REPORT

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Conception of Class "C" package for transportation of spent Russia-made nuclear fuel from research reactors

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Abstract

The problem of international transportations of spent nuclear fuel from research reactors (RR SNF) by air becomes presently more and more urgent. This problem has been solved neither in Russia nor in any other country. There is no presently a certified cask in the world for transportation of SNF by air.

This paper presents the conception of Class "C" package intended for RR SNF transportation. The conception was developed by RFNC–VNIIEF together with JSC SIF "Sosny" due to support of Oak Ridge National Laboratory.

Conception is the following. Cask SKODA VPVR/M was certified in Russia in 2006 as Class B(U) package for transportation of spent nuclear fuel assemblies (SNFA) from research reactors (RR) by ground and water vehicles.

Under the frames of this conception, it is suggested, making no any changes in the design of the cask SKODA VPVR/M, to place it in a special cartridge of a dynamic protection, which will provide the cask strength under conditions of increased mechanical effects simulating an airplane crash (impact against a barrier with velocity not less than 90m/s). In this case, cask SKODA VPVR/M, which is mounted in the cartridge of the dynamic protection, can be certified as Class "C" package intended for transportation of SNF from research reactors.

Designs of this removable dynamic protection were verified. It is a big-honeycomb metal construction.

Class "C" package has the following characteristics:

Weight of cask SKODA VPVR/M loaded with RR SNFA included in Class "C" package	~ 11150 kg
Weight of dynamic protection	~ 13500 kg
Total weight of package	~ 25000 kg
Length of package	~ 3500 mm
External diameter of package	~ 3000 mm

The basic advantage of the suggested package design is that it uses a serial certified cask SKODA VPVR/M without any updating. It will allow developing and certifying the Class "C" package for RR SNF during short time with minimum expenses.

The paper will present a design of the class "C" package and the basic results of calculation analysis of the package safety during accidental situations when transporting by air.

Introduction

International shipment of irradiated nuclear fuel (INF) from the research and power reactors via air becomes more and more important because:

- International air transportation of nuclear fissile materials (NFM) does not need approval of competent authorities from all countries over which the transport occurs. This facilitates and hastens establishing the transportation procedure;
- Some European countries forbid NFM transportation within their boundary;
- INF transportation from some countries in the Near East and Europe can only be done via air;
- INF and NFM transportations via water and ground are very sensitive to physical protection requirements.

A new edition of the IAEA Regulations for radioactive materials safe transportation, TS-R-1, accepted in 2000, virtually prohibits NFM air transportation using existing casks. Analyses of existing casks for fresh fuel and INF show that their design do not withstand high level mechanical and thermal impact as required by TS-R-1 for packages transported via air.

During the time period from 1998 to 2005, RFNC –VNIIEF, together with Rosatom, OAO "TVEL", OAO "MSZ", and OAO "NZKhT," successfully up-dated the fleet of existing Russian casks for air transport of fresh nuclear fuel from research and power reactors. But, the problem of irradiated nuclear fuel transportation via air is not yet solved. There is no current cask design, anywhere, that meets all TS-R-1 Regulations for safe air shipment.

Collaboration within the framework of the "Global Nuclear Energy Partnership" program (GNEP) makes the prospects of resolving the problem of the air transport of NFM (including INF and MOX fuel) promising, because air transportation is the safest method of shipping. The necessity of such transportation grows in connection with the implementation of the Russia- USA Agreement concerning the shipment of research irradiated nuclear fuel from some European, Asian, and African countries where research reactors that were fabricated by Russia were installed. Currently, when air transportation is required, it is carried out under emergency conditions.

RFNC-VNIIEF - together with the OOO "SOSNI," and in collaboration with ORNL – has developed transport package set (TUK) concept for research INF transportation and a concept for a universal TUK research and power INF transportation. These concepts meet all TS-R-1 requirements for Type C packages. This paper briefly describes these concepts.

A TUK concept for air transportation of research reactor INF.

Russia developed and licensed a new Russian cask made of high-duty cast iron - TUK-128 (Type B(U) cask) – in 2006. This package was designed for shipping spent nuclear fuel assemblies (SNFA) from research reactors (RR) via all land-transportation types. The Czech TUK SKODA VPVR/M (designed and built by SKODA JS) may also be used for this purpose. The SKODA cask has also been licensed as a Type B(U) package according to Russian regulations NP-053-04 and TS-R-1.

The first concept suggests using a TUK-128 and/or TUK VPVR-SKODA without a change in cask design, but with additional removable reactive armor instead of existing shock absorbers. That is, the reactive armor is also the shock absorbers. This innovation provides the necessary strength for the cask under high mechanical impact conditions that imitate a non-fatal aircraft accident (a shock impact at a speed no less than 90 m/s). In this case, both the TUK-128 and TUK VPVR-SKODA, with the additional removable reactive armor, may be licensed as a Type C package for the transportation of irradiated fissile materials.

A preliminary design of the removable reactive armor was undertaken for both casks - TUK-128 and TUK VPVR-SKODA casks. The removable reactive armor (a big-honeycomb metal structure) design provides maximum buffering. Under conditions imitating non-fatal aircraft accident (shock impact under speed no less than 90 m/s), the load onto load-bearing elements of TUK-128 and/or TUK VPVR-SKODA is equal to the load when TUK is dropped onto a rigid surface from 9 meters height. Under such load, all main load-bearing elements of TUK-128 and/or TUK VPVR-SKODA undergo elastic deformation.

Fig.1 presents the design-assembly scheme of RR SNF package with the proposed removable reactive armor.

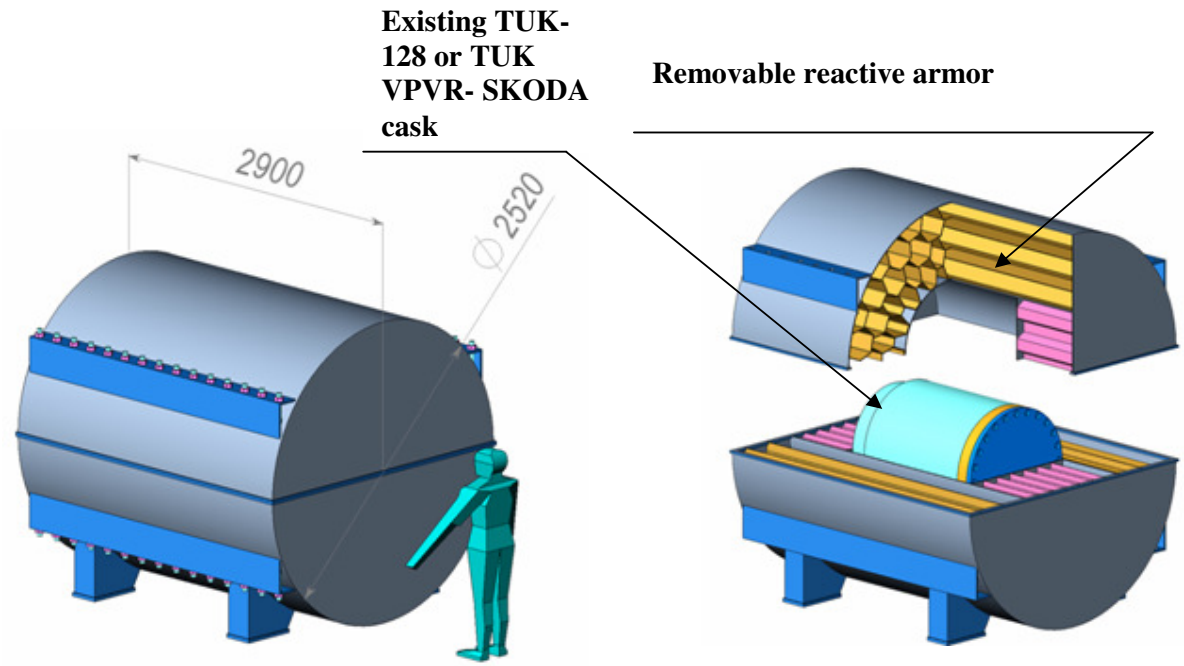

Fig. 1. Schematic for Air Transport Cask developed for INF from research reactors based on TUK-128 or TUK VPVR-SKODA

The characteristics of this package are given in the Table 1.

Table 1.

Characteristics	TUK-128	TUK VPVR-SKODA
Weight of the TUK loaded with RR SNFA, (no more than, kg)	9,300	11,150
Weight of a removable reactive armor, (kg)	~ 10,000	~ 12,000
Total Type C package mass, (kg)	~ 20,000	~ 23,000
Package height, (mm)	~ 3,000	~ 3,500
Outer package diameter, (mm)	~ 2,500	~ 3,000

Calculations indicate that this design, with the proposed removable reactive armor, retains necessary strength under strong mechanical impact conditions that simulate a non-fatal aircraft accident, according to TS-R-1 requirements.

The primary advantage of the proposed design is that the commercial licensed casks, TUK - TUK-128 or TUK VPVR-SKODA, are used without any changes. This facilitates the development and licensing of the Type C package for RR INF and reduces the package cost.

A TUK Concept for the Air Transportation of Universal INF from Research and Power Reactors

Too often casks are design for a reactor specific nuclear fuel type. In the previous cases, the developed designs are appropriated for the air transportation of research reactor INF. However, sometimes there is a need for air shipment of INF from power reactors. Therefore, a universal TUK cask for air transportation of MOX fuel and SNFA from both research and power reactors was conceptualized.

This proposed universal TUK cask design is oriented toward the transport of one SNFA from a VVER-1000 power reactor, or, 20 SNFA from research reactors. The design-assembly scheme of the proposed universal TUK design is presented in the Fig. 2.

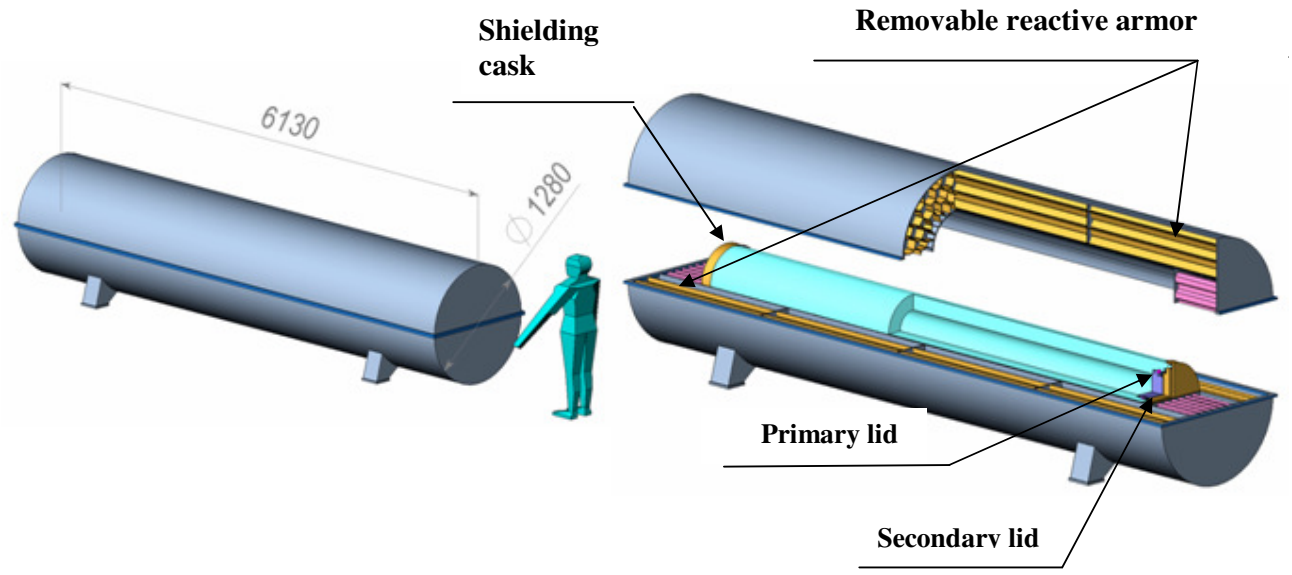

Fig. 2. Design-assembly scheme of a universal TUK cask.

The universal TUK includes a shielding cask with a removable reactive armor. The shielding cask is a pressurized cylinder that includes a body and two lids made from stainless steel 12Kh18N10T.

Lids are mounted on the upper part of the body in a step counter bore. Each lid is sealed by two pads.

The first lid -a thick disc that receives loading from the SNFA basket under emergency falls - is mounted onto the body by a wedge lock. Such a stress-relieved joint between the lid and the cask body provides the necessary strength under shock impact imitating a non-fatal aircraft accident. The second lid (a thin round diaphragm) is fastened to the cask body by bolts. This lid is not a load-bearing element and acts as the main seal.

The required strength of the shielding cask, in conditions imitating non-fatal aircraft accident (shock impact at speed no less than 90 m/s), is provided by the removable reactive armor.

A variant of the removable reactive armor is a honeycomb metal structure. The proposed reactive armor will provide load reduction onto load-bearing and pressurized elements in conditions imitating non-fatal aircraft accident (shock impact under speed no less than 90 m/s). This is the load level when load-bearing elements of the cask work in elastic area.

The shielding cask includes a set of baskets, made of atabor material (stainless steel with ~ 5% boron content). The baskets provide nuclear safety of the loaded cask during normal and emergency conditions. The proposed universal TUK has the characteristics shown in Table 2.

Table 2. Characteristics of a TUK Cask for Air Transport of Universal SNF

Mass of the loaded shielding cask, (kg)	~ 10,000;
Mass of the removable reactive armor, (kg)	~ 9,000;
Total Type C package mass, (kg)	~ 19,000;
Inner chamber length, (mm)	~ 300;
Inner chamber length, (mm)	~ 4,700;
TUK length (with dynamic shock absorber), (mm)	~ 6200;
Outer TUK diameter (with dynamic shock absorber), (mm)	~ 1300.

Preliminary safety calculations of the proposed universal TUK design were carried out for:

- strength and hermeticity of cask design;
- thermal conditions;
- nuclear safety;
- radiation safety.

The calculations show that the proposed universal TUK design will meet TS-R-1 safety regulations for Type C packages.

The main advantage of the proposed design is that it meets TS-R-1 requirements and can be used for air transportation of spent and fresh MOX fuel and SNF from both research and power reactors. The use of this universal package will reduce the cost of cask fabrication.

Summary

Preliminary, conceptual designs were developed for research reactor SNFA air transportable cask that meet Class C package criteria. This concept is a design based on serial TUK-128 and TUK VPVR-SKODA.

Additionally, a universal TUK design is suggested that can accommodate both research reactor and power nuclear reactor spent fuel. Calculations to date indicate that these designs will meet regulatory standards.