SPENT FUEL REPATRIATION FROM SERBIA

Јавно предузеће
Нуклеарни објекти Србије

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Public Company "Nuclear Facilities of Serbia"

International Conference on Research Reactors Safe Management and Effective Utilization

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Contents

1 Introduction

1.1 Fuel repatriation background

December 1999

Representatives of the USA, the Russian Federation and the IAEA came to an agreement to establish a programme for returning Russian-origin HEU fuel stored at foreign reactor facilities to the Russian Federation (RRRFR Programme).

October 2000

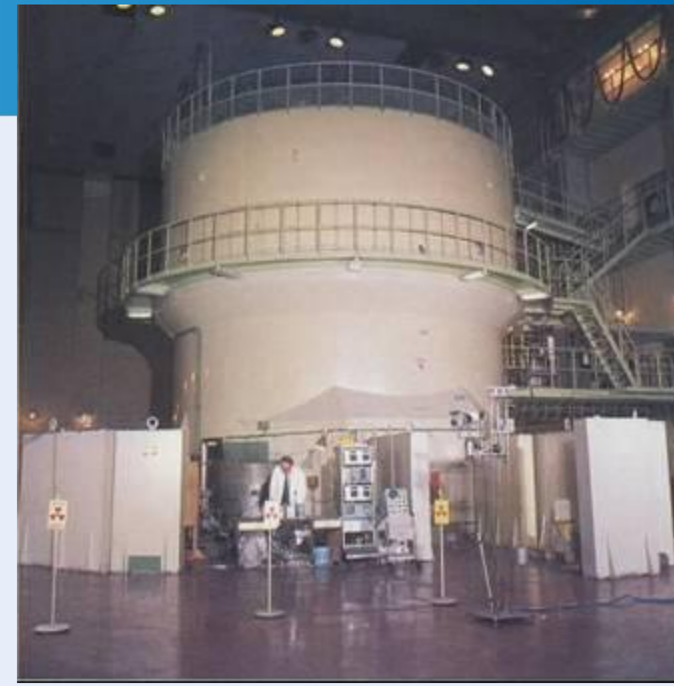
Director general of the IAEA invited 15 countries in possession of the Russian-origin nuclear fuel to indicate their willingness in returning HEU fuel to the Russian Federation.

February 2002

Government of the former FR Yugoslavia expressed strong interest in participating in the RRRFR Programme.
Determination to repatriate all fresh HEU and all spent HEU and LEU fuel elements, as well, has been announced.
Close cooperation with the IAEA has been established.

1 Introduction

1.2 Reactor facility



Design:	former USSR
Location:	Vinča (outskirts of Belgrade)
User:	Public Company ”NFS”
Type:	tank
Power:	**6.5 MW** (10.0 MW)
Moderator:	heavy water
Primary coolant:	heavy water
First start-up:	**December 1959**
Final shut-down:	**August 1984**
Decommissioning:	ongoing activity since **2003**

1 Introduction

1.3 Fuel type and inventory

Fuel type: TVR-S (produced in the former USSR)

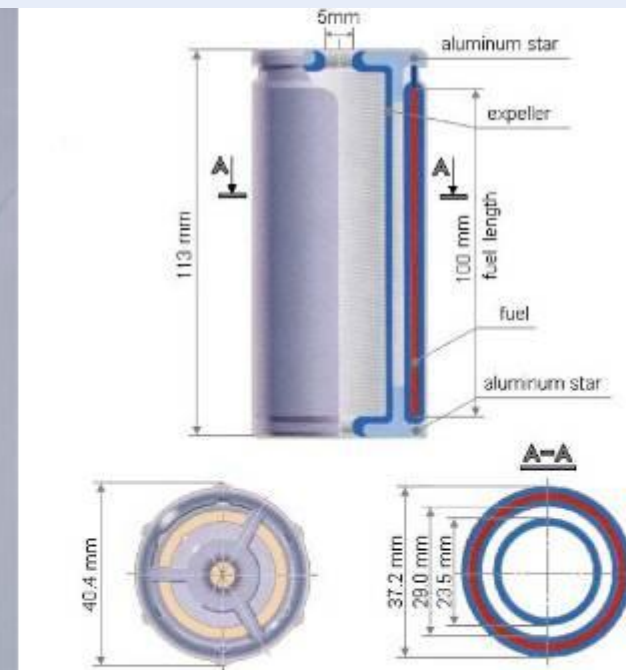
LEU type: 2% enriched U metal (7.25g ^{235}U; 370g U; 460g total mass)
HEU type: 80% enriched UO_2 in Al-matrix (7.7g ^{235}U; 9.6g U; 160g total mass)

Both types of fuel elements have the same geometry.

LEU used from 1959 to 1979
HEU used from 1975 to 1984

5046 fresh HEU elements

6656 spent LEU elements
1374 spent HEU elements



1 Introduction

1.4 Fresh fuel shipment

5046 HEU fresh fuel elements (app. **48 kg** of enriched uranium) were sent to the Russian Federation in **August 2002**.

This shipment was the first actual step in implementation of the RRRFR Programme.

2 Legal Framework

2.1 Decisions and agreements

February 2004	Government of the Republic of Serbia made a decision to repatriate the RA reactor's spent nuclear fuel to the Russian Federation.
May 2004	The Agreement between the Government of the USA and the Government of the Russian Federation, related to cooperation for transferring Russian-produced research reactors' nuclear fuel to the Russian Federation, was signed in Bratislava.
May 2005	Upon the invitation of the IAEA, an international consultancy meeting was held at the Vinča Institute. The goal was to draft the outlines of a bid for the transport of the RA reactor's spent nuclear fuel.
August 2005	IAEA put out an international tender for the RA reactor's spent nuclear fuel transport to the Russian Federation.
December 2005	Consortium of three Russian companies was chosen.

2 Legal Framework

2.2 Contract

September 2006 Contract for the transport of the RA reactor's spent nuclear fuel to the RF was signed by:

International Atomic Energy Agency, Research and Development Company "**Sosny**", Federal State Unitary Enterprise PA "**Mayak**", Joint Stock Company "**Tenex**", **Vinča Institute of Nuclear Sciences**.

Main objectives of the Contract:

- to develop repackaging and loading technology
- to design and manufacture required equipment
- to organize and realize transportation
- to perform necessary on-site preparations
- to carry out all on-site operations
- to provide for all at once shipment until the end of 2010

2 Legal Framework

2.3 Import of spent fuel to the Russian Federation

2.3.1 Government-to-Government Agreement

June 2009

The so-called “Government-to-Government Agreement” between the Government of the Russian Federation and the Government of the Republic of Serbia concerning cooperation for the transfer of the RA research reactor’s spent nuclear fuel to the Russian Federation was signed.

2.3.2 Foreign Trade Contract

September 2009

Contract between the Federal State Unitary Enterprise “Federal Centre of Nuclear and Radiation Safety” and the Public Company “Nuclear Facilities of Serbia” for importing spent nuclear fuel of the RA research reactor into the RF, its reprocessing and final disposal of radioactive waste material in the Russian Federation, was signed.

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2 Legal Framework

2.4 Financial support

Republic of Serbia has received substantial international financial support thus ensuring realization of the RA reactor’s spent fuel transfer to the Russian Federation.

Among the greatest contributors were:

- **International Atomic Energy Agency**
- **European Commission**
- **US DOE, National Nuclear Security Administration**
- **Russian Federation**
- **Nuclear Threat Initiative** (non-governmental organization, USA)
- **Czech Republic**

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3 Feasibility considerations

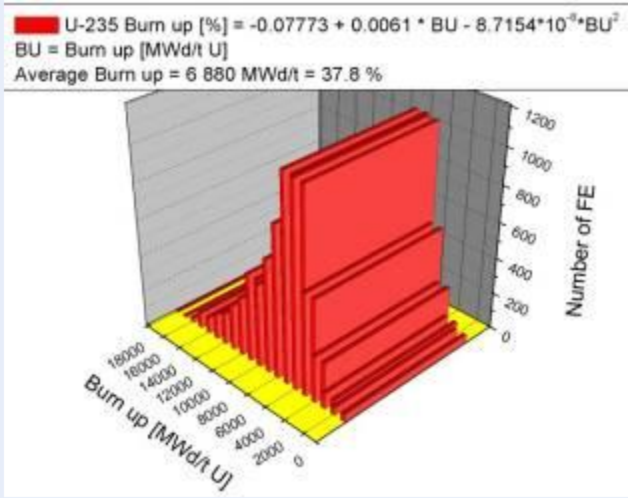
3.1 Characterization of the spent fuel

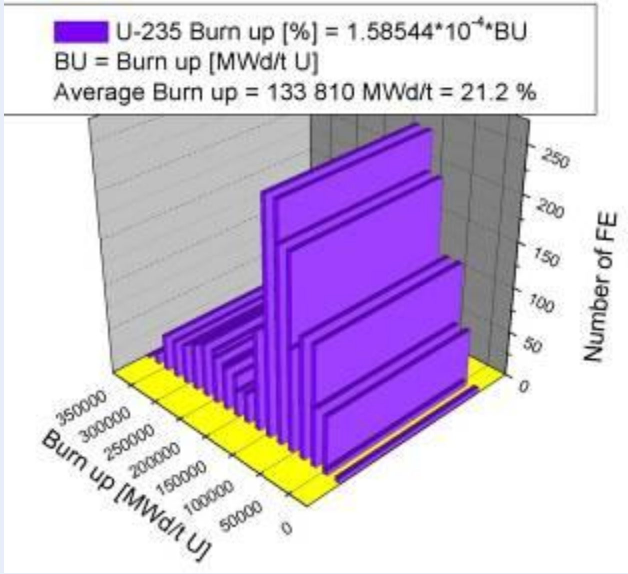
- Irradiation and cooling history of each fuel element
- Burn-up of each fuel element
  - LEU average: **6.9 MWd/kgU (38%)**
  - HEU average: **134 MWd/kgU (21%)**

- Total mass of uranium: app. **2.5 t**

- Maximum decay heat (in 2010)
  - LEU fuel element: **150 mW**)
  - HEU fuel element: **90 mW**)

- Several hundreds of LEU fuel elements may have had **breached cladding** (contamination of water inside containers with ^{137}Cs ranged from a few Bq/ml up to several tens of MBq/ml)





3 Feasibility considerations

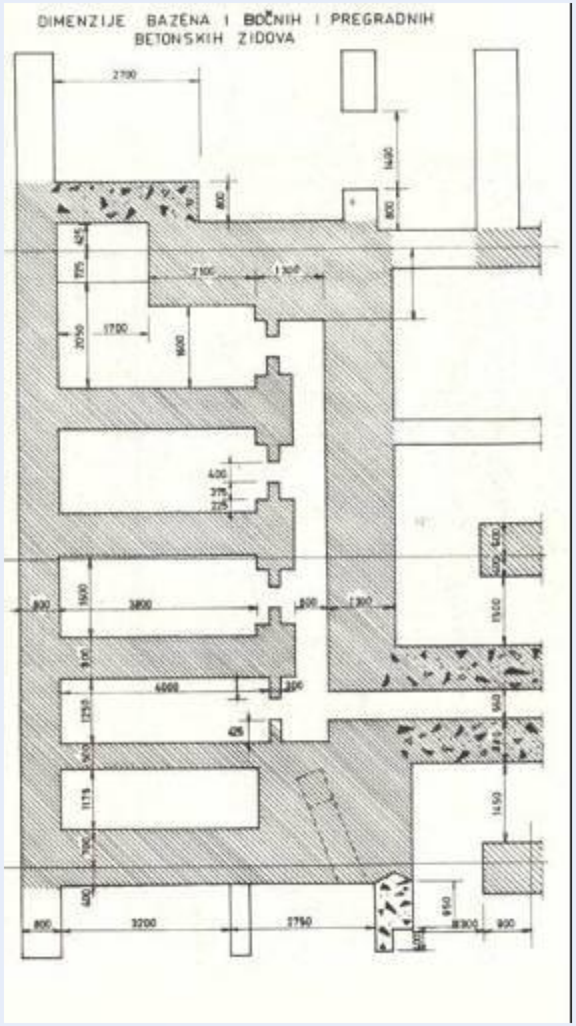
3.2 Fuel handling prospects

3.2.1 Spent fuel storage

Location:	within reactor building
Structure:	4 water pools; 1 dry pool
Pools' depth:	6.5 m
Water level:	5.8 m (max)
Water volume:	app. 200 m^3

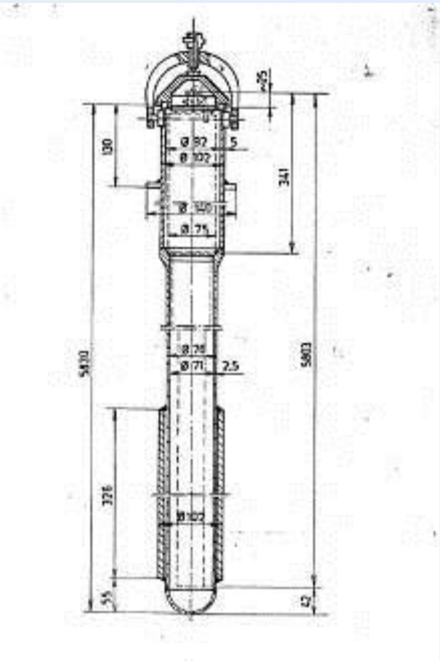
Bridge crane with
2 t lifting capacity.

The storage room was the most suitable area for performing majority of fuel repackaging and loading operations.



3 Feasibility considerations

3.2.2 Storage containers



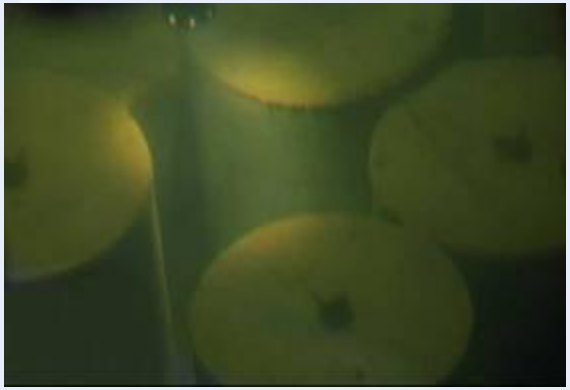
Container types: aluminium barrels (**30**)
stainless steel containers (**297**)

4929 fuel elements stored in aluminium tubes in barrels
3101 fuel elements stored in reactor-channel tubes in stainless steel containers

All fuel elements had to be repacked into new containers suitable for transportation.

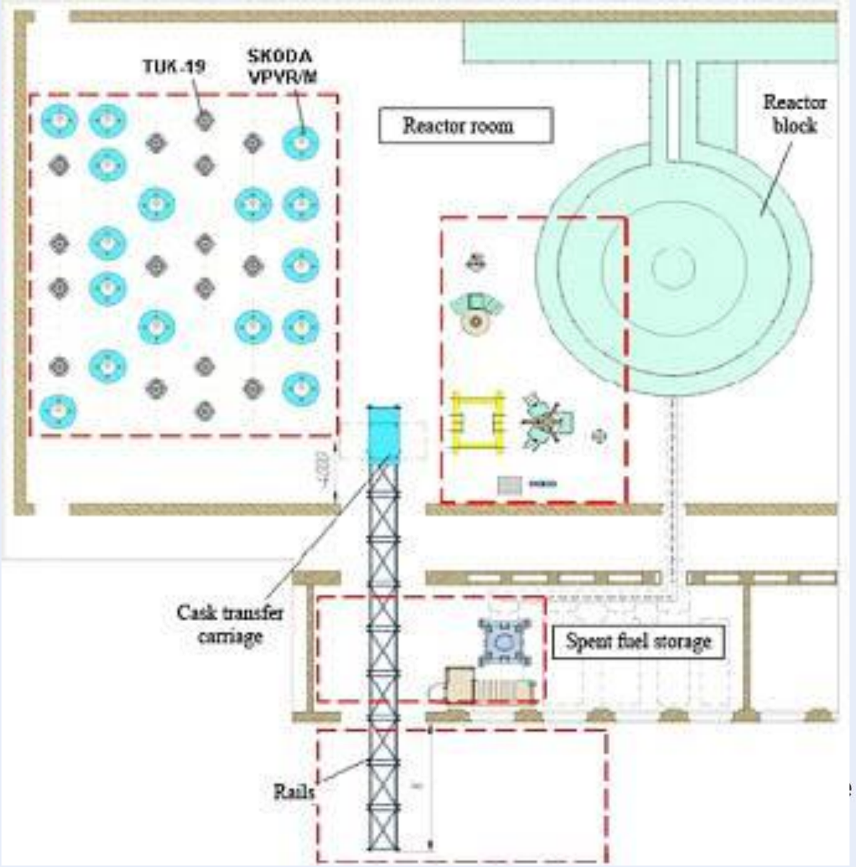
Efficient removal of ^{137}Cs from pools' water was indispensable.






3.2.3 Reactor room

- Reactor block is directly connected with pools in spent fuel storage
- Enough space for temporary storage of transport casks
- Bridge crane of 20 t lifting capacity
- Most suitable area to prepare transport casks for loading and transportation



3 Feasibility considerations

3.3 Transport casks selection

TUK-19 and **SKODA VPVR/M** casks have been chosen. Except for the storage space (up to 432 TVR-S fuel elements in SKODA cask and 132 in TUK-19 cask), these casks were:

- certified,
- acceptable for PA "Mayak",
- available.

32 casks in total (16 of each type) were needed for one time shipment of all RA reactor's spent nuclear fuel.

3 Feasibility considerations

Fuel type and transport casks used

Belarus	SKODA VPVR/M	EK-10, IRT-M, Pamir
Bulgaria	SKODA VPVR/M	EK-10, S-36
Czech Republic	SKODA VPVR/M	EK-10, IRT-2M
Egypt		EK-10
Germany	CASTOR	EK-10, VVR-SM
Hungary	SKODA VPVR/M	EK-10, VVR-SM, VVR-M2
Kazakhstan	TUK-19	VVR-K
Latvia	TUK-19	EK-10, IRT-2M, IRT-3M
Libya	TUK-19	IRT-2M
Poland	SKODA VPVR/M, TUK-19	EK-10, VVR-SM, VVR-M2, MR
Romania	SKODA VPVR/M, TUK-19	EK-10, S-36
Serbia	SKODA VPVR/M, TUK-19	TVR-S
Ukraine	SKODA VPVR/M	VVR-M2, VVR-M5, VVR-M7
Uzbekistan	TUK-19	EK-10, IRT-3M, S-36, IRT-4M,
Vietnam	SKODA VPVR/M	VVR-SM

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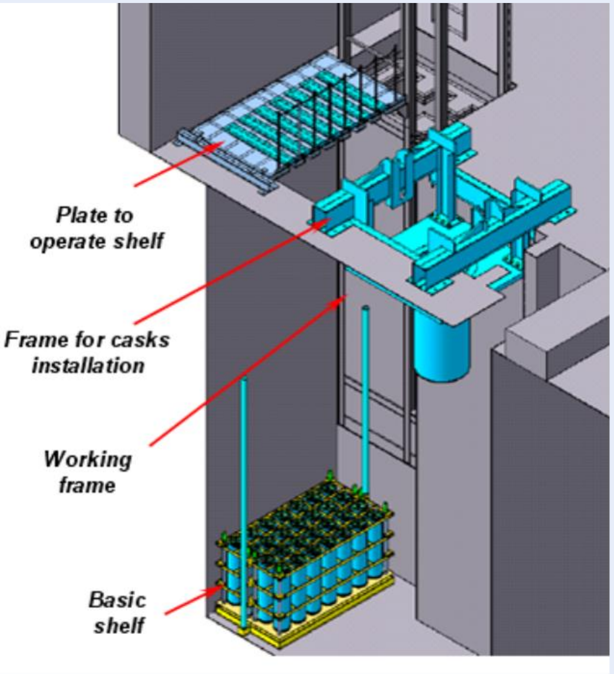
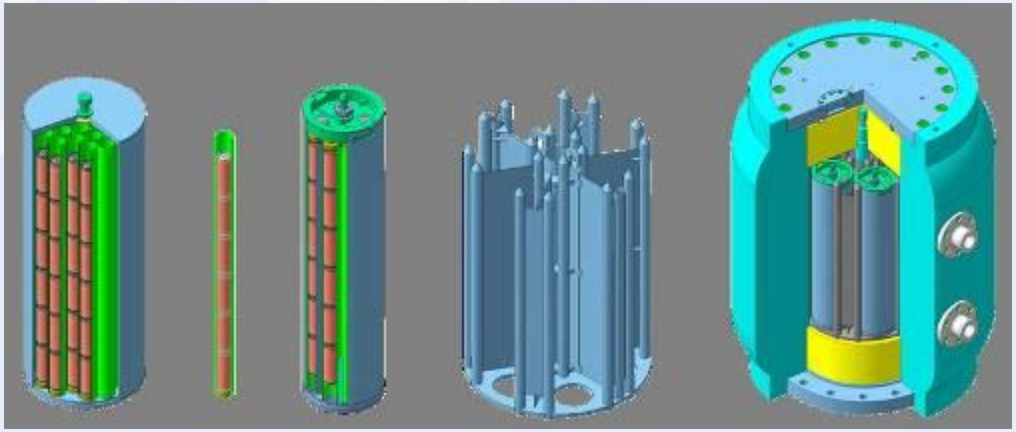
4 Preparations

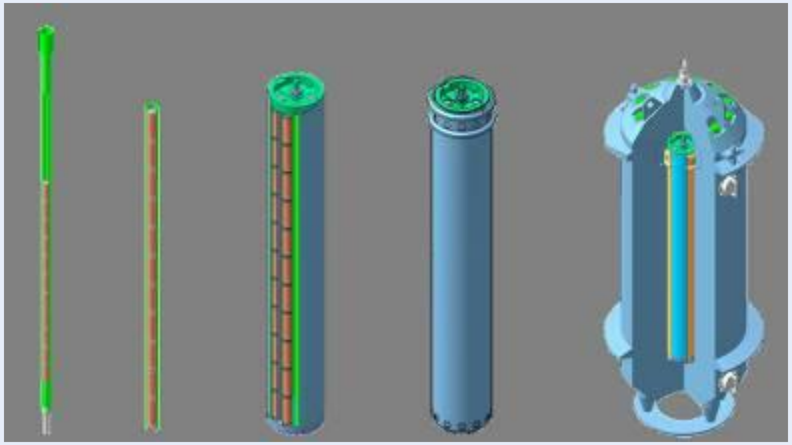
4.1 Engineering

4.1.1 Repackaging and loading technology

- Design of high capacity canisters and baskets
- Repackaging to be performed underwater at the special working platform in the storage pond
- Fuel elements to be repacked without (if possible) or with the corresponding tube
- Direct underwater loading of baskets into SKODA casks, or into the transfer flask (for TUK-19 casks)



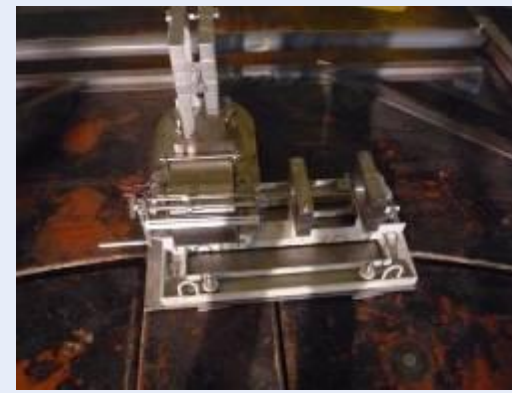


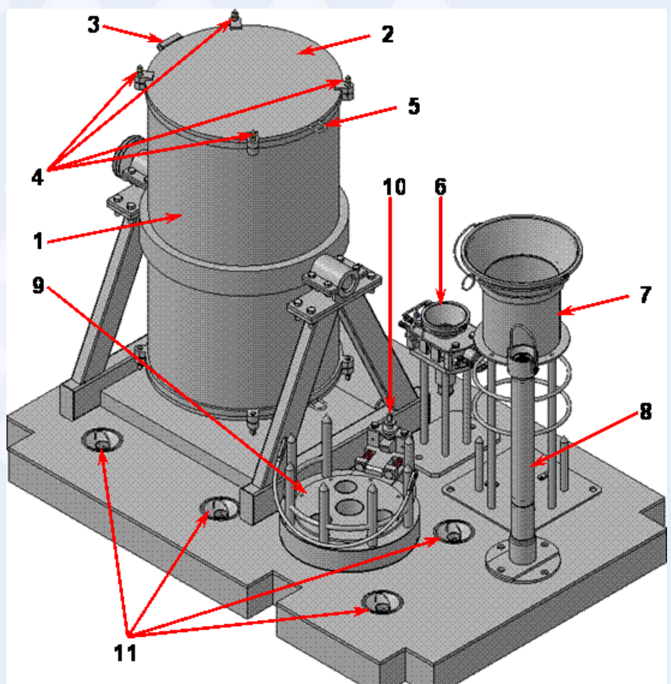


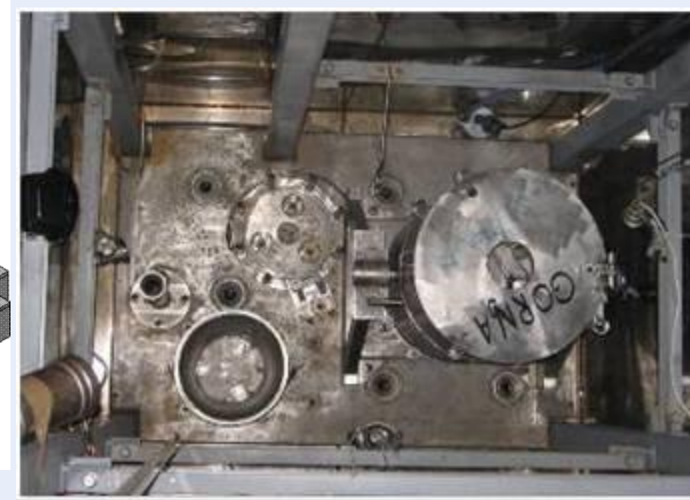
4 Preparations

4.1.2 Equipment design and manufacture

- Complex structure equipment (working platform, cutting devices, storage shelves, audio/video control system, lifting devices, …)

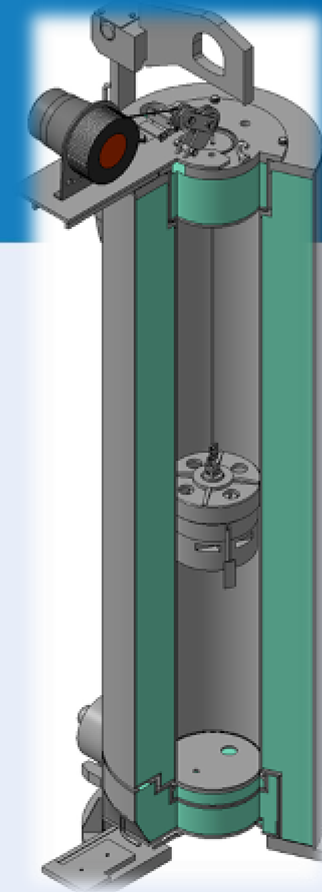






4 Preparations

- Numerous tools (with changeable parts)
- Platforms for casks and baskets
- Transfer flask
- Non-hermetic canisters (94+16)
- Baskets (16+16)
- Remote control devices

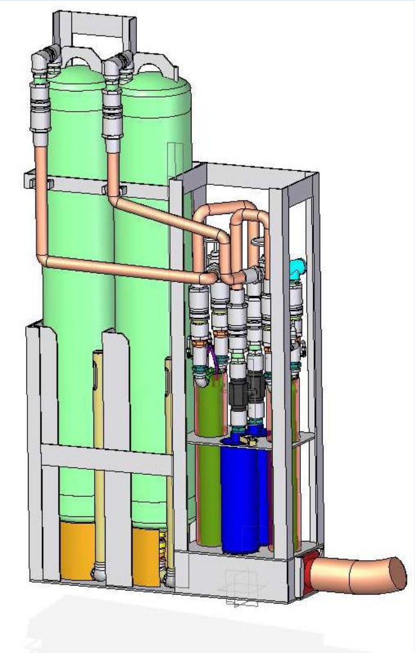


4 Preparations

4.2 Facility preparations

4.2.1 Working area adaptations

- Spent fuel storage pond adaptation (removal of metal structures, lids and joists; dry pool closure)
- Water drainage system manufacture
- Improvement of the floor bearing capacity
- Underwater lights provision
- Caesium removal system design and manufacture



4 Preparations

4.2.2 Auxiliary systems upgrade

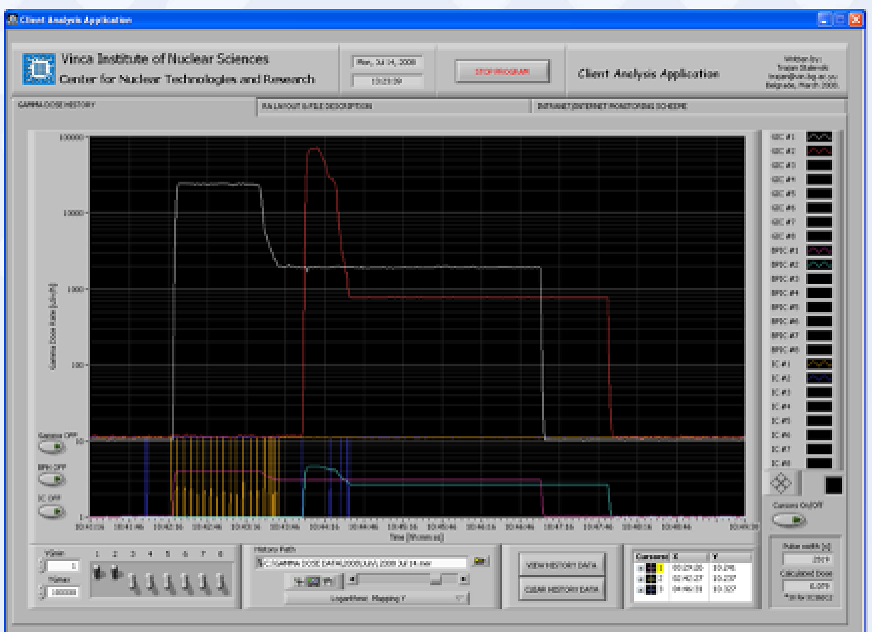
Special ventilation systems

- Pipelines replacement
- Interior adaptations
- Purchasing mobile ventilation units

4 Preparations

Radiation control and monitoring systems

- Stationary gamma-radiation monitoring system adaptation
- Exhaust effluents monitoring system purchase
- Mobile air-contamination monitors purchase
- Whole body contamination monitors purchase



4 Preparations

Electric power supply systems

Adaptations of regular and uninterrupted power supply systems at the working area:

- Stationary battery with DC/AC converter
- Diesel-electric generator (500 kVA)

4 Preparations

4.2.3 Transfer and lifting devices provision

- Replacement of the bridge crane in spent fuel storage (3 t lifting capacity, remote control, radio-frequency regulation)
- Upgrade of the bridge crane in reactor room (remote control, radio-frequency regulation)
- Forklift purchase (16 t carrying capacity)
- Cask rail-transfer system design and manufacture

4 Preparations

4.2.4 Construction works

- Spent fuel storage entrance adaptation
- Spent fuel storage control room reconstruction
- Reactor building access and communication roads modification
- Adaptation of the plateau in front of the reactor building

4 Preparations

4.2.5 Spent fuel containers preparation

- Reactor core unloading
- Non-fuel components removal
- Upper section of reactor channel tubes adjustment
- Relocation of existing fuel containers
- Specific reactor channel tubes identification
  (broken tubes, VISA-assemblies, tubes with highly contaminated water, …)

4 Preparations

4.3 Operational readiness

4.3.1 Safety assessment and operating documents

Safety analysis reports

- Metal structures removal (SAR)
- Fuel repackaging and temporary storing of canisters (Preliminary, Additional and Final SAR)
- Fuel loading and transportation (Preliminary and Final SAR)

Operating documents and procedures

- All-inclusive operating procedures (step-by-step instructions)
- Emergency response procedures
- Radiation safety documents
- Waste management instructions
- Nuclear material control documents

4 Preparations

All reports, documents and procedures were reviewed and approved until the middle of November 2009.

(Reviewers: Rostechnadzor, RRS-IAEA, Slovenian Nuclear Safety Administration, Serbian Radiation Protection and Nuclear safety Agency)

4.3.2 Equipment installation and testing

Special equipment received by the Sosny Company and other suppliers was installed (following the operations' execution sequence), tested and adjusted (multiple dry-runs were carried out).

4 Preparations

4.3.3 Personnel training

- Reactor staff received extensive trainings for executing repackaging and loading operations.
- Trainings were conducted by the specialists from “Sosny”, “NRI” (Řež) and “Mayak” organizations.

- Special trainings were organized for persons from supporting organizations engaged in fuel transportation.

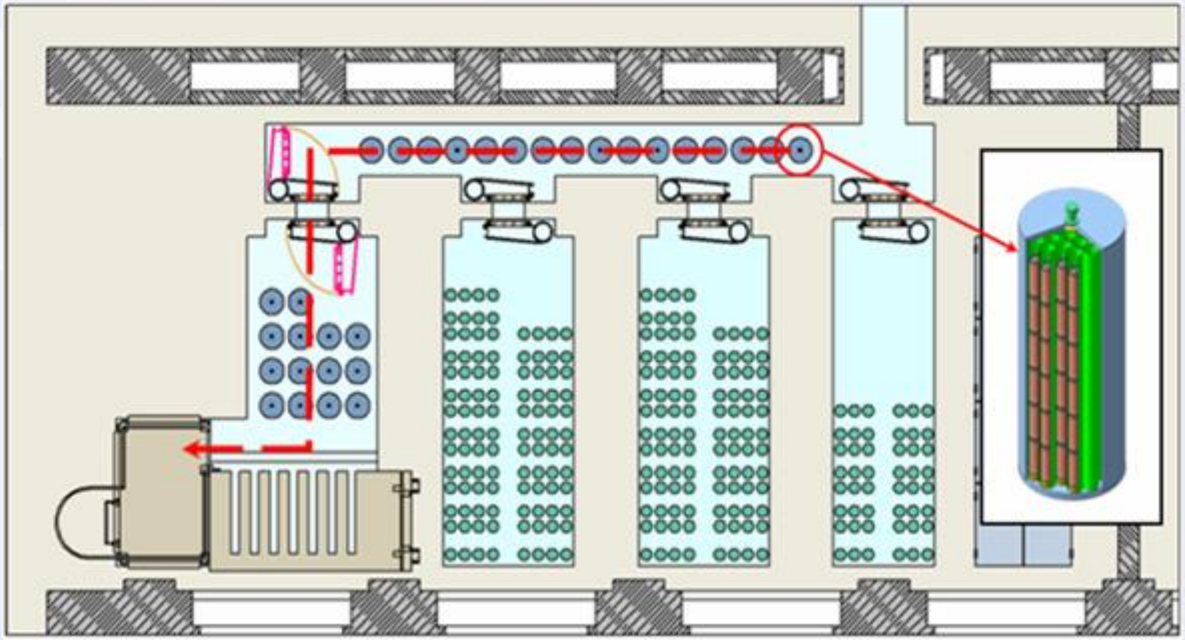
4.3.4 Safeguards verification

- Direct monitoring of working area established
- Record keeping of nuclear material evidence determined

5 Fuel repackaging

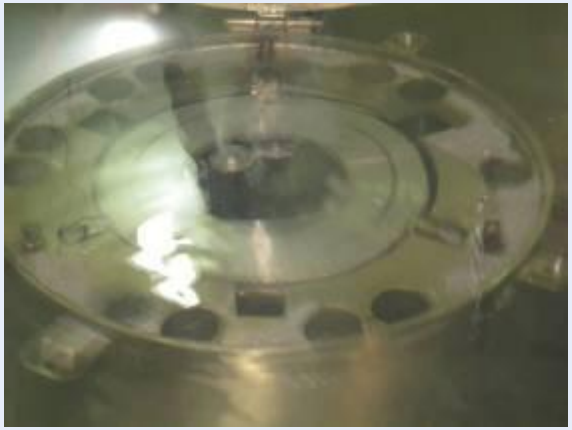
5.1 Aluminium barrels

- By the end of November 2009 all preparation activities have been completed
- Repackaging **began on December 2nd** and **ended on February 26th 2010**



5 Fuel repackaging

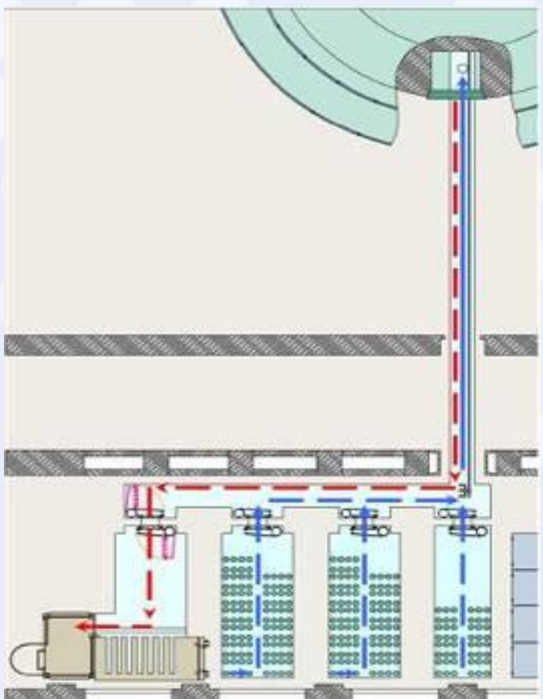
- **4929** fuel elements from **30 Al-barrels** have been repackaged into **75 SKODA-type canisters**

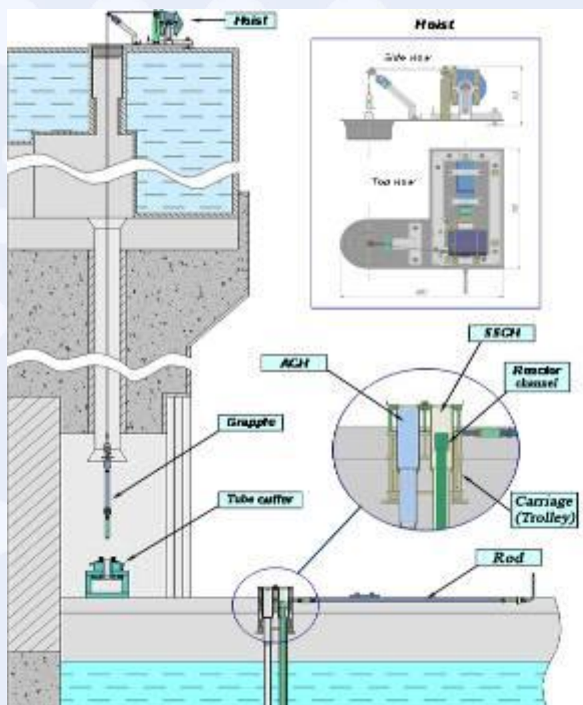


5 Fuel repackaging

5.2 Stainless steel tubes

- By the middle of March 2010 equipment rearrangements and personnel training have been completed
- Repackaging **began on March 22nd** and **ended on May 24th 2010**





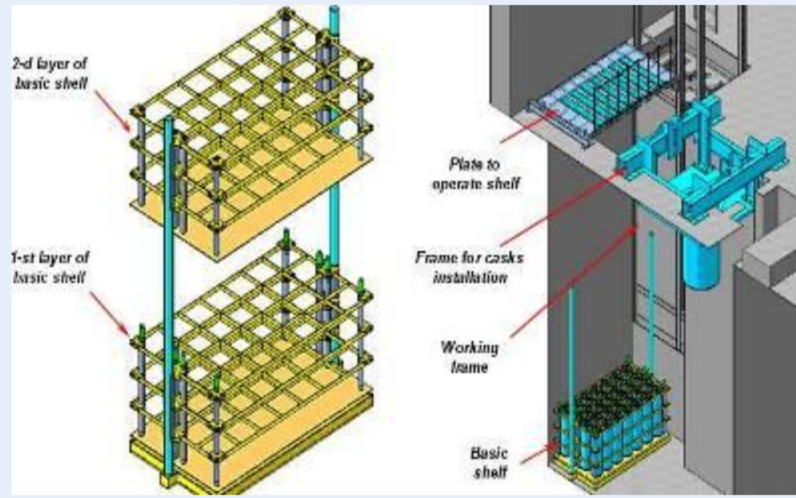
5 Fuel repackaging

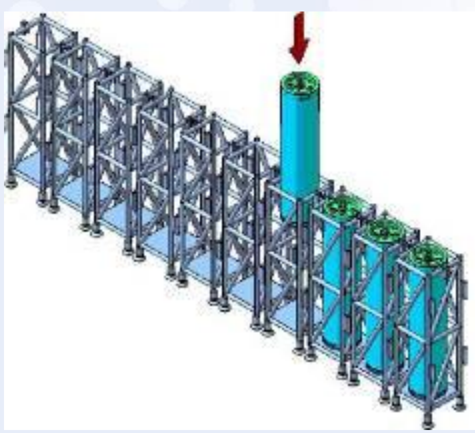
- **3101** fuel elements from **297 SS-containers** have been repackaged into **19 SKODA- type canisters** and **16 TUK-19-type canisters**

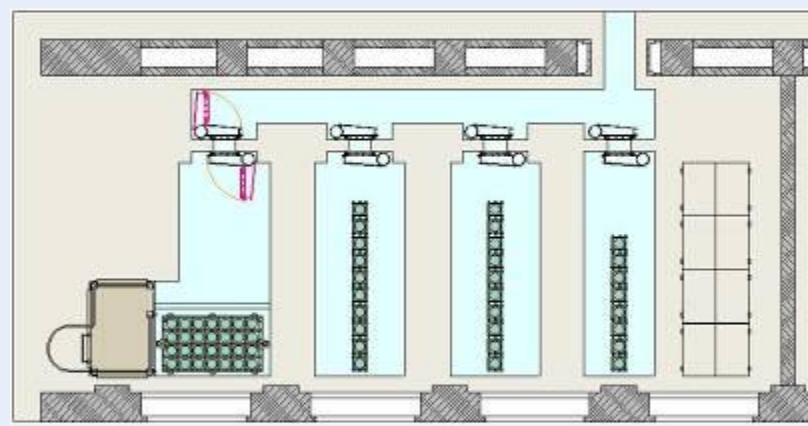
5 Fuel repackaging

5.3 Storing the canisters

- **110 canisters** were loaded with spent fuel elements.
- 83 stored in three racks of the **Basic shelf**; 27 stored in single sections of **Additional shelf** positioned in central corridors of storage pools.
- Canisters spent **4 to 11 months in the storage pond** before being loaded into transport casks.







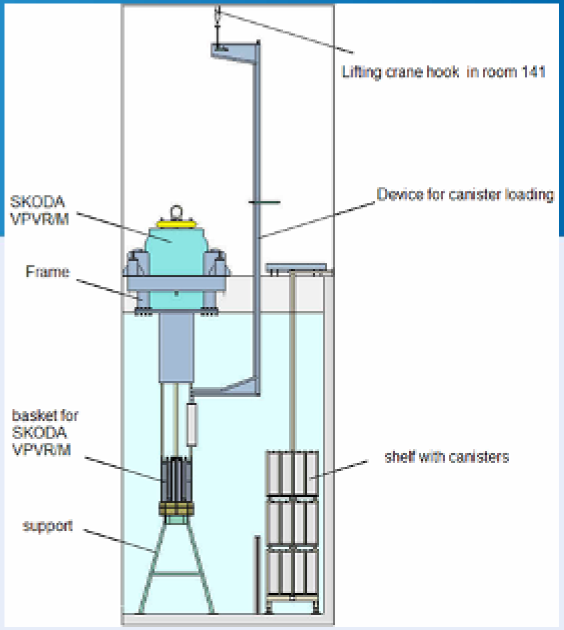
6 Fuel loading

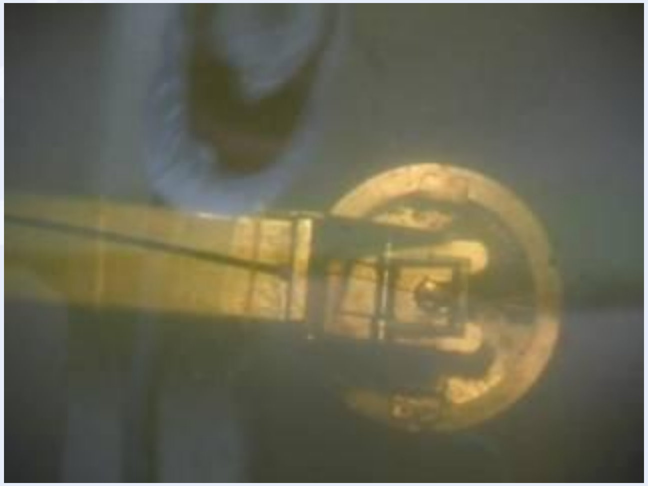
6.1 Loading SKODA casks

- First batch of 12 SKODA casks was delivered to the reactor facility in the second half of July. Completing necessary preparations, loading of canisters into these casks **began on August 12th** and **ended on August 29th**.
- The second batch of 4 SKODA casks was delivered at the beginning of November. Loading **began on November 5th** and **ended on November 12th**.

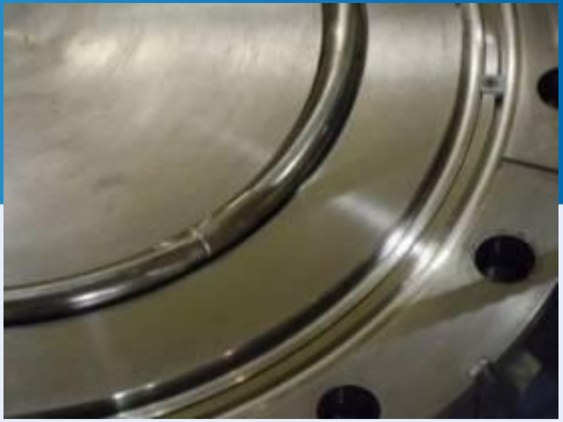
6 Fuel loading

- Total of **94 SKODA-type canisters** have been placed into 16 **SKODA VPVR/M casks**.





6 Fuel loading



6 Fuel loading

6.2 Loading TUK-19 casks

- All 16 TUK-19 casks were delivered to the reactor facility on October 23rd. In the meantime, necessary rearrangements of equipment and personnel training have been completed.

- Loading canisters into these casks **began on October 25th** and **ended on November 3rd**.

6 Fuel loading

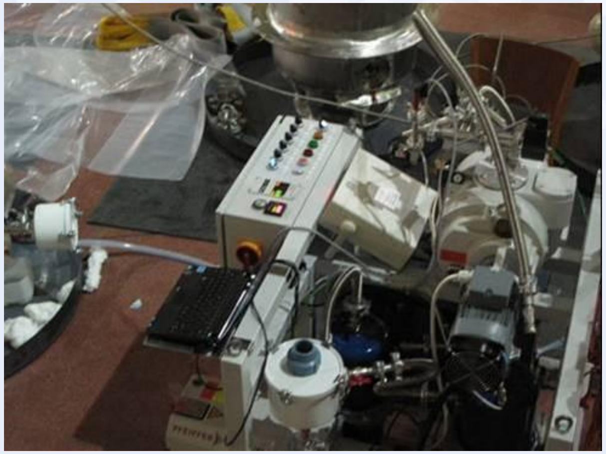
- Total of **16 TUK-19-type canisters** were loaded into 16 TUK-19 transport casks.

6 Fuel loading

6 Fuel loading

6.3 Preparation of casks for transportation

- **Drainage** of TUK-19 transfer flask (1 hour) and SKODA casks (18 hours) including **hot air drying** (for SKODA casks only; 120ºC, 75 l/min).
- **Cyclic vacuum-drying** of transport casks (6 mbar to 0.5 bar). It took app. 15 hours for SKODA casks and app. 10 hours for TUK-19 casks.
- **Exposing transport casks to vacuum** until absolute pressure of 2.5 to 3 mbar was reached. On average, a few hours per cask were needed to complete this operation.
- **Gas-filling** until absolute pressure of 0.7 bar (SKODA) or 1 bar (TUK-19) was reached (mixture of He and CO_2 was used).
- **Helium leak testing** of transport casks was the last phase in preparing the casks for transportation.



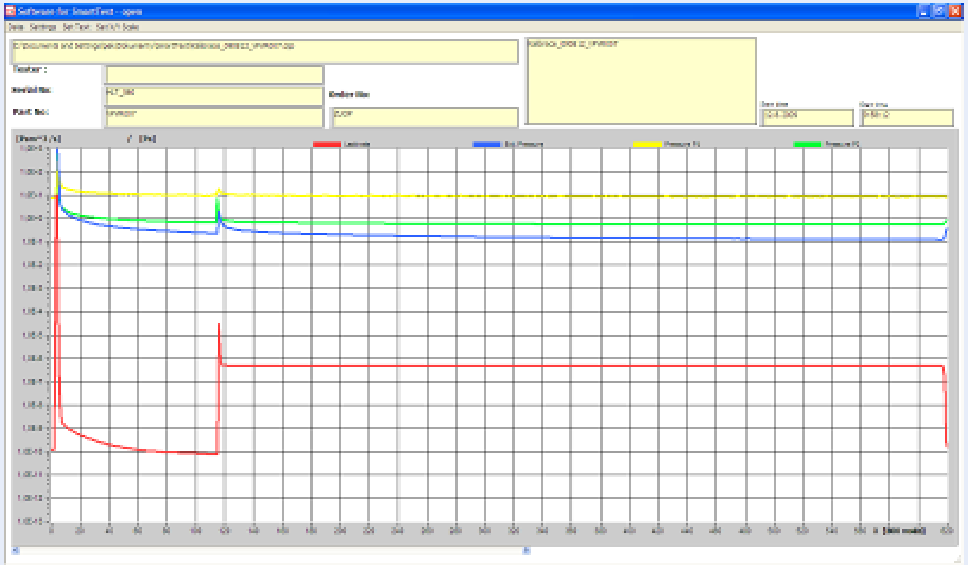
6 Fuel loading

Dryness criterion

- pressure gradient inside the cask must be lower than 3 mbar/15 min at absolute pressure lower than 6 mbar (content of residual water is not greater then 10g/m³).

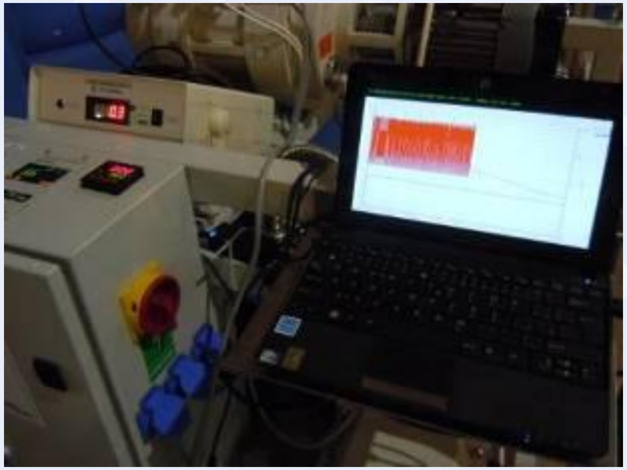
Tightness criterion

- helium leak test threshold was set to 10^{-7} Pa·m³/s.



6 Fuel loading

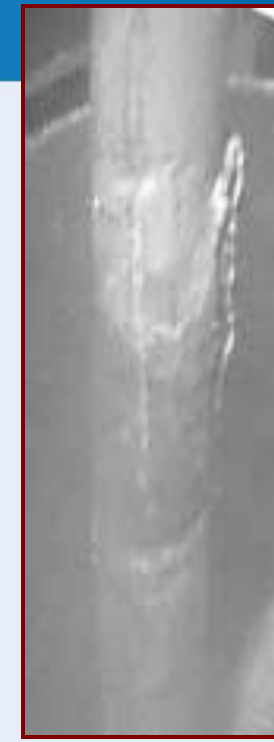
- **SDGL equipment from “NRI” (Řež)** was used.
- TUK-19 casks have been successfully exposed to vacuum-drying treatment for the first time.
- Most of the time, vacuum-drying processes have been **carried out simultaneously** for 2 to 4 casks.



6 Fuel loading

- **IAEA seals** were put on each transport cask prior to loading into ISO-containers.

7 Performed operations assessment



7.1 General characteristics

- Complex and delicate technology
- Sophisticated and reliable equipment
- Well trained and competent personnel
- Good planning and coordination
- Continuous on-site technical supervision and support

7 Performed operations assessment

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- Complex and delicate technology
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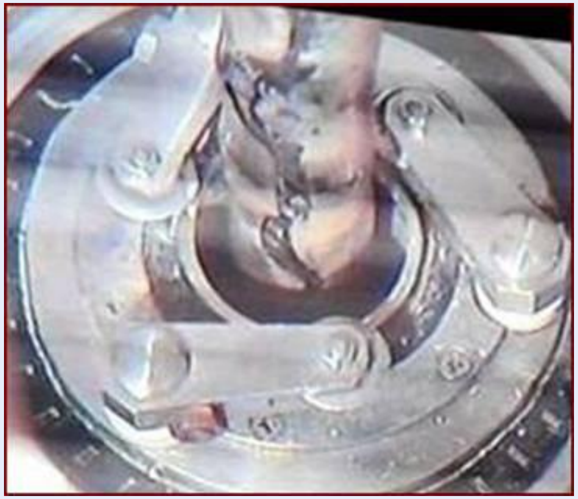
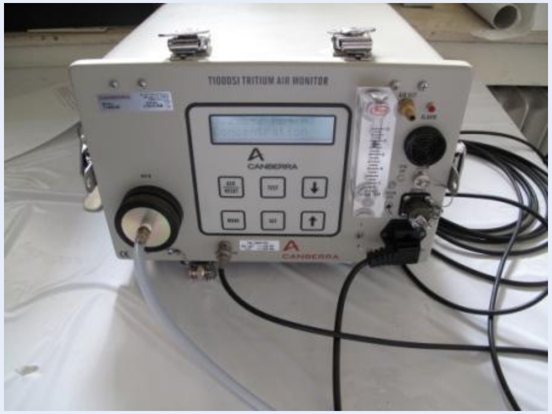
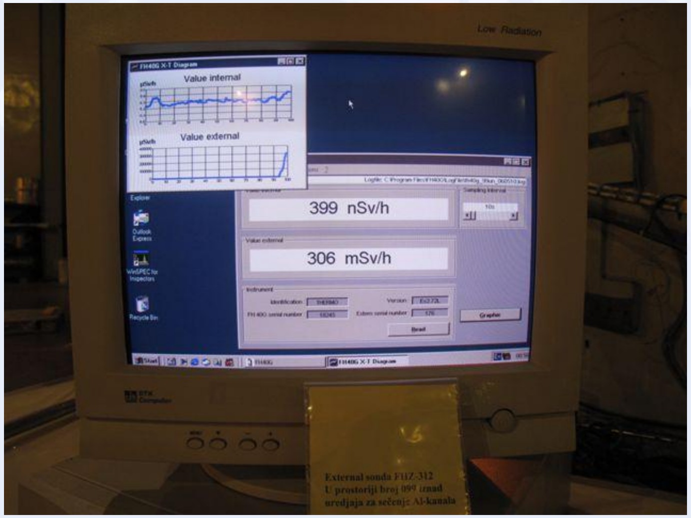


7 Performed operations assessment

7.2 Safety aspects

- No incidents and no injuries of personnel
- No exposures above irradiation dose limits (cumulative dose received by the staff was 14 man mSv; maximum dose was 0.72 mSv and average one amounted to 0.25 mSv)
- No radioactive release into the environment above allowable limits





8 Licencing and Authorizations

8.1 Transport package licences

- Licences for both transport packages (TUK-19 and SKODA VPVR/M casks loaded with TVR-S fuel elements) were issued by Rosatom in October 2009. Licences were in effect for two years.
- Republic of Serbia and the transit countries have validated these licences in 2010.

8.2 Legislative requirements in the Russian Federation

- **Government-to-Government Agreement**
- **Unified project** (set of documents covering an overall assessment of radiation, economic, social and environmental impacts on the country – Environmental Impact Assessment; State Ecological Review, …)
- **End-user certificate**
- **Foreign Trade Contract**
- **Import licence**

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Нуклеарни објекти Србије

8 Licencing and Authorizations

8.3 Legislative requirements in Serbia

- Set of accompanying documents (**transport package passports**, radiation control reports, packing lists, …)
- Set of plans (**Radiation protection plan**, **Physical protection plan**, **Emergency preparedness plan**)
- **Certificate of spent fuel origin**
- **Civil liability insurance** (third party)
- **Take-back guarantee**
- **Export licence**

8.4 Legislative requirements in transit countries

- Set of plans (**Radiation protection plan**, **Physical protection plan**, **Emergency preparedness plan**)
- **Trans-boundary shipment authorization**
- **Transit licence**

Јавно предузеће
Нуклеарни објекти Србије

8 Licencing and Authorizations

8.4.1 Authorization process in Hungary

Expert opinion of the Institute of Isotopes on the corresponding Safety Analysis Report on the package design
(3 months)

HAEA approval of package design
22 workdays

Approval of certification of civil liability for the nuclear damages by HAEA
(22 workdays)

Approval of transboundary shipment of SNF by HAEA (enclosed: Standard Documents (3 originals in English, 1 in Slovenian (official translation)), take back guarantee, duty stamps, Emergency Response Plan, authorization letters)
(30 + 60 (+30) days)

Radiation protection license by National Chief Medical Officer's Office of the National Public Health and Medical Officer Service
(22 workdays)

Route and date specific physical protection related license by National Police Headquarters
(22 workdays)

Only after having all other approvals

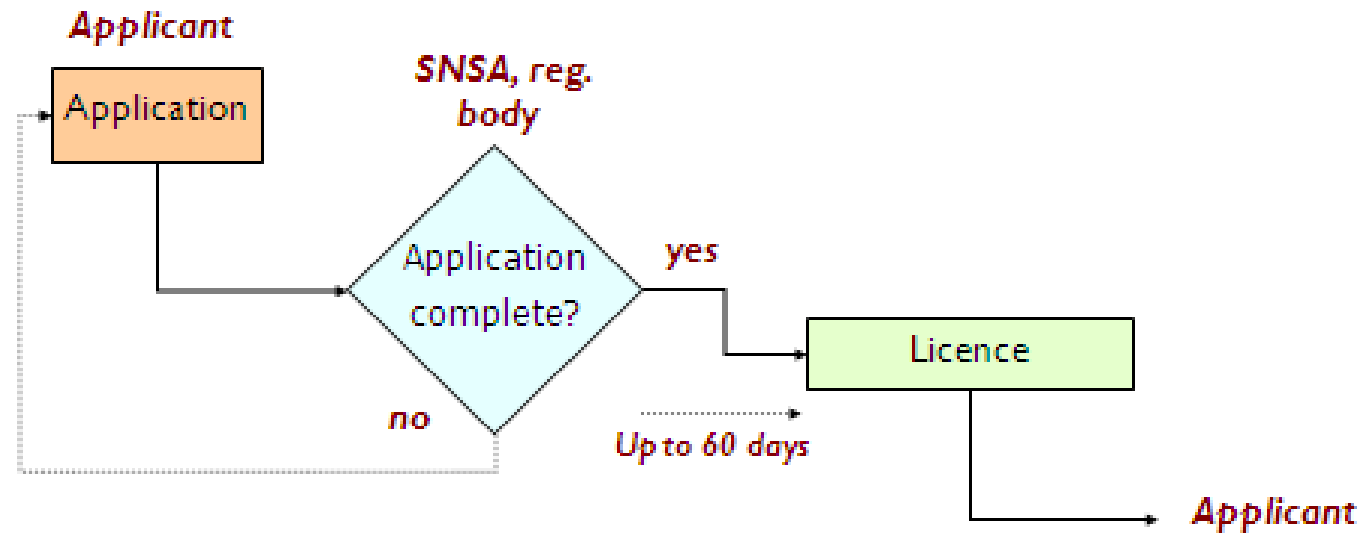
Transport after meeting all requirements of Hungarian Serbian Slovenian Russian competent authorities

8 Licencing and Authorizations

8.4.2 Authorization process in Slovenia

Common Licensing Process

(for transit, package re-validation, transport, and carrying out a radiation practice)



The content of application is prescribed by the regulation.

Administrative tax.

All applications have to be in Slovene language (some enclosures could be in English).

The licensee can authorize another (natural or legal) person to act on his behalf.

8 Licencing and Authorizations

8.5 Shipping documents

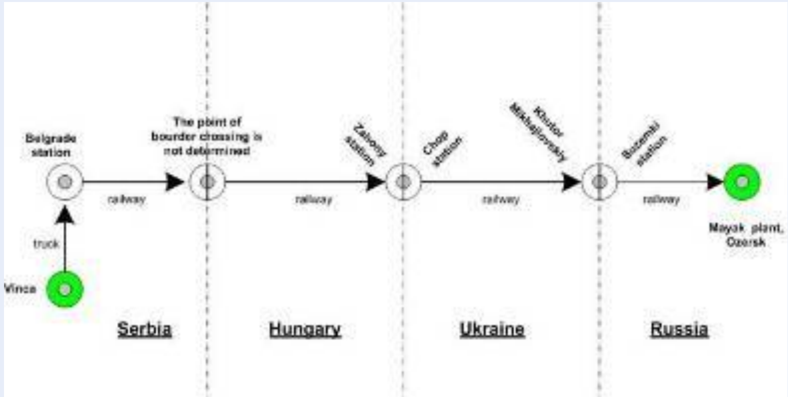
A set of **36 specific documents** had to be prepared for transportation. A lot of them consisted of many individual certificates, reports and data sheets (passports, licences, …). To list some of them, only:

- Canisters passports (110)
- Transport packages passports (32)
- Ownership transfer document
- Dangerous goods declaration
- Transport packages licences and endorsements (2x4)
- Dual use goods export declaration
- Reports of radiation control (32 + 16)
- Packing lists (for casks and auxiliary equipment)

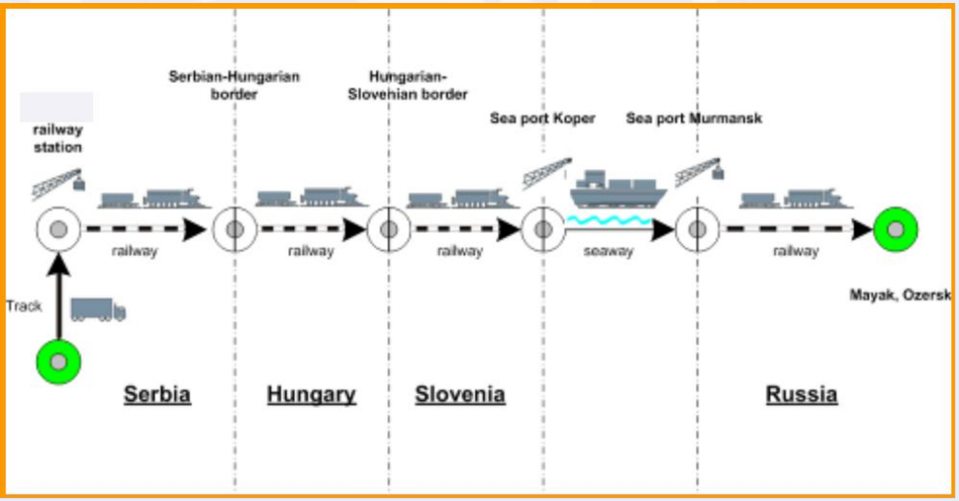
Јавно предузеће
Нуклеарни објекти Србије

9 Shipment Logistics

9.1 Transportation mode and route determination



- by **trucks** to Subotica (a town near the Hungarian border)
- by **train** to the port of Koper (Slovenia)
- by **ship** to the port of Murmansk
- by **train** to Ozersk (PA “Mayak”)



9 Shipment Logistics

9.2 Transportation

9.2.1 Loading casks into ISO-containers

- Whenever prepared for transportation, each group of casks was immediately loaded into ISO-containers (these containers were placed on the plateau in front of the reactor building).
- Getting loaded, ISO-containers were properly marked and sealed (Serbian customs and Public Company "NFS" seals were used).

9 Shipment Logistics

9 Shipment Logistics

9.2.2 Convoy formation

- On **November 18th** all ISO-containers (8+6+1) were loaded onto **15 trucks**.
- Truck-crane of **100 t** lifting capacity was used.
- The convoy was formed within the Vinča Institute.
- Last checks have been performed.

9 Shipment Logistics

9.2.3 Itinerary

November 19th - departure from Vinča-Belgrade
- reloading onto railway cars in Subotica

November 20th - departure from Subotica

November 21st - arrival at the port of Koper
- reloading onto the ship
- departure from Koper

December 15th - arrival at the port of Murmansk

December 16th - transfer of spent fuel ownership
- reloading onto railway cars

December 17th - departure from Murmansk

December 22nd - arrival at PA “Mayak”

Along the entire route to the port of Koper, significant police forces have been engaged to provide physical protection of the cargo.

9 Shipment Logistics

9 Shipment Logistics

9 Shipment Logistics





10 Summary

10.1 Shipment characteristics

Country	Republic of Serbia
Facility	Research reactor RA
Fresh fuel	5046 HEU TVR-S fuel elements (app. 48 kg U)
Spent fuel	6656 LEU TVR-S fuel elements (app. 2.5 t U)
	1374 HEU TVR-S fuel elements (app. 13 kg U)
Shipments data	
fresh fuel	August 22^{nd} 2002
spent fuel	November 19^{th} - December 22^{nd} 2010
Containers used	
fresh fuel	TK-S15 (20), TK-S16 (10)
spent fuel	TUK-19 (16), SKODA VPVR/M (16)
Modes of transport	
fresh fuel	road and air transport
spent fuel	road, rail and sea transport

Јавно предузеће
Нуклеарни објекти Србије

10 Summary

Number of operators	30
Total effective working time (hours)	app. 1500 (repackaging) app. 720 (loading)
Collective radiation dose	14 man mSv (operators)
Average personal dose	0.25 mSv (operators)
Average dose ratio to 20 mSv	1.25 %
Solid waste	app. 20 m^3 (uncompressed)
Liquid waste	not generated
Emission released into environment	app. 10^5 Bq
Human accidents, injuries	none
Radiation incidents	none
Technical damage	bending and breaking tools' components (changeable parts mostly)

Јавно предузеће
Нуклеарни објекти Србије

10 Summary

10.2 Conclusions

- Repatriation of the RA reactor’s spent nuclear fuel was a **complex and challenging task**.

- Unique fuel elements, bad storing conditions and poor fuel handling capabilities, combined with the requirement to repack all fuel elements, asked for **development of sophisticated operational methods** and efficient equipment design.

- **Multiple reviews and analyses of technology processes** contributed to overall safety of planned activities.

- **Applied technology was reliable**; safe for operators, facility and the environment (no incidents worthy of attention; low personnel exposures; no radioactive release into the environment above allowable limits).

Јавно предузеће
Нуклеарни објекти Србије

10 Summary

- **Good planning and organization** from the very beginning and **extremely good cooperation** with many international organizations and institutions, followed up with **substantial financial help**, enabled successful realization of this project.

- **Reliable and experienced project management,** as well as **well trained personnel** were crucial for safe, effective and timely completion of the project.

- **Experience gained** may well be used in other similar projects and in decommissioning of various nuclear facilities.

- In order to significantly simplify the spent nuclear fuel transportation, **airlift mode** should be worked out to become the primary option in general.

Јавно предузеће
Нуклеарни објекти Србије

Thank You

for your attention

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