# Air Shipment of Radioactive Materials in Depleted Uranium Shielded Packaging

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## Abstract

Under conditions of strong competition at the international radioisotope market not only the quality of the products themselves but the timeliness and punctuality of a delivery time-table and shortening the delivery period as well became more acute. The latter allows reducing losses of expensive products due to radioactive decay. Distinctive features for arranging transport of radioisotope products using depleted uranium shipping packing sets both in respect of regime of flight and IAEA Regulations (1996) are discussed below.

## Introduction

Since early nineties of the last century when RIAR appeared at the international radioisotope market the range of products to be delivered and the shipment geography have significantly enlarged. At the same time the problem of safe delivery of radioactive isotopes and articles became more acute. Thus annually RIAR deliveres isotope products of total activity about 600 000 Ci in 36 countries.
To shorten the delivery period and reduce products losses due to radioactive decay we in overwhelming majority cases use air mode of transport. On average RIAR makes for shipment up to 500 radioactive packages yearly including 400 type A and 100 type B packages.

## Choice of proper shipping container

When choosing appropriate shipping container for radioactivity air transport one should take in mind not only the efficiency of biological shielding but package mass and overall dimensions as well. Parameters of materials usually used as shipping containers biological shielding are listed in Table 1.

Table 1

Comparative parameters of materials for biological shielding

| Shielding material | Density, g/cm$^3$ | Emission energy, MeV | | | |
|---|---|---|---|---|---|
| | | 0.2 | 0.5 | 1 | 3 |
| | | Shield thickness, m | | | |
| Uranium | 18.7 | 0.0166 | 0.0670 | 0.1584 | 0.2774 |
| Iron | 7.2 | 0.2130 | 0.3840 | 0.5334 | 0.8869 |
| Lead | 11.3 | 0.0216 | 0.1341 | 0.2896 | 0.4968 |
| Tungsten | 19.2 | 0.0164 | 0.0914 | 0.1828 | 0.3002 |

Table 1 shows that at the same emission energy depleted uranium shielding of minimum thickness provides the safe operation of a shielding container. At the same time gamma radiation dose rate of depleted uranium itself is at the level of permitted dose rate limited by Radiation Safety Standards for the works of A category. Nevertheless radioactive properties of depleted uranium require keeping safety conditions even when transporting empty shipping containers of this type.
The natural uranium decay scheme is shown in Fig.1, and radiation properties of depleted uranium not irradiated in nuclear reactor facilities are listed in Table 2.
Comparing mass of radiation shield of various materials for different size containers one can see that on the same dimensions of charging socket the lightest, e.g. the most preferable for operations is depleted uranium shielded container (Table 3).
To weaken depleted uranium radiation when using it in biological shielding uranium parts are cased in 1.5 mm thick corrosion-proof steel. Measured gamma radiation dose rate of depleted uranium disk 80 mm diameter and 5 mm thickness does not exceed 2000 microroentgen per an hour. According to design estimation even in fire

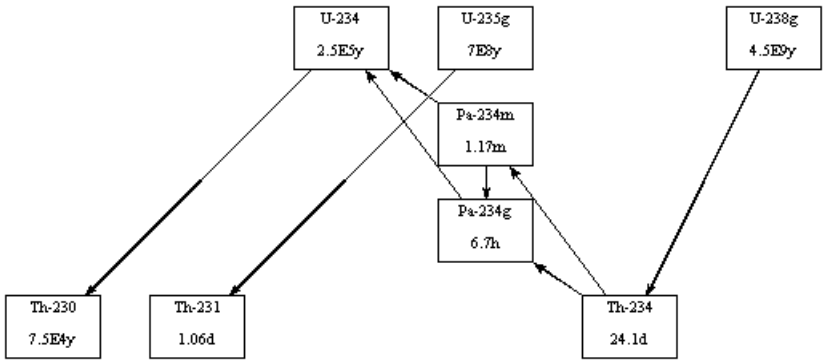



Fig.1
The scheme of the natural uranium decay

conditions the temperature at the steel-uranium contact does not exceed 190°C thus forming uranium-iron eutectic (725°C) initiating the container damage seems to be unlikely.

Table 2

Radioactive properties of natural depleted uranium

| Parameter | Isotope, mode of decay | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $^{238}$U-α | $^{234}$Th-β | $^{234}$Pa$_m$-β | $^{234}$Pa- β | $^{235}$U-α | $^{231}$Th-β | $^{234}$U-α | Total |
| $E_{\beta max}$ ,MeV<br>$E_{\gamma max}$ ,MeV | - | 0.19<br>0.09 | 2.29<br>1.8 | 1.16<br>1.94 | 0.2<br>- | 0.3<br>0.1 | 0.12<br>- | -<br>- |
| q, activity of natural uranium, Bq/g | $1.2\cdot10^4$ | $1.2\cdot10^4$ | $1.2\cdot10^4$ | $1.9\cdot10^1$ | $5.7\cdot10^2$ | $5.7\cdot10^2$ | $1.2\cdot10^4$ | $4.92\cdot10^4$<br>α-$2.46\cdot10^4$<br>β-$2.46\cdot10^4$ |
| γ-radiation rate share, % | 75.4 | | | | 22.2 | | 2.4 | - |

Table 3

Comparative mass of containers shielded with different materials

| Shield mass to uranium shield mass ratio | Diameter of charge socket, cm | | | |
|---|---|---|---|---|
| | 2.5 | 5.0 | 10.0 | 15.0 |
| Lead | 1.8 | 1.7 | 1.5 | 1.4 |
| Tungsten | 1.4 | 1.4 | 1.3 | 1.3 |

**Russian depleted uranium shielded containers**

In Russia UKT1B-60 series of shipping packing set for transporting and storing sealed cobalt-60 radioactive sources are produced and RIAR well uses them since 1998. The containers of this series are allowed to be loaded with the following limited cobalt-60 activity: UKT1B-60-1 –1 Ci, UKT1B-60-10 – 10 Ci, and UKT1B-60-100- 100 Ci. These containers are articles of heightened strength and thermal stability eliminating release and loss of

radioactive content and secure effective shielding against radiation in case of possible transport accident accompanied by thermal and mechanical influence.
The container of this series is single socket overfeed structure (Fig.2). The radiation shielding is stainless steel cased depleted uranium. Besides the container is provided with the thermal protection, and the protective case also is included to the set. The socket size is 25 mm.
UKT1B-60-1, UKT1B-60-10, and UKT1B-60-100 shipping packing sets are allowed for storing and transporting sealed radioactive sources based on another radionuclides too, with total activity limited by the Equivalent Dose Rate 2.0 mSv/hr (200 mrem/hr) in any point of the package outer surface and 0.1 mSv/hr (10 mrem/hr) at 1 meter from the outer surface.
IAEA regulates any travel of any radioactive materials. Thus even empty shipping containers with depleted uranium shielding are considered as "Class 7 Dangerous Goods, UN 2908. Radioactive material. Excepted package - the article made of either natural or depleted uranium". Owing to its physical, mechanical, technological properties depleted uranium is more preferable comparing with lead, steel or tungsten as container shielding material for air transport of radioactivity.
As for transporting uranium shielded containers as dangerous goods, it is not unusual for aircraft because 210 ton of modern airliner take-off mass include 80 ton of fuel resource, the volatile flammable liquid. At the same time the equalizers located at the tail-end are made of uranium-238. Thus the most important thing is strong compliance of the regulations for packing, marking and a goods fixing aboard. Also both a consignor and a carrier staff should be trained and the qualification should avoid unfounded fears and prohibitions for shipment on the one hand and goods classifying conceit on the other hand.

## Basic components of transportation safety

In accordance with the requirements of IAEA regulations for the safe transport of radioactive materials our institute has developed the series of special shipping capsules passed tests for compliance to Special Form Radioactive Material. Sources' body are also certified as Special Form Radioactive Material. For the last years the most share of RIAR produced radioactivity is transported as Special Form Radioactive Material independently on the package type, either A or B.
The package must be safety sealed, quite enough to attenuate the radiation, and economically reasonable shielding being able safety disperse thermal energy. Let us consider how these requirements are realized in the design of packages used by RIAR.
The container stock is equipped with type A packages, as well as type B ones. Their design was developed in cooperation with VNIITFA (Moscow) experts. There are also depleted uranium shielded packages by Skoda (Czech Republic). All these packages have been tested and certified. Standard dimensions are submitted in that way, that it is possible to choose necessary and sufficient shielding for the amount of radioactivity to be transported.

## Administrative measures

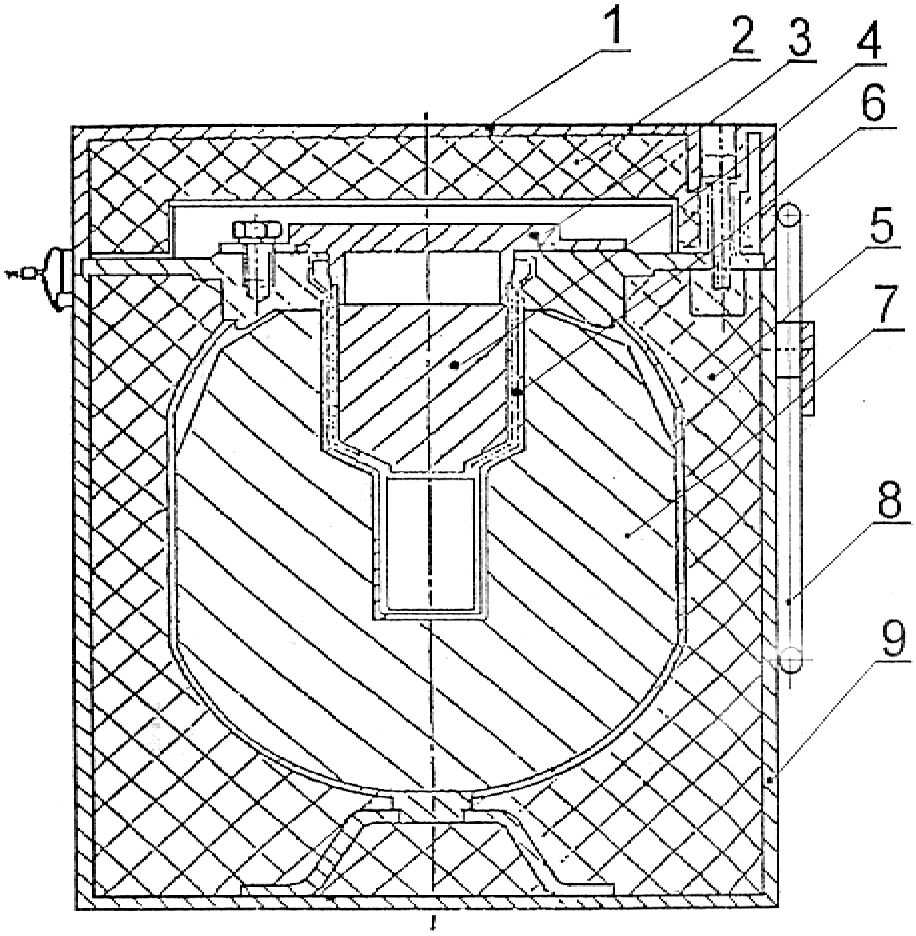
The sequence of lading, transportation and storing of packages with radioactive content is described in the Quality Assurance Program, where step by step the operating order and personnel responsibility are determined.
Transportation of the radionuclide products up to the point of departure is performed by RIAR own special vehicles equipped in accordance with the Europe Agreement on International Transportation of Dangerous Goods by Road (Fig.3). Covered body is provided with special equipment for fastening packages, completed with emergency facilities, as well as facilities for initial fire-fighting. The front wall of the body is provided with facilities for installation of the screen of extra radiation protection to assure the exposure dose rate in the cab not more than 0.02 mSv/h.
As it has been already mentioned empty shipping packing sets with uranium shielding are also Class 7 Dangerous Goods. Thus when storing and customs procedures they are made the same demands as radioactive goods to be transported. For example, this goods is prohibited to be stored together with the goods of another class at customs and airport storage facilities.
There are in Russian cities special customs posts for the control on radioactive and fissile materials having special warehouses. While in our small town Dimitrovgrad at the large nuclear centre having seven nuclear facilities under operation the special customs post was founded. It is equipped with dosimeters and analyzers but the special bonded warehouse is not available. Due to it we store usual lead containers at the municipal bonded warehouse, and the excepted packages with depleted uranium shielding at RIAR special warehouse according to the Agreement for Responsible Deposit. This circumstance should be taken in mind by that institutions in Russia who intends to export or import radioisotope products, i.e. first of all customs control issues are to be solved.


Fig.3.
Special equipped vehicle for shipping radioactivity

One more issue should be taken into account when transporting empty uranium shielded containers: it is the delivery from airports. Special equipped vehicles, special trained personnel are need, moreover the approval of local authorities of domestic affairs the territory of whom the transportation would be performed through is necessary, and special assigned transport routes as well.
Professional training of personnel involved in transportation of dangerous goods is required element in FSUE "SSC RIAR" activity. Every year both drivers and convoy study special training course in respect of the regulations for safety transportation of class 7 dangerous goods. Besides prior every run they get the instructions on safety handling radiation packages and their control under the way. Persons directly involved in preparation and transportation of radiation packages routinely get the consignor's training course according to the Ministry for Transport of Russia and Lufthansa Cargo programs.
Personnel activity in case of foreseen accidents are determined by OCT 95.10567-2002 Branch Standard, the "Instruction for prevention of accident and fire and their consequences elimination", as well as by the "Map of measures for prevention and consequences elimination of foreseen radiation accidents when transporting radioactive substances". Special trouble crew consisting of experts very much aware of radioactivity feature, and another properties of materials transported, package design and taking direct part in their loading, as well as radiation control expert is established at the institute.

**Summary**

RIAR experience, regulations being in force, as well as personnel qualification and technical conditions of containers allow to perform accident-free shipment over more than 20 years. Since this period none of radiation accident, or unrestricted personnel and habitants exposure took place.
The share of further air shipments of radioisotope products seems to increase so the RIAR container stock needs an improvement, in general in respect of materials for radiation protection providing effective attenuation of neutron and gamma radiation under minimum overall dimensions and mass of package that is important without doubt for this mode of transport. For this purpose depleted uranium shielded containers are the most suitable by the moment. Their safety is proven by wide use experience of course under strict keeping IAEA and ICAO Regulations.




1-package cover;
2-thermal protection;
3-plug;
4-radiation shielding;
5- thermal protection;
6-socket (glass);
7- radiation shielding;
8- handle;
9-body

Fig.2
Diagram of UKTIB-60-1 Shipping Packing Set