UDC 621.039.74

THE COMPLEX FOR COLLECTION, TRANSPORTATION, STORAGE AND DISPOSAL OF SPENT RADIOACTIVE SOURCES

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The article was received on 19 February 2018

Technology for collection, transportation, storage and disposal of spent short-lived (containing radionuclides with half-life up to 31 years) radioactive sources was developed and put into operation by specialists of FSUE "RADON". The technology allows safe packing of up to 100000 Ci of Co-60 sources within one specialized package with external dimensions similar to standard metal KMZ container. Also a set of special equipment and accessories was developed for source loading, conditioning into metal matrix, and periodic examination of storage conditions. The system is aimed at resolving the problems of management of non-reprocessible spent radioactive sources in accordance with the requirements of the Federal Law of 11.07.2011 No. 190-FZ.

Keywords: *spent sealed radioactive sources, container, disposal, storage.*

Sealed ionizing radiation sources, i.e. products that contain a specific radioactive material and have relevant design features preventing the release of contained radionuclides to the environment during their operation and planned wear, have found wide use in industry, agriculture, science and medicine. However, after the end of their operational lifetime or due to other reasons spent sealed ionizing radiation sources (SSRS) are transferred to the category of radioactive waste (RW). In accordance with item 1 of article 29 of the Federal Law of 11.07.2011 No. 190-FZ the spent sealed ionizing radiation source shall be transferred to the National operator for management of radioactive waste for disposal or to the manufacturing organization for reprocessing.

Most of SSRS received by FSUE "RADON" are beta- or gamma-emitting sources based on Cs-137, Co-60, Sr-90, Ir-192, i.e. short-lived radionuclides with half-lives under 31 years.

At the same time, residual activity of a single source may reach hundreds and thousands of curies. Thus the high level of gamma-radiation presents a problem in handling of these sources.

A design of well (borehole) storage facility for SSRS disposal was developed by SSDI in 1961. The storage facility consists of a stainless steel reservoir with a volume of 200 liters located at the bottom of steel-sheathed concrete well. A spiral loading pipe is used to load the sources and to prevent direct release of gamma-radiation from the storage facility. Cast iron loading funnel is located at the surface. The funnel is connected to a standard container used for transportation of KTB-26-12 sources (Fig. 1) or other transport containers with bottom unloading and similar design features.

These transport containers have a drum with channels for loading of sources.

Loading may be performed from both the top and from the bottom of the container using specialized equipment. Unloading of the container is performed through the bottom channel and may be performed remotely without additional equipment — the source is unloaded by gravity.

Such containers are currently used for transportation of sealed ionizing radiation sources in process of maintenance of radiation installations.

The translation is done by V. I. Shpinkov

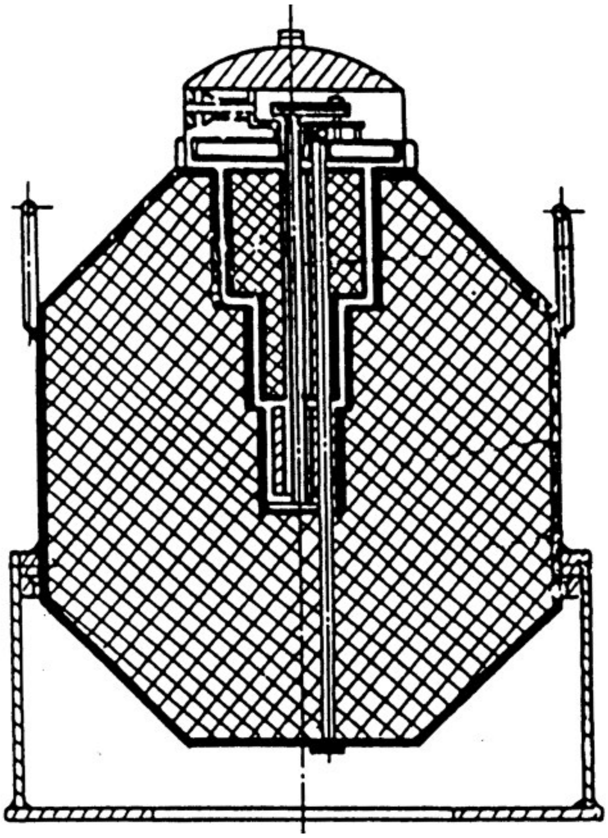

Fig. 1. Design of KTB-26-12 sources transportation container

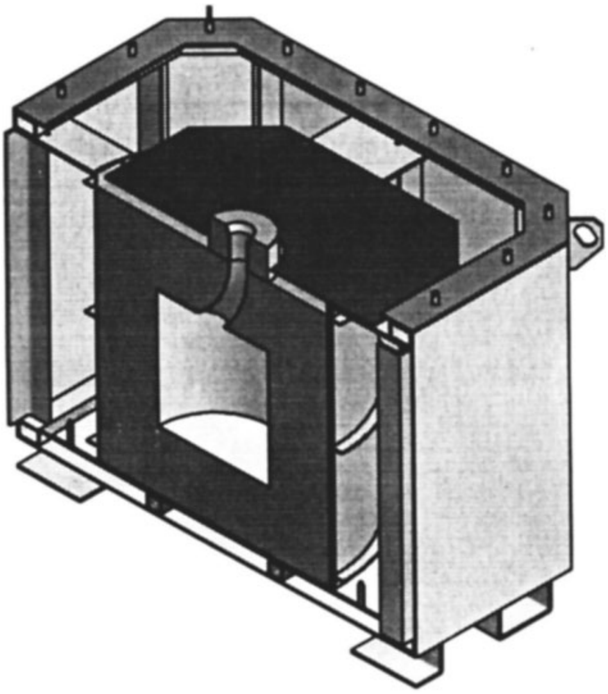

Fig. 2. Transport package design

With enactment of the Federal Law of 11.07.2011 No.190-FZ "On the management of RW" the use of well-type storage facilities no longer complied with legal requirements as removal of sources from these storage facilities for transfer to the National operator for disposal is a complex engineering problem connected with a high risk of personnel exposure. In fact, the problem of retrieval of sources from this type of storage facilities has not yet been resolved.

Technology of SSRS management based on specialized package KMZ-RNI-RADON was developed by the specialists of FSUE "RADON" to resolve the problem of collection, storage and subsequent transfer of spent sealed ionizing radiation sources to the National operator. The transport package, in contrast to the well-type storage facility, has the following capabilities:

- RW retrieval from the package at the end of storage time;
- placement of RW package inside an additional container or repacking as required;
- transportation of RW package for disposal;
- handling of RW package in process of disposal.

The main technical specifications of the transport package are given below:

- volume of inner reservoir for SSRS — 0.08 m^3.
- nominal activity (for Co-60) of SSRS — 100 000 Ci;
- maximum SSRS dimensions — Ø38×200 mm;
- mass of empty package — not more than 9000 kg;
- mass of loaded package — not more than 10000 kg;
- external dimensions (L×W×H)—1650×1650×1375 mm.

The package (Fig. 2) consists of an internal protective container (1), which has a vessel for sources (2) with a volume of 80 l surrounded by lead biological protection 25—30 cm thick. Curved loading pipe (3), sealed by a plug, is used for SSRS loading. The inner protective container is located inside a protective container, which is externally similar to the metal RW container of KMZ-RADON type (4) in order to ensure protection from ambient factors and to standardize the RW management operations.

The package allows use of standard containers with bottom unloading for SSRS transportation in case of use of additional equipment. The unloading mechanism is similar to unloading to well-type storage facility.

Lead biological protection limits the equivalent dose rate at the surface of the package and at the distance of 1 m for a load of 100 000 Ci of Co-60 at the levels specified in NP-053-16 for the III transport category, i.e. 2 and 0.1 mSv/h respectively.

Radiation fields calculations for justification of biological protection design and maximum allowed activity of the load were performed by "Robot" software based on Monte-Carlo method, in 3D setting and multi-group approximation.

Calculations were used to select the optimal parameters for biological protection and the source storage vessel in order to provide maximum capacity in terms of activity whilst maintaining the preset levels of gamma-radiation at the surface of the package and at the distance of 1 m and keeping the overall mass of the package within 10 t.

Calculation of radiation heating of SSRS package was based on solution of the heat conductivity equation applied to the container structure by a finite difference method. Calculations demonstrated

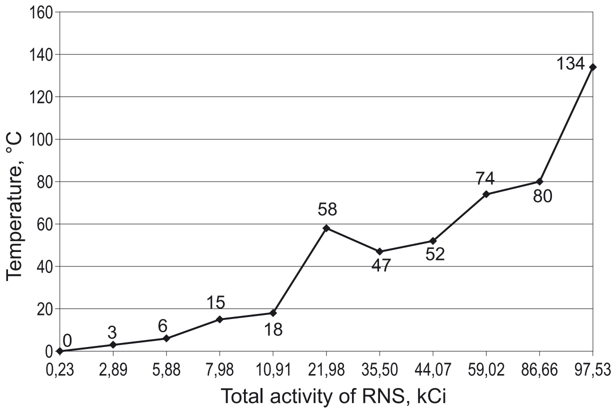

Fig. 3. Diagram of temperature change in the source vessel as a function of activity of loaded Co-60 sources

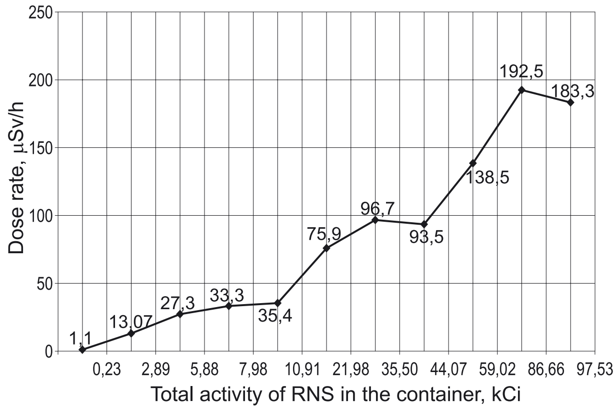

Fig. 4. Maximum gamma-radiation dose rate at the side surface of the package as a function of loaded activity

that in case of loading of 100000 Ci of sources based on Co-60 the temperature will not exceed the maximum design value of 230 °C.

Calculated temperature value in the source vessel with maximum activity load was verified experimentally with an electric heater of 1.5 kW power, which is an equivalent of decay heat of 100000 Ci of Co-60.

The experiment demonstrated that the temperature at control points after stabilization did not exceed the following values:

- at the source vessel — 100 °C,
- at the external surface of the inner container — 60 °C,
- at the external surface of the KMZ container — 5 °C above the ambient temperature.

Calculated values of temperature and dose rate at the surface were verified for the experimental package with loading of reals SSRS.

As shown in Fig. 3, the heterogeneity of temperature rise could be explained by the non-uniform layer of sources, which may cause additional heating in some areas. Nevertheless, the maximum temperature recorded for activity virtually equal to 100000 Ci was substantially lower than the maximum design value for the well-type storage facility, 230 °C. The recorded maximum temperature value in the SSRS vessel was higher than in the model experiment, however, this could be explained by non-uniform heating of some areas within the vessel due to heterogeneous spatial distribution of activity.

Fig. 4 shows the maximum gamma-radiation dose rate at the side surface of the package as a function of loaded activity. The heterogeneity of dose rate rise is explained by non-uniformity of loaded SSRS position. At the same time, it was experimentally proven that the dose rate at the surface of a fully loaded container is many times lower than the regulatory limits. The lower dose rate values at the surface of the package compared to the calculated values is explained by the conservative scenario used in the calculation — a point source located at the side surface of the vessel.

The real sources were distributed across the volume, therefore the dose rate at the surface was lower than the calculated value. This "reserve" makes loading of higher activities possible provided that the dose rate at the surface and temperature in the SSRS vessel are controlled.

A system of devices of SSRS conditioning complex was developed to ensure the capability of SSRS unloading from bottom-unloading containers to KMZ-RNI-RADON, SSRS conditioning in metal matrix, and monitoring of SSRS storage conditions at the same level of convenience and safety as in the well-type storage facility.

The complex includes the following elements:

- KMZ-RNI-RADON package;
- reloading kit;
- conditioning kit;
- maintenance kit;
- monitoring and emergency kit.

A specialized module comprising of a pad with railing located around KMZ-RNI-RADON ensuring safe and convenient working conditions for personnel working at an elevation of over 1 m is used for SSRS unloading from the bottom-unloading container (Fig. 5). Reloading module installed at the package is used to ensure radiation safety in process of SSRS unloading from the transport containers.

SSRS stored or disposed of in KMZ-RNI_RADON container may also be included in a lead-based metal matrix for considerations of radiation safety and security.

The lead matrix provides additional protection of source casing from ambient impacts, uniformly distributes the heat energy produced in decay of radionuclides and absorbs ionizing radiation. Welding of the plug of the inner protective container and the lid of outer KMZ container is possible for the loaded package sent for disposal. Thus, the KMZ-KNI_RADON package complies with the defence-in-depth requirements for RW disposal.

The operations of SSRS conditioning in a metal matrix are performed using the conditioning kit, which includes an additional pad with railing (Fig. 6) and "Moskit-T" facility (Fig. 7).

Safety assurance for SSRS storage in the package requires periodic control of source storage

Fig. 5. General position of package and system elements

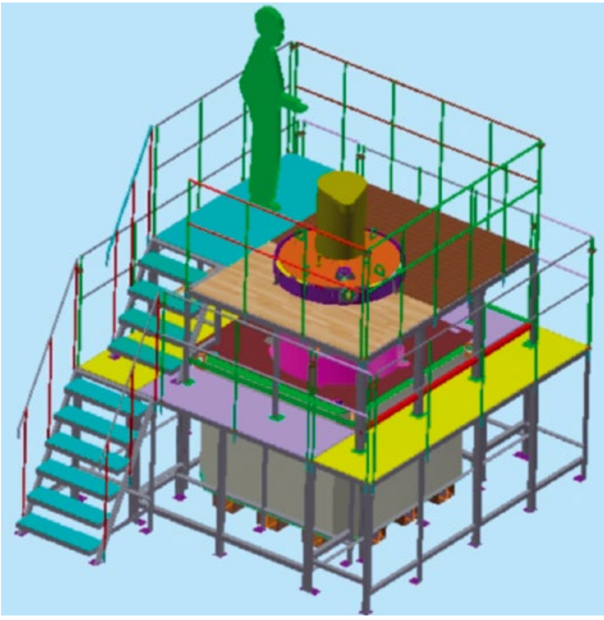

Fig. 6. Additional pad with railing of the conditioning kit

parameters, specifically: gamma-radiation dose rate measurement at the surface of the package, sampling of surface contamination of the loading pipe, video monitoring of the condition of the loading pipe, SSRS vessel and source casing, temperature measurement in the source vessel. A special equipment kit was developed for these operations, which includes a sampler, a number of auxiliary appliances, a radiation-resistant video surveillance device, and a dosimeter-radiometer, supplied on request.

Fig. 8 shows the image of SSRS inside the KMZ-RNI-RADON vessel obtained using the video surveillance device.

Utility model patent of the Russian Federation No. 155931 was received for the design of the container (Fig. 9).

Certificate-permit RUS/1073/B(U)-96T was obtained for the package, permitting transportation of radioactive materials in the package.

In accordance with the Decree of the Government of the Russian Federation of 19.12.2012 No.1069

Fig. 7. "Moskit-T" installation

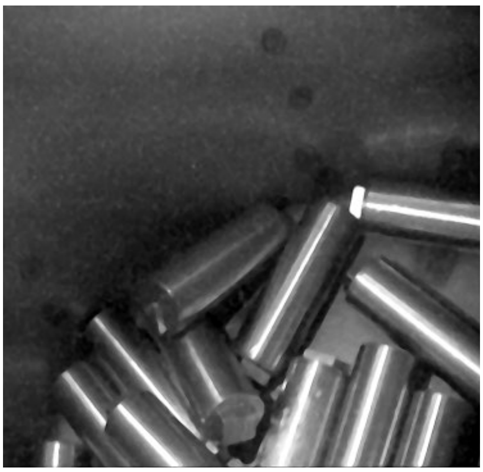

Fig. 8. SSRS inside the KMZ-RNI-RADON vessel

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ПОЛЕЗНУЮ МОДЕЛЬ

№ 155931

КОНТЕЙНЕР ДЛЯ РАДИОНУКЛИДНЫХ ИСТОЧНИКОВ

Патентообладатель(ли): *Федеральное государственное унитарное предприятие "Объединенный эколого-технологический и научно-исследовательский центр по обезвреживанию РАО и охране окружающей среды" (ФГУП "РАДОН") (RU)*

Автор(ы): *см. на обороте*

Заявка № 2014147639

Приоритет полезной модели 27 ноября 2014 г.

Зарегистрировано в Государственном реестре полезных моделей Российской Федерации *29 сентября 2015 г.*

Срок действия патента истекает 27 ноября 2024 г.

Руководитель Федеральной службы по интеллектуальной собственности

Г.П. Ивлиев

Fig. 9. Patent of the RF No. 155931

"On the Criteria of classification of liquid and gaseous waste as radioactive waste and criteria of classification of radioactive waste as special radioactive waste and retrievable radioactive waste and criteria of classification of retrievable radioactive waste", the resulting SSRS package would correspond to 2 class RW, as the SSRS correspond to the first or second hazard classes.

Long-term storage for the duration of 10-20 half-life periods at specialized storage facilities is possible for SSRS based on short-lived radionuclides, such as Co-60 and Sr-90, in order to reduce their activity prior to disposal.

The overall package complies with disposal acceptance criteria NP-093.

Conclusions

The developed complex for collection, transportation, storage and disposal of spent sealed ionizing radiation sources provides a solution for the problem of management of this type of RW in accordance with the requirements of the Federal Law of 11.07.2011 No.190-FZ "On the management of radioactive waste…". The developed package has a capacity of at least 100 000 Ci of Co-60 sources.

The equipment of the system covers the full cycle of works, including sources unloading from standard transport containers with bottom unloading, inclusion of sources into metal matrix for radiation safety and security during storage and disposal, monitoring of source storage conditions and mitigation of emergency situations.

The complex has been commissioned at FSUE "RADON", thus the capacity to accept spent sources for storage was retained.

Acknowledgements

Authors express their thanks to Yourii Karlin for his leadership, Oleg Nikolaev for thermal calculations performing, Alexander Sumenko and Vladimir Chicherin for their design effort, Sergei Staroverkin and Andrei Yurchenko for their invaluable help in container constructing.

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Bibliographic description

Diordiy M. N., Semenov V. E., Karlina O. K. The complex for collection, transportation, storage and disposal of spent radioactive sources. *Radioactive Waste*, 2018, no. 2 (3), pp. 73—78. (In Russian).