PERIODIC SAFETY REVIEW OF JSI TRIGA MARKII AND INSPECTION OF THE REACTOR

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ABSTRACT

Slovenian TRIGA Mark II reactor is in operation since 1966. Nuclear components are under strict supervision of operators and safety authorities. The Reactor Infrastructure Centre of the Jožef Stefan Institute decided to make an inspection of its TRIGA Mark II research reactor to verify the conditions for long-term future operation within the on-going periodic safety review.

1. Introduction

Almost every piece of industrial equipment has a projected life-time from the very beginning of its operation. The life-time is normally defined on the basis of operational experience and is always determined in a conservative manner. On one hand, poor maintenance shortens the life-time and on the other hand, good maintenance and good operation can prolong the predicted period of individual component operability. Very important facts are also received from new research results in the field of aging of different materials.

Nuclear components are under strict supervision of operators and safety authorities. The Reactor Centre of the Jožef Stefan Institute (JSI) decided to make an inspection of its TRIGA Mark II research reactor to verify the conditions for long-term future operation within the on-going periodic safety review (PSR). Main information for PSR comes from the in-service inspection. In-service inspection contains a program of examinations, testing, and inspections to prove adequate safety and to manage deterioration and aging effects [1].

The inspection of the reactor tank was planned to be performed within the PSR from the beginning as the reactor tank is critical for normal and safe operation of the reactor. In addition it is the structure that is the most difficult to replace. The tank is made of aluminium and holds de-mineralized water under normal pressure at temperatures below 37 °C. It was not expected to be significantly degraded or corroded. In order to verify this assumption, the operator decided to perform detailed inspection of the reactor tank wall. Q Techna d.o.o. was selected to perform the task; mainly due to professional references on other similar nuclear installations (e.g. inspection of the nuclear power plant (NPP) Krško spent fuel pool).

Two main inspection methods were used: ultrasonic and visual inspection. Ultrasonic inspection was selected to prove that there is no significant reduction of wall thickness anywhere in the tank. Detailed visual inspection confirmed that there are no visually detectable defects like cracks or any other unacceptable surface defects. The main challenge of the inspection was that it had to be done under water from the inner side of the tank and, especially at the bottom of the tank, very close to a strong source of radiation, as the core was not removed during inspection. The challenge was met by selection and professional use of appropriate equipment and techniques.

The purpose of the PSR is to systematically review ageing effects, effects of various changes in the facility, operating experience, new developments in the field, changes in characteristics of the reactor site and all other possible effects on nuclear and radiation safety. In addition it should be proved that the reactor facility is still compliant with the newest safety standards, legislation and international recommendations. All this is needed to confirm that the reactor is at least as safe as at the beginning of operation and that it is capable of future safe operation.

The PSR programme of the JSI TRIGA reactor was prepared in compliance with the valid Slovenian legislation [2], practical guidelines prepared by the Slovenian Nuclear Safety Authority (SNSA) [3] and with the IAEA guidelines for the review of the research reactor safety [4]. In addition we used IAEA safety standards [5], [6] and [7]. The programme was approved by the SNSA in November 2011. The reference date was determined to be January 1st 2011. The estimated duration of the PSR was three years and the financial costs were estimated to 700,000 €. The most important task within the PSR was the inspection of the reactor tank, as it had never been inspected before. In addition this component is critical as it is the one which cannot be replaced easily.

Every 6 moths report has to be made where our progress is described. These reports are sent to the SNSA. In addition thematic reports have to be made where is described how each topic was examined in detail and, where all important findings are described. Reports are sent to the SNSA, where they are reviewed. The PSR started in 2011 and it is planned be completed by May 2014. In October 2012 an IAEA INSARR mission took place at the reactor to support our efforts in performing the PSR.

As the PSR is not complete yet, this paper focuses on the most important component, the reactor tank, which had already been thoroughly inspected.

3. Inspection of the reactor vessel

The TRIGA Mark II research reactor at the JSI in Ljubljana, Slovenia was built in 1962-1966 and achieved first criticality on 31st of May 1966. It is a pool-type light water reactor with an annular graphite reflector and cooling by natural convection. The side view of the reactor is shown in Fig 1.

It is of essential importance to know and understand the construction of the TRIGA reactor when performing a PSR. This is the basis for evaluation of possible problems that could occur during the operation. The reactor is an open cylindrical vessel with a flat bottom end. It is 6252 mm high and 1982 mm in diameter. It is made from aluminium alloy 5052 H34. The minimum thickness of the vessel is 6.35mm. It was welded with fusion welding. All welds were inspected with radiographic examination (RT), with liquid penetrates and with bubble tests. The vessel as a whole was tested with a pressure test. The reactor is not stamped but it fulfils applicable portions of ASME Boiler & Pressure Vessel Code Section VIII requirements. The reactor tank during the construction is shown in Fig 2.

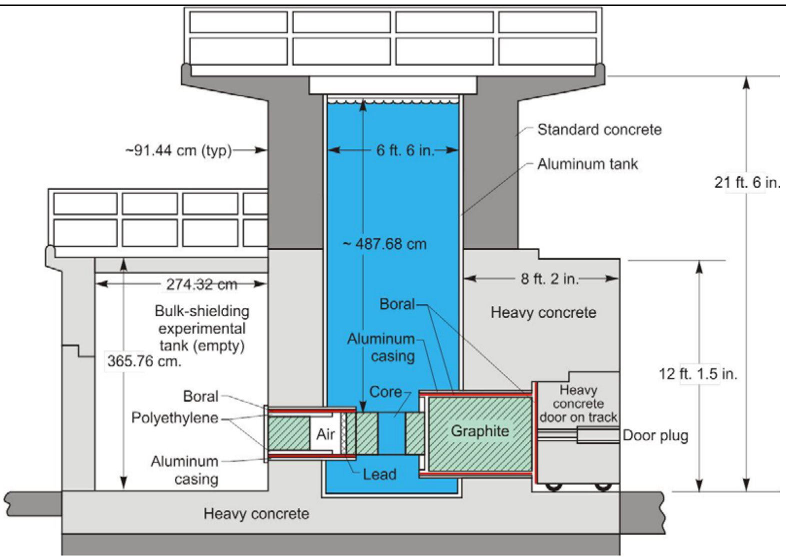

Fig 1. Side view of the TRIGA reactor.

Fig 2 Photo of the TRIGA reactor tank during the construction.

3.1 Analyses of possible degradation processes

De-mineralized water has been used as the reactor coolant and for radiation protection since the very beginning. Aluminium alloys are resistant to this fluid and from design point of view corrosion was not expected. But during the operation unexpected situation could occur like: an unintended change in water chemistry or contact with some other metals like stainless steel. These could provoke galvanic corrosion which is many times connected with submerged and embedded structures. In the case of the TRIGA reactor we have both situations. Since the structure is visible from the inner side larger degradation processes could be seen from the platform. Much more problematic is the embedded side. Galvanic corrosion is a local corrosion and could occur on a very small area that is not accessible or it is hidden. A typical area is the bottom of the reactor from the inner side, where a support construction for the reactor core is located.

Special emphasis always has to be put on welds. Aluminium alloy 5052 H34, or with ISO designation AlMg2.5, contains 2.5% of magnesium as a principal alloying element. Such a material has good weldability. Since the welds were examined by RT during construction it is presumed that there are no unacceptable volumetric irregularities in the welds. But despite this aluminium is sensitive to lack of fusion which cannot always be detected with RT. Welds have different structure as a base material; residual stresses, irregularities and discontinuities etc., are present. For that reason degradation processes like cracks could occur in welds or in the heat affected zone.

3.2 Inspection Methods

On the basis of analyses of possible degradation processes an inspection plan and scope of inspection was defined. It was foreseen that two main methods would be used:

- Visual inspection
- Ultrasonic inspection

Detailed visual inspection of all inner surfaces was performed. This included base materials, welds, bolting materials and surfaces of other internal components. The main purpose of this inspection was to detect possible degradation processes like corrosion, cracks and mechanical deformations.

Ultrasonic inspection gives information about processes from the outer side. If the wall thickness is not different from at the time of construction, this indicates well, that there are no corrosion processes from the outside. It is of essential importance that scanning is detailed enough, i.e. measuring points are not more than 500 mm apart.

3.3 Visual Inspection

In the case of the TRIGA reactor it was obvious that only remote visual inspection could be applicable. The reactor is filled with water continuously. For this reason it was decided to use a special underwater camera that could be used also very close to sources of radiation like fuel elements. For such an application charge coupled device (CCD) cameras could not be used. Radiation resistant Camera Mirion Technologies IST-REES R90 MK 3 CCU was used (Fig 3). It has built in an additional source of illumination. There was a requirement that at least 95 % of the tank have to be examined. At the end of the inspection, due to the convenient manipulator of the camera, 99 % of the inner surfaces were examined [8].

During the inspection no degradation processes like cracks or major corrosion areas were observed. There were also no other indications like mechanical damage due to the fall of heavy loads or collision with a sharp hard object. On the bottom of vessel some small foreign material and small local corroded areas were observed. It is assumed that corrosion areas appeared from foreign material which had been removed from vessel in the past.

All sections and positions were marked on recordings. This permits traceability for this inspection and also a possibility to compare recordings with new ones recorded in the future.

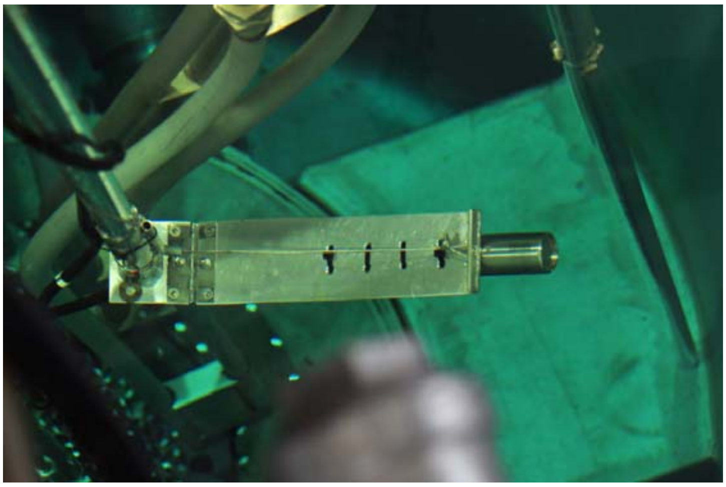

Fig 3 Camera Mirion Technologies IST-REES R90 MK 3 CCU for visual inspection.

3.4 Ultrasonic inspection

Ultrasonic inspection was used as an additional method for visual inspection. If during the visual inspection, critical areas would be found, they would be further investigated by ultrasonic method. That was not necessary in our case.

A plan was made. Thickness of the reactor tank was measured along eight vertical lines which were approximately 45° apart. Measuring points along vertical lines were between 30 and 50 cm apart. On each line, 13 measurements were performed. It was planned to measure the thickness of the bottom at 32 measuring point. Only 24 of them were accessible because of the thermal column [8].

Once again, special ultrasonic probe had to be used. Probe and all connections have to be water tight (Fig 4). Probe should not be in the contact with the aluminium tank. Distance between must be maintained constant.

Before the tank inspection, whole equipment was tested and calibrated in laboratory with identical aluminium that was used for the vessel construction.

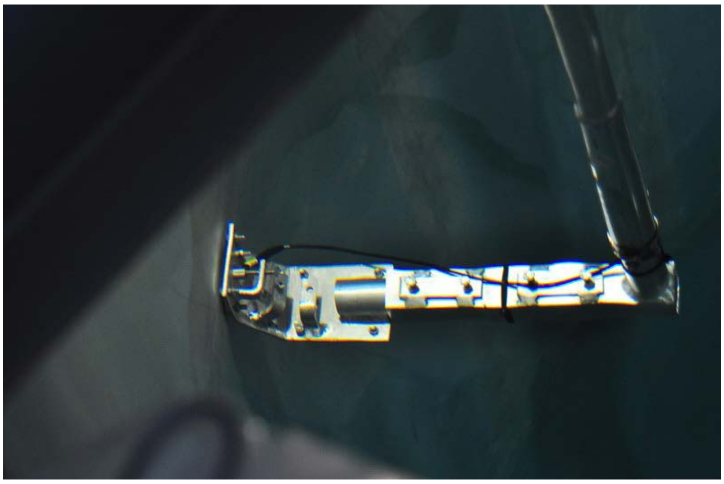

Fig 4 Ultrasonic probe K5K with 5 mm vibrator in diameter and a nominally frequency 5MHz.

Measured thickness of the wall is between 5.6 and 6.7 mm. Tank is the thinnest at the bottom. However, thickness of the aluminium is sufficient for further operation. Thickness of the bottom part is between 5.8 and 6.5 mm. The original thickness of the tank was 6.5 mm.

4. Conclusion

During PSR all systems structures and components have to be carefully checked. Reactor tank is one of the most crucial parts of the reactor. An appropriate method for visual and ultrasonic testing of the JSI TRIGA Mark II reactor vessel was successfully developed and applied. Visually the vessel is in good condition, and there were also no indications that wall thickness has diminished. All inspections performed show that there are no significant degradation processes taking place in the reactor tank. Such inspections will be performed every 10 years in the future.

5. References

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