AN OVERVIEW OF THE STRATEGIC UTILIZATION PLAN FOR THE MOROCCAN NUCLEAR RESEARCH REACTOR OVER THE PERIOD OF 2010–2015

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1. INTRODUCTION

The reactor is a standard design, 2 MW thermal power, natural convection cooled TRIGA Mark II reactor with a graphite reflector containing beam tubes and a thermal column. The reactor core is located near the bottom of a water filled aluminium tank 2.5 m in diameter and about 8.8 m deep. The reactor tank is surrounded by a massive monolithic block of reinforced heavy concrete with a density of 3.2 g/cm^3. The massive concrete structure provides radiological protection for personnel working around the reactor.

The TRIGA core is made up of 94 fuel-moderator elements, 2 temperature instrumented fuel-moderator elements, 5 fuel follower control rods, and other graphite elements. The reactor fuel is a solid, homogeneous mixture of uranium-zirconium hydride alloy with 8.5% by weight of uranium enriched to 19.9 % ^{235}U. Each reactor fuel element is encapsulated within a 0.51 mm thick stainless steel cladding. Table 1 and Figure 1 provide the basic characteristics and design of the research reactor.

TABLE 1. 2 MW TRIGA MARK II REACTOR TYPICAL NEUTRON AND GAMMA FLUXES

Location	Flux (cm^{-2}s^{-1})			
	Thermal <0.4 eV	Epithermal 0.4 eV–9.12 keV	Fast >9.12 keV	Gamma dose (rad/s)
Central thimble	4.4×10^{13}		4.0×10^{13}	
G-ring terminus	1.28×10^{13}	1.03×10^{13}	1.2×10^{13}	2.6×10^{4}
radial port (core edge)	1.12×10^{13}	7.1×10^{12}	1.0×10^{13}	2.63×10^{4}
Tangential port (core end)	1.03×10^{13}	6.4×10^{12}	9.0×10^{12}	2.5×10^{4}
Radial port at reflector edge	2.75×10^{12}	0.43×10^{12}	1.5×10^{11}	7.0×10^{2}
Rotary specimen rack	5.3×10^{12}		3.7×10^{12}	
Thermal column: (distance from outside core)				
305 mm	1.73×10^{11}	2.85×10^{9}	1.6×10^{9}	
609 mm	1.7×10^{10}	1.07×10^{10}	1.1×10^{6}	7×10^{2}
914 mm	1.7×10^{9}	4.3×10^{9}	8.2×10^{2}	

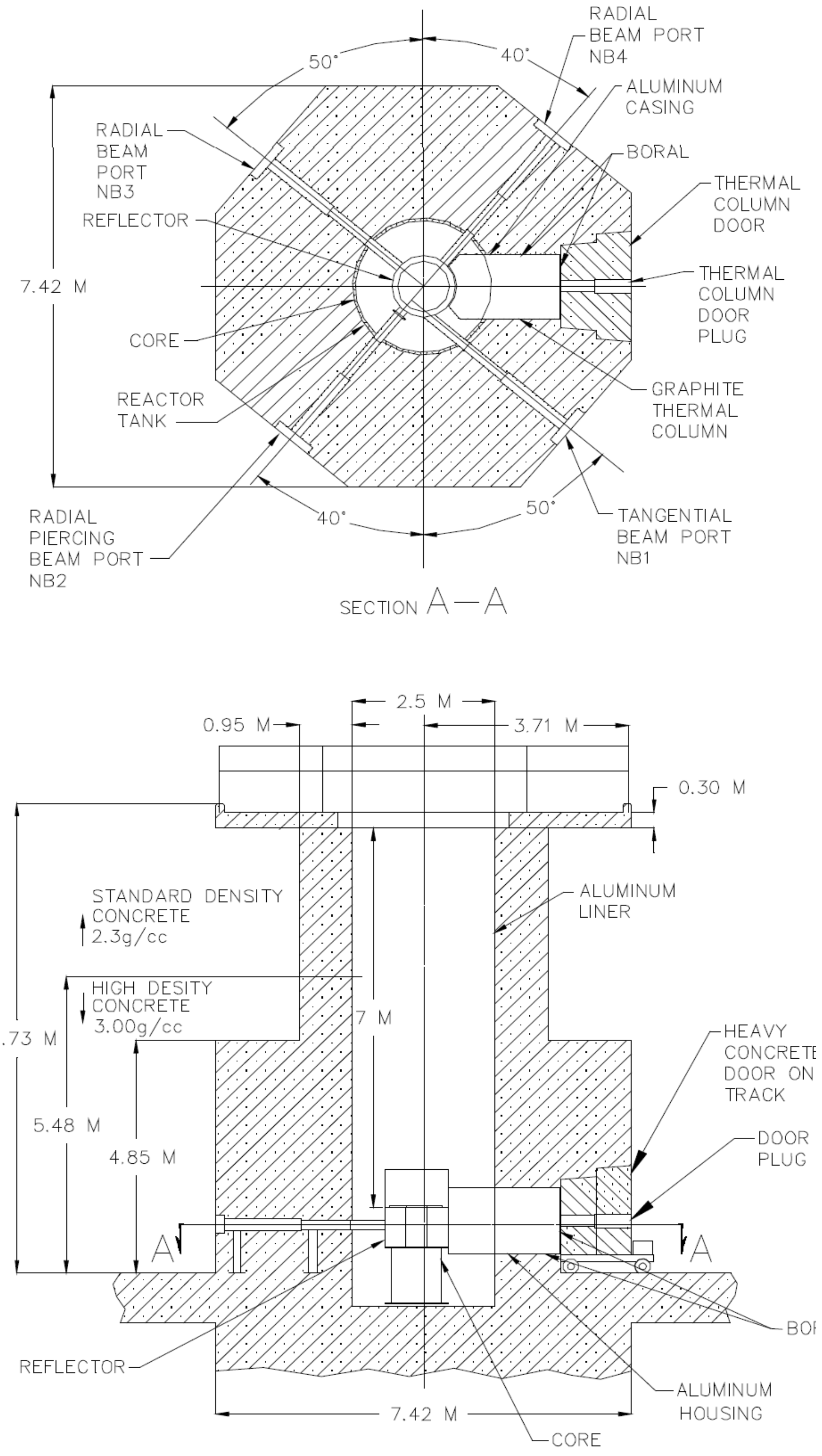

Fig. 1. General layout.

2. CAPABILITIES

The Moroccan Maâmoura Research Reactor (MMRR) is currently licensed as a 2 MW facility and has various capabilities both for fundamental as well as applied research, including industrial products and services. These can be categorized as existing and potential capabilities related both to those directly available (in-house) and support capabilities with regard to the national needs.

The utilization of the reactor for a variety of experiments and applications has already been carried out since commissioning, with the majority for irradiation coming from neutron activation analysis (NAA) experiments. Others were for the training and R&D in SANS and neutron radiography as well as isotopes for tracer studies.

2.1. Existing capabilities

The existing capabilities are NAA and radioisotopes production.

2.1.1. In-core and in-pool irradiation facilities

The reactor is equipped with a central thimble for access to the point of maximum flux in the core. The central thimble consists of an aluminum tube of 3.7 cm in its outer diameter and 3.38 cm inner diameter. A rotary, 40 multiple position specimen rack located in a well in the top of the graphite reflector provides for large scale production of radioisotopes and for activation and irradiation of multiple samples. All positions in this rack are exposed to neutron fluxes of comparable intensity. A pneumatic transfer system permits applications with short half-life radioisotopes. The in-core terminus of this system is normally located in the outer ring of fuel element positions, a region of high neutron flux. The sample capsule (rabbit) is conveyed to a receiver-sender station via 3.18 cm diameter aluminum tubing. The transfer time is 9 s for a 12 g sample.

2.1.2. Beam port facilities

There are 4 neutron beam tubes consisting of 3 radial beam ports and a tangential beam port. The inner section of each beam port is an aluminum pipe 15.2 cm in diameter. Two beam ports will be equipped with neutron diffraction techniques. A piercing radial beam port will be used for neutron powder diffraction, and SANS is a potential candidate around another radial beam port. The installation of a neutron imaging facility for computed tomography and real time neutron radiography is currently in progress around the tangential beam port.

2.1.3. Thermal column

Geochronology is planned to be also implemented.

2.1.4. Support services

The following in-house capabilities currently exist:

- Core reload management;
- Neutron and thermohydraulic computations and safety analysis;
- Reactor nuclear materials safeguards and materials accountability;
- Nuclear instrumentation including design and development;
- Primary and secondary cooling systems plus maintenance capability;

— Safety and security services:

  - Emergency preparedness, including fire brigades;
  - Radiation protection and health;
  - Industrial safety; and
  - Calibration and dosimetry and environmental monitoring.

2.2. Potential capabilities

The following capabilities are regarded as activities and services that probably could be performed at the MMRR but will require substantial resource development, specific equipment and probably power upgrading:

— Prompt neutron activation analysis;
— Neutron diffraction and small angle neutron scattering;
— Neutron radiography;
— Production of Tc-99m by irradiation of Mo-98 targets;
— Gem stone treatment coloration; and
— Neutron transmutation doping of silicon.

2.2.1. Beam port facilities

The reactor is equipped with one radial beam port

3. STAKEHOLDER NEEDS

3.1. Existing stakeholder needs

3.1.1. Government

— Regulatory body:

  - Building national capacity;
  - Acting as a TSO to the Safety Authority;

— Ministry of Higher Education and Executive Training:

  - Participation with teaching and supervision of graduate and undergraduate student projects;
  - Partnerships (mixed team, shared equipment and laboratories, etc.) with local universities and scientific institutions; and

— Ministry of Health:

  - R&D; production and supply of radiopharmaceuticals and radioisotopes; utilisation of nuclear techniques in endocrinology, infectious diseases, nutrition, etc.

Currently, there are 5 public hospitals (3 in Rabat, 2 in Casablanca) offering nuclear medicine services. In the near future, 5 other public hospitals (Marrakech, Fes, Oujda, Al Hoceima, Agadir) will include nuclear medicine services. In addition, there are more than ten private clinics that provide nuclear medicine services. The primary radiopharmaceuticals in Morocco are I-131 and Tc-99m, which is used in more than 90% of nuclear medicine procedures. It is also noteworthy that the Moroccan market is growing at a rate of 25% per annum.

- Ministry of Industry:

    - Analytical services for quality control, radiotracer applications to improve the performance of the industries;

- Ministry of Agriculture:

    - Soil analysis for fertilization and improvement of productivity, bioremediation, soil erosion and desertification phenomena, soil-plant relationship;

- Ministry of Energy, Mines, Water, and Environment:

    - Geological mapping, mineral ores analysis;
    - Environmental monitoring and pollution studies in food, water, air, soil, etc., using NAA;
    - Training and expertise in safety and security;
    - Preparation of nuclear public acceptance via seminars, reactor visits and conferences for the benefit of NGOs, students, members of civil society, etc., and

- Ministry of Culture:

    - Investigation on archaeological artifacts from museums.

3.1.2. Upper management

The foremost needs of upper management are ultimately the sustainable operation of the research reactor, justification of its national relevance and visibility on a national and regional scale, which can be accomplished by:

- Undertaking research and analysis for:

    - Multi-elemental analyses of samples of diverse materials and characterization of finished products
    - Geochemical mapping and mineral exploration
    - Soil fertility studies and soil mapping for improved agricultural practices
    - Environmental studies for baseline data generation and pollution assessment
    - Food nutrition and health studies
    - Pollution assessments;

- Production and application of radiotracers for mining, petrochemical and agricultural industries, and hydrological studies; and
- Research and development in nuclear and reactor physics, nuclear engineering, radiation shielding, nuclear waste management and nuclear energy for power generation.

3.1.3. Academic institutions

The research reactors serves to reinforce existing partnerships with universities and scientific institutions through research, educational and training programs in nuclear science and technology and to host and supervise undergraduate and graduate student projects and research theses.

At this point, CNESTEN has already agreements with all Moroccan universities (Rabat, Casablanca, Meknes, Fes, Marrakech, Tetouan, Kenitra, Oujda, Agadir, and others) in three major areas: Education and training, supervision of undergraduate and graduate student projects and research thesis, and common R&D projects at national and international levels.

3.1.4. Commercial clients

The main services and products are provided to:

- Hospitals and nuclear medicine services;
- Aircraft industry;
- Phosphate, petroleum ,wood, car industries;
- Electronics industry; and
- Mining industry.

Services may include training, certification, dosimetry, process assessment, NAA, neutron radiography, among others. Products may include radiopharmaceuticals and radioisotopes.

3.1.5. Public

CNESTEN can contribute to public debate by serving as a source of information on the safe use of nuclear energy and applications.

3.1.6. International cooperation

A priority for CNESTEN is the development of a wide cooperation network, including sister laboratories, common research projects, events organization and training. The concerned countries are the US, France, Spain, Belgium and Arabic and African countries.

3.2. **Potential stakeholder needs**

3.2.1. Expansion of isotope production scope and capacity

During the short term, Iodine-131 is a priority. In the longer run, other isotopes will be produced such as Tc-99m, Sm-153, Re-186, Ga-68, Lu-177, and others.

3.2.2. Neutron diffraction

- Polymer studies, car and electronics industries to study the evolution of some material structures and behaviour under specific conditions (e.g., high pressure, very low/high temperatures, etc.); and
- Regional and international clients.

4. SWOT ANALYSIS

TABLE 2. SWOT ANALYSIS

Strengths	Weaknesses
• Existence of powerful reactor facilities • Good neutron flux • Existence of advances techniques • Existence of well-trained staff • Existence of expertise within CNESTEN staff	• Lack of experience regarding marketing of some facilities
Opportunities	**Threats**
• Local market needs from radio-isotopes for medical and industrial applications. • Local needs for NAA. • Local needs for material characterization. • Local needs neutron radiography. • New opportunities for research and cooperation with national and international universities. • Regional market need in term of radioisotope and reactor services	• Existence of competitors (import companies supplying radioisotopes for medical applications) • Competing non-nuclear techniques • Economic crisis can affect the demand of products and services from industries • Too much dependency on IAEA support will hinder the internal drive for self-sustainability

5. MISSION AND VISION STATEMENTS

Vision: Utilization of the MMRR for socio-economic development within national development programmes.

Mission: The MMRR mission can be stated as follows:

— Promoting nuclear science technology applications;
— Participating among other national institutions to the preparation of the necessary political, regulatory and technical conditions for the introduction of nuclear power; and
— Acting as a TSO to the national nuclear safety authority.

6. STRATEGIC CONSIDERATIONS

6.1. Operational strategy

The MMRR will be operated according to the following policies to ensure safe, efficient application of the facilities:

— Frequency of operations at the current stage (2011–2012) is 8 h/day, 2–3 days/week, 15-25 weeks/year, and later (2013–2015), 8 h/day, 4–5 days/week, 25–40 weeks/year);
— Accessibility to facilities for outsiders is arranged through agreements, and the charged cost to partners will depend on the type of project, R&D (Cost sharing), commercial (full charge), and education and training (Government subsidy);
— ISO-9001 certification or 17025 accreditation is required for testing and calibration services, mainly for NAA; and
— Pharmaceutical good manufacturing practice (GMP) is required for isotope production;
— Training of personnel must be ensured.

6.2. Business strategy

- Participate with the main stakeholders to the establish CNESTEN strategic brainstorming;
- Secure MOUs and long term agreements with stakeholders and members of the CNESTEN board;
- Offer packages of products and services (e.g., radioisotopes, training, radiation protection, dosimetry, waste management, ...);
- Offer inter-comparison programmes, certification, accreditation;
- Arrange common research projects with stakeholders on new services and products;
- Participate with stakeholders in the installation of radioisotope utilization facilities;
- Host trainers from various stakeholders;
- Organize meetings, workshops, school programmes;
- Integrate research reactor utilization into advanced degree academic programmes;
- Organize reactor visits;
- Provide on-site demonstrations;
- Organize a regional promotional campaign; and
- Prospect the possibility to replace services offered by reactors in Europe at their end of life or decommissioned.

6.3. Academic involvement

- Common research projects, workshops, schools on RR services and products, training;
- Integration of RR utilization in high degree academic education,

6.4. Health, safety, environmental management and radiological protection

- Periodic assessment of operational compliance with national regulations, license requirements and IAEA standards;
- Follow-up of the implementation of recommendations from previous IAEA expert missions;
- Safety analysis report updates;
- Safety analysis of experiments;
- Follow-up the implementation of radiation protection programmes and industrial safety measures;
- Environmental monitoring;
- Peer review via the IAEA and international cooperation.

6.5. International cooperation and IAEA support

- Reinforcement of international cooperation and IAEA Support: training, common research programs, IAEA research contracts, expertise, participation to workshops, international events, hosting scientific events and training of fellows

7. CONCLUSIONS

The MMRR is a national asset in promoting nuclear applications for socio-economic development within national development programs.

For that purpose, CNESTEN is setting up a strategic plan to efficiently and effectively meet stakeholder needs.