Preparation for Testing, Safe Packing and Shipping of Spent Nuclear Fuel from IFIN-HH, Bucharest-Magurele to Russian Federation

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ABSTRACT

The Russian Research Reactor Fuel Return (RRRFR) program is promoted by IAEA and DOE in order to repatriate of irradiated research reactor fuel originally supplied by Russia to facilities outside the country. Developed under the framework of the Global Threat Reduction Initiative (GTRI) the take-back program [1] common goal is to reduce both proliferation and security risks by eliminating or consolidating inventories of high-risk material.

The main objective of this program is to support the return to Russian Federation of fresh or irradiated HEU and LEU fuel.

Being part of this project, Romania is fulfilling its tasks by examining transport and transfer cask options, assessment of transport routes, and providing cost estimates for required equipment and facility modifications.

Spent Nuclear Fuel (SNF) testing, handling, packing and shipping are the most common interests on which the National Institute of Research and Development for Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH) is focusing at the moment.

INTRODUCTION

The VVR-S reactor is a light-water-cooled-moderated-and-reflected, heterogeneous, thermal reactor at National Institute of Research & Development for Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH). The nuclear research reactor VVR-S from the National Institute of Research and Development for Physics and Nuclear Engineering "Horia Hulubei", Bucharest-Magurele, was first commissioned in July 1957 and it was shut down in December 1997. At the moment the reactor is in conservation state. The reactor is a Russian tank type model, using Russian fuel and it was the first nuclear reactor from its class build in a socialist country outside the Soviet Union.

After 23 years of operation a large number of spent fuel elements became available for storage exceeding the stocking capacity of the small cooling pond near reactor.

Therefore, in 1980 was commissioned the nuclear spent fuel repository that contains at present all the fuel elements burned in the reactor during years, minus 51 C-36 fuel ensembles, which are conserved in the cooling pond.

As a result of 40 years of intense utilization, 223 ensembles of burned fuel, were produced and stored in these special ponds.

To help Romania in its effort to manage the final disposal of spent nuclear fuel from VVR-S research reactor, an assistance contract was set-up between Department of Energy (DOE) and

National Commission for Nuclear Activities Control (CNCAN) to ship Russian High Enriched Uranium (HEU) Spent Nuclear Fuel (SNF) back to origin country.
This work is covered by the terms and conditions contained in the Agreement between the DOE and the CNCAN. The purpose of the agreement is to assist Romania with the transfer of Russian-origin HEU SNF from the VVR-S research reactor at Magurele-Bucharest, Romania, to the Russian Federation (RF) for further management.
The main goal of the project is to repatriate HEU SNF from Romania to RF for subsequent reprocessing and further management of resulted products.
The final result is long-term safe storage of reprocessed induced products on the territory of RF.

MAIN TASKS DEVELOPMENT

The IFIN-HH work is focusing on the following items:

1. Identifying the legal aspects regarding SNF export and shipping.

The purposes for this task are to determine the fuel and cask requirements of the agencies that will affect the shipment to, and receipt at, the reprocessing facility. These agencies include the regulatory agencies of Romania and the Russian Federation, the reprocessing facility authorities, and any other agencies that might affect the SNF transport.

2. Identifying the most representative tests to allow SNF to be safe packed and shipped.

The main goal for this task is to develop and approve fuel assembly inspection procedures to comply with the requirements identified in item 1, and perform the HEU spent fuel inspection. This task will develop and approve the fuel assembly inspection procedures required to ship the HEU SNF from the VVR-S reactor. These procedures should be developed to inspect the spent fuel assemblies for structural integrity, leak tightness, handling, and transportability. To be able to determine the fuel characteristics like mass of fissionable materials, activity, burn-up condition, and measurement tolerances for each fuel assembly. Parameters like radiation and thermal characteristics for each fuel assembly should also be determined by the procedures developed in this task.

3. Identifying the main modifications of the facility to allow handling, temporary storage and shipping. This work consists of evaluating, planning, and performing all facility or structural modifications required to load the spent nuclear fuel research reactor into the shipping casks and the modifications required to load the shipping casks onto approved vehicle prior to transport to the Russian Federation. Thoroughly studies to evaluate the existing buildings, structures, and equipment should be performed in order to be able to determine all modifications required to load and store the spent nuclear fuel in the shipping casks at the Magurele site prior to shipment. Also, an evaluation of the existing, structures, and equipment at the loading area should be performed to determine all modifications required to transfer empty and full shipping casks from, and to, the project-approved vehicle. For this purpose, it is necessary to identify all plans, procedures, training, and approvals that will be required to perform the modifications. For these activities IFIN-HH personnel will complete two sets of radiation and contamination surveys of all areas and equipment to be modified at the Magurele site and at the loading area. One set shall document the baseline conditions before starting any physical modifications and the second set shall be performed after completion of all modifications.

4. Identifying the appropriate preparations to load the transport cask and facilitate its maneuver and shipping. This task designs, fabricates, and installs all equipment required to position, handle and load the shipping cask with spent fuel assemblies from the VVR-S reactor storage pool. This work should also prepare operating procedures to load the shipping cask, use the transfer cask, trains operators to use the equipment, and perform a demonstration of the cask loading with dummy (non-fueled) spent fuel assemblies.
The work will consist in designing of all the equipment required to move, structurally support, and load the shipping casks in the VVR-S reactor hall and of all the equipment that will be required to interface the cask with existing structures or systems. Also, an important effort will be allocated to review and approve all designs in accordance with CNCAN, IFIN-HH, and Romanian requirements. The following equipment is the subject of this task development: a shipping cask holder to be used on the truck during transportation; shipping and transfer cask lifting and handling equipment; equipment to interface the transfer cask with the shipping cask and the cooling pond lids; shipping cask sealing and drying equipment; training mockups of the transfer and shipping casks.

TASK PLANS IMPLEMENTATION

All the task plans mentioned above were more or less completed, are in progress or in planning development. Several items are pending, but most of the strategy is clear set up and important progress is registered. The work status implementation discussed here is only an overview of the most important issues developed at IFIN-HH, Magurele. The sequence is the same as above order:

1. IFIN-HH was in charge to determine all Romanian spent fuel inspection regulatory requirements to export the HEU C-36 type SNF assemblies from the VVR-S reactor to reprocessing facility in Russian Federation, and to identify any other Romanian agencies that will affect the SNF transportation and determine their requirements. After the identification of all these agencies, their requirements should complete the existing working inspection procedures if necessary, and/or helping the IFIN-HH team to develop new procedures in accordance with the Romanian legislation. Taking into consideration that the main purpose of all these future activities is SNF export to Russian Federation, all the requirements should refer to:

- Safe transportation of SNF on the Romanian territory;
- Safe operation of the vehicle and safe handling of the package;
- Nuclear and radiation safety during SNF transportation and/or stationary;
- Customs statement at the Romanian border.

The issues listed above are generally accepted by international legislation and should be found again as well in Romanian laws, norms and regulations. Most of these were taken over from IAEA documents and/or European Union (EU) legislation. The organizations issuing these norms and regulations should comply with any other corresponding organization from EU or world wide.
The Romanian regulatory requirements should cover all the aspects usually encountered when facing with SNF inspection, transportation and exportation. We can divide these regulatory aspects in seven parts as following:
A. Regulations regarding protection against ionizing radiations;

B. Regulations regarding SNF and waste management;
C. Regulations regarding exportation of nuclear and radioactive materials;
D. Regulations regarding environment protection;
E. Regulations regarding the public health and sanitary protection;
F. Regulations regarding safe transportation of nuclear and radioactive materials on public roads;
G. Regulations regarding safe transportation of nuclear and radioactive materials on public railways.

The regulations mentioned above are usually defined by specific laws and norms issued by competent authorities for every specific domain.

With the respect of the seven parts of the regulatory aspects mentioned before we can detail our results and conclusions as follows:

A. CNCAN is the competent national authority in the nuclear field, with duties in regulation, authorization and inspection. In Romania all the activities and practices implying nuclear and radioactive materials including nuclear fuel and radioactive waste is regulated by the Law No 111/1996 [2]. CNCAN has no additional specific requirement regarding SNF inspection, cask and transportation an no other requirement are mentioned in the norms issued by CNCAN.

B. National Agency for Radioactive Waste (ANDRAD) is the competent authority for coordination at the national level of the safe management of the spent nuclear fuel and radioactive waste, including disposal. ANDRAD also has no additional specific requirement regarding SNF inspection, cask and transportation.

C. National Agency for Exports Control (ANCEX) is the national authority controlling the importation and exportation of strategic products. The exportation of nuclear materials, installations, equipments and especially of SNF needs to be licensed [3, 4 and 5] for exportation by ANCEX but previously authorized by CNCAN. ANCEX has no additional specific requirement regarding SNF inspection, cask and transportation.

D. National Agency for Environment Protection (ANPM) is the national authority for strategic planning, regulations, monitoring, and licensing of the activities in respect of environment protection and preservation. National Environment Guard (GNM) is the organization entitled for control and inspections regarding respecting environment legislation. ANPM and GNM have no additional specific requirement regarding SNF inspection, cask and transportation.

E. Directory of Public Health (DSP) is the national authority for implementing the policy and national programs of public health, preventive medicine, state sanitary inspection, monitoring of health state, performing health statistics, planning and development of the financial investments from government budget in the health domain. Inside DSP, the competent authority for the nuclear field is Laboratory for Nuclear Radiations Hygiene (LIRN). LIRN has no additional specific requirement regarding SNF inspection, cask and transportation.

F. Romanian Road Authority (ARR) is a national technical specialized organization designated mostly to assure inspection and traffic control, inspection of the technical state of vehicles and trailers, carrier licensing, and regarding the compliance with the national and international road safety transportation regulations. ARR has no additional specific requirement regarding SNF inspection, cask and transportation.

G. Romanian Railway Authority (AFER) is the national technical specialized organization notified to ensure, mainly the state inspection and the safety control of the railway and subway transport, the railway register specific activity, the licensing of railway carriers, the authorization and the technical survey of domestic suppliers of products and services in the railway field, the

examination and certificates granting, in case, for the staff working in the field of the traffic survey, the investigation of the railway events and accidents. AFER has no additional specific requirement regarding SNF inspection, cask and transportation.
Analyzing all the collected information's presented above, and taking into consideration the norms and regulations in force at present time, we can conclude that until now are no other Romanian agencies which can influence by their own specific requirements (in compliance with the law) the spent fuel inspection activities and there are no specific Romanian spent fuel inspection regulatory requirements regarding the exportation of HEU C-36 type SNF assemblies from VVR-S reactor to reprocessing facility in RF.

2. To accomplish this goal IFIN-HH developed the SNF inspection methodology [6]. To be in accordance with RF and reprocessing factory rules, the Romanian experts were assisted by Russian expert company. The main goal of the issued document is to present the methodology in use at IFIN-HH to determine the required parameters needed to export the HEU C-36 FA from the VVR-S reactor to RF. The document was revised in accordance with Russian experts remarks and observations and it respond to the determination of parameters stated in "Russian technical requirements and acceptance criteria for spent fuel assemblies" issued by the Russian expert company also. After concurrence and approval, the methods should be implemented through the existing working inspection procedures to inspect the SNF stored in at the IFIN-HH site. The data collected or calculated from original operating documents available at IFIN-HH VVR-S reactor should be treated as directly provided information. Taking into consideration that the main purpose of all these future activities is SNF export to RF, these methods are focusing on:
A. Visual and dimensional inspection of SNF assemblies;
B. Calculation of SNF burn up;
C. Determination of SNF weight;
D. Determination of SNF tightness;
The method "Calculation of SNF burn up" is used only for determination of burn-up data used to calculate (using computer codes) the parameters stated in the document "Calculation of Burning Parameters for High Enriched Nuclear Fuel C-36 to provide this for the transferring to Russian Federation".
A detailed description of every method is given below:
A. The method describes the visual and dimensional inspections (tolerances and geometrical changes) of the SNF assemblies using an underwater video camera and a pass/not pass caliber placed in the storage basins. Each inspection operation is digitally recorded by the on work video camera. The principal goal of the present method is to determine the maximum number of the main parameters stated in "Russian technical requirements and acceptance criteria for spent fuel assemblies".
The main parameters to be determined with this method are:
1) SFA identification number (ID) (Fig. 1); this number (for example C-11) is unique and identifies every C-36 fuel assembly. It is engraved on the ear located on the top of every C-36 fuel assembly. It should be easily visualized and recorded with an underwater video camera. This ID number of every fuel assembly should vary between C-01 to C-74.
2) Number of fuel elements (Fig. 1); for C-36 fuel assemblies this number is always 15.
3) Number of bevels (Fig. 1); for the C-36 fuel assemblies this number is 0 or 3.

4) Presence/absence of the gripping head (Fig. 1); the gripping head is used to manipulate the SNF during inspection and examination. Usually the gripping head is inside of the clamping interface from the manipulating rod and cannot be visualized with the camera. If the gripping head is missing or damaged it cannot be used for manipulating the SNF and a rod with a hook should be used instead.
5) The condition of the gripping head, damaged or not (Fig. 1); the same as for point 4 above.

Fig. 1. Visual inspection on determination of parameters 1-5.

6) The presence/absence of oxides on outer surface (Fig. 2); some of the SNF could present some oxide traces on the outer surface that could indicate the beginning of pitting corrosion. The overall oxide film layer normally present on the outer box surface is not subject for present examinations.

Fig. 2. Visual inspection on determination of parameters 6, 10 and 11.

7) Presence/absence of foreign objects on outer surface (particles, thermocouples, etc); all foreign objects as small particles, sludge, thermocouples, etc are mentioned here.

8) Presence/absence of visible deformations; all kind of visible deformations, even they influence or not the passing through the caliber is mentioned here.
9) Pass/not pass through a caliber (Fig. 3).

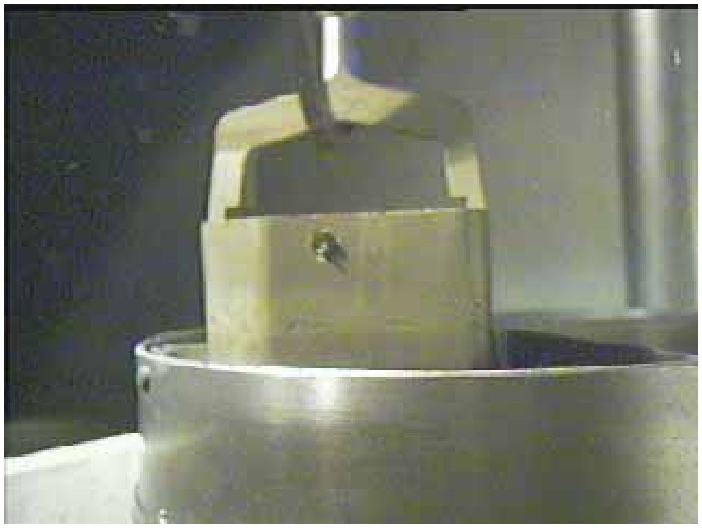

Fig. 3. Visual inspection on determination of parameter 9.

10) Presence of corrosion on outer surface [%] (Fig. 2); the surface approximation (in mm^2) of identified corrosion in comparison with the total SNF outer surface (in mm^2). For example 2.8%.
11) Type of corrosion (Fig. 2); identified corrosion type should be mentioned here (for example general corrosion, galvanic corrosion, crevice corrosion, stress corrosion cracking and pitting corrosion).
12) SNF suitable for transportation (yes/no) based on the parameters 9 determined above; after the inspection, in case the SNF assembly passes freely, without being forced, through one of the four caliber places, along the caliber, it will mean that the SNF assembly is dimensionally appropriate to tolerances and can be operated and loaded into the shipping container.

The visual inspection procedure (Fig. 4) with an underwater video camera is the most direct and suitable method for determination of the main parameter listed above.

The method consists in visualization of all these parameters by using a video camera and verifying the free passing of SNF assemblies through a caliber's compartment that simulates the shape and the dimensions of the transport container loading basket.

Each SNF assembly is taken from its original place in the storage rack, is lifted up to the test place and the examination with the video camera of the parameters is performed. After recording of the parameters 1-8, 10 and 11, the SNF assembly is lowered in the caliber to test geometrical deviation from the linearity and the tolerances. During visual examination and caliber test each appropriate parameter is recorded in a "Recording Form". After performing the visual examination and calibration test, the SNF is put back in its original storage place.

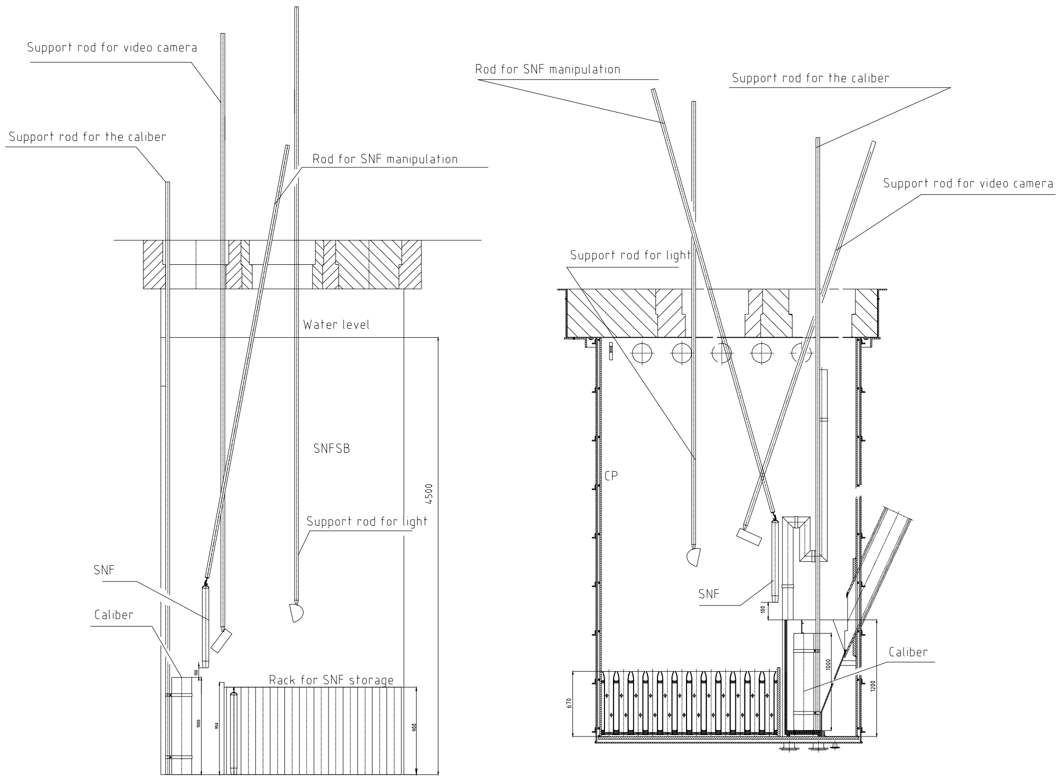

Fig. 4. Geometrical and tolerance verifications of SNF at IFIN-HH storage basins.

B. The method describes the burn up calculation of SNF assemblies, for their return in RF.
The current method is being applied to the calculation of the burn up of SNF assemblies, type C-36 and EK-10 irradiated in the VVR-S Reactor and stored in Spent Nuclear Fuel Storage Basins (SNFSB) and Cooling Pond (CP). The main parameter to be determined with this method is SNF burn-up. SNF burn-up describes the amount of fissionable material burned in reactor core, from the initial mass of fissionable material contained in SNF before irradiation. During its normal operation at 2MW nominal power, the VVR-S reactor active core use 51 fuel assemblies to produce an amount of energy depending of the time of functioning (f. e. hours/day, hours/month). Based on the successive location of every fuel assembly starting with its first introduction in the active core and finishing with its definitive withdrawal from the core, this method calculates the total amount of energy released by the fuel assembly during its life in the reactor active core. The total amount of energy released is in accordance with the total amount of fissionable material consumed.
C. The method describes the weight determination of SNF assemblies, for their return in RF. The current method is being applied to the weight determination of the SNF assemblies, type C-36 irradiated in the VVR-S Reactor and stored in SNFSB and CP. The main parameter to be determined with this method is FA weight. The main parameter to be determined is FA weight expressed in kg. The total amount of SNF of C-36 type is 70. Each SNF assembly is containing 15 fuel rods of C-36 type imported from the former Soviet Union. The importation was performed through the Russian Technabexport company.

By Romanian request to import fuel assemblies of EK-10 type, Technabexport company respond that the EK-10 fuel (enrichment 10%) is out of fabrication and is replaced by C-36 type (enrichment 36.63%) with similar characteristics. The new C-36 fuel is not supplied in assemblies, but only rods with identical outside dimensions to EK-10 rod. The importer is responsible for manufacturing the cladding to be used with the new type of fuel. The letter was accompanied by a technical drawing representing a cladding with 3 bevels capable to house 15 C-36 fuel elements. In the same letter is mentioned that due to these similarities all calculations performed for the EK-10 fuel can be done in the same way for the new fuel C-36. Therefore, it was imported from Soviet Union 1200 fuel rods of C-36 type. Only 1050 rods were used and are present in the 70 SNF assemblies. From the total amount of 70 SNF assemblies, 8 assemblies are of original Russian EK-10 type (square cross section, no bevels) and 62 assemblies are Romanian made (square cross section, with 3 bevels) in accordance with the drawing provided by Russian supplier. Two types of weights will be provided, the weight of Russian EK-10 fuel assembly containing 15 fuel rods of C-36 type and one fake rod made entirely of aluminum and the weight of Romanian made assembly containing 15 fuel rods of C-36 type. The method consists in extracting the required data from the original documents and weight measurements. The weight measurements were performed on a fake aluminum rod identical with the one used in the 8^{th} EK-10 type assemblies.

D. The method describes the determination of SNF assemblies' tightness, for their return in RF. The current method is been applied to determine the tightness of SNF assemblies, type C-36 irradiated in the VVR-S Reactor and stored in SNFSB CP. The main parameter to be determined with this method is the amount of Cs-137 released by C-36 SNF assemblies during their time of storage in CP and SNFSB. If one or more than one SNF loose its tightness the main fission product released in surrounding storage water is Cs-137. The amount of Cs-137 released depends strongly of the breach dimensions. This method consists in collecting data from the documents available at IFIN-HH VVR-S research reactor. The water parameters are continuously monitored based on a periodically sampling program and analyzed by an authorized laboratory from IFIN-HH. There are 54 C-36 SNF assemblies stored in CP and 16 C-36 SNF assemblies stored in SNFSB. The water sampling is performed monthly from every basin containing SNF assemblies. The presence of Cs-137 in water is detected by gamma spectroscopy. The Minimum Detectable Activity (MDA) of the spectrometer using a Hyper Pure Germanium detector is 170 Bq/l. Monthly, the authorized laboratory is providing the "Analyses Report" code AC-PS-CPRLAB-15-02 were the activity of the Cs-137 is included. All the laboratory results are centralized in tables and kept in department archive with the other documents. Based on these tables, a report with the water parameters status is issued every month and sent to the CNCAN. Usually, in the reactor operational log books are mentioned every noticeable events regarding the status of fuel and installation. Analyzing the activities performed on 19-Dec-1997 (when reactor was finally shut down) and on 23-Dec-1997 (when the active core was completely discharged to the CP), no special events regarding the fuel status are mentioned in the reports. The utilized document is the log book No. 53 code EO-PT-01-01 from 23 October 1996 to 21 August 1998. This mean that fuel integrity during last reactor operation and transfer to CP was not changed.

The most recent Analyses Reports from January 2004 to June 2006 shown that the values of Cs-137 activity in SNFSB is no greater than MDA and no greater than 241 Bq/l in CP.

After examination of the tables with water analyses results from the last 2 years we can conclude that the presence of Cs-137 in the water basins is as follows:

- In the SNFSB containing 16 C-36 SNF assemblies, the activity is less than MDA = 170 Bq/l;

- In the CP containing 54 C-36 SNF assemblies, the maximum detected activity is 240 Bq/l in March 2004 and 241 Bq/l in May 2004.

Taking in consideration the above results we can conclude that there is no Cs-137 activity for the SNFSB and a very low activity (practically negligible) for the CP.

3. This task consists of evaluating, planning, and performing all facility or structural modifications required to load spent nuclear fuel from the VVR-S research reactor into the shipping casks and the modifications required to load the shipping casks onto transport vehicle prior to transport to the Russian Federation. This task is in progress all the studies and evaluations of the existing buildings, structures, and equipment are performed. The studies and evaluations have already determined all the modifications required to load and store the spent nuclear fuel in the shipping casks at the Magurele site prior to shipment. All the plans, procedures, training, and approvals that will be required to perform the modifications were properly identified. The first set of radiation and contamination surveys of all areas and equipment to be modified at the Magurele site and at the loading area are complete. This set document the baseline conditions before starting any physical modifications. The construction process on the site is in progress.

4. This task is under development. It consists in fabrication and deliver of the designed and approved cask interface equipment. Perform quality assurance inspections and acceptance of the equipment in accordance with CNCAN, IFIN-HH, and Romanian requirements. Prepare and approve all procedures required to use the TUK-19 cask and the transfer cask in the VVR-S reactor facility and on the Magurele site. The procedures and approvals shall be in accordance with CNCAN, IFIN-HH, and Romanian requirements.

This work shall prepare and approve procedures for the following situations:

- Unloading and loading the shipping casks from and to the transport vehicle;
- Loading and unloading the shipping casks to and from the transport vehicle;
- Transporting empty and loaded shipping casks between the reactor hall and the loading area;
- Preparing the shipping cask and the transfer cask for use;
- Loading the shipping cask baskets with spent fuel assemblies;
- Moving the loaded transfer cask and shipping cask in the reactor hall;
- Sealing, drying, and leak testing the shipping cask;
- Physical protection during shipping cask loading, temporary storage, and transport on the Magurele site;
- Operator training. Train operators to load and handle the shipping and transfer casks with the approved procedures and the mockup equipment. Training and proof of satisfactory training shall be in accordance with CNCAN, IFIN-HH, and Romanian requirements.

The final item for this task is loading demonstration. Demonstrate that the TUK-19 cask can be loaded with spent fuel assemblies from the VVR-S reactor. Perform a "wet run" demonstration by positioning the transfer cask above the reactor pool; loading dummy (non-fueled) assemblies into the transfer cask; transferring the basket of dummy subassemblies from the transfer cask to the shipping cask; sealing, drying, and leak testing the shipping cask and loading the cask onto the transfer vehicle.

CONCLUSION

The present work refers to the activities performed by the Reactor Decommissioning Department (DDR) team from the National Institute of R&D for Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH), in the framework of the Russian Research Reactor Fuel Return (RRRFR) project. Analyzing all the collected information's presented above, and taking in to considerations the norms and regulations in force at present time, we can conclude that until now there are no specific Romanian spent fuel inspection regulatory requirements, able to influence in a way or another the exportation of HEU C-36 type SNF assemblies from VVR-S reactor to reprocessing factory, in RF. As a consequence, no new or additional procedures are necessary to be developed to fulfill requirements for spent nuclear fuel inspection or transport cask.
A big amount of planning and construction work is in progress on the IFIN-HH Magurele site, most of the efforts focusing to complete equipment procurement, facility and loading area modifications, in order to allow SNF loading and shipping to RF.

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