REPORT
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Russian expertise in certification of packages for transportation of fresh nuclear fuel in accordance with safety requirements of IAEA Rules (TS-R-1) concerning transportation of fissile materials by air

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Abstract

Issue of new edition of the international Rules TS-R-1, where requirements for FM transportation by air are stricter, imposes actually a ban on transportation of fresh nuclear fuel (FNF) from power reactors and research reactors by air with use of the existing fleet of packages, which have been developed and certified without account for these new requirements.

This circumstance would strongly complicate conduction of obligations, including international obligations, by the RF Rosatom plants, which are responsible for FNF transportation.

Due to this reason, RFNC–VNIIEF performed a large complex of works for updating and certification of the basic row of packages for FNF from research reactors and power reactors for adequacy of them to the requirements of TS-R-1 on safety of FM transportations by air.

The following scope was accomplished.

1. Numerical research was performed for response of all types of packages to loadings simulating an airplane crash.
2. Full-scale tests were conducted using the packages in accordance with the requirements of TS-R-1, including tests with impact against a target with velocity of 90m/s.
3. Basing on results of the tests and the research, certification were performed for the packages intended for FNF transportation.

As a result, Russia has presently a new certified fleet of transport packages for transportation of FNF and its components, which comply with the safety requirements of TS-R-1 for packages transported by air. All types of packages got certificates-approvals from the RF Rosatom.

Basing on these certificates, internal and international air transportations of FNF are currently accomplished, including under the frames of the intergovernmental Russian-American Agreement on collaboration for returning of Russia-made nuclear fuel from research reactors to the RF. The Agreement was signed in May, 2004. In total, nearly 240 kg of uranium-235 were returned presently to Russia from Yugoslavia, Libya, Bulgaria, Rumania, Czechia, Uzbekistan, Germany, Latvia.

The paper will present results of analysis and tests, which were performed during the certification works for the basic row of packages intended for transportation of FNF by air.

REPORT

Every year in Russia, a large amount of domestic and international transportation of fresh nuclear fuel (FNF) used in Russian and foreign energy and research atomic reactors and referred to fissile materials based on IAEA Regulations is performed. Here, bulk transportation is performed by air, and it concerns international transportation in particular.

A long-standing experience in accident free transportation of FM has shown that such approach to provide nuclear and radiation security pays for itself completely.

Once in 10 years the International Atomic Energy Agency on every revision of the "Regulations for the Safe Transport of Radioactive Materials" places more stringent requirements upon the FM and transportation thereof, resulting from the objectively increasing risk associated with constant rise in volume and density of transportation, and also strained social and economical situation in a number of regions in the world.

In the new edition of the IAEA Regulations (TS-R-1) the requirements to FM packages conveyed by aircraft were radically changed. These requirements are completely presented in new Russian "Regulations for the Safe Transport of Radioactive Materials" (НП-053-04) which will be brought into force in the time ahead.

In accordance with new regulations, FM packages conveyed by air transport must ensure safety after additional strengthening tests simulating the accident of an aircraft, and including two series of transportation accidents as follows:

First series (complex tests):

- the test unit is free falling on a rigid barrier from a height of 9 m;
- test on dynamic damage when a 500 kg body is falling on the package from a height of 9 m;
- test on puncture/ rupture when a 250 kg package is falling on a pin (or pin on the package) from a height of 3 m;
- exposure of the package to an external heat field with an average temperature of 800°C for about 60 minutes.

The package condition in this series must be assessed based on observed damages in the specified order of accident effects.

Second series:

- The shock impact of the package on a target (hard undeformable barrier) with the velocity of not less than 90m/s at an angle to the target, ending in maximum damage of the package.

The existing now in Russia arsenal of standard packages to transport nuclear fuel (NF) for energy and research reactors was designed in compliance with the requirements imposed by the IAEA-85/90 Regulations on transportation of FM by aircraft following which one did not need to inspect the packages by performing additional severe tests simulating the aircraft accident.

Thus, subsequent to the issue of new IAEA-96 Regulations in 1996 the Minatom (the Ministry of Atomic Energy) and its institutions that produce and supply nuclear fuel enjoyed dilemma: to give up completely the aircraft transportation of NF both at home and abroad, or without any greater delay to turn to the development and certification of national arsenal of packages meeting the new IAEA-96 Requirements.

Results of examination have shown that the abandonment of the aircraft transportation of NF will result in significant complication, rise in prices, and reduction of security in NF transportation, and international in particular, and in a number of events will lead to terminate the contracts, severance of stable ties.

Due to this reason, activities were started in 1997 for recertification of all Russian fleet of casks intended for FNF transportation. For this purpose, RFNC-VNIIEF experts developed methodology for numerical-experimental justification and confirmation of safety of casks with

FM as complied with requirements of Rules TS-R-1 concerning FM transportation by air vehicles.

To solve the problem, the Minatom has faced, of the development of national arsenal of NF packages conforming up-to-date security requirements placed by the IAEA on aircraft transport of FM in the shortest possible time, a large complex of scientific and methodic, computational and theoretical, design, technological and experimental works have been performed, the main of which are given below:

1. In RFNC-VNIIEF based on up-to-date program complexes, the precision computation methods (codes) to investigate the response of all types of NF packages to high-intensive thermal and physical loads that simulate an aircraft accident, and to define their limiting conditions have been developed. Algorithms for the assessment of nuclear and radiation safety of NF packages in aircraft accident have been developed.

2. A unique method for testing NF packages in wide range of mass and overall dimension on the shock impact on an undeformable target (barrier) with the velocity of not less than 90m/s has been developed and certified by the RF GAN (State Atomic Supervision).

The method is based on the employment of a horizontal rocket track, available in RFNC-VNIIEF, by rail guides of which the packages are accelerated to a specified velocity with the help of rocket sleds (Figures 1). Technical capabilities of the track allow to reach velocity of cask acceleration up to 130 m/s and higher, and to test casks having weights up to 6 tons.

Fig.1 Horizontal rocket track of RFNC-VNIIEF, which is used for tests where casks are impacted against target with velocity not less than 90m/s

To realize this method, vertical target (barrier) was designed for the package that flies horizontally at a specified angle to impinge on. Due to RFNC-VNIIEF initiative, the new edition of IAEA Rules dated 2005 allows application of a vertical target.

The vertical barrier is a complex structure weighing about 600 tons, which is full accord with the IAEA requirements, and ensures testing packages weighing about 6 tons.

Moreover, to measure parameters of the impacts of the package on the target, a number of unique metrologically certified techniques for measurement have been devised.

The method for testing having been developed in the context of said work to simulate the aircraft accident has analogy neither in Russia nor abroad.

3. Under the frameworks of activities for recertification of serial casks, safety of design and transportation was confirmed in accordance with the IAEA Rules for the following casks, which are the basic row of Russian cask fleet intended for FNF from energetic and research reactors: TC-C55 (updated TC-C4), TC-C5-V, TC-C7M, TC-C14, TC-C15, TC-C16.

Besides, in 2005, an absolutely new type of casks was certified with use of the numerical-experimental method. This cask is intended for transportation of powders of uranium oxides by air vehicles.

A large complex of computational and theoretical studies of the strength and nuclear and radiation security of all the five existing standard packages with the use of the devised and certified methods has been performed.

4. Experimental prototypes for five types of packages with dynamic FM-free FA models designed to conduct tests have been developed, justified, and fabricated.

5. Tests on the impact of all types of packages on the target with the velocity of 90m/s at various angles to the target were conducted at the RFNC-VNIIEF rocket track with the use of the test method developed in the context of this work. On the whole ten tests of full-scale packages and two tests of one-fourth scale prototypes were conducted.

Figures 2 present photos with tests of cask TC-C5-V.

Comparative analysis of the test results, and computational and theoretical studies have shown a good agreement both the general presentation of package damage in accidents, and precise disclosure of poor structure elements, testifying the high precision of the computational methods used (Figures 3).

6. Relying on the test results and computational investigations, the modified arsenal of packages designed to transport FNF was certified with the conformity to the IAEA-96 Regulations. Certificate-permissions on the design and transportation by all types of transport, including air transportation, have been given each package type by the State competent body.

The methodology developed is also suitable for certifying air transportation of packages containing radioactive materials of higher total activity (C-type packages according to the IAEA-96 Regulations). In 2001, the C-type UKTIIV-RITEG package designed to transfer a Plutonium-238 radionuclide source-containing generator was certified by the given methodology.

It should be pointed out that the said methodology has been approved by the RF GAN (State Atomic Supervision of Russian Federation), and represented by the new Russian НП-053-04 Regulations; it has also been indicated to be employed in Europe countries carrying out FM transport by aircraft.

As a result, Russia has presently a new certified fleet of transport packages for transportation of FNF and its components, which comply with the safety requirements of TS-R-1 for packages transported by air. All types of packages got certificates-approvals from the RF Rosatom. These certificates were also approved by the competent authorities of all foreign countries, where Russia performs FNF transportations.

Basing on these certificates-approvals, internal and international air transportations of FNF are currently accomplished, including under the frames of the intergovernmental Russian-American Agreement on collaboration for returning of Russia-made nuclear fuel from research reactors to the RF. The Agreement was signed in May, 2004. In total, nearly 240 kg of uranium-235 were returned presently to Russia from Yugoslavia, Libya, Bulgaria, Rumania, Czechia, Uzbekistan, Germany, Latvia.

With participation of DOE, Oak Ridge National Laboratory and JSC SIF “Sosny”, works are currently performed for development of a cask intended for transportation of spent nuclear fuel from research reactors by air vehicles. Transportation of this type of fuel is presently very urgent, and it is arranged in accordance with the Russian-American Agreement. It is the subject of the other presentation at this Symposium.