite reasonable and are accordingly easily realized.

Because of presence at Pu-238 neutrons of spontaneous fission, creation of SNS without of neutrons in the switched off condition, it is not obviously possible. As for such source with the yield \( 10^5 \) n/c about 20 mg Pu-238 is required, in the switched off condition it will emit about 40 neutrons per second. For a source on the basis of Am-241 this problem does not exist, as it practically does not have spontaneous fission.

The most advanced for today are LANL works which has developed pulsing SNS on the base of Am-Be (http://dx.doi.org/10.1117/12.624962). In several laboratories of the USA works on perfection of pulsing SNS which application allows more effective using of different algorithms of data processing are conducted.

Our purpose is development of a small-sized – 30x30x100мм, low-activity (up to \( 5 \times 10^5 \) n/s) switched off source of neutrons for compact portable devices and creation of the contraband search device of on its base.

In difference from mentioned above works, our development is directed on working out simple, inexpensive, manually switched on/off source of neutron radiation. Simple designs of radio isotope SNS sources are accordingly offered and specifications on injector and target manufacturing are formulated. Some variants of possibility of designing, e.g., on parallel displacement (fig. 2, 5) or on a turn round an axis on 180\(^0\) (fig. 3, 4, 5)
Taking into account construction of a simple technological chain, some sketches of a mechanical design of a source are developed (Fig. 6, 7). Their optimization passed with the requirement of minimization of the sizes and ensuring of effective fixing of both condition of a source. Especially, fixing of the switched off condition.
The metal case of a device provides biological protection from accompanying soft gamma-emmanation.

![Image of device with ruler](image1.png)

**Fig. 8** Source switched on.  
**Fig. 9** Source switched off.

Researchers of Lawrence Berkeley National Laboratory have developed the innovative neutron generators which configuration can meet the mostly diversified technical requirements. The whole series of rather compact neutron generators and tubes for wide application, from НДТ to brachytherapy is presented. But today their application in compact portable devices is improbable because of still big sizes and high power consumption [http://www.lbl.gov/tt/techs/lbnl1764.html].

The comparative analysis of possibility of application of radio isotope SNS and compact DD neutron generators as the search devices for prevention of illegal circulation of the explosive substances, drugs and highly enriched Uranium (HEU) has been carried out within the framework of the project.

On Fig. 10 dependence of the signal/background ratio on volume of contraband of an organic origin with application of different SNS and DD generator is shown.
Fig. 10 Dependence of the signal/background ratio on volume of contraband for different sources (M-C).

On fig. 11 dependence of the data of the search device detector on the contraband simulator weight for neutron’s different energies is shown (Monte-Carlo simulation).
Among our workings out, installation on detection of Highly Enriched Uranium (HEU) in luggage is least exacting to the sizes of SNS. Detailed study of installation and Monte-Carlo modelling of measurement process have shown that it is possible to use (DD) generator and the radioisotope SNS made on a basis Pu-238 or Am-241 with Be or LiF targets, practically with identical success.

The device for detection of (HEU) in luggage can be used in a complex as a part of stationary roentgen-visual installations, and also in a portable variant with compact blocks of detecting and an irradiation. In this case the luggage is checked individually, out of a conveyor stream.

For study of dependence of efficiency of HEU detection on energy of primary neutrons, calculations in a range of energy of sources of neutrons 0.1 - 15 Mev in the optimized geometry have been carried out (fig. 15).
The obtained results show weak dependence on energy of primary neutrons, that is on source type. From diagram it is visible that in rather wide interval of energy (from 0.1 to 5 MeV) efficiency of detection changes all in 2 times. These results give enough ample opportunities in a choice of type of a source and do not exclude possibility of use of different isotope sources Am - Li, Am-LiF, P-Be, Am-Be etc. including DD generators

![Graph showing relationship between Neutron energy and arbitrary units](image)

**Fig. 15**

Results of some researches of a problem of detection of fission materials in luggage of passengers [] are known. Demonstration installations on the basis of small-sized pulse neutron (DT) generators are created. In this case for maintenance of sensitivity of detection of 5g (HEU) in 5 seconds the stream of neutrons up to $10^7$ n/s is required. However at such activity and neutron energy, radiating protection of the personnel becomes of a primary importance. We have conducted settlement researches, for detection in luggage hidden HEU on the basis of SNS application. The scheme and configuration is shown on fig. 16.
Parameters of the device for hand luggage within the standard geometry of control volume (50x60x60 cm) have been optimized:

1. The maximum density of a stream of thermal neutrons in working volume of installation is provided.
2. Peak efficiency of registration of fission neutrons at suppression of primary radiation is structurally provided.
3. Data of the minimum activity of radiation depending on energy of sources of neutrons, for the purpose of achievement of the set sensitivity are defined.
4. The Offered scheme of the luggage control installation has high sensitivity. The source having activity $1 \times 10^6$ neutrons in a second provides 99% of probability of detection of 8-10 g HEU for one second.
5. Installation Dimensions, with necessary radiating protection, do not exceed the sizes of modern roentgen-visual devices.
6. The modern technical base is quite accessible to a technical embodiment of the developed technique of HEU detection in luggage. The question costs in development and manufacture SNS.

Our analysis has shown that deliberate screening of fission substances, e.g., with Cadmium, easier to identify trough characteristic gamma-radiation of radiating capture of neutrons.

Still 10-12 years ago, we have been searching for interested partners in order to develop working model of SNS with reference to compact devices. We have been convinced that
devices with SNS remain highly claimed on the market. In this time we tried to develop the general interests with three leading nuclear centers of Russia, for creation of the joint project. However, the projects approved and technically coordinated at level of leading experts, unfortunately did not find the due consent in a institutes administration. Probably, the mode system in the large research centers remains conservative.

Participation in SRP МАГАТЭ rather effectively and favorably influenced project development; In the spring of this year we have got the state support in a grant kind the Georgian National Science Foundation; With the help of our colleagues from Germany, had been got into business contacts with Eckert & Ziegler Nuclitec GmbH this summer for the purpose of the contract conclusion on manufacturing an α-emitter for operating SNS model. Later, additional materials on results of our findings and the analysis of prospect of SNS application have been transferred in Braunshveig.

We expect that preliminary results of studying of prospect of need of SNS in the market will convince our colleagues from Eckert and Ziegler Nuclitec GmbH of commercial perspectives and our relations will not end with manufacturing α - injector only for one working breadboard model.