METALLIC URANIUM: PROTECTIVE MATERIAL
WITH ENHANCED $\gamma$-RAY ABSORPTION

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Research performed at the Bochvar All-Russia Research Institute for Inorganic Materials (VNIINM) and the All-Russia Research Institute of Experimental Physics (VNIIEF) on the development of the TUK-117 multipurpose transport packaging is presented. The TUK-117 packaging possesses biological protection based on depleted uranium and intended for transporting and storing spent nuclear fuel. The higher capacity of the metallic uranium alloy for absorbing of $\gamma$-rays and the alloy’s high mechanical characteristics have made it possible to develop a design meeting IAEA specifications. The technology for fabricating safety-engineered articles from uranium and its alloys by pouring the alloy into a prepared mold made of corrosion-resistant steel is patented.

The accumulation of spent nuclear fuel is outstripping the possibility of radiochemical reprocessing. For this reason, there is an objective need for containers for shipment, temporary storage, and disposal of sources of radiation [1]. The problem can be solved by developing multipurpose universal containers.

It’s high density makes uranium and low alloys based on it among the best materials for use as protection from high-energy $\gamma$-rays in universal-container designs. The protective properties of different metallic materials as a function of the energy of the radiation, which secure the safety of transport packaging, are presented in Table 1. In Fig. 1, above the ordinate $U = 1$, the outer diameter of cast iron (1) and concrete (2) protection versus the parameters of the transport container with uranium protection as well as the mass per unit length of cast iron (3) and concrete (4) protection are shown in relative units. Below the ordinate $U = 1$, the capacities of cast iron (5) and concrete (6) containers versus the inner diameter of the protection are shown as fractions.

Depleted metallic uranium and its alloys and compounds can be used effectively for biological protection of radiation-engineered articles: transport containers for transporting spent elements of nuclear reactors, spent fuel, containers for transporting and storing sources of ionizing radiation, flaw detectors, apparatus, setups, and others.

There is one other important circumstance that makes it necessary to turn to uranium-containing products for developing biological protection for containers. About $1-10^6$ tons of depleted uranium wastes in the form of metallic uranium and its alloys as well as byproducts of enrichment have now been accumulated worldwide. Their stocks have no practical application and are increasing. The presence of extensive repositories of depleted uranium creates environmental problems and requires increasing expenditures on maintenance. One possible method of salvaging the stocks is to use the byproducts of uranium enrichment to obtain metallic depleted uranium and depleted uranium dioxide for use in containers or protection engineering. The experience gained in developing transport containers with biological protection made from metallic depleted uranium is described in the present article.
General Requirements of and Uranium Usage in Containers. Multipurpose universal containers for transport and storage of spent nuclear fuel must meet international and national specifications, the most important of which are:

1) conformance to the IAEA-2000 specifications (TS-R-1);
2) maximum safety in design-basis and beyond design-basis accidents as well as possible terrorist acts;
3) maximum capacity for prescribed mass and size characteristics;
4) minimum dimensions with a prescribed load, admitting transport by all forms of transportation; and
5) comparability of the specific cost of newly designed containers and metal concrete structures.

The mechanical characteristics of uranium alloys best meet the requirements of the structural materials used for biological protection. The comparative characteristics of biological protection materials in the cast state are presented in Table 2.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density, g/cm³</th>
<th>0.2</th>
<th>0.5</th>
<th>1</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>7.2</td>
<td>0.213</td>
<td>0.384</td>
<td>0.533</td>
<td>0.887</td>
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<tr>
<td>Lead</td>
<td>11.3</td>
<td>0.022</td>
<td>0.134</td>
<td>0.290</td>
<td>0.497</td>
</tr>
<tr>
<td>Uranium</td>
<td>18.7</td>
<td>0.017</td>
<td>0.067</td>
<td>0.158</td>
<td>0.277</td>
</tr>
<tr>
<td>Tungsten</td>
<td>19.2</td>
<td>0.016</td>
<td>0.091</td>
<td>0.183</td>
<td>0.300</td>
</tr>
</tbody>
</table>

Fig. 1. Relative mass versus size characteristics of containers with uranium, cast iron, and concrete containers.

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The UKTIV-60-1, -60-10, and -60-100 packaging has operated successfully since 1998 at the Research Institute for Atomic Reactors (NIIAR). These containers were designed for transport by air and disposal of closed radionuclide sources of radiation based on $^{60}\text{Co}$ with activity to 37, 370, and 3700 GBq, respectively. These articles, having enhanced strength and heat resistance and eliminating losses and spread of radioactive substances, provide effective protection from radiation during possible accidents occurring in transport and accompanied by temperature and mechanical actions. Structurally, the packaging consists of single-cavity (cavity diameter 25 mm) containers with loading and unloading from the top. The radiation protection is comprised of depleted uranium, which is located in a jacket made of corrosion-resistant steel. The packaging sets possess heat protection and are furnished together with the protection package.

**Radiation Properties of Unirradiated Depleted Uranium.** The $\gamma$-ray dose rate of depleted uranium is acceptable and falls within the radiation safety standards for category-A work. It follows from Table 3 that natural uranium and its decay