MOROCCAN TRIGA MARK II RESEARCH REACTOR UTILIZATION

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1. BRIEF HISTORY & DESCRIPTION

The TRIGA Mark II research reactor of Morocco is part of the National Center of Energy Sciences and Nuclear Techniques (CNESTEN). The reactor is covered by the Project and Supply Agreement INFCIRC/313, January 1984, between the Kingdom of Morocco, the United States of America and the International Atomic Energy Agency (IAEA). It is a standard TRIGA reactor design that operates at 2 MWth with natural convection- cooling with a graphite reflector, contains in-core and ex-core irradiation facilities including a thermal column and four beamports, three radial and one tangential.

The core is located near the bottom of a water-filled aluminum tank which is 2.5 m in diameter and approximately 8.8 m deep. The water provides adequate shielding for a person standing at the top of the reactor. The control of the reactor is assured by five independent (B_4C) control rods, controlled from stepping motor driven rack-and-pinion drives mounted at the top of the tank on a bridge structure. The reactor uses General Atomics' (GA) solid, homogenous fuel-moderator elements ($UZrH_{1.6}$) that are routinely used at all TRIGA-type reactors. The fuel uses low-enriched uranium, enriched to 19.75 wt% in U-235. The reactor is currently fueled with standard 8.5 and 12 wt%U $UZrH_{1.6}$ fuel assemblies. Future reload fuel could utilize the higher density UZrH-Er fuels to achieve longer core life. Figure 1a shows an overall view of the TRIGA reactor structures and key systems. A unique feature of this particular TRIGA design and construction however, is the built in structures to allow a future upgrade to a forced downflow cooled for operation up to 3 MWth.

The reactor reached initial criticality on 2^{nd} May of 2007. The commissioning program culminated with the successful completion of full power endurance testing on 6^{th} September, 2007 [1]. The operating license was given by the Ministry of Energy and Mines (Safety Authority) in February 2009.

The reactor building (Figure 1b) houses the reactor confinement and beam hall, balance of plant systems and laboratories. Additional buildings for housing staff offices and laboratories like Neutron Activation Analysis laboratory, Life Sciences laboratory and Material Sciences Laboratory were also constructed at the CNESTEN site located in the La Maamora forest near the town of Kenitra, Morocco.

FIG. 1a. CNESTEN TRIGA Mark II Reactor.

FIG. 1b. CNESTEN TRIGA Mark II Reactor Building and Associated Laboratories.

2. CURRENT STATUS

There are currently 9 persons forming CNESTEN's reactor operations unit staff: the reactor manager, a safety engineer, an experiment manager, a quality assurance and maintenance manager, one shift supervisor, 2 reactor operators and 2 technicians. The reactor manager and the experiment manager are also licensed to operate the reactor.

The reactor is operated to meet the demands of experimental programs and service work. The major demands received are for instrumental activation analysis to quantify the different elements present in samples derived from mines at the national level.

A project has been developed recently with Saint Etienne University (France) to irradiate optical fibers. The purpose is to study the fiber optic property changes under irradiation in a TRIGA environment. Previous irradiations have been done in the rotary rack and reached 22 MWh irradiation time. To optimize the reactor utilization, an empty position in the outer ring of the core will be used for the upcoming irradiations. This position will be equipped in the near future with a special aluminum device to facilitate the insertion and the removal of samples.

For establishing a program for the routine production of radioisotopes, numerous hot commissioning tests have been performed in order to validate the overall processes related to establishing production of Iodine-131. At least 5 irradiation cycles have been done in varying independently power, irradiation times and target masses. During each test, the whole process has been assessed in order to define the weaknesses and improve the production processes. The assessment included target preparation, insertion, irradiation, removal of target, transfer of the irradiated sample, and the post irradiation processes.

In addition to these, the reactor supports educational programs for institutions which are not able to conduct their own full fledge programs for education in nuclear science and engineering, and which is not limited to Moroccan Universities. CNESTEN's program is used for classes in nuclear engineering at both the graduate and undergraduate levels to demonstrate numerous principles that have been presented in the classroom. Also, shorter-term demonstration experiments and practical courses are performed especially for master's students.

To date, the experiments that can be performed around the reactor for E&T use the instrumentation that was given by the reactor supplier and constructor. These experiments are listed below:

1. Reactor start up:
    - Reactor control (operation modes);
    - Reactor stabilization at different power levels;
    - Excess reactivity and Shutdown margin measurements.
2. Reactivity effects:
    - Fuel elements worth;
    - Graphite elements worth;
    - Impact on reactivity of some materials.
3. Control rod worth measurement:
    - Positive period method;
    - Rod drop method.
4. Reactor dynamics:

- Void effect & coefficient;
- Temperature effect & coefficient.

5. Thermal power measurement:
    - Calorimetric method;
    - Ballistic method.

6. Neutron flux measurement:
    - Foils activation.

3. APPLICATION AND UTILIZATION EXAMPLES

Under the law that created the institution of CNESTEN, the reactor’s to effectively implement the various fields of basic nuclear research, training and production of radioisotopes for their use in agriculture, industry and medicine. To fulfill these objectives the reactor is equipped with a variety of irradiation facilities providing a wide range of neutron flux levels and neutron flux qualities, which are sufficient to meet the needs of most users, such as:

- The pneumatic transfer facility enables samples to be inserted and removed from a remotely located laboratory to an outer core position in a few seconds. Consequently, this facility is normally used for neutron activation analysis involving short-lived radionuclides.
- The central thimble facility which consists of an aluminium tube is located at the core centre and used mainly for radioisotope production.
- Three in-core irradiation positions designed to interchangeably use fuel elements or remove them to insert large experiments in high-flux regions of the core.
- A Rotary Specimen Rack (RSR), located at the edge of the active core in the inside part of the graphite reflector, is used for much longer irradiation of samples (e.g. hours). The RSR consists of a circular array of 40 tubular positions, each of which can hold two sample tubes vertically. The rotation of the rack ensures that each sample will receive a uniform neutron flux during irradiation.
- The reactor's thermal column consists of a large stack of graphite blocks which slow down neutrons from the reactor core in order to increase thermal neutron activation of samples. Graphite blocks can be removed from the thermal column to enable samples to be positioned inside the column for irradiation.
- The four beam ports, which are tubular penetrations from the core through the tank, and in the reactor's main concrete shield, and which enable neutron and gamma radiation to stream from the core when a beam port's shield plugs are removed.

Since the reactor was licensed, it has been used for:

- Neutron activation analysis (NAA),
- Irradiation of optical fibres in the frame of a collaboration with a French university (up to 22 MWth irradiation time),
- Training and education of students at national and international level in the frame of collaboration with Moroccan universities and also through the IAEA, (around 30 students between 2012 and 2013)
- Production of I-131 (the hot commissioning test are on-going),
- Research and development (an average of 3 international publications per year).

Additionally, the reactor receives about 200 scientific visitors per year from several governmental and non-governmental organizations, including international ones. Figures 2, 3 show the reactor irradiation facilities, and Fig. 4 gives an overview of the irradiated samples for the aim of NAA between 2010 and 2013 [2].

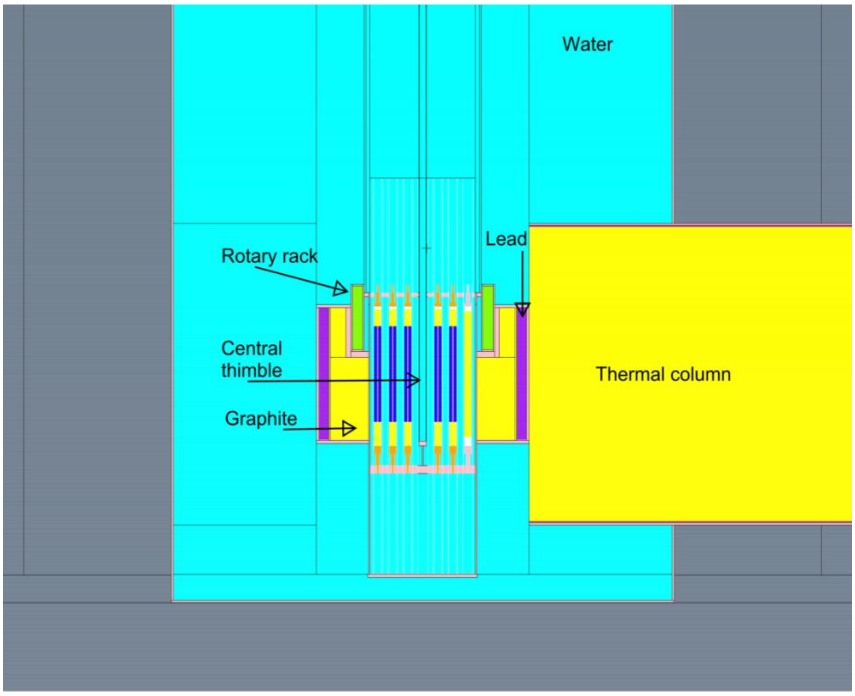


FIG. 2. In-core irradiation facilities.

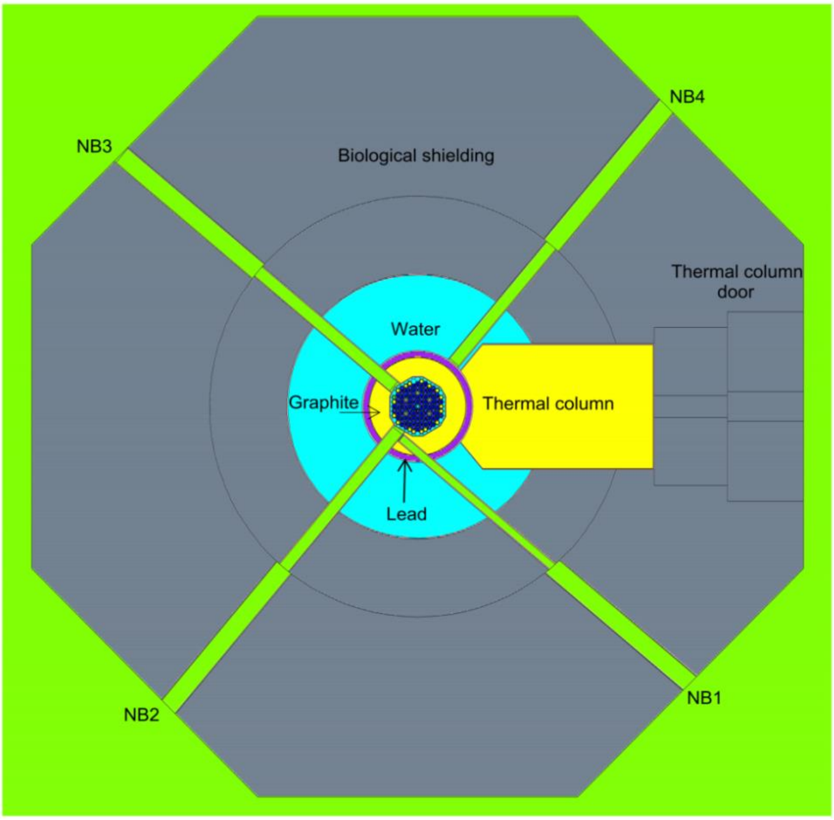
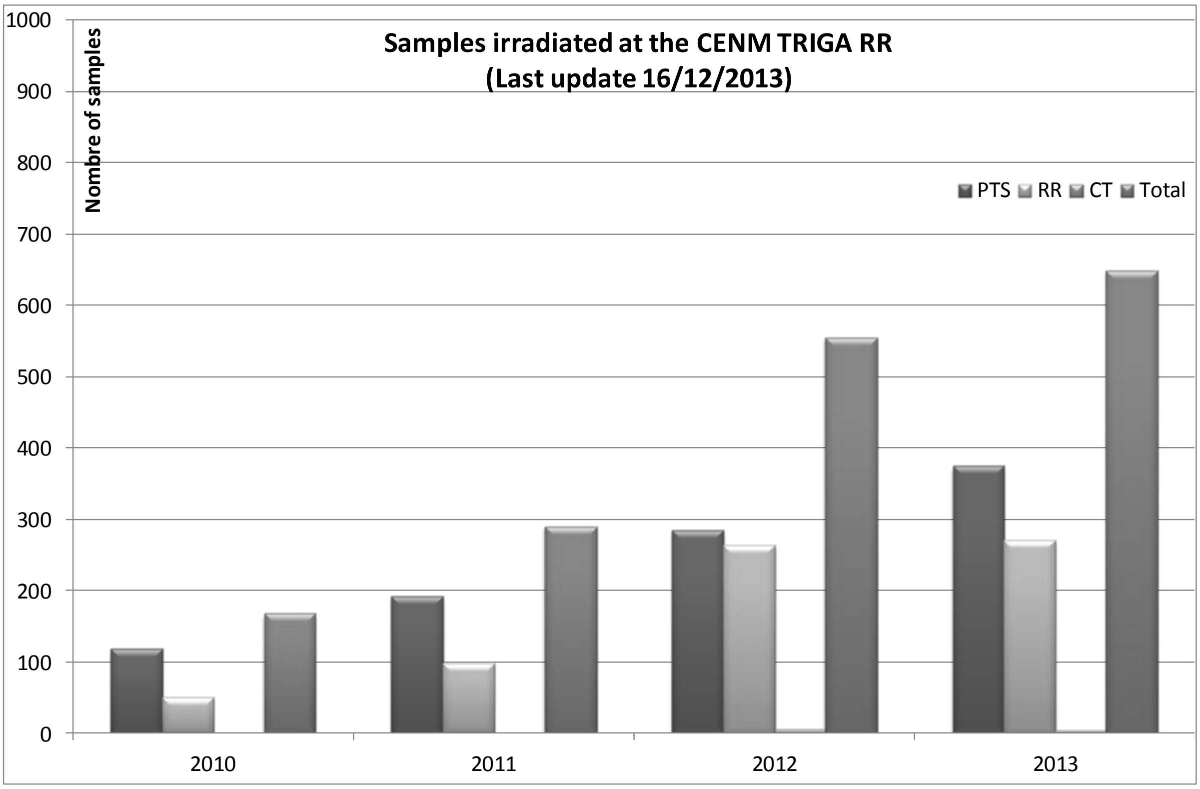


FIG. 3. Out-core irradiation facilities.



(PTS=Pneumatic Transfer System, RR= Rotary Rack, CT=Central Thimble)

FIG. 4. Overview of the irradiated samples between 2010 and 2013.

4. SUCCESS STORIES AND MAJOR ACHIEVMENTS

We believe that this TRIGA reactor has several success stories and several major achievements, the most important of which are mentioned below:

- Access and use of the reactor irradiation facilities is offered, free of charges, to countries without a research reactor. In the light of the IAEA technical meeting on "Access and Utilization of Research Reactors by non-host Member States" organized in Vienna, 10-14 October 2011, we succeeded in 2013, with IAEA assistance, to make several irradiations for some samples from Sudan. This event showed that Morocco is open to share safely its TRIGA reactor with non-host Member States.
- The organization of the International workshop on "Enhanced Use of Research Reactors for E&T Purposes", 23-29 September 2013. During this event, a number of experiments to demonstrate hands-on-training using a TRIGA Mark II research reactor have been performed and participants were allowed to operate the reactor at different power levels under the supervision of qualified Moroccan operators.

Other points that can be cited as a major achievement are:

- In addition to the inherent safety characteristics of the TRIGA reactor itself, a high level of safety awareness and safety culture characterize this facility and the reactor staff as well No safety related, significant human error incident has occurred to date both during its construction and commissioning periods. This is due principally, to the attention given by the management of CNESTEN to the safety and security of the reactor and also to the qualification and requalification program that is undertaken for the reactor staff and the instilling of a safety culture [3].

- The establishment of the reactor Management System that has been reviewed, in June 2013, by the IAEA experts in the frame of a safety review mission on the operating procedures and quality assurance for the operation phase of the TRIGA Research Reactor. This Management System met high level of satisfaction and encouragements from the experts.

5. FUTURE PROSPECTS

In the future, and as any other research reactor, we will continue to strive to: increase the utilization of this new reactor by increasing the irradiations in the frame of NAA, the start-up of iodine 131 production for commercial phase, promote the use of the reactor beam ports, increase in the number of the trainees and seek out new national and international collaboration projects dedicated to research and development. All these objectives can be considered as challenges since they require: an appropriate budget to continue to operate, maintain and upgrade the facility systems as needed, a well established marketing program and a plan for the continued long term supply of TRIGA fresh reload fuel to ensure long term operation.

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