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RETURN OF HEU FUEL FROM THE PORTUGUESE RESEARCH REACTOR

J.G. Marques, N.P. Barradas, A. Kling, A.R. Ramos
Instituto Tecnológico e Nuclear
Estrada Nacional 10, P-2686-953 Sacavém, Portugal

C. Anne
AREVA NC Transnuclear Inc.
7135 Minstrel Way, Suite 300, Columbia, 21045 MD, USA

V. Garcia
AREVA TN International
1, rue des Hérons, BP 302, F-78054 Saint Quentin en Yvelines Cedex, France

ABSTRACT

Thirty one fresh and spent HEU fuel assemblies from the Portuguese Research Reactor were recently returned to the US. Limitations on the floor loading of the reactor building and on the capacity of the crane prevented the placement and loading of the TN-MTR transport cask inside the containment building. The cask was thus placed outside, under permanent surveillance, in a support structure built around it. A small transfer cask was used to carry individually the spent assemblies from the storage racks to the transport cask. A forklift was used as a shuttle between the pool and the TN-MTR cask. A detailed description of the procedures followed is done.

INTRODUCTION

The Portuguese Research Reactor (RPI) is a 1 MW, pool-type reactor, built by AMF Atomics and commissioned in 1961. The activities currently underway in the RPI cover a broad range from irradiation of electronic circuits to calibration of detectors for dark matter search, as well as by more classical subjects such as neutron activation analysis. Most of these activities use in-pool irradiations.

The RPI was commissioned in 1961 with LEU fuel. However, it was later converted to HEU fuel. This fuel was delivered in 1974 but only started being used in 1990, at a time when a significant number of reactors was instead being converted to LEU. In 1999 Portugal declared its interest to participate in the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program

(FRRSNF). A commitment was made to stop using HEU after May 12, 2006 and return all HEU fuel until May 12, 2009.

The core conversion to LEU was done within IAEA's Technical Cooperation project POR4016 with financial support of the US and Portuguese governments. An extension on the use of HEU until May 31, 2007 was granted by the Department of Energy, in order to minimize the downtime of the reactor. The actual conversion was done in September 2007.

The starting LEU core has the same size of the corresponding HEU core, through the use of high-density (4.8 g/cm^3) uranium silicide dispersion fuel. The performance of the new LEU core for in-core irradiations is similar to the one of comparable HEU cores [1].

The return of all HEU fuel assemblies, fresh and spent, was performed in the summer of 2008.

PREPARATION FOR THE SHIPMENT

DOE's receipt process requires the fuel proposed for shipment to be classified based on the materials of construction, physical dimensions, decay heat load, dose rate, fissile content, selected isotope content and physical condition [2]. These parameters were determined from the fabrication drawings and specifications, the fabrication quality control records, and the operating history of the fuel assembly. RPI had two types of HEU assemblies: standard assemblies, with 18 parallel plates, and control assemblies, with 10 plates. All assemblies were of U-Al alloy, 1100 grade aluminium cladding, enriched to $93.15 \pm 0.15\%$ in ^{235}U.

The RPI produces an annual integrated power up to 60 MW•d and thus the uranium burnup rate is relatively small. Core management is reduced to shuffling of assemblies, in order to get comparable burnup levels, and addition of fresh assemblies whenever necessary. A typical HEU core configuration with 7 standard assemblies and 5 control assemblies is shown in Fig. 1.

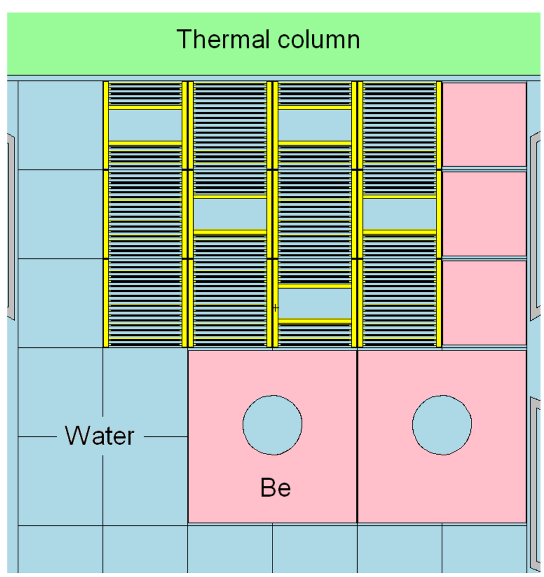

Figure 1. Typical HEU core configuration, with 7 standard and 5 control assemblies.

All assemblies were visually inspected to verify their structural integrity. The visual inspection was done in an auxiliary platform located 2 m below the pool water surface. The assemblies were found to be in good structural conditions and without any corrosion spots. The spent assemblies have always been kept in 6061 grade aluminium racks in the reactor's pool, with water conductivity below 1 μS/cm and pH of 6.0±0.5. An independent evaluation of the status of the assemblies was also done by Westinghouse Savannah River Company personnel.

The fissile content of the irradiated assemblies was determined interpolating data from ANL/RERTR/TM-26 [3]. The isotopic composition and decay heat were determined using the PHDOSE [4] and ORIGEN [5] codes. An analytical expression given by El-Wakil [6] was also used for cross-checking the decay heat values.

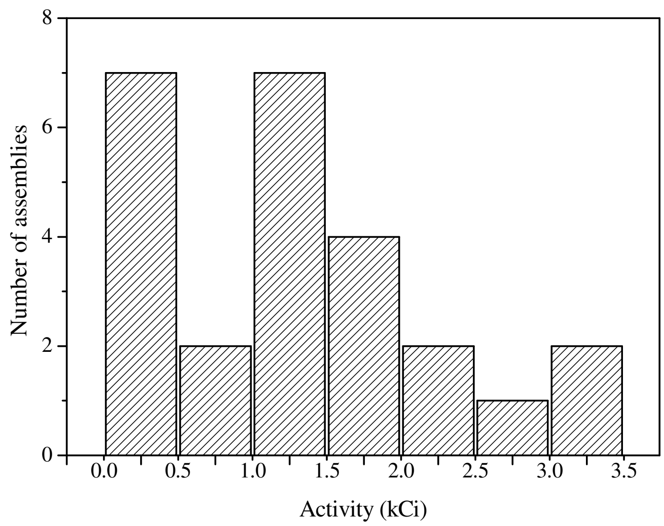

Figure 2. Distribution of total activity of the spent HEU fuel assemblies.

The distribution of the total activity of the irradiated assemblies is very asymmetric, as shown in Figure 2, built with values calculated by ORIGEN. The average value and maximum values are 1.3 kCi and 3.1 kCi. The dominant isotopes were $^{144}Ce/^{144}Pr$ in the assemblies with less cooling time (ca. 1 year) and $^{137}Cs/^{137m}Ba$ plus $^{90}Sr/^{90}Y$ in the remaining assemblies. The average and maximum decay heat values were 4 W and 11 W, respectively. The total decay heat value for the irradiated assemblies was 112 W.

TRANSPORT CONTAINER SUPPLY

TN International was selected as supplier of the transport cask by the IAEA as a result of an international call for bids within project PO4016. TN International is an AREVA NC subsidiary specializing in the packaging, transportation and storage of nuclear materials, with over 40 years of experience. TN International is responsible for all aspects concerning the packaging of radioactive materials: packaging design, safety documentation, qualification, monitoring, and maintenance of shipping and storage casks.

AREVA NC has logistical sites in 3 major world regions: in Europe, via TN International and its subsidiaries, in the US, with one subsidiary (Transnuclear Inc.) that specializes in the design and production of nuclear materials packaging and shipping organization, and in Japan, with a specialization in engineering, transportation organization and packaging maintenance studies on power station sites via its Transnuclear Tokyo subsidiary.

For the RPI reactor, TN International has provided an integrated package including:

- TN-MTR transport cask, with 52S basket able to accommodate both fresh and spent HEU assemblies.
- Transfer cask for transport of individual assemblies from the reactor's pool to the TN-MTR cask.
- Basin for loading of the cask outside the reactor's pool.
- Loading plan of the TN-MTR cask, optimized for minimization of the radiation dose at the surface of the container.
- Technical assistance during loading.

The schedule for the completion of this project was short, starting at the end of January 2008 with the technical and commercial evaluations of the bids by the IAEA and being achieved with the delivery of the transport cask and auxiliary equipment at the RPI reactor site in the early summer of 2008.

LOADING OPERATIONS

The TN-MTR cask weights nearly 20 t and has a 1.6 m diameter. The low capacity of the reactor's crane (10 t) and the characteristics of the floor at the service entrance which was planned for a load inferior to 7 t/m^2, prevented handling of the cask inside of the reactor building. It was thus necessary to reuse a loading station previously built for an IU04 cask, about 10 m away from the service entrance [7, 8]. The cask rested on I-beams placed inside a basin connected to the radioactive waste piping. The cask was provided with a loading skirt, adaptable to its upper part, which was used to create a water basin where the assemblies could be manipulated. All manipulations inside the cask were done from a platform 2.7 m above the concrete support. The operators were protected by the water inside the cask and the loading skirt, whose Pb shield extended from the top of the cask until 0.2 m above the platform.

Since the shipment would take place during summer, no special measures were necessary regarding meteorological conditions. In any case, a cover for the whole structure was on stand-by and could be mounted within a few minutes.

To carry out the operations inside the reactor building a supplementary structure was placed on the NW side of the pool, to secure the fuel handling tools. The platform previously used for the visual inspection of the assemblies was then used as an intermediate station in the movement of the fuel assemblies out of the pool. The region of the floor close to the service entrance was reinforced with 1 cm thick steel plates to better distribute the load.

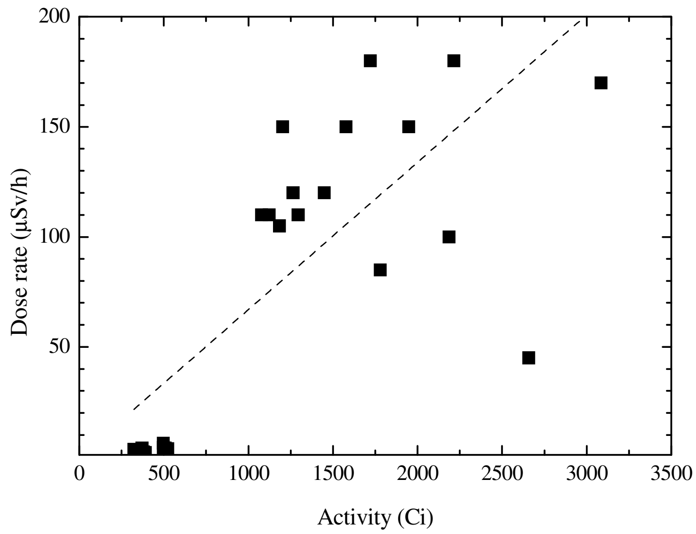

Figure 3. Measured gamma dose rate at contact with the transfer cask, as function of the total assembly activity.

Loading an assembly on the transport cask required a series of steps of which the most relevant were the loading and unloading of the transfer cask (3 t weight), the identification of the assembly and its placement in the TN-MTR basket, according to a previously established loading diagram. Each assembly was taken from the storage racks to the auxiliary platform where its identification was confirmed. The transfer cask, held by the reactor crane, was placed above the assembly with its bottom about 1 m below the water surface. Then the assembly was raised into the transfer cask by means of a cable provided with a hook which grabbed the assembly by the handling rod. The admission of the assembly was done via a small door at the bottom of the cask, which was closed once the cable was secured. Before leaving the pool area the surface of the transfer cask was dried to minimize water spillage. The cask was then lowered to the entrance level of the building and loaded on a forklift, which was used as a shuttle between the reactor hall and the transport cask. A special basin was constructed to ensure the fixation of the cask during the movement of the forklift and to collect any spilled water.

Figure 3 shows the measured gamma dose rate at contact with the transfer cask, as function of the total assembly activity (as obtained with ORIGEN). The dashed line is a linear fit, passing by zero, and is given as an indication only. The dispersion of the values reflects mostly factors that could not be controlled for these measurements, such as the orientation of the assembly inside the transfer cask. Also, a correlation with the total activity is an over-simplification, since different isotopes are dominating in the higher activity and lower activity assemblies. The values demonstrate, nevertheless, the performance of the transfer cask.

Outside of the reactor building all the handling was performed with a mobile crane. Each assembly was put initially in a temporary position above the TN-MTR basket, where its identification was rechecked before going to its final position. The transfer of control assemblies required the attachment of an adapter piece to the stainless steel shock absorber, since these were only removed after the placement of the assembly in the TN-MTR cask. The transfer cask was also used to carry the absorber back to the pool. The 31 assemblies were transferred within three working days. All steps were monitored by a EURATOM safeguards inspector.

The loading procedure had been previously optimized to reduce the radiation exposure of the staff. The main exposure was expected to occur during the transfer of the assemblies from the transfer cask to the transport cask, since shielding at this stage was provided only by the water-filled skirt and the biological shield [9]. The measured collective dose of the reactor staff (11 persons) was 0.1 mSv during the 3 days of loading.

Once loading was complete, water samples from the transport cask were taken at regular intervals. The measured ^{137}Cs activity increase over a 12 h period was 0.2 ± 0.1 dpm/ml, well below the 705 dpm/ml limit imposed by DOE. Once this result was obtained, the TN-MTR cask was closed, the water was drained and the required dryness and containment tests were performed. The outer surface of the cask was cleaned in fulfilment of the transportation requirements. Finally, the TN-MTR cask was placed inside a 20 foot ISO container kept close to the reactor building under permanent surveillance by armed police officers, in addition to the normal security arrangements of ITN.

SHIPMENT

Portugal was planned as the last stop of a joint shipment before leaving to the US. This meant that upon its arrival in Portugal it would be carrying nuclear and radiological materials from other facilities. ITN centralized the contacts with all entities responsible for the transport and transit of nuclear and radiological materials. The Ministry of Defence kindly offered the use of a naval base located on the south of Lisbon, as had been done in a previous shipment [7, 8], thus avoiding the use of any of the commercial port facilities in or around Lisbon, where public exposure would be potentially higher. Adjustments made close to the shipping date made Portugal the first stop of the joint shipment and anticipated the arrival date by about one week.

The truck transport of the ISO container from ITN to the Navy base was done overnight in a military convoy, via a route that included the Vasco da Gama Bridge, avoiding areas of large population density. The ship had own crane facilities and left within 1 hour after its arrival at the Navy base. It was escorted by a Navy vessel while in Portuguese waters.

In the previous shipment there was some press coverage, with one newspaper reporting in its last page on the day of the shipment “a depleted uranium shipment of uncertain origin”. No press coverage occurred in this shipment.

CONCLUSIONS

This HEU shipment successfully closed the actions of IAEA’s project POR4016 “Core Conversion of the Portuguese Research Reactor to LEU fuel”, which included the core conversion to LEU fuel and the return of the HEU fuel to the US. It benefited greatly from the experience acquired with the previous shipment done in 1999. All operations went essentially as planned. The excellent collaboration with all the involved partners was essential for the success of the shipment.

References

1. J.G. Marques, A.R. Ramos, J.P. Santos, J.G. Stevens, J.E. Matos, "Commissioning of the New LEU Core of the Portuguese Research Reactor", Transactions 12th International Topical Meeting on Research Reactor Fuel Management, Hamburg, March 2008, European Nuclear Society (Brussels, 2008), ISBN 978-92-95064-04-1.
2. United States Department of Energy, "Provisional Reactor Site Assessment Checklist", http://www.rertr.anl.gov/FRRSNF/CHEKLIST.html
3. R.B. Pond, J.E. Matos, "Nuclear Mass Inventory, Photon Dose Rate and Thermal Decay Heat of Spent Research Reactor Fuel Assemblies, ANL/RERTR/TM-26 (Rev. 1)", Argonne National Laboratory (Chicago, 1996), available from http://www.rertr.anl.gov/FRRSNF/TM26REV1.PDF
4. R.B. Pond, J.E. Matos, "Photon Dose Rates from Spent Fuel Assemblies with Relation to Self-Protection", ANL/RERTR/TM-25, Argonne National Laboratory (Chicago, 1996), available from http://www.rertr.anl.gov/FRRSNF/TM25.PDF
5. A.G. Croff, "ORIGEN2: A Versatile Computer Code for Calculating the Nuclide Compositions and Characteristics of Nuclear Materials", Nuclear Technology 62 (1983) 335-351.
6. M.M. El-Wakil, "Nuclear Heat Transport", International Textbook Company, Scranton, PA (1971), cited in reference 3.
7. A.J.G. Ramalho, J.G. Marques, F.M. Cardeira, "Return of Spent Fuel from the Portuguese Research Reactor", Transactions 4th Int. Meeting on Research Reactor Fuel Management, Colmar, March 2000, European Nuclear Society (Berne, 2000) pp. 75-79.
8. J.G. Marques, A.J.G. Ramalho, "Portuguese Experience on Return of Spent Fuel to the USA", TECDOC 1593, IAEA (Vienna, 2008).
9. A. Kling, J.G. Marques, A.J.G. Ramalho, "Monte Carlo Simulations for the Estimation of Dose Rates During Handling of Spent Fuel at the Portuguese Research Reactor", Proceedings of the Monte Carlo 2000 Conference, Lisboa, October 2000, Springer-Verlag (Heidelberg, 2001) pp. 529-534.