VINCA INSTITUTE SAFETY AND LICENSING ACTIONS FOR CARBON STEEL STRUCTURE REMOVAL FROM RA RESEARCH REACTOR SNF POOL

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ABSTRACT

Carbon steel structure, inserted in water of the spent nuclear fuel pool of the RA research reactor in 1960 for decontamination of primary cooling circuit components, was recognized as the main source of corrosion in the pool. Inappropriate water chemical parameters have initiated corrosion of aluminum cladding of spent fuel elements stored in aluminum barrels. It was confirmed by measuring of activity of ^{137}Cs nuclide in the pool water samples. A complex project was developed with the IAEA assistance and R&D Company OEC NIKIMT (RF) to remove the carbon steel structure from the pool, since 2004. After long preparation process, including safety analysis of the operation and Serbian regulatory authority approval, the structure was removed, packed and stored at the Vinca radioactive waste storage from November 2006 to February 2007. This paper underlines major safety and licensing actions taken by the Vinca Institute to safely remove the structure and make a room in the pool basin for future spent nuclear fuel repackage operation.

1. Introduction

Trying to improve conditions in the spent nuclear fuel (SNF) storage located in the RA reactor building, it has been decided in 2002 to remove metal construction from the basins No. 4. This structure (consisting of a metal construction and two tubes) was more than 40 years in this basin, and its major part has never been used. It was considered as a significant source of corrosion products since the majority of its components were made of carbon steel. Besides, this structure was taking up a large part of the space that could be used for repackaging of SNF elements for shipment to the country of origin, which is planned in the near future. This space might be used for temporary storage of new containers into which the repackaged SNF elements will be placed.

Fig. 1. Carbon steel structure and inner tubes

After removal technique proposed by the OEC NIKIMT R&D Company from Obninsk (RF), has been accepted by the IAEA and the Vinca Institute in 2004, special tools and equipment were manufactured by this company. Based on designed technology, the corresponding Safety Analysis Report (SAR) has been prepared [1] by the Vinca Institute and approved by the Regulatory Commission for Nuclear Safety (SRA) of the Ministry of Science of the Republic of Serbia. In September and October 2006 special equipment has been tested on the site and installed. Training of Institute's personnel was carried out afterwards and in November 2006, removal operation began. By the end of February 2007, this operation has been finished successfully.

Technology for removing metal structure consisted in underwater cutting of this structure into several components and further cutting of these components into smaller pieces inside the special tent to be mounted on the platform of the SNF storage. Underwater cutting of metal structure has been foreseen to be carried out by the contact arc cutting equipment; cutting of metal construction components inside the tent, as well as cutting several metal components on the SNF storage platform had to be carried out by the plasma arc cutting equipment. The transfer of cut out components of the metal structure, from basin No. 4 to the stand for further cutting inside the tent, had to be carried out by the special grapple, using the bridge crane in the SNF storage.

2. Safety and Licensing Actions

2.1. Equipment testing and installation

Testing of the contact arc cutting equipment and the special grapple was carried out firstly in the OEC NIKIMT Company in the middle of 2005. Final verification of all the components and their testing has been performed at the testing stand in the RA reactor hall during September and October 2006. The manufactured equipment has fulfilled all the required demands and then was moved to SNF storage at the actual operation place.

In order to enable proper ventilation of the SNF storage room during cutting operations, two mobile (with HEPA filter) ventilation units have been used. The funnel of the intake hose of the first unit was placed close to the cutting area while intake hose of the second unit was placed towards the contaminated area. Connection of exhaust hoses of these units to the ventilation line V_1 (leading to the reactor stack) was achieved through special exhaust pipe being mounted on the wall of the SNF storage room and connected to this line in the corridor of the reactor building.

Increased number of personnel and material transfer from non-contaminated to the contaminated area and vice versa in the SNF storage room, demanded for establishing temporary sanitary admittance area in the corridor at the entrance of the room, while the metal structure removal operation was going on.

2.2. Personnel training

Due to its complexity, the overall operation was divided into several specific tasks with a relevant working teams created and trained by experts of the OEC NIKIMT in the reactor room. A special part of the training was devoted how to cope with possible malfunctions or incidents with the equipment and tools. The training for using plasma-cutting device was carried out outside the reactor building cutting metal components being placed on the cutting stand. Training of the staff has been successfully carried out in October 2006 and the experts from the OEC NIKIMT produced a certificate stating which participants were trained for performing assigned tasks [2].

2.3. Operational procedures

All the standard operations, performed regularly at the RA reactor and at the Institute, being related to radioactive material handling, or in the environment exposed to radiation, are conducted according to the existing regulations [3-4]. But most of activities related to removal of the metal structure demanded for developing special procedures. Totally seventeen such procedures [9] were written and approved by the competent Institute authorities and SRA:

Procedures for metal structure block removal

1. Removal of the upper part of the frame
2. Removal of both the middle part of the frame and the table
3. Removal of the lower part of the frame

Procedures for tubes block removal

4. Removal of the bottom section
5. Removal of the right tube
6. Removal of the left tube
7. Removal of the upper section

Procedures for plasma arc cutting

8. Cutting the storage platform components
9. Cutting the metal components inside the tent

Radiation protection procedures

10. Radiation monitoring

11. Sanitary admittance area control
12. Decontamination of metal components and the storage platform
13. Packaging of metal components into waste barrels
14. Transport of waste barrels to the radioactive waste repository

General technical procedures

15. Procedure for restarting operations after power failure
16. Procedure in case of fire in the spent fuel storage
17. Procedure in case of ventilation systems failure

2.4 Safety Analysis Report

Based on technology developed, a safety assessment of the whole operation was done firstly, in close cooperation of experts from the Vinca Institute and OEC NIKIMT. This assessment was reviewed by experts of IAEA Research Reactor Safety Section and experts from the Slovenian Nuclear Safety Agency (SNSA) and SRA. Then, complete SAR was developed (in period of November 2005 to May 2006) including following chapters: Introduction; Properties of the working environment; Planned activities; Organization and management of the removal operation; Safety and radiation protection; Hazards identification and risk assessment; Operation limits and conditions (OLC); Radioactive waste management; Quality assurance; Summary and Appendices.

OLC are determined according thorough safety analyses of all anticipated incidents: Explosion; Fire; Power supply failure; Ventilation systems failure; Damage of the basin lining; Damage of the fuel containers; Metal construction collapse; Occupational exposure above determined limits and Injuries.

The SAR was systematically reviewed few times by SRA, IAEA RR Safety Section staff and experts from SNSA and many suggestions were included before FSAR was approved by SRA which, then, had issued a permit to the Institute to carry out the whole operation.

3. Operation

The cutting operations in the SNF storage began in the second half of November 2006. In order to ensure better protection of the aluminum barrels having SNF elements inside, being placed in one half of the basin no. 4 at its bottom, special plastic shield has been mounted to separate the two parts of the basin.

In less than a month (until December 15), envisaged underwater cuttings of the carbon steel structure block have been carried out. These cuttings have been performed completely according to the designed technology and procedures (Fig. 2).

Then, a part of platform above the basin no. 4 was removed to allow access to the metal tubes to be cut. Then, a direct visual inspection to top parts of the tubes was possible. It was appeared that one of two tubes (left, closer to the basin no. 3) was disconnected from the platform completely due to corrosion. The other tube (right) was heavy corroded and almost disconnected (Fig. 3). Both tubes we filled with pool water, instead to be empty. Thickness of the tubes' wall appeared

to be 2 mm to 3 mm only, leading to faster damage of their walls due to corrosion. This information has also shown that total mass of the block is about 250 kg, about half of foreseen the total mass, determined according existing drawings and measurements done earlier at the top of platform.

Fig. 2. Removing of parts of the metal structure

This situation was unforeseen in the FSAR and it was considered as a near-to-incident, because of there was possibility that one (left) or both tubes could fall down into the basin no. 4 above the aluminum barrels with SNF and damage the fuel elements inside. Faced with such possibility, it was necessary to pull the whole tube block out from the basin as soon as possible.

Fig. 3. Top part of two metal tubes and Safety case team evaluation of the proposed solution

According to the written procedures and the FSAR developed, two tubes were supposed to be removed by underwater cutting, starting from the bottom side of tubes upwards, since their top parts were fixed initially to the platform of the pool.

Firstly, the disconnected tube was secured to prevent its fall to basin no. 4 with SNF storage containers: a long metal rod was inserted into the tube, preventing uncontrolled dissipation of the tube parts in a case of the tube collapse. The second tube was secured at the same way. A brief incident report stating current situation, preventive measures taken and further actions planned, was written and sent to the SRA.

Thorough examination of conditions the tubes' walls was conducted using underwater light (inside and outside tubes) and underwater TV camera. Unfortunately, due to heavy corrosion deposits on walls, it was not possible to make any firm conclusion on the walls strength. It was noted, only, that there were no big holes at the walls. TV camera has shown also that the plate

connecting tubes' bottoms is bended to the pool floor under the disconnected tube. Gamma-ray dose rates (up to 1 mSv/h) from deposits was measured along tubes' walls using electronic personal dosimeters (EPD) in watertight casings.

Based on these additional information collected, it was obvious that planned technique for underwater cutting of the tubes, starting from their bottom upwards, cannot be applied. Moreover, no underwater cutting was possible any more. OEC NIKIMT design engineers and the VIND SNF safety case team worked together to propose the most efficient and safe solution of the existing situation at the site for few days. After review of various proposals from safety, technology, construction and radiation protection aspects, new technology for the tubes removal was adopted.

New procedures for the tubes removal were written [10] and forwarded to SRA. Modification to the existing tools were done, new tools are manufactured and verified for strength and ability to carry out weight of the tubes. Operators were introduced to new technology, possible problems and trained in using new tools. Safety assessment and analysis of the whole operation were done and amended to FSAR that has been forwarded to SRA for authorization. Finally, the cutting team has removed the tubes according these procedures without any incident (Fig. 4).

Fig. 4. Removing metal tubes

4. Operating Conditions Overview

4.1 Protective and safety measures applied

For both regular and incidental conditions during removal of the metal structure from the SNF storage of the RA reactor, the management of the removal operation fulfilled the ALARA principle. During operations it was taken care that all unnecessary exposure be avoided. Overall planning of working procedures was applied as the vital part of ALARA principle.

Possibilities for further optimization have been noticed during operation, by analysis of video records of previous operations at the lessons learned meetings held with involved operation

participants, noticing the weaknesses, reduction of exposure times and overall active participation of all personnel in planning of operations. All additional safety and protection measures foreseen by SAR have been applied and had functioned during the all time of conduction the operation.

Radiation protection measures planned in the SAR and approved by the SRA and applied during the operations were in compliance with national legislation in this field, safety standards of IAEA and Institutes' internal acts (Regulation on radiation protection in Institute Vinca, Radiation Protection Manual of Institute Vinca, Accident response plan in the Institute Vinca).

4.2 Limiting and control of external exposure

Dose limits - Authorized dose limit for RA research reactor personnel is 10 mSv per year.

The assessment of external exposure levels - It has been assessed in the SAR that the levels of doses received by the personnel due to external exposure will be less then 4 mSv during the whole operation. Total time of operation was longer than planned (55 days), but the time that operators spent in radiation field was significantly reduced by careful planning during the operation. Further, although it has been noticed during the operation that dose rates on surface and in the vicinity of the carbon steel structure and the tubes were significantly higher than expected, it had been provided for the values of individually received doses during the operations by personnel to be significantly lower than planed and approved exposure levels, by thorough planning and analysis.

Personal dosimetry control - It has been conducted according to the SAR. It can be concluded that application of EPDs significantly increased effectiveness of the planning and personnel overall dose reduction.

Characterization of radiation parameters - Radiation surveys in SNF storage room have been conducted after each activity that could change parameters and increase exposure levels. In the case of contamination of working platform, before the continuation of next step of the operations, platform decontamination had been performed.

4.3 Limiting and control of internal exposure

During duration of the whole operation, all planned and approved measures for internal exposure limitation have been applied (air filtration, continuous contamination control of air, working area, equipment, protective clothes, access control and respiratory protection). Working surface, equipment and protective clothes for which it has been concluded to be contaminated, were decontaminated before further use and effectiveness of decontamination process proved by appropriate measurements. None of elements of this protective and control system whose failure could lead to internal contamination and exposure of employees has failed in any moment of operation**.**

4.4 Limiting and control of public exposure

All planned and approved measures for public exposure control according to the SAR have been applied continuously during the whole operation. At the very location of the operation,

conduction of air ventilation through two absolute filters of the mobile ventilation units has been provided. According to the results of continuous monitoring of emission gamma airborne effluents at the exit of the ventilation stack, there was not a single case of radioactive emission of effluents during duration of the whole operation. Environmental monitoring of radioactive contamination has been conducted according to long term Vinca Institute environmental monitoring program.

4.5 Incidents report

All planned measures for prevention of accidents and hazards control have been continuously applied providing that none of those incidents have been occurred. On the last day of operation, two operators have contaminated slightly a skin of the fingers, due to failure of protective gloves. After initial decontamination on spot, they have been completely and successfully decontaminated in the Human decontamination unit of the Vinca Institute.

4.6 Operational conditions and limits

Measuring of gamma ray dose rates at corrosion sediments, nonhomogeneously deposited the surface of metal parts, during rising of the first part of the carbon steel construction above the water level, has shown values from 250 μSv/h up to 750 μSv/h. Dose rate was higher than anticipated based on results of earlier measured activity of sludge collected from the pool bottom and gamma ray dose rate measured from a sample taken from deposits bounded at surfaces of the carbon steel structure. Having in mind expected duration of plasma cutting operation and number of cuts and these dose rate values, the procedure for waste preparation and packaging has been modified in consultation with SRA. Modification was related to reduction of number of cuts and preparation of tailored metal containers - boxes for waste storage.

As the operation continued, gamma ray dose rate were measured under water in vicinity of carbon steel structure and tubes, before under water cutting. It has proved that chosen strategy for waste handling and packaging is optimal for the time being, as measured dose rates in air on other parts of the carbon steel structure and tubes ranged up to mSv/h at hot spots. Thus, each subsequent operation had to be carefully planned with the application of all basic protective factors such as time, distance and shielding.

4.7 Radioactive waste management

In accordance to the Guidance for waste collecting and segregation, 25 standard 200 L barrels of low active compressible waste (paper, trash, protective clothes, gloves, caps, smears, etc.) have been collected during the operation, including preparatory activities, operation and final cleaning and decontamination activities at the SNF storage area. Barrels have been properly declared, transported, stored in the Hanger H2 and recorded.

Small metal peaces originated from the carbon steel construction cutting and removal of the metal platform construction above the basin No. 4. (close and above to the underwater carbon steel construction and tubes) are packed in additional 3 standard 200 L barrels, according the SAR. Barrels have been properly declared, transported, stored in the Hanger H2 and recorded. Parts of cut carbon steel construction and tubes have been packed in 6 different metal boxes

purposely constructed during the operation. The boxes are stored in the container C1 next to the Hanger H1 at the radioactive waste storage. Dose rates at the surface of each container are in conformity with WAC. Preliminary waste characterization has been performed by the Isotope identifier and nuclides ^{137}Cs and ^{60}Co have been recognized.

4.8 Cleaning of the equipment and working area

When the operation of the removal of the carbon steel construction, tubes and parts of metal platform was finished, subsequent activities were carried out to clean the working area, including:

- removal, decontamination (if possible) and storage (inside room No. 141 or the reactor room of all used equipment from the spent fuel storage area;
- removal, decontamination if possible and storage (inside room No. 141 or the reactor room) of all used equipment from the basin No. 4 and annex of spent fuel storage area;
- decontamination of the surface above basins of the spent fuel area and the 'clean' area at the entrance of the spent fuel storage room;
- removal of the sanitary admittance area in north corridor of the building in front of the spent fuel storage area and in the reactor room.

5. Conclusion

Removal of metal structure from the SNF storage located in the RA reactor building has been performed in a safe and reliable manner both for the RA reactor facility and the staff involved in this operation. There were no unfavorable environmental effects. The operation has been carried out in compliance with the corresponding SAR and operating procedures, both reviewed and approved by SRA. Acting according to ALARA principle and radiation protection safety standards, it has been decided not to proceed immediately with planned further cuttings of metal components taken out of the basin, but to pack them directly into corresponding waste metal boxes. and store at Vinca RAW storage.

All additional safety and protection measures foreseen by the SAR have been applied all the time the operation lasted including measures planned for accidents prevention and hazards control. Good planning and proper work organization made the whole operation successful. Full report on the operation was prepared and submitted to relevant organizations [11].

The space in basin no. 4 gained by removal of metal structure will be used for temporary storage of new containers into which the repackaged SNF elements will be placed, before shipment to the country of origin.

6. Acknowledgement

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7. References

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