Licensing Air and Transboundary Shipments of Spent Nuclear Fuel

S.V. Komarov[a], M.E. Budu[a], D.V. Derganov[a], O.A. Savina[a], I.M. Bolshinsky[b], S.D. Moses[b], L. Biro[c]

[a] R&D Company "Sosny", Russia

[b] DOE, USA

[c] CNCAN, Romania

Abstract. Since 1996 the IAEA TS-R-1 regulation included new requirements applicable to transport of fissile materials by air. The later 2005 and 2009 editions confirmed the validity of those provisions. Despite the fact that the IAEA TS-R-1 allows for air shipments of SNF in Type B and Type C packages, the examples of such shipments are not abundant. Nuclear regulatory bodies and transport safety experts are cautious about air shipments of SNF. Why so? What are the risks? What are the alternatives?

In this new regulatory framework, in 2009, two air shipments in Type B packages of Research Reactor (RR) Spent Nuclear Fuel (SNF) from Romania and Libya were performed under the U.S. DOE/NNSA RRRFR Program. The first licensing process of such shipment brought up many questions about package and shipment safety from the licensing experts' side and so the scope of analyses exceeded the requirements of IAEA. Under the thorough supervision of Rosatom and witnessed by DOE and CNCAN, all questions were answered by various strength analyses and risk evaluations. But the progress achieved didn't stop here. In 2010-2011, an energy absorption container (EAC) with titanium spheres as absorbers based on the SKODA VPVR/M cask was designed as the first Type C package in the world destined for RR SNF, currently under approval process.

At the same time, intense preparations for the safe removal of the Russian-origin damaged RR SNF from Serbia, Vinca were in progress. The big amount of SNF and its rapidly worsening condition imposed as requirements to organize only one shipment as fast as possible, i.e. using at the maximum extent the entire experience available from other SNF shipments. The long route, several transit countries and means of transport, two different casks, new European regulations and many other issues resulted for the Serbian shipment in one of the most complex SNF shipments' licensing exercise.

This paper shows how the international regulatory framework ensures the safety of any SNF shipment by bringing together for comparison two radically different experiences that together cover all possible aspects of licensing for this type of activities. The report can also be used for harmonizing national regulatory requirements for transboundary transports of radioactive material by any conveyances (road, rail, water, air).

1. Introduction

In 1993-1994, two air transports of research reactor spent nuclear fuel (RR SNF) took place from Iraq to Russia organized under special arrangement, in the context of extraordinary conditions resulted from the 1991 war. The Regulations for the Safe Transport of Radioactive Material in force at that time (IAEA, 1985) didn't impose any limitations on utilization of air transport for transportation of highly radioactive materials.

However, potential consequences of an air transport accident are far more severe than on land or sea transport, as a result of which the 1996 edition of the IAEA TS-R-1 regulation was amended to include stricter requirements applicable to packages that are intended for transport

of fissionable materials by air. The later 2005 and 2009 editions of this IAEA regulation confirmed the validity of those provisions.

In this new regulatory framework, in 2009, two air shipments in Type B packages of RR SNF from Romania and Libya were performed under the US DOE/NNSA Russian Research Reactor Fuel Return (RRRFR) Program. The first licensing process of such shipment brought up many questions about package and shipment safety from the licensing experts' side and so the scope of analyses exceeded the requirements of IAEA. Under the thorough supervision of Rosatom and witnessed by DOE and CNCAN, all questions were answered by various strength analyses and risk evaluations. For the given shipments special emergency cards were issued.

In 2010-2011, an energy absorption container (EAC) with titanium spheres as absorbers based on the SKODA VPVR/M cask was designed as the first Type C package in the world destined for RR SNF, currently under approval process.

In the period 2006-2010, intense preparations for the safe removal of the Russian-origin damaged RR SNF from Serbia, Vinca started under the IAEA management. The big amount of SNF and its rapidly worsening condition imposed as requirements to organize only one shipment as fast as possible, i.e. using at the maximum extent the entire experience available from other SNF shipments. The transit through Hungary and Slovenia, the long route over the Mediterranean Sea and Atlantic Ocean, the multiple means of transport (road, rail and sea), two different casks (TUK-19 and SKODA VPVR-M), new European regulations and many other issues resulted for the Serbian shipment in one of the most complex SNF shipments' licensing exercise and the biggest project in the history of IAEA.
In this context, we chose to present here for comparison two entirely different recent SNF shipments. One of them is the world's first SNF air shipment licensed under the new IAEA requirements (2005 edition of the IAEA TS-R-1) which took place from Romania in 2009 in Type B casks. The second example presented further is the Serbian SNF shipment which took place in 2010, due to the complexity of its licensing process caused by two transit countries. The two examples will reflect the differences in the licensing process, showing by comparison pluses and minuses of the two options and also key schedule information. In addition, the last achievements in Russia in the SNF air shipments licensing process are presented. The specific organization for the licensing of the first Type C cask design and compliance with the latest IAEA TS-R-1 requirements (2009 edition) will be addressed in detail.

2. Licensing Air and Transboundary Shipments of Spent Nuclear Fuel

2.1. General Applicable Issues

2.1.1. International Regulatory Basis for SNF Shipments

The international regulatory basis for SNF shipments is formed by the following world-wide applied standards and conventions:

— The IAEA TS-R-1,
— The European Directive 2006/117 on the supervision and control of shipments of radioactive waste and spent fuel,
— The Council Regulation (EC) No. 428/2009 of 5 May 2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items,
— The United Nations Security Council Resolution 1540, adopted in 2004,

— International conventions for physical protection, third party nuclear damage liability, and transport of dangerous goods by different means of transport (in particular Technical Instructions for Safe Transport of Dangerous Goods by Air (ICAO document, 9284 –AN/905) for air shipments),
— The Gov-to-Gov Agreements.

The IAEA TS-R-1 had to be mentioned first, as it is the most important safety and administrative-related regulation for shipments of radioactive material.

The European Directive 2006/117 has the purpose of standardizing the procedure and easing the authorization process for shipments of radioactive waste and spent fuel through several countries at the European Union level.

Also at the European Union level, the Council Regulation (EC) No. 428/2009 for the control of exports of dual-use items was recently issued (replaced the EC No. 1334/2000). This regulation, mentioned together with all similar national regulations of non-EU countries, is an implementation of the United Nations Security Council Resolution 1540, adopted unanimously in 2004, which required all UN Member States to develop and enforce appropriate legal and regulatory measures against the proliferation of chemical, biological, radiological, and nuclear weapons and their means of delivery, in particular, to prevent the spread of weapons of mass destruction to non-state actors.

Not of less importance for transboundary shipments of radioactive materials are the international conventions for physical protection, third party nuclear liability, and transport of dangerous goods by different means of transport.

The Technical Instructions for Safe Transport of Dangerous Goods by Air (ICAO document, 9284 –AN/905) give additional requirements for air shipments of radioactive materials (for example, minimal distances between the packages and the pilots' cabin or other areas where the staff may be located).

The Gov-to-Gov Agreements are actually the fuel of threat reduction and non-proliferation programs, including SNF reprocessing or repatriation programs, and they bound the cooperation between participating countries to achieve their common goals.

2.1.2. National Regulatory Basis for SNF Shipments

The national regulatory basis for SNF shipments includes in different stages of the project implementation all licensing practices in the nuclear field, in compliance with specific national norms and international standards: radioactive materials transport, nuclear safety, quality assurance, nuclear materials export, radiation protection, nuclear technology design, physical protection, nuclear safeguards, nuclear technology fabrication, emergency preparedness, 3rd party nuclear damage liability, personnel training and authorization (operators, carriers, technical escorts, emergency teams etc.), radiological safety of nuclear technology.

At least one approval for each of the listed fields should be in place. Each country has its own authorities and procedures for licensing these aspects. The widest range of licensing duties belongs to the Consignor's (Origin) and Consignee's (End User) countries.

2.2. Analyzed SNF Shipments

2.2.1. Peculiarities Important for the Licensing Process

Our two examples of SNF shipments to Russia are described below. The SNF shipment from Romania was completed in June 2009. The relatively small SNF quantity in good conditions and the long cooling period resulted in an overall activity smaller than 3000 A_2 per one package (as prescribed in IAEA-TS-R-1 for shipments of radioactive materials in Type B casks by air). In addition, the route over the Black Sea and without transit countries implied the lowest risk for the first licensing process of SNF shipments by air in compliance with the new requirements (2005 Edition of IAEA-TS-R-1).

The SNF shipment from Serbia was completed in December 2010 under the IAEA management. The big amount of SNF and its rapidly worsening condition imposed as main requirement to organize only one shipment as fast as possible. This resulted in the necessity to use two types of casks (SKODA VPVR/M and TUK-19) and a risk-free route for the licensing process – a route that was successfully used before in SNF shipments, that is transiting Hungary and Slovenia. A summary of the peculiarities important for the licensing process of the two SNF shipments is given in Table I.

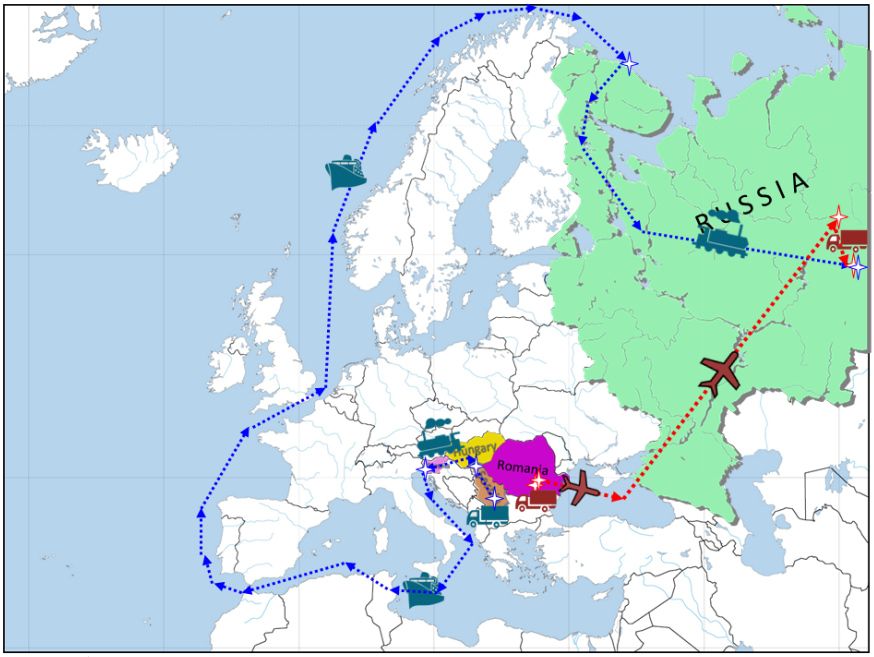
Table I. Peculiarities of two SNF shipments

Aspect	From Romania	From Serbia
Mode of Transport, Transit	– Road+Air+Road (4 days); – No transit countries	– Road+Rail+Sea+Rail (34 days); – Transit Hungary and Slovenia
Quantity, Type, Package	– 70 SFA type S-36 (Fig.1); – 18 TUK-19; – 6 ISO Containers	– 8030 SFA type TVR-S (Fig.1); – 16 TUK-19 + 16 SKODA VPVR/M; – 6 + 8 ISO Containers
Fuel Condition	– Well cooled for 10 years; – Tight undamaged SFAs	– Leaking SFAs due to corrosion; – Repacked in untight canisters
Safety Requirements	– Requirements for air shipment in type B packages fulfilled; – First SNF air shipment licensed under new regulations	– Drying untight SNF repackaged in untight canisters in transport containers for preventing formation of H2-O2 explosive mixtures; – The time limit to replace the gaseous medium in an airtight container volume; – Inert gas filling of the casks; – Rapidly deteriorating condition of the fuel imposed a single shipment
Political Considerations	– No available short land/sea transit option (Black Sea ports closed for class 7, reconsideration of transit procedures by Ukraine in 2008)	– Same as for Romania; – (Air – not an option); – Recent successful experiences of RR SNF transiting Hungary and Slovenia

a) *b)*

FIG.1. Spent fuel assemblies: a) TVR-S (shipped from Serbia), b) S-36 (shipped from Romania).

Another peculiarity important for the licensing process is the geography aspect. This aspect has a big influence on choosing the route, the used means of transport and the transit conditions. The geographical situation of the two analyzed SNF shipments is presented in Fig. 2.



Loading/Reloading/ Unloading Points: Magurele (ROM)/Otopeni Airport (ROM)/Koltsovo Airport (RUS)/Ozersk (RUS)
Vinca (SER)/Border Railway Station (SER)/Koper Port (SLO)/Murmansk Port (RUS)/Ozersk (RUS)

FIG. 2. The SNF Shipments from Romania and Serbia to Russia.

The Romanian SNF shipment was completed in 4 days, from the start point at the institute near Bucharest until the final destination at the Russian Reprocessing Plant FSUE PA "Mayak", including time for loading/unloading at airports and customs procedures on the route. There were 4 points of reloading the SNF. The Serbian SNF shipment was completed in 34 days. There were 5 points of reloading the SNF.

Both shipments took place normally, without delays occurred by factors like bad weather, missing approvals, or customs procedures etc.

With regard to physical protection, we note the fact that air shipments are safer than any land shipments of nuclear materials, from the point of view of potential terrorist attacks or actions of non-governmental organizations. It is more difficult to attack or obtain control over an aircraft than over a sea ship, train or truck, and also the duration of air shipments is significantly smaller than for the land shipments, so that the time of action of potential shipment impediments is also much smaller.

2.2.2. Licensing Process Comparison

A summary of the main licenses issued by all countries involved in the two shipments is given in Table II. The name and scope of the licenses are harmonized here for comparison purposes, but they differ from one country to another.

Table II. Main licenses issued for the two SNF shipments

License (Competent Body)	Russia (End User)	Romania (Origin)	Serbia (Origin)	Hungary (Transit)	Slovenia (Transit)
Package Design Approval (NRB)	YES (Combined) (1 for RO, 2 for SER)	YES (1)	YES (2) (for two casks)	YES (2) (for two casks)	YES (2) (for two casks)
Shipment Approval/Consent (NRB)		YES (1)	-	YES (1)	YES (1)
Import License (ECS)	YES (1 for RO, 1 for SER)	NO	NO	NO	NO
Export License (NRB)	NO	YES (1)	YES (1)	NO	NO
Transit License (NRB)	NO	NO	NO	NO	YES (1)
Export License for Dual-Use Items (ANCEX/MinEc)	NO	YES (1)	YES (1)	NO	NO
Transport Licenses for Carriers (NRB and/or TA)	YES (2 for RO, 2 for SER)	YES (2)	YES (1)	YES (1)	YES (2)
Physical Protection (MIA)	YES (1 for RO, 1 for SER)	YES (1)	YES (1)	YES (1)	YES (1)
Other Approvals	YES	YES	YES	YES	YES

Competent Bodies:
NRB – Nuclear Regulatory Body (All countries)
- For package design and shipment approval in Russia the NRB is the State Corporation for Atomic Energy – Rosatom;
- For carrier transport licenses in Russia the NRB is the Federal Service for Ecological, Technological and Nuclear Supervision – Rostechnadzor.

ECS – Technical and Export Control Service under Ministry of Defense (Russia).
ANCEX – Agency for Export Control under Ministry of Foreign Affairs (Romania).

MinEc – Ministry of Economy and Regional Development (Serbia).
TA – Transport Authority (All countries).
MIA – Ministry of Internal Affairs or subordinated structures (All countries).
The number in brackets show the number of licenses given by each country.

We can observe that for the implementation of the European Directive 2006/117, Hungary issued one full-scope transit (or transboundary shipment) license in compliance with the mentioned directive, but also in compliance with all Hungarian specific norms. For the implementation of the same directive Slovenia issued stand-alone transit (transboundary shipment) consent which verified the fulfillment of the requirements stated in the European Directive only, and in compliance with all Slovenian specific norms issued a separate transit license. So here the scope was divided between two licensing documents.

A specific licensing approach is the fact that the Serbian shipment approval is included in the export license issued by the NRB. Also, the Serbian licensing of the Slovenian carrier was actually a verification of its current national license, due to dangerous goods regulatory framework changes that took place in the period of the shipment licensing.

Analyzing the experiences of licensing the most difficult international shipments of RR SNF, the following issues should be mentioned:

- The multilateral approval of the design and shipment certificates prescribed in the IAEA TS-R-1 is being implemented in many different ways by each country;
- The combined package design and shipment certificates issued in Russia were never as such endorsed in the other involved countries:
  - (a) most countries endorse the Russian certificate as multilateral approval of package design, and separately issue a shipment approval (not endorsement);
  - (b) for the package design multilateral approval certificate different countries require different support documents, sometimes the initial design analyses of the container is required, where the actual radioactive content and shipment configuration are not considered and even though the container itself transported many times before radioactive material of similar characteristics;
  - (c) a clearer differentiation between the “package (container+actual radioactive content) multilateral approval” and the first package design approval of a container as package for radioactive materials transports shall be made and harmonized at international level;
  - (d) some countries perform independent safety analysis as-per the first certification of the given package, even though the container was used before in other shipments in that country; some other countries don’t require independent analysis but thoroughly review the already performed analyses during the issuance of the Russian package design and shipment certificate;
  - (e) the shipment approval certificate has different names and forms in different countries.

Other interesting issues were noted during the organization of RR SNF air shipments. According to the requirements, the emergency card has to be available during the shipment along with the cargo, but in the case of an air crash, this approach may be not useful since it may get destructed. A more useful way to make available the emergency card to the intervention teams would be, for example, if the air line company would fax it to the emergency teams together with the notification of emergency.

A supplementary licensing document has to be prepared in Russia for air shipments of radioactive materials, entitled Shipment Special Technical Requirements, which is approved also by authorities of air transports, but it is idle (useless). This aspect was not encountered in other countries and it may be useful to study it for legislation harmonization purposes. The other approvals mentioned in Table 2 generally refer to acceptance by the NRB of specific documents or aspects (not of less importance), usually checked for compliance separately or also as preliminary conditions for the issuance of one of the main licenses listed in the table. Other approvals may include radiation protection and emergency preparedness plans and procedures, 3rd party nuclear damage liability insurance, operators' permits etc. Some of these approvals may be issued by other authorities and not by the NRB, according with specific national procedures of a given country. For example, the radiation protection plan in Hungary requires additional approval from the National Public Health and Medical Officer Service, while in Romania from the NRB only.

Overall, Russia issued 5 main licenses for Romania and 6 for Serbia, Romania issued 7 main licenses for its shipment, and Serbia together with Hungary and Slovenia issued 19 licenses. We can draw the conclusion now that Russia deployed the same amount of efforts for licensing both shipments as End User country, while for Serbia the amount of licensing efforts was double than for Romania, due only to transit countries licensing. In addition, for Serbia two types of casks were used, and so two package design approvals were required for each country, which actually rises the proportion to 2.7 times more licensing efforts than for Romania.

Each of the two licensing processes for the Romanian and Serbian shipments had to overcome different challenges as a result of the different shipment configurations. A summary of these challenges, together with the approaches of the authorities and of the shipment responsible organizations is presented in Table III.

Table III. Summary of licensing challenges for the SNF shipments from Romania and Serbia

Aspect	For Romanian Shipment	For Serbian Shipment
Biggest licensing challenge	Package Design and Shipment Approval in Russia (9 months)	1) Untight fuel assemblies repackaged in untight canisters. 2) Transboundary Shipment Approval in Hungary and Slovenia (5 months)
Issue	First air shipment of RR SNF in Type B package under new requirements	1) Preventing formation of H_2-O_2 explosive mixtures in tight transport packages. 2) Relatively new procedure (European Directive 2006/117) involving exchange of many official documents between 4 countries
Authorities' Approach	– Accident and risk assessments required by Russian authorities, in addition to the IAEA requirements; – Supplementary independent safety assessments to the ones required by Russian procedures; – Transparency to Romanian	1) Detailed analyses performed by Russian Expert Organizations to prove safety and to determine packaging conditions, including fire and explosion safety analysis. 2) Close cooperation between Slovenian and Hungarian NRBs. 3) Transparency to all other involved countries and responsible partners.

Aspect	For Romanian Shipment	For Serbian Shipment
	NRB	4) Expediting the procedure by the Hungarian NRB as coordinator (the first transited EU country)
Shipment Responsibles' Approach (NRB in ROM and Sosny for SER)	Observing the licensing process in Russia for expediting the Romanian multilateral approval	1) Designer's team present on site during all operations, assuring compliance with the requirements. 2) Keeping close contact with all involved authorities for facilitating fast provision of justifications, information and documents exchange

For the Romanian SNF shipment, the biggest licensing challenge was the issuance of the package design and shipment certificate.

The risk assessment established that there are no credible events ($P>1x10^{-7}$) that would fall into the 'accident' category according to the INES scale (Fig. 3). The most probable events would be characterized as 'incidents' according to that scale, while the events with the most severe consequences (accidents) turned out to have a low probability. Several studied events were both low-probability and without any severe consequences (incident).

In addition to the sustained support and transparency of Rosatom, another advantage for solving this challenge was the fact that in Romania the organization responsible for the SNF repatriation program to Russia was the NRB, and not the Consignor owning the SNF. For this reason, the NRB participated directly in the entire program, from the design of new SNF handling technologies and witnessing the licensing process in Russia, until the license endorsements and its own licensing process in Romania.

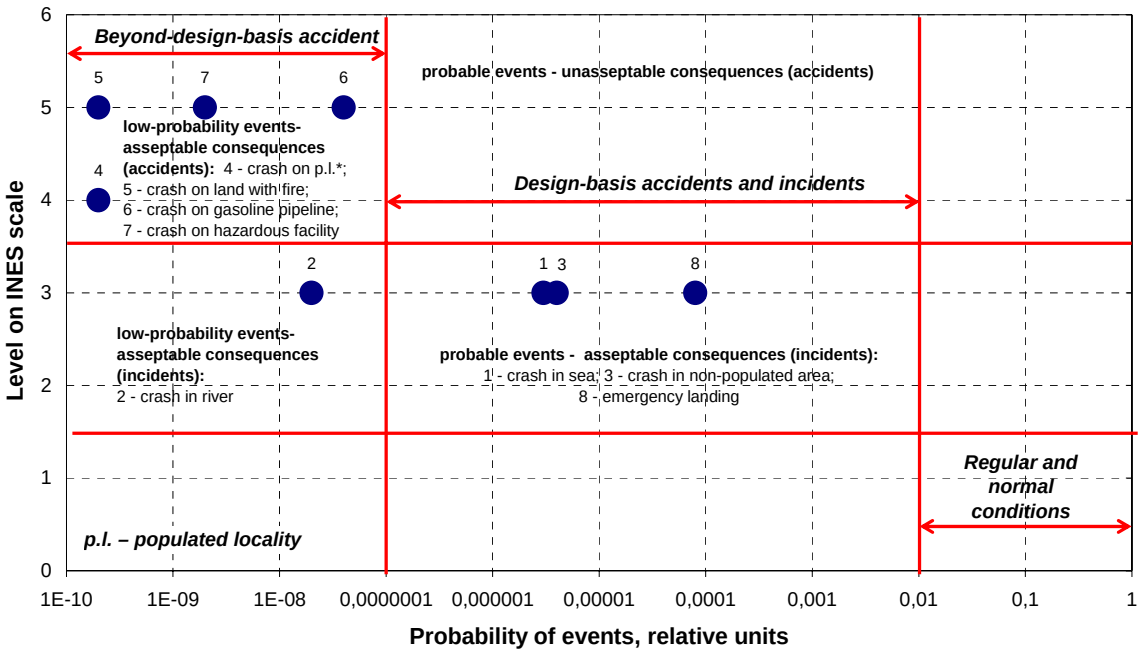


FIG. 3. The risk assessment of the air shipment from Romania.

For the Serbian SNF shipment, the biggest licensing challenge was the difficulty to justify the safety of shipment in tight transport containers of untight (failed) spent fuel assemblies repackaged in untight canisters (Fig. 4). New approaches had to be identified to assure the safety from the point of view of fire and explosion of H_2-O_2 mixtures. For this purpose, the technical support from NRI (Rez, Czech Republic) to adapt the technology provided by them to perform the drying of the untight canisters inside the transport casks (both SKODA VPVR/M and TUK-19) and to operate this technology on site during SNF loading was indispensable and well appreciated. Except for a proper labeling in case of explosive (or other dangerous) properties of the packages (Art. 506), the IAEA TS-R-1 doesn't contain specific technical safety requirements for these cases.

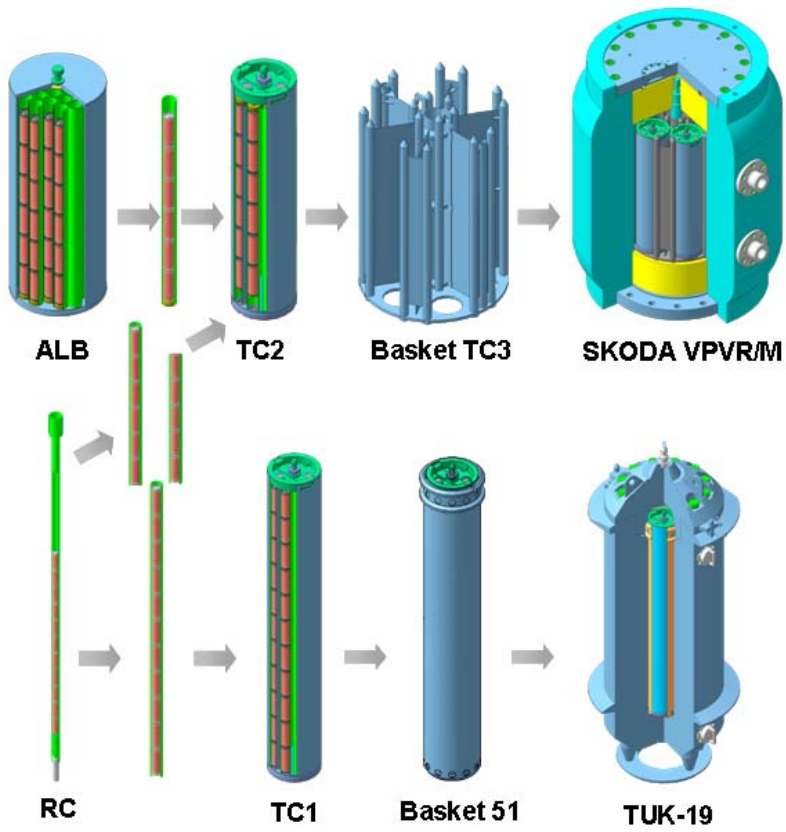


FIG. 4. Repackaging principle in untight canisters of the Serbian SNF.

Another challenge was the transboundary shipment approvals in Hungary and Slovenia, in addition to the approvals required from the Russian and Serbian sides. Here a challenge was to implement the relatively new European Directive 2006/117 (in force in EU Member States since the end of 2008), in parallel with national licensing requirements and procedures in Hungary and Slovenia. However, the Hungarian NRB representing the first transited EU country and coordinator for both Hungary and Slovenia helped expediting the procedure. Another advantage for solving this challenge was the empowerment by the Serbian Consignor of Sosny to manage the licensing process in Hungary and Slovenia. As Russian contractors' coordinator, Sosny participated in the entire program, from the licensing process in Russia to contracting all carriers on the route until Murmansk. For this reason, an effective control of documents, procedures, schedule and information exchange between all the involved authorities and partners contributed to solving this challenge.

Each authority has defined in its regulations a maximum period of time in which an answer (license or denial) have to be given to the applicant. These durations for issuance of licenses are given in Table IV.

Table IV. Licensing standard durations

License (Competent Body)	Russia (End User)	Romania (Origin)	Serbia (Origin)	Hungary (Transit)	Slovenia (Transit)
Package Design Approval or Validation (NRB)	5 Months – 9 (RO) – 5 (SER)	1 Months	2 Months	4 Months	2 Months
Shipment Approval/Consent (NRB)		1 Month	–	6 Months	2 Months
Import License (ECS)	1 Month	NO	NO	NO	NO
Export License (NRB)	NO	1 Month	1 Week	NO	NO
Transit License (NRB)	NO	NO	NO	NO	2 Months
Export License for Dual-Use Items (ANCEX/MinEc)	NO	2 Weeks	1 Month	NO	NO
Transport Licenses for Carriers (NRB and/or TA)	3 Months	1 Month	–	1 Month	2 Months
Physical Protection (MIA)	1 Month	1 Month	1 Month	1 Months	2 Months
Other Approvals	–	–	–	–	–

For the Russian package design approvals, the actual durations for the two shipments are also included and they contain the duration of performing/verifying safety analyses by technical support organizations (TSOs). We can observe that for the first air shipment certificate the duration in Russia (9 months) was almost twice bigger than normally (5 months), while the duration for 2 certificates (in parallel) of casks, routes and conveyances that were many times before used in other shipments didn't exceed the regulated duration.

The critical duration of the transboundary shipment approval for Hungary is given here strictly by the European Directive 2006/117 and its standard documents procedure. It includes obtaining the consent of the countries of transit and of the end user country and the verification of compliance with all requirements of this Directive.

Usually, the transport licenses for carriers are issued by NRBs for a category of nuclear materials to be transported and for specific equipment used during the mentioned shipments. They may be valid for a few years and endorsed (checked) in other countries, renewed or

modified as required for given cases. Requirements for transport of dangerous goods (Class 7) for the given conveyance are usually regulated by national transport authorities and should be fulfilled by the carrier prior to the licensing by the NRB.

Of course that in most of the cases, the licenses are being issued before the established periods of time expire, if all requirements are met. But the licensing schedule of a SNF shipment has to be defined in function of these maximum periods of time, and should also include some safety margin.

Many of the licenses mentioned in this paper are conditioned by the prior existence of one or more of the other licenses or approvals. Many of them require prior consultancy and acceptance from other authorities.

The licensing support documents must be prepared well in advance and submitted following a very strict schedule dictated by the various procedures of each country. This, together with the provision of answers to authorities in due time, is the control point of the Applicant for the licensing process.

The licensing schedule depends on the project developments, on the authorization procedures of each country, and on security issues (for example physical protection authorizations are given in the last moment before the shipment, possibly even 24 hours or less in advance).

Proven fact for all shipments of this type: essential is the coordination of the entire licensing process of all aspects, for all involved countries and in tight connection with all the project activities.

The total duration of the licensing process for Romania was of 1 year, and for Serbia of 1.5 years, starting from the application for package design and shipment approval submitted to Russian authorities.

A physical protection specific difficulty appears each time during the organization of transboundary shipments of radioactive materials, connected to the guards change at border crossings. This aspect usually is regulated by departmental international agreements case by case and requires supplementary time and efforts especially due also to the confidential character of the information exchanged. This difficulty may be solved by further harmonizing the specific international regulatory framework.

3. Licensing the First Type C Package

An idea to develop a package for air shipments without restrictions on radioactive content activity (Type C Package) has arisen after the completion of RR SNF air shipment in TUK-19 casks (Type B).

Despite the fact that the two air shipments of RR SNF from Romania and Libya were already performed under the close attention of international experts in the field of safety provision, everybody still treats such transportations cautiously.

The main concern is based on the society overcare to air accidents. The TS-R-1 Regulations and the corresponding national regulations use probabilistic approach to determine severe accidents' consequences. Tests indicated in TS-R-1 are covering possible real consequences of emergency situations with a probability 95%.

The general questions, which arise during the licensing of RR SNF air shipment, are:
1) Type B Package subcriticality during impact test onto a target at the velocity not less than 90 m/s is analyzed only for a single package, and at that its damage and depressurization are allowed. Some experts think that this requirement is not conservative. During RR SNF licensing from Romania it was additionally proved by calculations that in the case of an air accident (at the velocity not less than 90 m/s) the nuclear material will remain inside of the transport package with high probability level (Fig. 5).

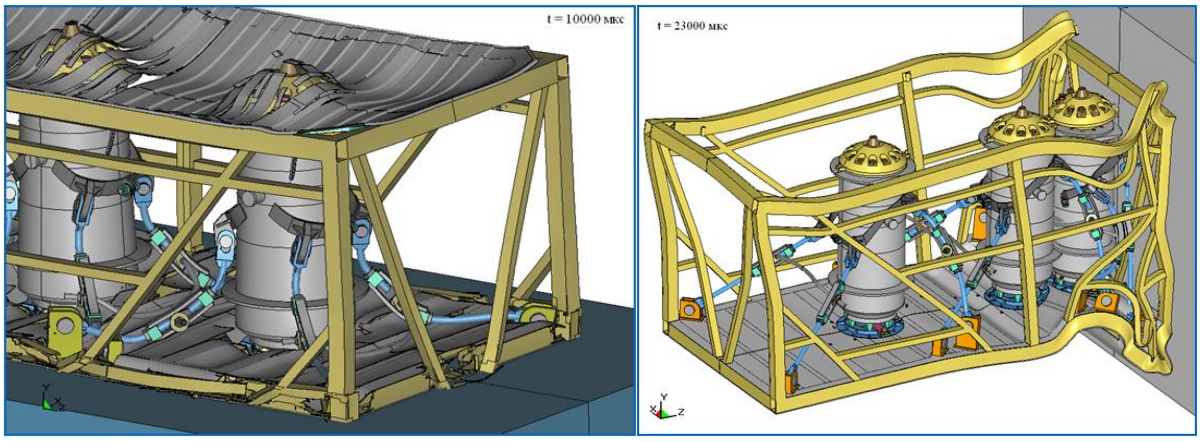


FIG. 5. Additional dynamic deformation analysis of a group of TUK-19 packages during impact onto a target at the velocity 90 m/s.

2) Heightened requirements to the safety culture of air carriers. RR SNF shipments from Romania and Libya were performed by Russian air company "Volga-Dnepr" that has Rostechnadzor license for shipment of radioactive materials. Additionally Volga-Dnepr Air Company documents and references in the field of quality assurance and safety culture (incidents that happened in the past during transportation of dangerous goods) were reviewed on the request of the regulating (Rostechnadzor) and competent (SC "Rosatom") authorities during the preparation of the first air shipment to the Russian Federation (Table V).

Table V. Quantity of air events

Type of event	RF civil aviation (aircrafts of 1-3 classes)	AC "Volga-Dnepr"
Air accidents	2	0
Incidents	803	6
Damage of aircrafts on the ground	81	1

3) The most severe consequences of air accidents during RR SNF transportation can occur in densely populated areas. In this connection the routes are specially located above the sea (as far as possible from land) and bypassing large cities.

Our experience indicates that licensing of air shipments especially of RR SNF provokes heightened interest (and even negative reaction of individual experts in the field of safety provision of radioactive materials transportation) to the possibility itself of realizing such shipments. However it is necessary to note that the shipment of irradiated nuclear fuel from

the viewpoint of nuclear and radiation safety provision stands in the same line as numerous shipments of non-irradiated nuclear materials performed in Type B Packages (due to the fact that the subcriticality analysis for SNF shipments don't consider the material's burnup conditions) and radioisotopes (including in liquid condition, conservative case from the viewpoint of radiation safety).

In 2009 the work on development of Type C Package on the base of SKODA VPVR/M cask for air shipment of research reactor spent nuclear fuel was started under the U.S./Russia Research Reactor Fuel Return (RRRFR) program under Order of the U.S. Department of Energy. The activities aimed to enhance safety of air shipments of radioactive material. Requirements of Russian and international regulations to Type C Packages do not impose any additional limits on activity of radioactive content but require maintaining the package tightness after testing on impact with a speed not less than 90 m/s and fire during one hour.

Type C Package (Fig. 6) that is currently registered in Russian Register under number "TUK-145/C" consists of two main elements:

— an Energy Absorption Container (EAC) intended for absorption of dynamic acceleration in case of an air crash,
— a SKODA VPVR/M cask inside the EAC, that ensures radiation shielding and prevents a loss of radioactive contents under normal and accident condition of transport.

The EAC is a cylinder made of upper and lower halves similar in design and a welded body filled with energy-absorbing elements – hollow spheres made of titanium. The SKODA VPVR/M cask is placed into the inner cavity of the EAC. The main characteristics are presented in the Table VI.

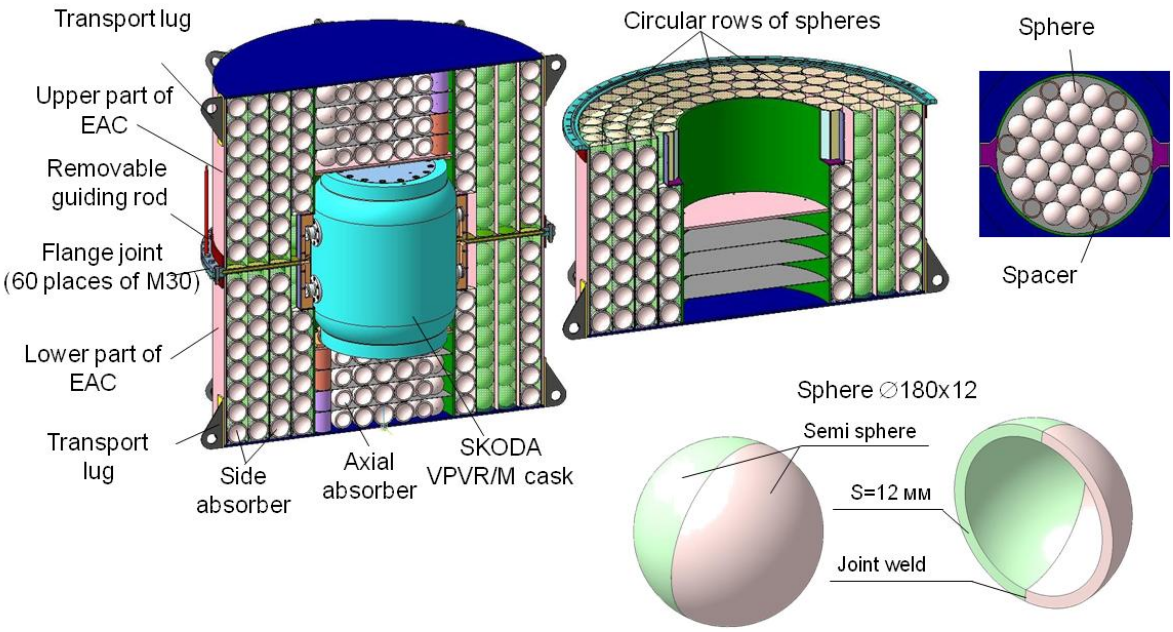


FIG. 6. TUK-145/C.

Table VI. Technical characteristics of TUK-145/C

Parameter	Value
Mass of loaded TUK-145/C, kg	29 650
Mass of empty TUK-145/C, kg	29 200
Mass of EAC, kg	18 500
Maximal mass of SNF loading, kg	450
Number of cells for SFAs	36
Useful lifespan, years	30
Height, mm	3065
Width, mm	3168
Diameter, mm	2816

The EAC, which is fulfilling a function of dynamic protection in the case of an air accident, was developed to absorb the force of impact against a rigid target at the velocity of not less than 90 m/s up to the load levels that the SKODA VPVR/M cask body can endure in emergency situations during a land shipment.

The design of TUK-145/C allows performing multimodal shipments. Air shipment could be fulfilled using an AN-124 aircraft (in vertical position up to three TUK-145/C packages placed on the transport frames or two TUK-145/C packages placed on the trucks) or an IL-76 aircraft (in horizontal position using the special handling frame).

In May of 2011 on the rocket track of FSUE “RFNC-VNIIEF” (Sarov, RF) the certification testing of TUK-145/C mockup (in the scale of 1:2.5 and mass app. 2t) was performed since the Type C Package was developed for the first time (Fig.7). As a result, the VPVR/M mockup of the TUK-145/C package remained tight after the impact against the target at the velocity of 92 m/s.

FIG. 7. Testing results of TUK-145/C mockup.

At present moment work on creation of the Type C Package based on the Czech SKODA VPVR/M cask for RR SNF shipment is continuing. By the end of 2011 it is planned to draw up a certificate for TUK-145/C package design in the Russian Federation; in 2012 it is planned to fabricate Unit 1 that will be used for RR SNF Shipment from Vietnam in 2013.

At a whole the experience is showing that air shipment of SNF is still an exotic mode of transportation and it is unlikely that it will become wide-spread. However in some cases it could be called-for as most effective (comparing with land transport modes), for example international shipments of radioactive materials in small batches:

— SFAs of power and research reactors transported for materials research of new fuel types and for causes of failure analysis, or for the study of irradiating devices with nuclear material;
— when it is impossible or not reasonable to organize the shipment through the territory of several transit countries;
— in extreme situations (examples of needs for such shipments are well known and, unfortunately, nobody is immune to these situations in the future).

4. Conclusions

The international regulatory basis and in particular the IAEA-TS-R-1 is generally applied in all countries. However, the administrative procedures for the licensing of radioactive material shipments differ very much from country to country. This is due to the different context existing in each country, given by the different volume of nuclear activities (shipments of nuclear materials in particular) and different organization of competent authorities and functions. At national level, all countries have well defined systems of administrative procedures which comply to the international regulatory framework applicable to radioactive materials shipments, but they differ one from another.

In our opinion, to further develop the international cooperation in the safety and security of transportation of radioactive materials and for the harmonization of transport safety regulations, we should focus on exploring the following questions:

— A better definition at the international level of the “shipment” versus “transit” approval concepts;
— A better definition of the “package (container+actual radioactive content) multilateral approval” versus the first package design approval of a container as package for radioactive materials transports;
— A more uniform terminology used at international level for licenses, authorizations, certificates, approvals, permits, consents for specific aspects;
— A further development of the international regulatory framework and its harmonization at the national levels concerning:
  (a) physical protection guards exchange at border crossings;
  (b) intervention in case of emergencies occurred during international transports of radioactive materials.
— Strengthening the administrative support mechanisms for international shipments of radioactive materials by the proposed methods described below:
  (a) Transport Safety Appraisal Service (TranSAS) missions should be considered and requested by all IAEA Member States, especially by the ones that don’t frequently ship radioactive materials and don’t have a strong experience in this field, for the purpose of obtaining valuable guidance in improving and harmonizing national regulatory frameworks with international tendencies.
  (b) It may also be beneficial if the Integrated Nuclear Infrastructure Review (INIR) missions could include a separate issue on radioactive materials transport infrastructure to provide guidance to new nuclear countries in this regard.

(c) New TECDOCS on radioactive material shipments issues like peculiarities of national regulatory frameworks, transboundary shipments licensing, and shipment of untight spent fuel assemblies would be appreciated.
(d) Considering the great IAEA input in the Serbian project, we think it would be valuable if IAEA could manage any projects involving transboundary shipments of radioactive materials, especially for complex projects and for countries with very little experience in radioactive material transports.

Analyzing the past few years' developments in the transport and nuclear industries we can observe the following:

— In 2009 the first 2 fully certified by new international regulations SNF shipments in Type B packages took place (from Romania and Libya to Russia);
— In 2011 the first in the world Type C package successfully passed the tests required by IAEA TS-R-1;
— Many previously non-nuclear countries are preparing to start peaceful nuclear programs;
— Only a few countries own technologies for nuclear fuel enrichment and for spent nuclear fuel reprocessing;
— Final repositories for high level radioactive waste are planned to be developed, and maybe one center for several countries;
— The number and complexity of transports of radioactive materials is, therefore, rapidly growing and their security and schedules will be harder and harder to control.

Therefore, we may draw the general conclusion that air transport of radioactive materials can be commonly used in the future for a much wider extent, to improve the world's safety and security and the efficiency of transports of radioactive materials.

REFERENCES

[1] A. SMIRNOV, S. KOMAROV, M. BARYSHNIKOV, M. BUDU, "Serbia: Complex Project, Long Transport Route", Environmental Safety, No. 1, 2011 (special edition).
[2] A. SAMSONOV, S. AMOSOV, A. IVASCHENKO. "Handling Degraded Spent Fuel at Vinca Institute", Environmental Safety, No. 1, 2011 (special edition).
[3] S. KOMAROV, D. DERGANOV, A. IVASHKIN, O. SAVINA, "Project of Creation of Type C Package", RRRFR Lessons Learned Workshop, Jackson, Wyoming, June 7-10, 2011.
[4] O.P. BARINKOV, S.V. KOMAROV, A.E. BUCHELNIKOV, V.I. SHAPOVALOV, A.I. MORENKO, "Preparation of the First Air Transport of Spent Fuel Certified to New Requirements", Environmental Safety, No. 1, 2011 (special edition).
[5] IGOR BOLSHINSKY, KEN ALLEN, ALEXEY SMIRNOV, SERGEY KOMAROV, LUCIAN BIRO, MADALINA BUDU, "RRRFR - Romanian Project Achievements", ATOMTRANS International Forum 2009 (Conference Proceedings), Sankt-Petersburg, Russia.
[6] I. BOLSHINSKY, K. ALLEN, L. BIRO, M. DRAGUSIN, B. KANASHOV, M. BUDU, "Romania: brand-new engineering solutions", Environmental Safety, No. 1, 2011 (special edition).
[7] M. BUDU, M. BARYSHNIKOV, A. IVASHCHENKO, S. KOMAROV, L. YUNGEROVA, "Transboundary Shipment Authorization from the Viewpoint of Applicant", RRRFR Lessons Learned Workshop, Jackson, Wyoming, June 7-10, 2011.

[8] S. KOMAROV, A. IVASHCHENKO, M. BARYSHNIKOV, M. BUDU, "Serbian RRRFR Project - Status of Authorization Process in Serbia, Hungary and Slovenia", Serbian RRRFR Project Management Meeting, June 21-23.06.2011, Belgrade, Serbia.
[9] INTERNATIONAL ATOMIC ENERGY AGENCY, The air transport of radioactive material in large quantities or with high activity, IAEA-TECDOC-702, Vienna.
[10] IAEA Regulations for the Safe Transport of Nuclear Material, 2009 Edition. Safety Requirements No. TS-R-1.
[11] European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR).
[12] International Road Transport Convention (TIR).
[13] International Rule for Transport of Dangerous Substances by Railway (RID).
[14] International Convention for the Safety of Life at Sea (SOLAS).
[15] IAEA Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, 2002 Edition. Safety Guide No. TS-G-1.2.
[16] IAEA Radiation Protection Programmes for the Transport of Radioactive Material, 2007 Edition. Safety Guide No. TS-G-1.3.
[17] IAEA The Management System for the Safe Transport of Radioactive Material, 2008 Edition. Safety Guide No. TS-G-1.4.
[18] IAEA Compliance Assurance for the Safe Transport of Radioactive of Radioactive Materials, 2009 Edition. Safety Guide No. TS-G-1.5.
[19] NP-053-04 Safety Rules for the Transport of Radioactive Materials. Russian Federation.
[20] NRB-99/2009 Norms for Radiation Safety. Russian Federation.
[21] OSPORB-99/2010 Main Sanitary Rules for Assuring Radiation Safety. Russian Federation.
[22] SanPiN 2.6.1.1281-03 Sanitary Rules for the Radiation Safety of the Personnel and Population during Transport of Radioactive Materials (objects). Russian Federation.