Russian Research Reactor Spent Nuclear Fuel Repatriation from the Reactor Country to the Russian Federation for Reprocessing – 14149

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ABSTRACT

In May 2004, the Global Threat Reduction Initiative agreement was signed by the governments of the United States and the Russian Federation. The goal of this initiative is to minimize, in cooperation with the International Atomic Energy Agency (IAEA) in Vienna, the existing threat of misuse of nuclear and radioactive materials for terrorist purposes, particularly highly enriched uranium (HEU), fresh and spent nuclear fuel (SNF), and plutonium, which have been stored in a number of countries. Within the framework of the initiative, HEU materials and SNF from research reactors of Russian origin will be transported back to the Russian Federation for reprocessing/liquidation. The program is designated as the Russian Research Reactor Fuel Return (RRRFR) Program and is similar to the U.S. Foreign Research Reactor Spent Nuclear Fuel Acceptance Program, which is underway for nuclear materials of United States origin. These RRRFR activities are carried out under the responsibilities of the respective ministries (i.e., U.S. Department of Energy (DOE) and Russian Federation Rosatom). The Czech Republic and the UJV Řež, a. s. (UJV) joined Global Threat Reduction Initiative in 2004.

With the significant technical and financial aid of the US Administration and the US DOE the Czech Republic shall become a pilot country, which will carry out such shipment from the UJV to the RF by means of special developed and tested casks, which are compatible with the technology of research reactors of Russian design as well as the technology of the reprocessing plant in the RF. Tender for such casks took place under the auspices of IAEA. Six famous manufacturers from the USA, RF, Germany, France and the Czech Republic participated therein. The ŠKODA JS a.s. was chosen as a supplier. 16 casks were produced for this project. All casks have been further used for return shipments of SNF from other countries to the RF by agreement between the UJV and the US DOE taking into account experience of the UJV from preparation and implementation of the transport from the Czech Republic to the RF. First shipment of SNF from UJV was finished at the end of 2007. From this date, SNF shipments were performed from Bulgaria (3 casks), Hungary (22 casks), Poland (30 casks), Ukraine (11 casks), Belorussia (3 casks), Serbia (16 casks), Vietnam (1 cask) with use of Škoda VPVR/M casks.

The Vietnam shipment carried out at 2013 was unique, since for the first time the type C package (Type C package as per the classification of the Regulations for the Safe Transport of Radioactive Material, TS-R-1, IAEA) was used for this purpose. This package consists of Škoda VPVR/M cask and energy absorption container (together TUK 145 C) certified for transportation of spent nuclear fuel of research reactors by air. Type C package TUK 145 C was developed by Russian company SOSNY and total two containers were produced. This type C package was used for second Hungarian shipment (6 casks).

INTRODUCTION

ÚJV Řež, a. s.

The ÚJV Řež, a. s. (formerly Ústav jaderného výzkumu Řež a.s., Nuclear Research Institute Řež) is a leading institution in all areas of nuclear R&D in the Czech Republic. The ÚJV has had a dominant position in the nuclear field since it was established in 1955 as a state-owned research organization, and has subsequently developed to its current status.

The activities of ÚJV encompass nuclear physics, chemistry, nuclear power and many other topics. The main issues addressed at ÚJV in past decades have included research, development and services for nuclear power plants operating VVER reactors, development of chemical technologies for the fuel cycle, and irradiation services for research and development in the industrial sector, agriculture, food processing and medicine.

ÚJV`s daughter company, Centre of Research Řež, operates the LVR-15 research reactor, which has been in operation since 1957. After more than 50 years of operation of this reactor, a large amount of SNF of Russian origin has been accumulated.

Joining the Global Threat Reduction Initiative (GTRI)

The Czech Republic was included in the GTRI program in 2004. In 2005, a contract between the US Department of Energy (US DOE) and ÚJV was signed. Fig. 1 shows the structure of the GTRI program and the participation of the Czech Republic.

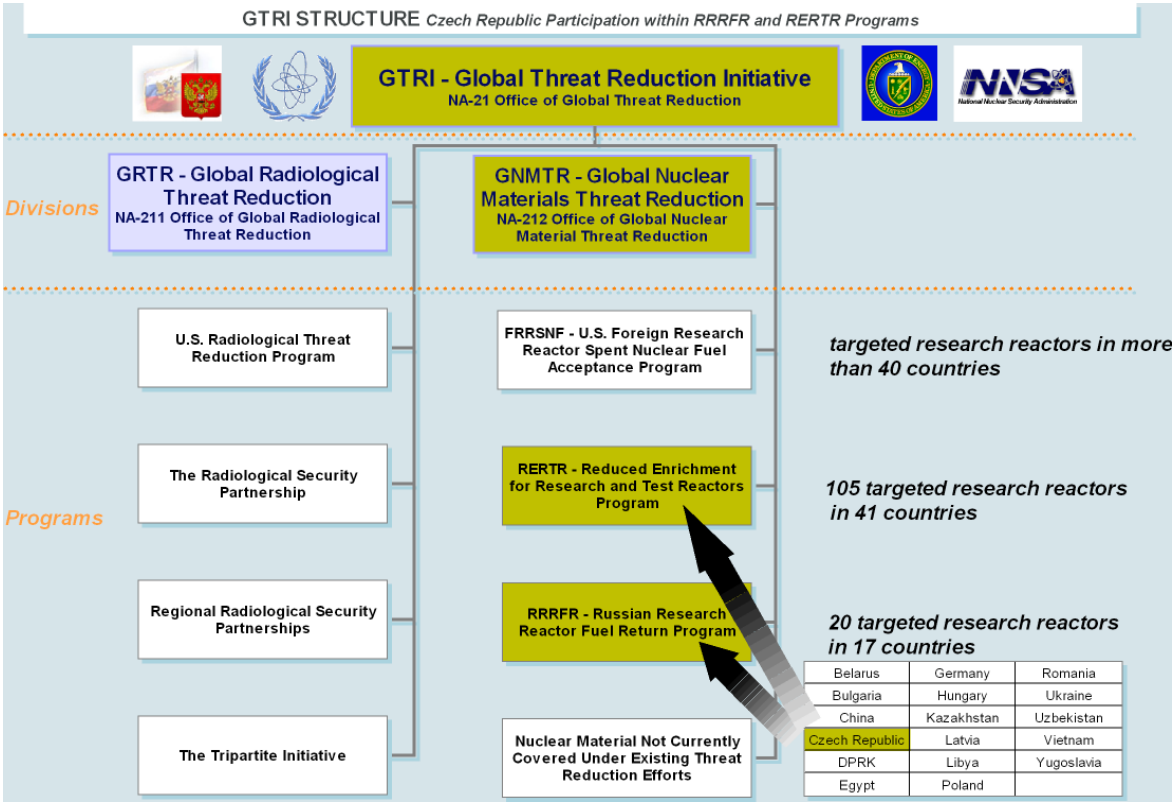

Fig. 1. GTRI structure and participation of the Czech Republic.

With significant technical and financial aid from the US administration and US DOE (total of approximately 31 mil. USD), the Czech Republic became a pilot country, carrying out this shipment from ÚJV to the RF by means of specially developed casks, which are compatible with the technology of research reactors of Russian design as well as the technology of the reprocessing plant in the RF. The Ministry of Finance of the Czech Republic paid approx. 15 mil. USD in the frame of elimination of the ÚJV`s old environmental liabilities.

ŠKODA VPVR/M TRANSPORT AND STORAGE CASK

The ŠKODA VPVR/M cask (see Fig. 2) is a type B(U) and S cask system designed and licensed for the transport and storage of SNF from research reactors of Russian origin.

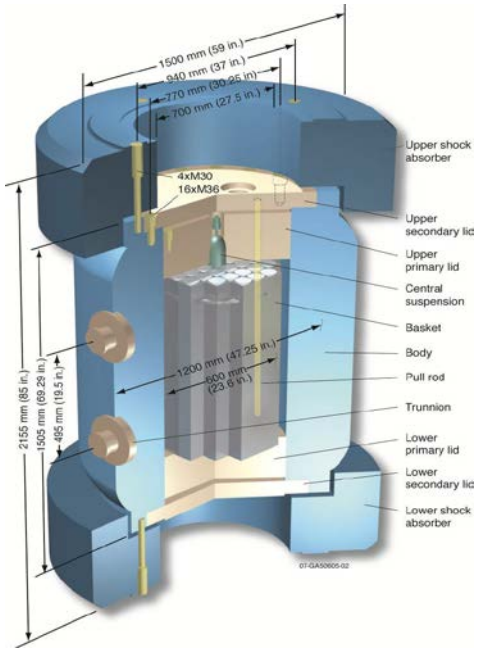

Fig. 2. Scheme of the ŠKODAVPVR/M cask

The unique design of the cask allows for easy use at almost any research reactor facility. The cask is closed by means of a system of two upper and two lower lids. The cask is loaded from the bottom, being placed above the SNF storage pool. It eliminates the need for a transfer cask, thereby reducing the number of manipulations and increasing the level of nuclear safety and radiation protection. The cask has a capacity of 36 FAs, and 16 casks are now available. This means that 576 FAs can be transported in one shipment.

The TPS consists of:

- ŠKODA VPVR/M casks
- Cask baskets
- Special ISO containers for cask shipment
- Auxiliary equipment sets for cask handling
- Service ISO containers for shipment of auxiliary equipment

- Drying and He-leak testing equipment sets for cask testing after loading
- Service ISO containers for shipment of drying and He-leak testing equipment

The VPVR/M cask loading procedure is divided into the following activities:

- Cask transport to the SNF loading site, dismantling the cask
- Transport of the cask to the SNF storage facility (pool, hot cell)
- Putting the basket inside the loading facility (pool, hot cell)
- Loading the SNF into the basket, basket retraction into the cask
- Cask flushing with hot air, desiccation of the cask, cask completion, helium leak test
- Cask sealing with IAEA and EURATOM seals

A specially designed basket handling tool is used for lowering the basket from the cask into the storage pool. The basket is filled manually with the FAs by a special manipulation rod. The crane and lift fixtures are equipped with a digital dynamometer that is used to monitor the weight of the basket during reinstallation into the cask. This prevents the disruption of the central suspension/hanger. Photographs from the loading procedure are provided in Fig. 3 - 5.

Fig. 3. ŠKODA VPVR/M cask prepared for loading onto the storage pool

Fig. 4. Loading SNF inside the pool into the basket

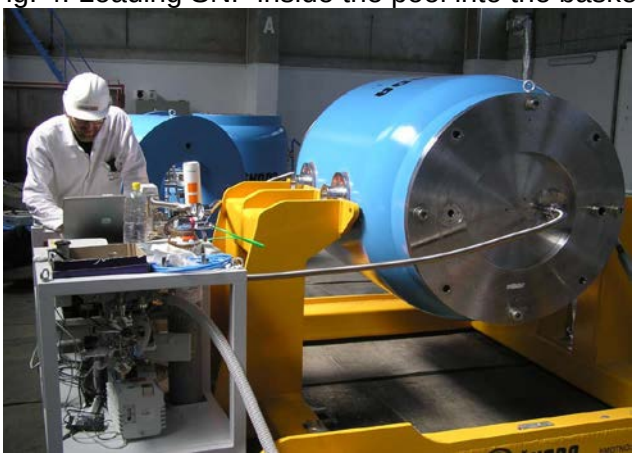

Fig. 5. Cask drying, helium leak test

Special equipment for the loading of SNF at a facility which does not allow for the disposition of the cask on the storage pool was designed and developed by the SOSNY company (RF) and financed by the US DOE. It consists of a transfer cask, serving for the transfer of single FA from a storage pool to the ŠKODA VPVR/M casks, and auxiliary equipment. In Fig. 6, the scheme of reloading FA from the transfer cask to the ŠKODA VPVR/M cask is provided.

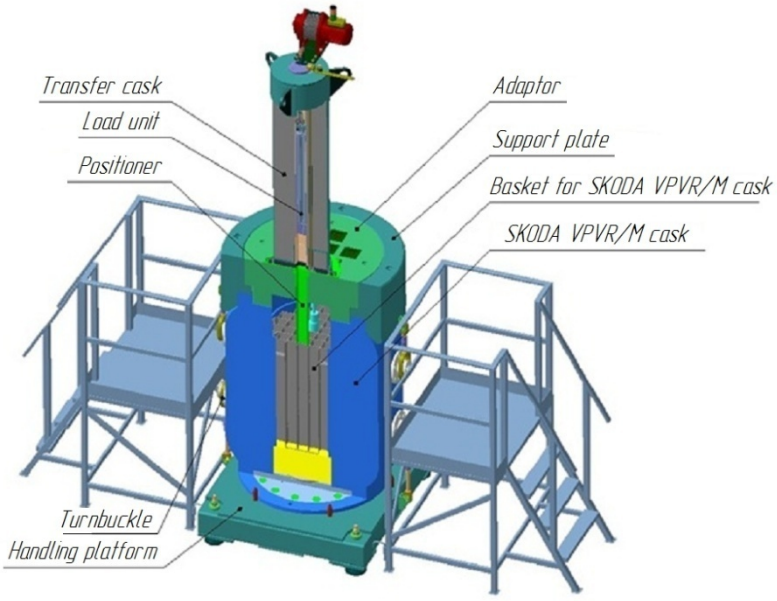

Fig. 6. Scheme of reloading FA from the transfer cask

The ŠKODA VPVR/M TPS can now be used at any research reactor facility. The equipment was used for the first time for loading SNF at the Dalat research reactor, Vietnam (see Fig. 7).

Fig. 7. Reloading of FA from the transfer cask, Vietnam

The ŠKODA VPVR/M TPS can be used not only for road, railway, river and marine transport but, with the energy absorption container (EAC) which forms the TUK-145/C Type C package, also for air transport. The TUK-145/C Type C package was designed and developed by the SOSNY company (RF) and financed by the US DOE.

The Type C package is designed for transportation of radioactive material without any restrictions on activity through different transport modes. It is a vertical cylinder made of two halves with a flange joint and filled with hollow titanium spheres (see Fig. 8).

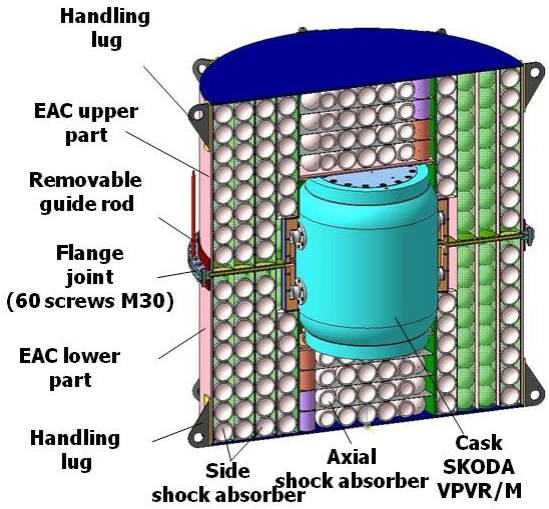

Fig. 8. TUK-145 / C Type C transport package

This package was used for the first time for shipment of SNF from Vietnam (see Fig. 9), and was used also for shipment of SNF from Hungary to the RF.

Fig. 9. Forming the TUK-145 / C transport package (Vietnam)

ÚJV'S PARTICIPATION IN SHIPMENTS OF SNF FROM OTHER COUNTRIES

As a result of the successful performance of the first shipment from the Czech Republic, ÚJV is also participating in shipments of SNF from other countries. The services of ÚJV comprise: ŠKODA VPVR/M TPS leasing, providing service and maintenance inspections of the TPS,

transportation of the TPS, providing TPS documentation, training of personnel in TPS use and SNF loading, technical oversight and expertise during cask handling, SNF loading and cask closing and sealing, drying and helium leak testing of casks, and return transportation of the empty casks and auxiliary equipment to ÚJV. A review of the performed shipments, including shipments from the Czech Republic, is shown in Table 1.

TABLE I. Shipments of SNF under the RRRFR program performed by ÚJV

Country (Facility)	**Shipment date**	**No. of casks**	**SNF Data**	**No. of shipped FA**	**Transport Route**
Czech Republic 1 (LVR-15)	Dec 2007	16	HEU: IRT-2M LEU: EK-10	568	Road, rail
Bulgaria (IRT-2000)	Jul 2008	3	HEU: S-36 LEU: EK-10	108	Road, rail, river
Hungary 1 (BRR)	Oct 2008	16	HEU: VVR-M, VVR-M2 LEU: EK-10	576	Road, rail, sea
Poland 1 (EWA)	Sept 2009	16	HEU: VVR-M2	864	Road, rail, sea
Poland 2 (EWA)	Feb 2010	8	HEU: VVR-M2		Road, rail
Ukraine 1 (VVR-M)	May 2010	7	HEU: VVR-M2	252	Road, rail
Belarus (PAMIR-630D, IRT-M)	Oct 2010	4	HEU	144	Road, rail, sea
Serbia (RA)	Nov 2010	16	HEU: TVR-S LEU: TVR-S	576	Road, rail, sea
Ukraine 2 (VVR-M)	Mar 2012	4	HEU: VVR-M2	98	Road, rail
Poland 6 (EWA)	Oct 2012	3	LEU: EK-10	90	Road, rail, sea
Czech Republic 2 (LVR-15)	Mar 2013	6	HEU: IRT-2M	112	Road, rail, sea
Vietnam (DNRR)	Jul 2013	1	HEU: VVR-M2	36	Road, air, rail
Hungary 1 (BRR)	Sept 2013	6	HEU: VVR-M, VVR-M2	144	Road, air, rail
Total		**100**		**3424**	

Photographs from the shipments are provided in Fig. 10 - 13.

Fig. 10. Loading of SNF in Hungary

Fig. 11. Loading of SNF in Poland

Fig. 12. Loading of SNF in Belarus

Fig. 13. Casks ready for loading of SNF in Serbia

A second shipment of HEU from Hungary was provided at the autumn in 2013. Six casks was used for a combined road, air and railway transport. The shipment of SNF from Uzbekistan is planned in 2014. One cask will be used for shipment of liquid SNF in special canisters.

It is expected that the experience and results gained will be applied to the preparation and completion of SNF repatriation from Chinese Miniature Neutron Source Reactors (MNSR) in the near future. The SNF is planned to be shipped from Ghana, Nigeria, Pakistan, Iran and Syria to China. ÚJV will be responsible for project management and service activities. New cask internals will be developed and manufactured by CIAE (China Institute of Atomic Energy) and ŠKODA JS (Czech Republic).

RETURN OF RAW FROM REPROCESSING

Usually SNF reprocessing is connected with RadWaste return. RF offers two possibilities in this project – RadWaste return back to country SNF of origin or to keep the RadWaste in RF for ever. Czech republic decided to take RadWaste back to Czech Republic.

One license – a license for re-import of vitrified waste back to the Czech Republic - represents a challenge for both the ÚJV, as an applicant, and the regulatory body, as it will be the first time when an application of this type will be dealt with. According to the Foreign Trade Contract (FTC) between the ÚJV and Federal Centre for Nuclear and Radioactive waste Safety (FCNRS) concerning the SNF export and reprocessing in RF, the vitrified waste from reprocessing of SNF should be shipped back to the Czech Republic after 2024 (first shipment) or 2033 (the second shipment), respectively.

While there is enough time for planning such a return, setting down requirements for the composition, physical parameters and properties of this waste was urgent, as the vitrification of waste is done two years after shipment. Pursuant to this, it was necessary to address the return of waste in the FTC very carefully with an assumption of extrapolating existing “legislation” to the period around the year 2025.

The fact that vitrified waste will have to be returned to the Czech Republic had been one of the basic conditions of the project. It was fixed in several clauses of the FTC and backed up by an explicit requirement from the Russian side – a commitment/guarantee of re-acceptance of the waste, to be confirmed by the authorized governmental body prior to signature of the FTC. The commitment on the return of waste from the reprocessing of SNF in the RF is also included in the Amendment of the Russian-Czech Intergovernmental Agreement on Co-operation in Nuclear Energy of 15.4.1999 (Coll. No. 154/1999).

The Czech side insisted on the condition that the return of waste will have to comply with legislation in both countries, understanding that this means both the legislation valid at the time of signing the FTC and the legislation which will be in place at the time of the return of waste to the Czech Republic. From a legal point of view, such a requirement was rather challenging, as it undermined the return of waste by something which was not yet known. The fact that the FTC was signed proves that both sides had realized, in the end, that the only realistic approach was to commit themselves to the fact that the return of the waste in 2026 would have to comply with standard international practices and valid legislation of both countries, regardless of what they might be.

The following three types of licenses condition the return of waste, according to existing legislation of the Czech Republic:

a) A license authorizing re-import of the radioactive material recovered from SNF, exported from the Czech Republic for reprocessing

b) A license for transporting a package with RAW through the territory of transit countries and the Czech Republic in compliance with current international safety standards

c) A license for the package system, ensuring that the RAW to be returned, package type and sealing will meet the conditions of storage and handling up to the time of scheduled removal into the deep geological repository (DGR) in 2065.

In order to obtain these licenses, the applicant will have to submit a number of documents specifying the nomenclature, composition, physical form, amount, package type, etc., of waste to be returned.

For the sake of avoiding any future misunderstandings and difficulties regarding the return of waste to the Czech Republic, both sides made maximum efforts to define the conditions of this return as far as possible and fixed them in the FTC. The FTC and its Appendices include additional regulatory requirements for the re-import of this waste, such as QA programmes for the vitrification process, instructions on the safe handling of vitrified waste, etc., all aimed at a smooth licensing process for re-importing the waste.

MANAGEMENT OF RAW FROM REPROCESSING

As Czech`s SNF will be reprocessed together with other spent fuel (from NPPs, propulsion and research reactors), the separation of the waste from the Czech`s SNF is not possible. A so called “equivalent” of radionuclides will be returned to the Czech Republic. Amount of the reprocessing products to be returned is evaluated by the mutually agreed procedure in account of condition of equivalence of supplied SNF activity and activity of returned reprocessed products with regard to the natural decay of radionuclides during temporary storage of SNF and reprocessed products as well as during SNF reprocessing.

In case of the long-term exposure of radionuclide mixture its potential biohazard is evaluated by individual effective dose (Committed Effective Dose). Effective dose from internal intake of radionuclides in both of the supplied SNF batch, and in the batch of returned waste is assumed as the dose equivalent of total activity of radionuclide mixture. The total dose equivalent is the sum of products of radionuclide activities and relevant exposure factors.

The waste from reprocessing will be vitrified and will contain fission products, actinides and uranium, plutonium and neptunium remaining unextracted. U, Pu and Np isotopes are targeted conversion products that are not taken into account in calculating the equivalent quantity of the radioactive waste returned except for a small fraction of U, Pu and Np mass remaining in the RW after reprocessing. The regenerated U and Pu cannot be returned to the Czech Republic, since this contradicts Russia’s non-proliferation commitments. In the following table, there are the main radionuclides contained in the vitrified waste. Contribution of these radionuclides to the total dose equivalent is about 99.6 %.

TABLE II. Radionuclides contained in vitrified waste

Fission products	Actinides
^{137}Cs (^{137m}Ba) ^{90}Sr (^{90}Y)	^{238}Pu, ^{239}Pu ^{240}Pu, ^{241}Pu ^{241}Am, ^{243}Am ^{244}Cm

The vitrified waste produced is poured into 200l canisters made of carbon steel. Two canisters are put inside one cylinder with a maximal total weight of 1350 kg. Sketches of the canister and the cylinder are given in Fig. 14.

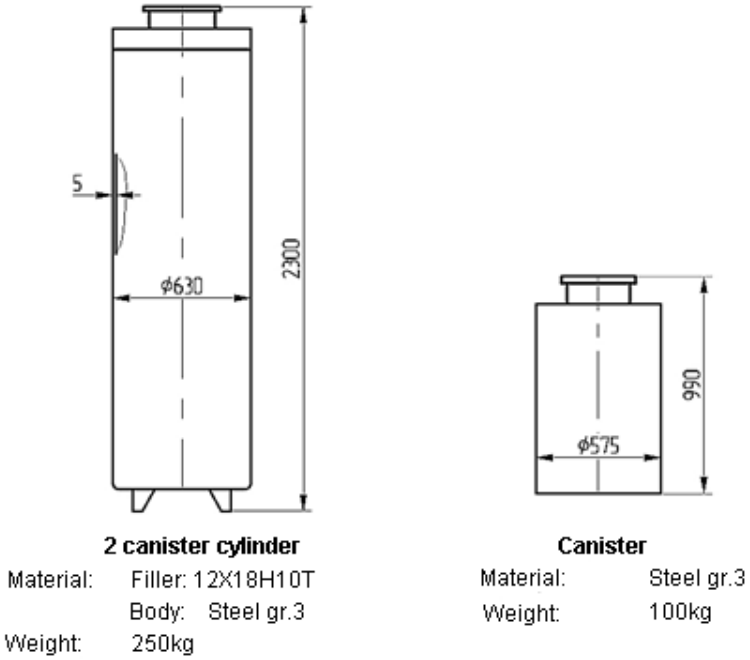

Fig. 14. Sketches of the canister and the cylinder (dimensions in mm)

Four canisters with vitrified waste in two cylinders will be produced and returned to the Czech Republic.

The waste will be shipped to the Czech Republic in the Russian transport casks TUK-32 or containers TUK-108/1 for the long-term storage. The use of another transport cask is also possible.

DISPOSAL OF VITRIFIED WASTE AND/OR SPENT NUCLEAR FUEL

Vitrified Waste

According to the FTC, the vitrified waste from reprocessing of SNF should be shipped back to the Czech Republic after 2024 (the first shipment) or 2033 (the second shipment).

The vitrified RAW will be transferred in accordance with the Atomic Law to the Radioactive Waste Repository Authority (RAWRA) for storage after its return from the RF. The waste will probably be stored in the High Level Waste Storage Facility operated by the ÚJV Řež, a. s. The proper cask will be purchased or developed for storage until the disposal into the DGR. Also for disposal of the waste, a suitable disposal cask must be developed.

Spent Nuclear Fuel

It is planned that up to 286 spent FAs of IRT-4M type with initial enrichment of 19.7% will be produced from operation of the LVR-15 reactor until its shut-down. There are two possibilities how to eliminate the SNF – reprocessing or disposal into DGR.

As reprocessing of SNF is very expensive, this way will depend mainly on the available financing. The second possibility – disposal – seems to be more probable because DGR is planned to be available in the Czech Republic since 2065. It will require the safe solution of long-term SNF storage and the development of a suitable disposal cask.

CONCLUSIONS

All SNF produced after more than 50 years of operation of the LVR-15 (or VVR-S) research reactor has already been shipped to the RF in the frame of the GTRI initiative. Two shipments were performed in 2007 and 2013.

ÚJV is also participating in shipments of SNF from other countries. The ŠKODA VPVR/M TPS was used for shipment of spent fuel from the Czech Republic and eight other countries to the Russian Federation for reprocessing within the framework of the GTRI project. Twelve shipments using a total of 100 casks have already been completed without any incident or accident. Two other shipments will be carried out. A project for repatriation of SNF from Chinese Miniature Neutron Source Reactors (MNSR) is currently being prepared.

HLW will be generated from the SNF reprocessing. The vitrified HLW will be returned back to the Czech Republic as it is stated in the Russian-Czech Intergovernmental Agreement on Co-operation in Nuclear Energy. The return of the waste represents a very complex and complicated scope of work, technically, legally and contractually.

HLW will be disposed (probably with the SNF produced by the LVR-15 reactor after 2010) into DGR. The technology for long-term storage before disposal must be developed together with a disposal cask both for HLW and SNF.

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- Research reactor operators
- State administrations, regulators in respective or transit countries