TRANSPORT OF HIGH ENRICHED URANIUM FRESH FUEL FROM YUGOSLAVIA TO THE RUSSIAN FEDERATION

by

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This paper presents the relevant data related to the recent shipment (August 2002) of fresh highly enriched uranium fuel elements from Yugoslavia back to the Russian Federation for uranium down blending. In this way, Yugoslavia gave its contribution to the Reduced Enrichment for Research and Test Reactors (RERTR) Program and to the world's joint efforts to prevent possible terrorist actions against nuclear material potentially usable for the production of nuclear weapons.

Key words: HEU, fresh fuel shipment, VINČA Institute, RERTR

INTRODUCTION

After negotiations with USA administration and non-governmental organisations that included participation of experts designated by the Ministry of Atomic Energy (MINATOM) and responsible transportation-expert organisations from the Russian Federation, that took place during spring and summer of 2002, Yugoslav government made an agreement to return all unused high enriched uranium (HEU) fuel elements back to their country of origin – the Russian Federation. Appropriate decisions on final shutdown and decommissioning of the RA research reactor and the HEU fresh fuel shipment were also made by the Government of the Republic of Serbia and the Government of the Federal Republic of Yugoslavia during July and August 2002. Preparations for the shipment of more than 5000 HEU fuel elements were made at the VINČA Institute of Nuclear Sciences, Belgrade, Yugoslavia, and in the Branch Federal State Institute "Safe Transportation of Nuclear Materials" (STNM Institute), Dimitrovgrad, the Russian Federation. Safeguards department of the International Atomic Energy Agency (IAEA), and non-proliferation specialists from the Oak Ridge National Laboratory, working for the Department of Energy (DOE), USA, took part in the preparations and transport of the HEU fuel elements, as well. The shipment took place in mid-August 2002 under highest physical protection measures available in the VINČA Institute and, especially, during the transport of the fuel from the VINČA Institute to the Belgrade airport.

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TVR-S FUEL DESCRIPTION

All the fresh HEU fuel elements at the VINČA Institute were bought in ex-USSR in the period between 1976-1985. These elements have been used for the operation of 6.5 MW heavy water research reactor RA [1] and for experiments at the RB heavy water critical assembly [2]. The same fuel elements were also used at the TVR heavy water research reactor [3], operated by the Institute for Theoretical and Experimental Physics (ITEP) in Moscow, Russia, in the period from 1964 until 1986 (when the reactor was shut down permanently). The TVR reactor was, in fact, the genetic one for other two similar reactors built in Beijing (People Republic of China) and in Vinča near Belgrade (Federal Republic of Yugoslavia) at the end of the fifties. The reactor in Beijing was put in operation in 1958, and after modernization, it is still operational. The RA reactor in VINČA Institute reached the first criticality in December 1959.

The HEU fuel elements, known as the TVR-S type of fuel elements ("slug") [4], were produced in Novosibirsk Chemical Concentrates Plant (NCCP). The TVR-S fuel element is a 11.30 cm long cylinder with a 3.72 cm outer diameter (Fig. 1). The fuel layer of the TVR-S HEU element contains 80% enriched uranium in the form of UO_2 dispersed in Al matrix. The Al matrix is 100 mm long and its inner/outer diameter is 31/35 mm. The mass of ^{235}U nuclide in TVR-S fuel element is 7.7 g ± 0.3 g. The fuel layer is covered by 1 mm thick aluminum cladding. The inner tube, made of aluminum (known as the "expeller" or "ejector"), within the slug serves to adjust the coolant flow rate. The top and the bottom of the slug are covered by 3 mm thick (aluminum) "stars" with sprockets, so that the total length of the slug is 11.30 cm. The aluminum, used in the construction of the TVR-S slugs, is known as the SAV-1 alloy (0.985 weight fraction of aluminum with very low contents of neutron high-absorbing impurities, *e. g.*, boron and cadmium). The average mass of TVR-S slug is 162 g. The detailed material composition of the TVR-S HEU fuel element is given in [5].

During the operation of RA reactor, about 1400 HEU slugs were spent by the end of 1984 [6-9]. The total amount of the fresh HEU fuel elements at the RB and RA reactors at VINČA Institute was 5046. The fresh and spent nuclear fuel elements at the VINČA Institute are under regular safeguard control of the IAEA. The HEU fresh fuel elements were stored in original, Russian made, packages (containers) used for transport and storage (Fig. 2). Beside police guards engaged for physical protection of the reactors' building, the storage rooms for fresh HEU elements at the RA and RB reactors were also under constant surveillance of an automatic electronic alarm system applied since 1996, according to the DOE (USA) recommendations.

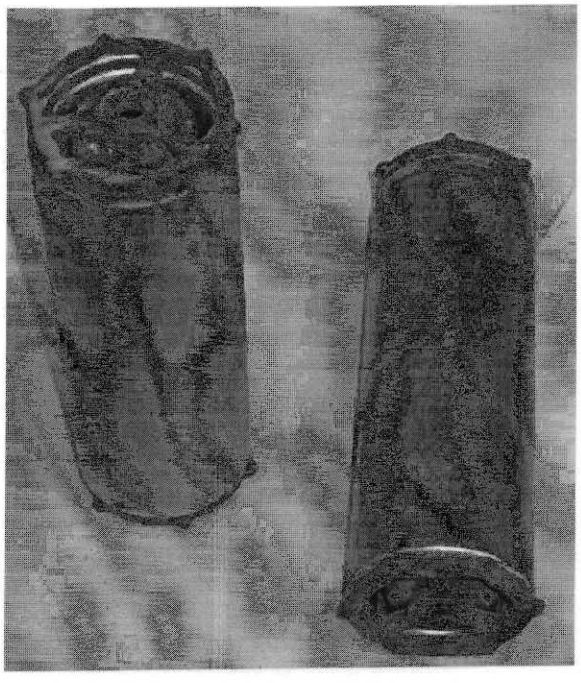

Figure 1. TVR-S fuel element

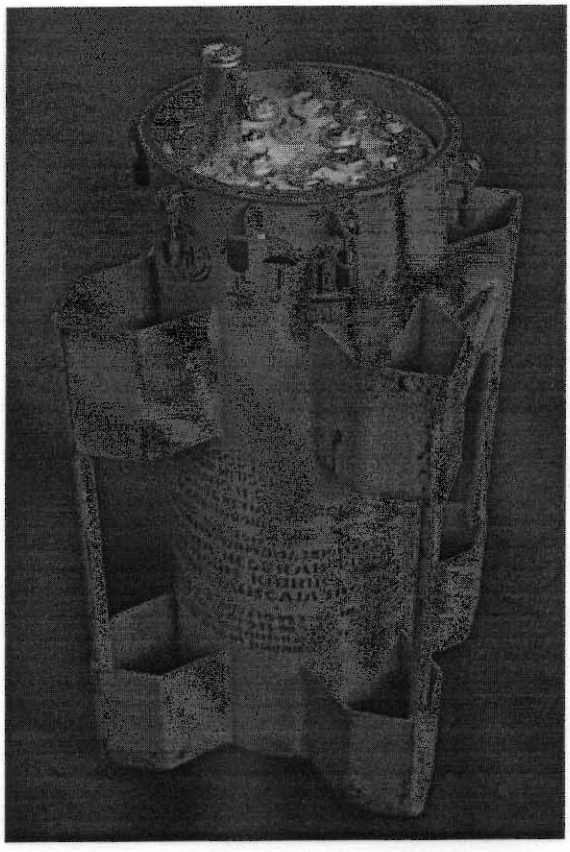

Figure 2. Package for TVR-S fuel elements designed in Russia in 1970-es

IP-2 TRANSPORT PACKAGES

In spring 2002, the existing packages, (*i. e.*, original Russian made transport containers, Fig. 2), in which the HEU slugs were stored at the VINČA Institute, were inspected by DOE experts from the Oak Ridge National Laboratory (ORNL) and the Los Alamos National Laboratory (LANL), USA, and Russian experts from the MINATOM, the ATOMSPECTRANS and the STNM Institute. They established that the containers did not fulfil the modern standards and requirements [10] for the planned shipment of fission nuclear material. The Russian counterpart, the STNM Institute, proposed the use of Russian industrial package IP-2 type TK-S15 and TK-S16, produced by the NCCP, Novosibirsk, Russia, for the shipment. The TK-S15 and TK-S16 containers are designed and used for transport of fresh fuel assemblies (FA) that are nowadays used for the operation of MR, MIR, *i. e.*,

IRT-2M, IRT-3M and IVV-10 type of Russian research reactors, respectively.

New packaging procedures were proposed by the STNM Institute according to the available space within TK-S15 and TK-S16 containers, and according to the safety requirements in respect to the Criticality Safety Index (CSI) and to the Transportation Index (TI). These containers, and packaging procedure for transport of the TVR-S type HEU fuel elements were certified by Russian certificates, licensed on July 1, 2002. Criticality calculations [11, 12], according to the requirements given in [10], were carried out independently in the State Scientific Centre of the Russian Federation "Fizichesko Ehnergeticheskij Institut – FEI", Obninsk, Russia, and in the Centre for Nuclear Technologies and Research "NTI" of the VINČA Institute of Nuclear Sciences, Yugoslavia. Results of the calculations showed that an unlimited number of the TK-S15 and TK-S16 packages, filled with the proposed number of 80% HEU fuel slugs of TVR-S type, could be used in transportation by truck or by aircraft, *i. e.*, that CSI = TI = 0 even in case of the worst assumed accident.

The TK-S15 packaging assembly includes: a container, the inner equipment and accessories. The container consists of a steel case, two covers, heat insulation and a wrapper. The container case is welded. The inner equipment is a welded construction of seven aluminium tubes. The capacity of TK-S15 is seven FA. The mass of TK-S15 is 240 kg. The dimensions of the TK-S15 package are: length 1650 mm, width 400 mm, and height 420 mm.

TK-S16 packaging assembly includes: a container, inner equipment and accessories. The container case is a welded construction in the form of a barrel with double walls. The gap between the walls is filled with heat-insulating material. The inner equipment is a welded construction of seven aluminum tubes. The capacity of TK-S16 is also seven FA. The mass of TK-S16 is 160 kg. The dimensions of TK-S15 package are: diameter 655 mm, maximum width 740 mm, and height 1200 mm.

In each tube of TK-S15 packaging, 13 couples of TVR-S slugs (the total of 26 slugs, tied together by Scotch tape) can be stored. In this way, in a single TK-S15 package, the total of $7 \times 26 = 182$ TVR-S slugs may be stored. The total mass of ^{235}U per TK-S15 package is 1401.4 g. The total of 20 TK-S15 packages were delivered to the VINČA Institute for the shipment (17 were used, while three were spare ones).

In each tube of TK-S16 packaging eight bundles of four TVR-S slugs (the total of 32 slugs, tied together by Scotch tape), were placed one above the other. In this way, in a single TK-S16 package, $7 \times 32 = 224$ TVR-S slugs may be stored. The total mass of ^{235}U per TK-S16 container is 1724.8 g. The total number of TK-S16 packages, delivered to the VINČA Institute and used for fresh HEU fuel shipment was 10.

PREPARATORY ACTIVITIES

All preparatory activities related to packaging procedures were carried out at the VINČA Institute in the course of July and the beginning of August 2002, in close cooperation with safeguard inspectors of the IAEA and experts from the STNM Institute. These activities included:

- establishment of management structure and Transport Program Team,
- elaboration of repackaging procedures, preparation of repackaging area, organisation of necessary logistics support and personnel training,
- provision of increased physical protection at the Institute and appropriate police escort during the transport of fresh fuel elements from the Institute to the airport in Belgrade,
- after all decisions were made by the Govern ments of the Federal Republic of Yugoslavia and the Republic of Serbia, and the Steering board of the VINČA Institute, all documents, required permissions and certificates issued in Yugoslavia were provided,
- provision of appropriate transport vehicles and close cooperation with the Customs at the airport in Belgrade,
- presentation of the task and training of members of various supporting teams (*e. g.*, health physics department, medical protection department, fire department, *etc.*) for the regular and possible incidental situations that may happen during realisation of the activities, and
- preparation of necessary equipment for packaging, radiation protection measurements, marking and sealing of packages.

The whole task was kept a secret in order to reduce the possibility of a terrorist attack or of any conflicts with the green-peace members during the transport.

As the first step, all HEU fuel elements used at the RB reactor were unloaded from the core. They were returned to the storage containers (Fig. 2) placed at the RB reactor room. These containers were verified for the fuel type and number by RB staff. The IAEA safeguard inspectors verified the contents of the containers. The containers were closed and sealed by safeguard inspectors from the IAEA, too. At the same time, in the presence of the IAEA safeguard inspectors, the storage containers with fresh HEU fuel elements at the RA reactor storage site, were unsealed and opened, one by one. In this way, the total of about 4000 fuel slugs were released from their original protection packaging (paper and plastic foils) and returned back to their positions in the containers. The reason for this preparatory

activity was fact the that only "naked" fuel elements could be inserted, according to proposed procedures, inside tubes of the TK-S15 and TK-S16 containers. Each container was closed and sealed by the safeguard inspectors of the IAEA again, as soon as the procedure mentioned above, was completed.

The repackaging area, *i. e.*, the TK-S15 and TK-S16 loading area, was prepared within the RA reactor room. Three additional areas (so called "arrays") were also marked for the location of 51 existing storage containers, and for 20 TK-S15 and 10 TK-S16 new transport packages. Two working (packaging) lines ("A" and "B") were set, including all necessary tools and supporting material needed for repackaging. A place was designated for control measurements of fuel element samples by the IAEA safeguard inspectors, along with a place for gamma-ray dose rate measuring, sealing and marking of loaded containers. Record forms for all procedures were also prepared. The requested radiation control included contamination monitoring of the area, used equipment and new transport packages and gamma-ray dose rate measurements. For all the staff personnel engaged in the work within the RA reactor room, appropriate protective clothes, gloves, overshoes and TLD were provided, although the gamma-ray dose rate from the fresh fuel elements was very low. A special metal detector gate was set at the only allowed exit/entrance of the RA reactor room in order to prevent any deliberate removal of fuel slugs from the room. Only personnel wearing special badges approved and allowed by the managers of the Transport Program Team were permitted to enter the reactor room. With just a few exceptions, the use of mobile phones and cameras was not allowed inside the RA reactor room during repackaging activities.

All existing storage containers loaded with HEU fuel elements were transferred from their regular storage places at the RA and RB reactors, to the RA reactor room, one day before the aircraft with TK-S15 and TK-S16 transport packages arrived from STNM Institute, to the Belgrade airport.

PACKAGING ACTIVITIES AND TRANSPORT

The aircraft was unloaded at the airport immediately after landing and all TK-S15 and TK-S16 packages were loaded into the transport vehicle in a few hours, including radiation and contamination control and customs procedures. The transport vehicle was escorted by police cars during its way from the airport to the VINČA Institute. After arrival of the vehicle at the parking place in front of the RA reactor building, the TK-S15 and TK-S16 packages were unloaded, one by one, using a lifting carriage, and transported to the transport entrance of the RA reactor room. There, the packages were reloaded to the transport cart and carried to marked positions in the reactor room. The existing crane in the RA reactor room was used to unload the cart and locate the package at the desired position within the marked array area. This activity took about 3 hours.

The next day, all ten TK-S16 packages were fully loaded, closed, sealed, measured for the transport index, labelled and moved back to their position in the reactor room. The HEU fuel slugs were prepared according to the proposed procedure – four in each bundle, and eight bundles connected in a row, using strong nylon string that was pulled through central axial holes of every two slugs in each bundle by means of a special needle prepared. The nylon string was used for moving the whole row of eight bundles from the repackaging table to the aluminium tubes in the TK-S16 package. The nylon string also enabled unloading of fuel elements from the containers.

In the next two days, all seventeen TK-S15 packages were fully loaded, closed, sealed, measured for the transport index, labelled and moved back to their position in the reactor room. The HEU fuel slugs were prepared according to a proposed procedure – two in a bundle, and 13 bundles connected in a row, using strong nylon string that was passed through the central axial holes of both slugs of each bundle by means of a prepared needle. The nylon string and plastic supporter designed as a long semi-tube was used for moving the whole row of 13 bundles from the repackaging table to the aluminium tubes in the TK-S16 package. The nylon string also enabled unloading of the fuel elements from the containers.

Figures 3 and 4 show the top view of TK-S15 and TK-S16 opened package completely filled by TVR-S fuel elements, before closing by the top cover.

The IAEA safeguard inspectors monitored repackaging activities in the reactor room and carried out measurements of randomly selected HEU fuel slugs according to the procedures prepared in advance. About 1% of all HEU fuel slugs were verified without any remark or objection by the safeguard inspectors. Due to the well-trained staff and using some additional supporting tools for packaging, these activities were completed in about 50% shorter time than expected by the plan.

The repackaging activity was completely monitored by two transportation experts from STNM Institute, and by two representatives of the ORNL, DOE, one being a non-proliferation and the other a transportation expert. Yugoslav customs officers also inspected the activity in the RA reactor room and put their seals on the containers. The Minister of the Ministry of Science, Technologies and Development of the Republic of Serbia visited the

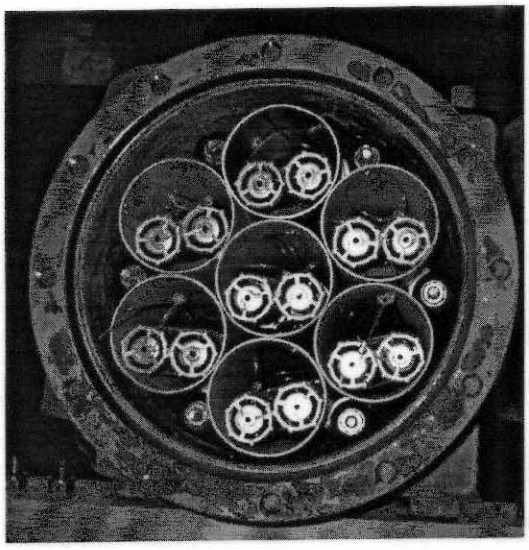

Figure 3. TK-S15 loading

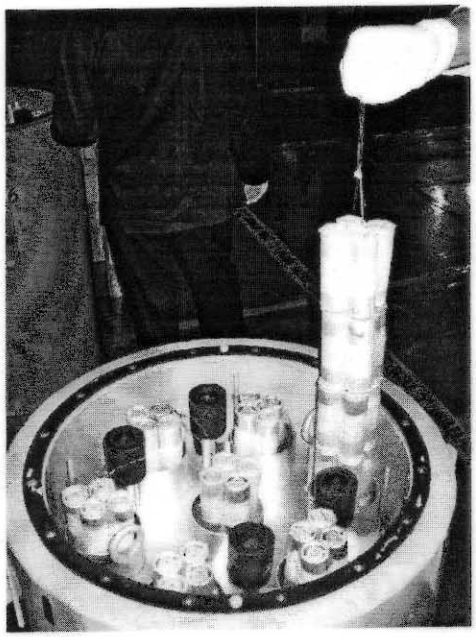

Figure 4. TK-S16 loading

repackaging area in the reactor room and the departure area at the Belgrade airport during loading of the transport packages with nuclear fuel to the cargo aircraft, expressing the importance of the whole event to the Government of Republic Serbia. A representative of the Federal Ministry of the Economy and Internal Trade, responsible for safeguarding nuclear material and nuclear safety, also monitored the repackaging activities carried out at the VINČA Institute.

The TK-S15 and TK-S16 packages filled with HEU fuel slugs, including the three spare empty ones, were moved from the reactor room to the entrance by using the crane in the reactor room and the cart. The lifting carriage picked up the packages there and loaded it into the transport truck. This activity took about 2.5 hours, including measuring of the transport index of the packages loaded on the vehicle.

The core of the Transport Program Team consisted of about 30 members of the operation staff of RA and RB reactors, while the whole activity at the VINČA site engaged about 50 persons including two IAEA safeguard experts, two STNM Institute experts and two ORNL DOE monitoring experts. About 1200 policemen, including members of the Special Antiterrorist Unit ("SAJ"), were also engaged during loading of the packages on to the vehicle at the VINČA Institute, transport of the fuel elements from the VINČA Institute to the Belgrade airport and during loading of the aircraft at the airport.

The transport itself took place after midnight, when police forces closed for traffic the lanes in both directions along the whole route and blocked all intersections on the way from the VINČA Institute to the Belgrade airport. The transport caravan, beside two transport vehicles (one loaded by the nuclear fuel and the other, the so-called "dummy"), included various police escort units, radiation protection, medical protection and fire protection units and the vehicles carrying experts. The transport caravan, escorted also by a police helicopter, moved smoothly along the route from the VINČA Institute to the Belgrade airport without any incidents in less than 50 minutes. The whole transport, due to closed roads, helicopter escort and heavy police forces, attracted attention and curiosity of Belgrade citizens and public media. The cargo aircraft was loaded in about 3 hours including fixing packages in their locations in the aircraft, measuring the transport index in the aircraft, customs procedures and preparation of the final export documents. The aircraft departed from Belgrade airport the same morning, on August 22 at 08:05, escorted by two Yugoslav army air-fighters to the Yugoslav border. The transport aircraft landed at the Uljanovsk airport near Dimitrovgrad after about a four hour flight. The successful landing of the aircraft with fuel cargo was immediately reported by Russian experts who escorted the shipment. The same day at 12:15 in Belgrade, the Ministry of Science, Technologies and Development of the Republic of Serbia and the Director General of the VINČA Institute held a Press Conference about these activities and the success of the whole operation.

CONCLUSION

In order to carry out the whole fresh HEU fuel shipment operation at the VINČA Institute, about 50 persons were engaged, including the safeguard inspectors from the IAEA, STNM Institute experts

and monitoring experts from ORNL, DOE. The executive team consisted of 30 experts from the operation staff members of the RA and RB research reactors. In order to provide adequate security measures during the shipment operation, about 1200 policemen, including special task forces, helicopter and two military air-fighters were engaged.

This operation was a very useful experience for various government and non-governmental institutions and management personnel in all the three countries involved in this operation, the first, planned and realized, shipment of the fresh HEU fuel of Russian origin from one research reactor back to Russia for uranium down blending. This paper shows the experiences gathered during organization, planning and undertaking of such a task. For the Yugoslav party, the successful conduct of the operation is considered as a test for performing the much more complex task that awaits it in the future – the shipment of spent nuclear fuel from the RA research reactor back to the Russia for reprocessing.

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REFERENCE

[1] Pešić, M., Cupać, S., Vukadin, Z., Management of Ageing Research Reactors in the VINČA Institute, IAEA International Symposium on Research Reactor Utilisation, Safety and Management, Lisbon, Portugal (September, 6–10, 1999), paper IAEA-SM-360/042P, CD ROM CSP-4/C, IAEA, Vienna, Austria, June, 2000, pp. 042P.1-042P.9

[2] Pešić, M., RB Reactor In-core Fuel Management, Transaction of the ENS 3rd International Topical Meeting on Research Reactor Fuel Management, RRFM'99, Bruges, Belgium, March 28–30, 1999, pp. 177–181

[3] Krupchitskij, P. A., ITEP Report No. 121 (in Russian), Moscow, Russia, 1962

[4] Enin, A. A., An Overview of Russian Research Reactor Fuel Types, Their Fabrication and Quality Control, IAEA TCP RER/9/058 Workshop on Characterisation, Management and Storage of Spent Fuel from Research and Test Reactors, Limited Distribution, Swierk, Poland, May 8–12, 2000, pp. 1–30

[5] Pešić, M. P., RB Reactor: Lattices of 80%-Enriched Uranium Elements in Heavy Water, International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03/II, Vol. II, contribution HEU-COMP-THERM-017, 2001 Edition, OECD/NEA, Nuclear Science Committee, Paris, France, September 30, 2001, pp. 2–189

[6] Matausek, M. V., Vukadin, Z., Plešaš, I., Pavlović, R., Šotić, O., Safe Disposal of Research Reactor RA Spent Fuel Activities, Problems and Prospects, *Proceedings*, YUNSC-2000, pp. 187–192

[7] Aden, V. G., Bulkin, S. Yu., Sokoliv, A. V., Matausek, M. V., Vukadin, Z., Spent Fuel from RA Reactor Inspection of State and Options for Managements, *Proceedings*, YUNSC-2000, pp. 198–202

[8] Milošević, M., Vukadin, Z., An Analysis of Spent Fuel Characteristics for Reactor RA Spent Fuel Elements, YUNSC-2000, pp. 203–216

[9] Matausek, M. V., Vukadin, Z., Pavlović, R., Plećaš, I., Šotić, O., Pavlović, S., Iđaković, Z., Underwater Inspection of the State of Aluminium Containers and the State of Reactor RA Spent Fuel Packed in Them (in Serbian), *Nuklearna Tehnologija, 16* (2001), 1, pp. 3–9

[10] ***, Regulations for the Safety Transport of Radioactive Material – Requirements, IAEA Safety Standard Series, No. TS-R-1 (ST-1, Revised), 1996 Edition (Revised), STI/PUB1098, IAEA, Vienna, Austria, June, 2000

[11] Pešić, M., Steljić, M., Antić, D., Criticality Safety Evaluation for TWR-S Fuel Assembly Transportation Using TK-S16 Containers, *Proceedings*, YUNSC-2002, to be published

[12] Milošević, M., Dašić, N., Ljubenov, V., Nuclear Criticality Analysis of Transport Casks TK-S15 and TK-S16 with RA Reactor Fresh Fuel Elements by SCALE-4.4a Code System, *Proceedings*, YUNSC-2002, to be published

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Милан ПЕШИЋ, Обрад ШОТИЋ, Виљем Х. ХОУПВУД млађи

ТРАНСПОРТ ВИСОКООБОГАЋЕНОГ СВЕЖЕГ УРАНИЈУМСКОГ ГОРИВА ИЗ ЈУГОСЛАВИЈЕ У РУСКУ ФЕДЕРАЦИЈУ

Приказани су релевантни подаци о скорашњем транспорту (августа 2002. године) свежих нуклеарних горивних елемената са високообогаћеним уранијумом из Југославије назад у Руску Федерацију ради осиромашења уранијума. Овим је Југославија дала свој допринос Програму смањења обогаћења за истраживачке и тест реакторе (РЕРТР Програм) и удруженим напорима светске заједнице да спречи могуће терористичке акције у циљу присвајања нуклеарног материјала који се може користити за производњу нуклеарног оружја.