

## **The Core Conversion of the TRIGA Reactor Vienna**

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### **ABSTRACT**

The TRIGA Reactor Vienna has operated for many years with a mixed core using Al-clad and stainless-steel (SST) clad low enriched uranium (LEU) fuel and a few SST high enriched uranium (HEU) fuel elements. In view of the US spent fuel return program, the average age of these fuel elements and the Austrian position not to store any spent nuclear fuel on its territory, negotiation started in April 2011 with the US Department of Energy (DOE) and the International Atomic Energy Agency (IAEA). The sensitive subject was to return the old TRIGA fuel and to find a solution for a possible continuation of reactor operation for the next decades. As the TRIGA Vienna is the closest nuclear facility to the IAEA headquarters, high interest existed at the IAEA to have an operating research reactor nearby, as historically close cooperation exists between the IAEA and the Atominstitut. Negotiation started before summer 2011 between the involved Austrian ministries, the IAEA and the US DOE leading to the following solution: Austria will return 91 spent fuel elements to the Idaho National Laboratory (INL) while INL offers 77 very low burnt SST clad LEU elements for further reactor operation of the TRIGA reactor Vienna. The titles of these 77 new fuel elements will be transferred to Euratom in accordance with Article 86 of the Euratom-US Treaty. The fuel exchange with the old core returned to the INL, and the new core transferred to Vienna was carried out in one shipment in late 2012 through the ports of Koper/Slovenia and Trieste/Italy.

This paper describes the administrative, logistic and technical preparations of the fuel exchange being unique world-wide and first of its kind between Austria and the USA performed successfully in early November 2012.

### **1 HISTORICAL BACKGROUND**

The TRIGA Vienna reactor was one of the last remaining TRIGA reactors which still used High Enriched Uranium (HEU) fuel. Due to the US Fuel Return Program, the Vienna University of Technology/ATI was obliged to return its 9 HEU FE(s) by 2016. Moreover, most of the 102-types LEU FE(s) in the current core were close to reach their maximum burn-up values. Therefore, it was also an option to return these high burned FE(s) along with the HEU fuel. The fuel inventory at the institute before shipment can be seen in the next two tables.

Table 1: Fuel inventory as per 01.08.2012

Date	Number of fuel elements	Type	Remarks
05.12.61	+66	Al, 20%	2 instrumented fuel elements
07.07.62	-2 (retour)	Al, 20%	
19.02.65	+2	Al, 20%	
02.08.66	+3	SST, 20%	
21.10.68	+3	SST, 20%	1 instrumented fuel element 5284 TCE
19.10.72	+9	SST, 70%	
02.12.80	+1	SST, 20%	1 instrumented fuel element 8257 TCE
09.08.82	+3	SST, 20%	
15.02.83	+2	SST, 20%	2 instrumented fuel elements 8730, 8731 TCE
21.08.87	+3	SST, 20%	
19.10.88	+3	SST, 20%	
01.02.90	+3	SST, 20%	
14.12.00	+8	SST, 20%	
Total	104		

Table 2: Fuel element situation as per 01.08.2012

Number of FE	Location	Al Cladding	SST Cladding	Enrichment	Remarks
83	core	54	29	75 FE 20% 8 FE 70%	2 instr. FE
4	Storage pits	3	1	3 FE 20% 1 FE 70%	
8	Fresh fuel storage	-	8	20%	2 instr. FE
8	Spent fuel storage	8	-	20%	1 instr. FE
1	Hot storage facility	1	-	20%	Cut into 2 pieces
Total: 104		66	38		

From the 104 FE(s) at the institute it was decided to keep the eight fresh FE(s) and the five FE(s) with the lowest burn-up in the core. Therefore, 91 spent fuel elements were prepared for shipment to the INL.

## 2 TECHNICAL PREPARATIONS

To be compliant with the NAC-LWT Certificate of Compliance (CoC) for packaging and transport of TRIGA fuel (the fuel to be shipped must cool down for 90 days prior to transport), the reactor was shut down on April 27, 2012. With more than 6 months cooling time prior to the scheduled shipment date all radiation levels are expected to be below the allowed limits. Till April 27, 2012, the TRIGA Mark II reactor Vienna had 10257 days (8 hour working days) of operation. Since the first criticality on March 7, 1962, 12318 MWh of energy has been produced.

## **2.1 Fuel inspection Vienna**

On June 9, 2012 staff from the INL travelled to the Atominstitut Vienna, to perform the fuel examination. Ninety-one (91) TRIGA fuel elements were examined at our facility. The elements consisted of sixty-six (66) aluminum clad and twenty-five (25) stainless steel clad TRIGA fuel elements. Of the 25 SST clad elements, nine were high enriched uranium (HEU) TRIGA Fuel Life Improvement Program (FLIP) fuel elements. The elements were inspected to facilitate the preparation of the required documentation for storage at the Idaho Nuclear Technology and Engineering Center (INTEC) in the Irradiated Fuel Storage Facility (IFSF).

Each element was visually examined over 100% of its surface. All but five (5) of the fuel element's identification/serial number were verified using an underwater camera system. Four (4) of the five (5) were verified using a finger camera and the fifth one was done through a lead glass window in our hot cell.

Eighty-one (81) of the elements appeared to be in a condition that would allow them to be shipped to the US without further packaging. The inspection revealed mainly light scratches, dings, scrapes, small dents and scuffing which is common due to handling during removal and insertion into the core. Ten (10) fuel elements appeared to have a damaged cladding. This ten fuel elements required to be placed in sealed failed fuel cans prior to placement in the NAC basket and cask for shipment and storage in Idaho.

## **2.2 Fuel inspection Idaho**

From August 27 till September 14, 2012, experts from the Atominstitut performed an optical inspection of very low burnt 104-types SST clad LEU elements stored at the INL. Out of a list of one hundred and twenty (120) fuel elements, seventy-seven (77) have been chosen. Seventy-five (75) FE(s) were chosen from the former TRIGA reactor in Musashi, Japan, and two (2) FE(s) from the former TRIGA reactor in Cornell, USA. Each element was visually examined over 100% of the surface through the window of a hot cell. The entire examination was recorded to DVD including a backup DVD recording. Significant scratches or dents were the main criteria to reject two FE(s) from the facility in Musashi. The average burn-up of the chosen 77 FE(s) is below 1%.

## **3 SITE ASSESSMENT**

A meeting was held at the Atominstitut Vienna facility on Friday, March 24, 2012 to discover and discuss the processes, possible methodologies and particularities of handling, unloading and loading the NAC-LWT cask at site with the irradiated TRIGA nuclear fuel inventory at the TRIGA Mark II research reactor.

The company NAC International (NAC) has been awarded a contract from the Vienna University of Technology (VUT) to perform packaging and transport of irradiated TRIGA fuel from the DOE's Idaho National Laboratory (INL) to the Atominstitut Vienna. There to exchange this fuel with the spent fuel inventory currently at the Atominstitut Vienna and to package and transport the spent fuel to INL.

During this site assessment, the outside work area where all the NAC equipment had to be placed and the existing infrastructure outside the building was evaluated. As an output of this evaluation, addition external light was installed to guarantee compressed air during the fuel exchange an external diesel-powered compressor was rented. The outside door was found to be large enough to accommodate the movement of the NAC Intermediate Transfer System (ITS) container through a standard 5 to 10 ton fork lift. The assessment of the inside work area revealed that there is enough floor space and that the ground floor is adequate for handling the load of the fork lift. The capacity of the crane and the 7.7 m of height clearance

from crane full up to the reactor platform also fulfilled all requirements. Afterwards the reactor and the fuel storage racks were inspected. All the necessary criteria like water clarity, water purification, water radioactivity and working space were reached. To handle and load the 10 damaged FE(s) a shielding with concrete blocks and a working procedure was developed. At the end of the assessment a detailed list of additional infrastructure supplied by the institute and an assignment of skills between the institute and NAC was developed.

The following support equipment and plant services were defined to guarantee the cask loading.

To be supplied by TU Wien:

- Two 2-man scissor lifts to support cask operations outside
- Large 10 ton fork lift
- 80 ton (minimum) mobile crane
- 3 -5 ton fork lift
- Electrical service (220 VAC, 50 Hz)
- Electrical power extension cords and plug adapters
- Electrical connection for NAC electric chain hoist, 380 VAC, 3 phase
- Clean compressed air (100 psig, 80 cfm) available outside at cask loading area
- Helium gas, Grade 4 minimum (99.99%) with high/low pressure regulator
- De-min water
- Shield cave for loading and testing of TRIGA Sealed Failed Fuel Cans
- Plastic sheeting and bags
- Decontamination materials
- RAD waste disposal
- Four bags of clean sand to assist with cask base plate leveling
- Site approved solvent (i.e. denatured alcohol) to clean the cask seal area

Skill sets needed:

- Security – TU Wien
- Rad Protection - TU Wien
- Reactor Operators – TU Wien
- Crane operator and fork lift operator - TU Wien
- Transportation Specialists – NAC
- Certified Cask Operators – NAC
- Helium Leak Test Examiner – NAC

Afterwards, a detailed project plan covering the project description, the participating organizations, the project interfaces, the quality assurance, the project administration and the task plans were developed by NAC. To control the progress and to avoid possible delays a punch list was developed. During a weekly telephone conference with all the participating organizations, the progress punch list and the on-going progress was discussed.

After all this information a detailed working procedure for the fuel exchange was developed by the Atominstitut. This working procedure was evaluated and approved by the Regulatory Body. After the project was finished, a detailed radiation protection report for the exchange of the reactor core at the TRIGA research reactor in Vienna was submitted to the government.

#### **4 ADMINISTRATIVE PREPARATIONS**

The Vienna University of Technology (VUT), as the owner of the fuel, signed two contracts. One contract covered the supply of the new fuel, and the other one covered the shipment of the 91 spent fuel elements plus one Pu-Be neutron source. Beside the DOE and the VUT also the European Supply Agency (ESA) had to sign the contracts.

Beside the agreement of the ESA concerning the content of the two contracts, Euratom had to be informed by the Federal Ministry of Science and Research. The **Council Directive 2006/117/Euratom** of November 20, 2006 on the supervision and control of shipments of radioactive waste and spent fuel, covers shipments of radioactive waste or spent fuel which have a point of departure, transit or destination in an EU Member State if the quantity or concentration are over certain limits fixed by Directive 96/29/Euratom, Article 3(2)(a) and (b). After the process was finished, the Ministry issued the license to the University to ship back the spent fuel and the source to the United States.

In parallel, the Euratom safeguard division was informed about the physical inventory leaving and entering Austria with Annex VI and Annex VII reports using the enmas light format.

- The Federal Ministry of Economy, Family and Youth had to issue an export license for components with dual use.
- The Federal Ministry for Transport, Innovation and Technology had to validate the NAC-LWT cask for the use in Austria.
- The Federal Ministry of Interior had to issue a license to cover the additional amount of U-235 stored at the institute during the time of the fuel exchange. This license forced the institute to increase the physical protection during this time.

To get the authorization to ship the fuel from Vienna, Austria, to the INL, Required Shippers Data (RSD) forms 434.28, 434.28A and 434.28B had to be submitted to the project manager of the INTEC fuel group. In addition, the form 434.30, the proposed shipment content (PSC) has to be submitted.

The shipment of the Atominstitut Vienna fuel was joined with irradiated nuclear material from Italy in the Adriatic Sea. As a result, additional documents for the Italian authorities concerning the spent fuel composition had to be prepared as well as coordination with the Slovenian authorities to use a Slovenian ocean port. To fulfil the requirements of the Slovenian authorities, additional nuclear liability insurance during the cargo transits Slovenian territory was put into force.

## 5 FUEL EXCHANGE

The fuel exchange was performed based on standard procedures developed by NAC during the last years. For the transportation of fuel on the road and over sea the NAC-LWT cask was used. This cask with a weight of 22.4 tons, could host up to 120 TRIGA fuel elements in 5 fuel baskets. The transfer of the 5 fuel baskets was performed using the NAC-LWT Dry Transfer System (DTS). The DTS was connected with a shield gate adapter to the LWT cask. The handling of the DTS was performed with a 120 t crane. To transfer the fuel in the reactor pool an ITS with an inner and outer shield was used. The transfer of the inner shield in the reactor hall was performed by a 10 t fork lift. In the reactor hall the inner shield was transferred with an overhead crane under water in the reactor pool. Once the inner shield was in the pool, the shield was opened and the fuel was transferred one by one out of the shield into the underwater storage racks.

The transfer of the spent fuel was performed the opposite way. Detailed photo documentation can be found in the corresponding presentation.

The DOE transferred title of the supplied seventy seven (77) LEU Fuel Elements to the Vienna University of Technology upon delivery. The University afterwards transferred the title of these 77 new fuel elements to Euratom in accordance with Article 86 of the Euratom-US Treaty.

## **6 TRANSPORT**

Transport of the DOE supplied LEU Fuel Elements and the irradiated HEU and LEU fuel from VUT spanned Austria, Slovenia, Italy, the global commons over international waters and the United States. Appropriate transportation and security plans were developed and implemented. The ground transport was carried out with appropriate transport companies and with significant security management and oversight. Security responsibility transition between security forces was well managed and occurred seamlessly. In addition to the security management provided by the ocean-going vessel, the Italian government maintained security surveillance of the vessel during its transit in the Adriatic Sea. Then the U.S. Coast Guard provides security escort when the vessel is in or near U.S. territorial waters.

## **ACKNOWLEDGMENTS**

The authors wish to thank the Federal Ministry of Science and Research, the Federal Ministry for European and International Affairs, the Federal Ministry of Economy, Family and Youth, the Federal Ministry for Transport, Innovation and Technology, the Federal Ministry of Interior, the Department of Energy and the IAEA for the continues support during the whole project. This project would not have been possible without the professional support of NAC International, Nuclear Cargo Service GmbH, Edlow International and all the colleagues at the Idaho National Laboratory as well as at the Atominstitut.