# Transactions

## RRFM 2009

Vienna, Austria
22 -25 March 2009

IAEA
International Atomic Energy Agency

ATOMINSTITUT

TU WIEN

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ISBN 978-92-95064-07-2

These transactions contain all contributions submitted by 20 March 2009.

# KEEPING AGING RESEARCH REACTORS IN GOOD SHAPE

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## ABSTRACT

During the 47 years of reactor operation of the TRIGA Mark II reactor Vienna many highly specialized maintenance and inspection methods have been developed which in several cases have been acquired by other research reactors. Further in some cases the TRIGA Vienna team plus equipment was rented for up to two weeks to carry out i.e. reactor tank, cleaning or visual inspections and documentation of tank internals or fuel elements. In addition complete systems such as pool water cleaning systems were tailored according to local needs. These services were either carried out by direct bilateral contracts between the counterpart institution and the Atominstitut or upon request of the IAEA which supported the inspection financially for low-income countries. This paper presents the experience of inspections and maintenance of several research reactors and gives some recommendations about the optimal maintenance frequency of research reactor tank internals in order to keep low power research reactors in good condition.

## 1. Introduction

The TRIGA Mark-II reactor started up initially on March 7, 1962, with a steady state power of 250 kW and with pulsing capability up to 250 MW. Within the past 47 years no major incidents occurred, however, a number of reconstructions and modifications of reactor systems were carried out. Since the implementation of the Atomic Law in the mid 1970 a detailed re-inspection plan had to be prepared covering all reactor related components and systems to be re-inspected regularly. The completed reinspection forms are controlled by a government appointed expert and are the basis for the continuation of the operating license [1].

One major issue was the renewal of the TRIGA reactor instrumentation in 1992 when the old transistor type instrumentation was replaced by a computer controlled up to date instrumentation. Since this time experience has accumulated with this digital instrumentation which will be presented in this paper.

Another important task is the periodic optical inspection of the reactor tank internals and the regular cleaning of the primary water system. Optical inspection is carried out with a rigid underwater endoscope. This is a modular optical device which allows optical inspection in any place of the reactor tank, including the fuel elements in the core. With integrated lights and various objectives, 0° foreward, 45° foreward and 90° sidewards practically all areas in the reactor tank can be inspected. This endoscope can also be used to inspect a spent fuel element in a special lead container placed in the reactor hall. The spent fuel is transferred from the reactor tank into this container and through several holes the endoscope can be inserted to view directly the fuel surface without being exposed to radiation.

Regular cleaning of tank internals in three months intervals is also very important. A high pressure water jet is used to stir up all deposits from tank surfaces and a special pump with integrated filters is used to collect the deposits.

The endoscope together with the water jet and the tank cleaning pump has been applied succesfully in several other research reactors through bilateral cooperation and assistance. In fact in one case the visual inspection and maintenance saved the operator a tedious repair work of several monthes or a possible permanent shut-down.

The fuel elements are measured with an underwater device for elongation and bowing every two years. Since 1962 out of 104 fuel elements only 8 had to be removed only one due to a cladding defect, the others due to excess elongation. A dry spent fuel storage has been developed to accommodate the removed fuel elements in a controlled atmosphere.

## 2. Special inspection and maintenance equipment

### 2.1 Underwater endoscope

The most important in-service inspection equipment is a modular underwater endoscope. It consists of seven 1 m long rigid endoscope modules which are watertight and can, therefore, be inserted directly into the reactor tank water. As the diameter of the system is only 18 mm it can practically be inserted into empty fuel element positions and allows therefore inspection inside the core volume. In many cases it can even be lowered through the lower core support plate (grid) and allows to view the volume below the core. The front end of the endoscope is equipped with an integrated lamp and several viewing angles are possible like 0°, 45° foreward, 90°, 45° backward. To the ocular standard video- or photo equipment can be connected [7-9].

### 2.2 High-pressure water jet

To clean the tank and the core structures from debris a compressor is used producing a water jet which can be regulated up to 100 bar pressure. The water is taken directly from the tank, compressed and ejected through various types of nozzles (flat, rotary, point direction) to the surfaces to be cleaned. Using a special small nozzle the water jet can be introduced directly into the core volume between top and bottom grid.

### 2.3 Tank cleaning pump

While the high pressure jet is used, an additional tank cleaning pump is operating with several stages of gross and fine filters. The pump inlet tube is directed to the area of highest debris. All materials are collected in the filters and the cleaned water is returned into the tank. The overall cleaning of a typical TRIGA tank with a typical amount of stirred-up debris takes about 24 hours. During a recent tank inspection a number of washers, screws and metal pieces were removed, some of them with a dose rate up to 0.1 Sv/h (10 rem/h).

### 2.4 Pick-up tool

To pick up flat or fine objects from the tank bottom (such as coins, washers, buttons) a special pick-up tool was developed at the Atominstitut which acts on a string-and-pull system. The tool is so small that it can be transported in a shoe box. It can pick up items from as far as 10 m below the water surface.

The above mentioned equipment (endoscope, water jet, tank cleaning pump) can easily be transported to any reactor station in Europe with costs of approximately € 1000.-- round trip on road. If the more bulky high pressure water jet pump and the tank cleaning pump are omitted, the endoscope itself can even be shipped by ordinary mail or transported in a passenger car.

All components and systems are re-inspected following an elaborate re-inspection program [2]. This consumes about 4 man-days per month. Once a year all the reactor systems are inspected in presence of an expert nominated by the regulatory body and his expertise is the basis for the annual renewal of the operation license valid again for the coming year. This annual inspection requires approximately 1 man-month (four persons for two weeks). Some of the inspection methods have been successfully applied in other TRIGA reactors [3-6].

## 3. Recent applications of the endoscope in European research reactors

Pavia, Italy: Upon request of the 250 kW TRIGA reactor in Pavia, the equipment was used to, identify damaged core installations such as the regulating rod guide tube fitting to the lower grid plate and a deformed central irradiation tube (details see below).

Munich, Germany: The endoscope was used to identify a leak in the primary coolant pipe of the 4 MW MTR type reactor and helped to supervise and control its repair.

Imperial College, UK: The endoscope was used during a general inspection and clean-up of the 100 kW CONSORT reactor.

Rome, Italy: Upon request from ENEA a contract was signed between ENEA/Rome, Italy, and the Atominstitut/Vienna, Austria, to carry out the following tasks

- Visual inspection of the TRIGA RC-1 tank
- Maintenance and cleaning of the reactor using special tools
- Removal of objects found during inspection
- Preparation of a final report

Kinshasa, Democratic Republic of the Congo: Visual inspection and verification of the spent fuel of the TRIGA-I facility, CREN-K upon request from the IAEA.

Before the start of visual inspection, the operations staff from the TRIGA-I facility was able to start and operate the mobile purification system supplied by the IAEA one year ago. It was then possible to clean the pool water of the TRIGA-1 facility. After one hour of purification system there was a visible improvement in the water clarity due to a decrease in turbidity. The operation staff of the counterpart then began to clean up small objects and debris from the bottom of the reactor tank and the three fuel storage racks. It should be noted that the reactor 'tank' of the TRIGA-1 consisted of a poured concrete circular wall and base. The visible condition of the concrete walls and base appeared to be excellent.

As the inspection equipment with the underwater endoscope had not been delivered from the customs office by the beginning of the mission, a different approach to inspect and identify the fuel elements stored in the pool of the TRIGA-1 facility was tried. Together with the operation staff from TRIGA-I facility each fuel element was individually lifted about 1-2 m with the fuel element handling tool and transferred into an aluminum bucket. The fuel element and bucket assembly was then raised to an elevation where the top of the fuel element was just below the water surface of the TRIGA-1 pool. The fuel element and aluminum bucket assembly was then rotated until a handheld digital camera picture of the serial number could be taken, see figure 1.

As all the elements, except one, had the number written up side, the identification could only be done afterwards on the screen of the digital camera by rotating the picture. After this was done the surface of the corresponding fuel element was visibly viewed, by lowering the aluminum bucket beneath the fuel element. A picture of the fuel element was then taken, see figure 2.

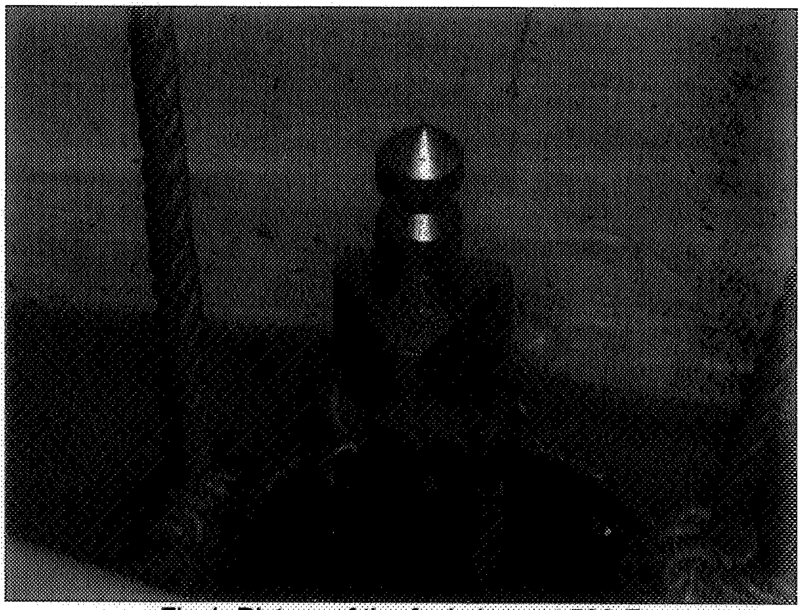

Fig 1. Picture of the fuel element 539 E

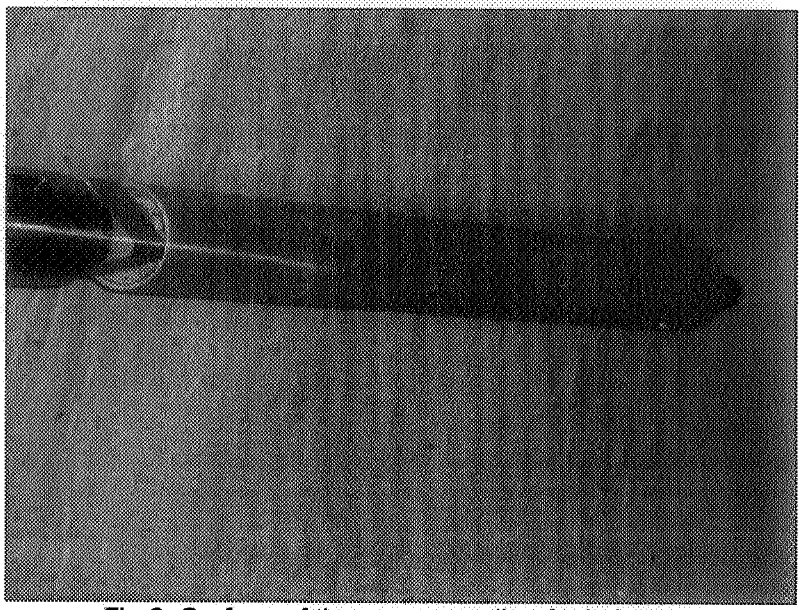

Fig 2. Surface of the corresponding fuel element

Gamma radiation levels were then measured at a fixed distance, about 50 cm, from every fuel element. These measurements then provided a crude measure of relative burn-up of the elements. No previous information on element burn up was available. Each fuel element was then transferred back into a storage rack position at the bottom of the pool. The elements were replaced into their original rack storage locations unless reinsertion proved difficult.

All of the R2 fuel elements were in good condition, with no visible corrosion spots or mechanical damage. Some elements had a visible black or white discoloration at the axial interface locations between the fuel and the top and bottom axial graphite slugs. The discolorations are normal and are attributed to the heat flux variations of the aluminum cladding at these interfaces. No corrosion or mechanical defects of the cladding were observed. Every fuel element was verified to be in excellent condition with no evidence of any mechanical deformation or defect.

After the inspection was finished, several screws, wires and electrical insulation material, from the former control rod drives, were removed from the bottom of the pool with the pick-up tool.

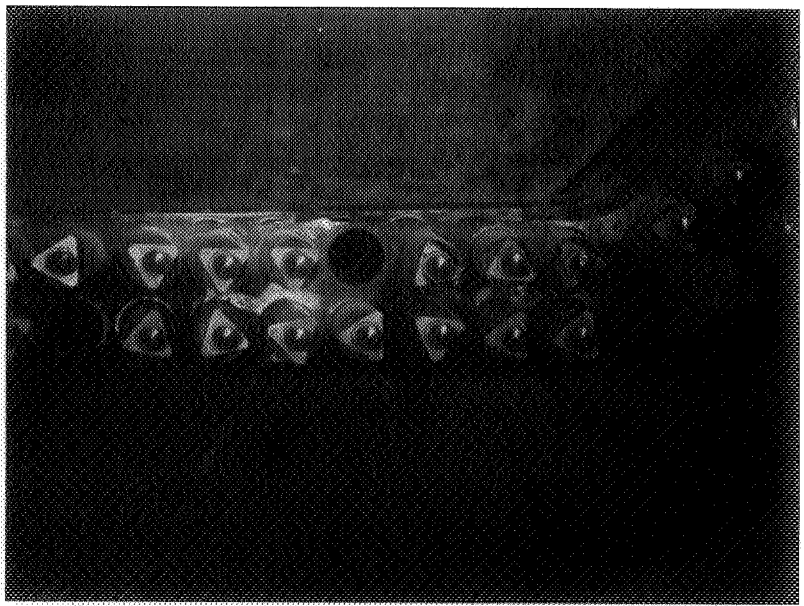

Fig 3. Storage racks located at the bottom of the pool

## 4. Conclusions

It is obvious that careful maintenance and periodic in-service inspections of the research reactor components have a positive influence on the technical state of the reactor and may extend its lifetime considerably. Reactor facility life extension is best accomplished by establishing and completing a maintenance program at an early stage in the facility's operation. However, high quality routine maintenance of all reactor safety systems and operation within the established technical specifications is also essential to ensure the safety of the reactor and the public. During the past 47 years maintenance and inspection methods have constantly improved and new methods with digital systems have been developed. Together with an elaborated in-service inspection program the TRIGA reactor Vienna and all the other low power reactors around the world could be kept in excellent technical state without any major ageing effects. It is hoped that this facility will "still be going strong" for many more years.

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