The operational and logistic experience on transportation of Brazilian spent nuclear fuel to the United States of America

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Abstract. In 1999 a shipment of 127 spent MTR fuel assemblies was made from IEA-R1 Research Reactor located at the Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP), São Paulo, Brazil to Savannah River Site Laboratory (SRS) in the United States. This paper describes the operational and logistic experience on this transportation made by IPEN staff, EDLOW International Company and the Consortium NCS/GNS.

1. Introduction

IEA-R1 is a pool type research reactor, moderated and cooled by light water, and utilizing graphite and beryllium as reflector. The construction is a Babcock & Wilcox design and the first criticality was achieved on 16 September 1957. After initial tests, the reactor started operating at 2 MW. Due to the growth in radioisotope demand, in 1997 after necessary modifications and upgrading process, the power was increased to 5 MW [1].

Along 40 years of the reactor operation, 127 SFA's had been stored at the facility, 40 in a dry storage and the others 87 were stored inside the reactor pool. As reported in the 21th RERTR [2], in 1996 the Brazilian Nuclear Energy Commission (CNEN) started negotiations with DOE to return the SFA's of IEA-R1 Research Reactor to USA. Finally, in 1998, an agreement was achieved between CNEN and DOE and in November 1999, the shipment was realized with success.

2. Fuel information

The SFA´s transported to USA were used in IEA-R1 RR as follows: the first load corresponds to the first core of the reactor. It was composed of U-Al alloy fuel with 20wt% enrichment, having 19 curved fuel plates produced by B&W. These fuel assemblies failed at the earlier stages of the reactor operation, due to pitting corrosion caused by brazing flux used to fix the fuel plates to the support plates. As the burn up and the dose rate was very low, the assemblies were placed in a dry storage composed of horizontal silos in a concrete wall located at the first floor of the reactor building.

These fuels were replaced in 1958 by new ones, also produced by B&W. They were identical to the earlier ones (U-Al alloy, 20wt% enrichment, 19 curved fuel plates) but brazing was not used for assembling. The fuel plates were fixed mechanically to the support plates.

The third load corresponds to a complete substitution of the core. Fuel assemblies made with U-Al alloy, 93 wt% enrichment, having 18 flat fuel plates were bought from UNC (USA). To comply with the new flat plate type fuel, the control rod mechanical concept was also changed from rod type to fork type (plate type), and the control fuel assemblies were fabricated by CERCA (France), using U-Al alloy, HEU and flat plates.

The fourth load was characterized by the restriction of buying HEU fuel in the international market. IPEN bought, from NUKEM (Germany), 5 fuel assemblies of UAl_x-Al dispersion type, with 20wt% enrichment and having 18 flat fuel plates per fuel assembly.

All the four loads, summarized in Table 1, were returned to the United States, after being inspected by Brazilian [3] and DOE teams [4].

It is important to mention that after the four initial loads, all the fuel assemblies used in IEA-R1 were constructed in IPEN. Many of them with uranium from USA origin, and not yet returned to the US.

TABLE 1. SUMMARY OF THE FUEL ASSEMBLIES USED IN IEA-R1 REACTOR CORE

LOADING	FIRST	SECOND	THIRD	FOURTH
Year	1957	1958	1968	1981
Country	USA	USA	USA/France	German
Enrichment	20	20	93	20
Standard assembly	34	33	33	5
Control assembly	5	4	10	-
Partial assembly	1	2	-	-
Total assembly	**40**	**39**	**43**	**5**

3. Companies contracted for the transport operation

The contract between the CNEN and the Department of Energy (DOE/USA) was signed in 1998. Edlow International Co. and the Germany Consortium formed by Nuclear Cargo + Services (NCS) and Gesellschaft fur Nuklear-Service (GNS) were hired to performe the transport. Tec Radion Comercial Ltda (TRION) was subcontracted by Edlow to provide the necessary local infrastructure for the loading, transport and customs documents.

The German Consortium provided 4 transport casks (two GNS-11 and two GNS-16), a transfer cask, equipment and experts to handling their equipment. IPEN/CNEN-SP performed the necessary work to accomplish the Brazilian legislation as the export license, a detailed transport and security plan, safeguards documents, and the Appendix A. It also provided the operational and radiological protection support to the entire operation.

4. Transport equipment description

The transport cask GNS 11 and GNS 16 are designed in a sandwich construction. The cylindrical cask basically consists of the following components: inner liner with inner liner bottom, lead filling, wall with bottom plate, side wall cover sheet with spacer wire, head ring, primary lid and protective plate. The maximum weight of the cask is 13 230 kg [5,6].

The components of the cask body and the primary lid are manufactured in stainless steel. In the terms of the transport regulations, the “leak-tight containment” consists of the inner liner, the inner bottom plate, head ring, primary lid, with the bolt joint, and the internal seal of the two concentrical Viton seals.

Cap screws are used in order to fasten the primary lid. The closure lid is also fastened to the primary lid using cap screws. In order to achieve the shielding effect, the space between the inner liner and the shell is filled with lead casting. A pair of trunnions are bolted on to the head ring in order to attach handling devices. During transport, the cask is provided with a protective plate. In order to reduce the shock loads arising during the eventual drop of the cask, as stipulated for type B packaging, impact limiters made of wood with a steel-plate shell are attached to the ends of the cask body on the lid and bases sides. Because of the different geometry of the fuel assemblies (FA’s) to be transported, the inner cavity of the cask can accommodate any one of three different baskets, as follows: FR 2/33 to accommodate 33 box-shaped FA´s, FR 2/28 for 28 tubular FA´s and FR 2/15 for 90 rod-shaped

TRIGA FA´s. The two casks, GNS 11 and GNS 16, are similar. A summary of the characteristic data for fissile material and burn-up or box-shaped MTR fuel assemblies that can be transported on the two casks is shown in Table 2.

TABLE 2. CHARACTERISTIC DATA FOR FISSILE MATERIAL AND BURN-UP – BOX SHAPED MTR-FA

	GNS-11	**GNS-16**
Max. Number of FE per cask	33	33
Max. FE lenght, mm	630	915
Max. FE cross section, mm^2	81 x 76.1	84 x 77
Max. FE mass, kg	2.65	7.0
Min. Cooling time	180 days	> 1.5 years
Max. Initial enrichment, weight % of ^{235}U	94	95.1/HEU 45.7/MEU 20.3/LEU
Max. Initial weight of ^{235}U,g	268	459/HEU 328/MEU 420/LEU
Max. Burn-up, MWd/FE		184/HEU 181/MEU 222/LEU
Max. decay heat, W	48.5	40
Max. FE length, mm	610	-
Max. activity (x E14 Bq)	3.3E02	6.3E2

5. Fuel cutting equipment

Before the beginning of the loading operation, the external part of the 19 control fuel assemblies were cut leaving 1.27 cm away from the interior fuel plates. This cut was necessary due to the cask length limitation and a SRS request. The cutting operation of five control fuel assemblies stored in the dry-storage was performed in the first floor of the reactor building. A conventional saw normally used for aluminum profile cut was utilized. The assemblies were manually removed, one by one, from the carbon steel piping of the dry storage and placed in a lead shielding. A second technician cut the plastic that was involving the assembly and took it to the saw for the cutting. The cutting pieces were put in a special place as waste and the assembly was stored again. This operation was possible due to the low burn up and dose rate of these SFA´s.

For the cutting of the 14 SFA´s stored in the reactor pool, it was used a underwater saw machine specially designed and constructed in Brazil under supervising of Edlow/Trion. This saw machine was positioned 2.5 meters below the surface of the water inside an aluminum box covered with an acrylic plate. The saw was of stainless steel construction with an electrical motor that remained above the surface of the water and was controlled from poolside. The fuel assembly was fixed pneumatically inside of the aluminum box.

6. Loading and transport description

On September 16, four containers with two GNS-11 German casks and equipment arrived at IPEN. The two GNS-16 casks had already arrived in IPEN on 7 October. German experts supported by IPEN technicians and the transportation company staff hired by Edlow/Trion removed the equipment from the containers and placed them on a truck which transported the equipment to the reactor building. With the help of a crane with 25 tonnes capacity, equipment were placed on a iron platform located in front of the access hall of the building. With the help of a mobile lift, the platform was moved inside of the reactor building and positioned under an access previously open to the 3rd level (pool surface level). Part of the equipment, as the transfer cask, rotary lid and water tank were lifted by the reactor crane with 10 tonnes capability until the 3rd level. In the same way , the cask was moved inside of the reactor building and positioned in the first level, under the access to the 3rd level.

On September 21, the primary lid was removed from the GNS-11 cask and lifted to the 3rd level. The rotary lid was positioned in the upper part of the cask and a cold test, using a dummy assembly, was made by the Brazilian and German teams. A transfer cask, 4 tonnes weight was used to transfer the assemblies from the wet storage to the transport cask. After the succes of the cold test, t hen the SFA's, one by one, were lifted from the storage racks inside of the reactor pool using a special handling tool and placed inside of a plastic tube located on a metallic platform located about 2 meters below the water surface. In the sequence, the transfer cask was sunk inside of the reactor pool, over the assembly to be removed, and a special tool took the assembly and put it inside of the transfer cask which was lifted by the reactor crane and positioned on top of the rotary lid and transport cask located in the first level, as shown in Fig. 1. Finally, the assembly was guided to one of the 33 positions of the cask. In order to remove the rotary lid and put the primary lid, after cask loading, a water tank was positioned on top of the cask and filled with 4 000 liters of water. Finally, the cask was closed and the water was drained to a water tank positioned close to the transport cask.

This operation was repeated for the 87 assemblies stored in the wet storage. For the others 40 SFA's stored in the dry storage, the transfer cask was not used. Instead of it, a water tank was positioned in the upper part of the cask and the operation was performed as follow: the SFA's were taken from the storage, one by one, by hand, and put in a cylindrical lead shield positioned close to the cask. An operator located in the 3rd level, using a nylon rope with a hook in its extremity lifted the SFA and put it inside of the water tank. Finally, the operator guided the SFA visually to the final position in the transport cask.

On October 15 the four GNS casks had been loaded with the 127 Brazilian spent fuel assemblies. Then, the decontamination procedures were performed.

On October 20 and 21 all the equipment and cask were removed from the reactor building to the containers. The casks were stamped and controlled by safeguards inspectors from ABACC (Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials) and supervised by IAEA.

On November 3, the transport operation was initiated after approval from the Brazilian regulatory bodies (Nuclear and Environmental). The transport licenses were issued by CNEN and IBAMA (Environmental Brazilian Agency) which required detailed documents related to the transport, radiation and physical protection as well as an evaluation of the environmental impact. Also the GNS 11 and GNS 16 certificates issued by American and German authorities had to be revalidated in Brazil. It is worthwhile to mention that to obtain these licenses, an enormous effort was done by IPEN staff. Also opposition from Greenpeace, local politicians and harbor union demanded a political work to overcome this opposition and avoid legal prosecute against the operation, including debates and press clearance.

On November 4 at down a huge convoy consisting of 4 trucks escorted by Federal, State and County Police arrived in the port of Santos. It is also worthwhile to mention that the Highway and the main avenues and streets in São Paulo and Santos had been closed for circulation during the operation. At 2h10min am, the shipment of the containers started, and it was concluded after 42 min. Before and during all shipment the workers had been monitored by IPEN radiation protection staff. At 4h50min am, the ship left the port escorted by boats of the federal police. In the exit of the port, these boats were substituted by a frigate of the Brazilian Navy which followed the ship until a distance of 200 miles away from the Brazilian coast.

FIG. 1. View of the transfer cask used to transfer the assemblies to the transport cask.

7. ^{137}Cs Leaking rate and sealing system of the casks /5//6/

After the cask loadding and before the transportation, two tests were performed. The first one was to evaluate the ^{137}Cs leaking rate inside of the cask. In order to perform this test, three water samples were taken from each cask after 0, 4 and 12 hours. The water sample was collected in a small plastic bottle (1 500 ml) and submitted to gamma-ray spectrometry analysis. All bottles used for sampling were identical. The results of this test are shown in Table 3.

TABLE 3. RESULTS OF THE 137-CS LEAKING RATE TESTS IN THE CASKS

Cask	sample 1 dpm/ml	Sample 2 dpm/ml	sample 3 dpm/ml
GNS11-1	1.24	1.86	3.96
GNS11-2	27.6	12.8	24.0
GNS16-1*	1.48	14.0	24.6
GNS16-2*	233.8	875.1	743.3

Obs. limit value for the GNS after 12 hours is below 992 dpm/ml
*this casks was loaded with the SFA´s stored in the dry-storage

A second test was performed in order to verify the sealing system. The primary lid and the protective caps with their screws and testable O-rings are decisive for guaranteeing the retention of the inventory. Grooves are turned into the primary lid in order to accommodate two O-ring seals on the bottom sides of the lid flanges. The O-ring which is part of the containment boundary is insert into the inner groove on the primary lid. The O-ring inserted in the outer groove is not component of the containment boundary. No account is taken of its sealing effect. It forms a testing volume for the leak test. Each protective cap has a groove to accommodate the respective O-ring of the containment boundary.

The leak tightness of the primary lid is proven with a pressure-drop test via the testing connection “B” of the O-rings of the primary lid. For the protective caps the pressure drop tests is performed on a test volume built by a test adapter covering each cap. The measured leakage rate thus is the combination of leakage through both O-rings or other seals forming the boundary of each test volume. The leakage rate for the O-rings, which are part of the containment boundary, thus in reality is lower than the measured value. However, this is ignored and the measured value of the sealing assigned to the O-rings, which are part of the containment boundary.

As a consequence of Type B tests no systematic deterioration of the sealing characteristics can be assumed. This was proven by tests on transport casks with a comparable sealing system. For the transport cask GNS 11 this test is the guarantee that during and after the Type B tests, the leakage rate specified for normal conditions of transport will not be exceeded. For the GNS 16, the test is similar. Results are shown in Table 4.

TABLE 4. SEALING SYSTEM TEST

Cask	Test nº 1 $hPa.l.s^{-1}$	Test nº 2 $hpa.l.s^{-1}$	Test nº 3 $hPa.l.s^{-1}$
GNS11-1	9.1E-06	9.6E-06	1.9E-05
GNS11-2	2.1E-06	9.9E-06	3.2E-06
GNS16-1	8.4E-06	1.2E-07	-
GNS16-2	7.0E-07	1.9E-06	-

Limit value for the GNS11: below 1.0 E-04 $HPa.l.s^{-}$
Limit value for the GNS16: below 2.0 E-05 $HPa.l.s^{-1}$

8. Conclusions

IPEN-CNEN/SP considered that the loading operation, shipment and transport were performed with success once it occurred without any incident and the 127 spent fuel assemblies burned in the reactor IEA-R1 in the last 40 years were loaded and transported to Santos as planned in the Transport and Security Plans. Also, all the loading operation was successfully achieved due to the professional and friend relationship between the Brazilian and German teams.

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