Utilization of Egyptian Research Reactor and Modes of Collaboration

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Abstract. The new Egyptian Research Reactor (ETRR-2) is a Material Testing Reactor (MTR) and it was commissioned in 1997. It is open pool Research Reactor (RR) using low enriched MTR fuel elements (less than 20% enrichment), cooled and moderated with light water and reflected by beryllium. The reactor power is 22 MW with high neutron flux irradiation positions (flux > $10^{14}$ n/cm$^2$.s) and can be operated up to 19 days providing high neutron fluence. Also, the reactor has two fast irradiation positions, two silicon irradiation positions, three radial and one tangential beam tubes, and thermal column.

ETRR-2 is a multipurpose reactor, several experimental and production facilities have been installed for Radio Isotope (RI) production (I-131, I-125, Cr-51, Ir-192, and Co-60 ), Neutron Activation Analysis (NAA) applications, Neutron Transmutation Doping (NTD), neutron radiography experiments, and training of personnel. A special hot cell for irradiated material testing has been installed where the impact tests, tensile tests, and other material characterization can be applied for irradiated samples of materials used in Nuclear Power Plant (NPP) and advanced reactors.

In this paper, the utilization of ETRR-2 and future plan for development some of existing and new facilities are presented as well as modes of collaboration with regional countries for sharing RR services.

1. Introduction
Applications of research reactor include irradiations, neutron beam work, and training of personnel. Every research reactor is capable of being used for training purposes, but RRs with higher neutron flux have more capabilities for irradiation and neutron beam applications and should have effective utilization plan [1].

The ETRR-2 plan for utilization has been updated to achieve an effective use of its irradiation and beam tube facilities. Modifications to some irradiation facilities have been proposed to increase the utilization and improve the provided services. The proposed modifications will achieve and maintain an increase of the utilization through enhancement of the existing facilities or installation of new facilities. In view of increasing and improving the provided service, collaboration with other RR institutes will help to share available services and encourage the better utilization.

In section 2, the current utilization of ETRR-2 and potential capabilities are described. The proposed modifications and new facilities are presented in section 3. The services and modes of collaboration with other RR institutes are summarized in section 4 and the conclusions are presented in section 5.
2. Current Utilization of ETRR-2 and Potential Capabilities

An important element in RR utilization is the evaluation current utilization and potential capabilities of the reactor. ETRR-2 existing irradiation facilities and beam tubes are shown in Fig. 1.

2.1. Sample Irradiation and RI production

Irradiation positions in core and in reflector area are dedicated for sample irradiation and RI production. High thermal flux positions (flux $> 10^{14}$ n/cm$^2$.s) [2] meets the requirements of radioisotope production of Cr-2, Ir-192, Co-60 and other isotopes produced in low and medium thermal flux reactors.

The isotopes I-131, I-125, Cr-51, and Ir-192 can be produced using irradiation facilities at ETRR-2. Target samples are prepared and placed inside of aluminum can (23.5 mm x 70 mm) and loaded in can holder. Loading operation is performed inside of transfer cell, and then can holder are transferred to the main pool using sample carrier to be placed in irradiation box at irradiation grid. Once reach irradiation time the can holder will be handled and transferred to the transfer cell using sample carrier. Once cooled, irradiated cans will be unloaded and transferred to the universal cell using interconnection conduit and be loaded in the shielded container and send to RI Production Facilities (see Fig. 2).
As shown in Fig. 1, core center position is dedicated for Co60 production (up to 50,000 Ci can be produced per year) [2]. Loading operation of cobalt irradiation device in shielded container is performed under water. Cobalt hot cell is installed for Co-60 engineering processing and sealed source production.

2.2. Material testing cell
A material testing hot cell is installed for performing destructive tests on irradiated samples (standard specimens). The cell is provided with Impact machine, Microhardness tester, and tensile machine. Irradiated samples are transported under water from main pool to the auxiliary pool using proper operational tools. The cell is connected to the auxiliary pool, sample carrier is used to transport irradiated samples from the lower part of the auxiliary pool into the testing cell where mechanical tests can be carried out (see Fig 2).

2.3. Neutron Activation Analysis
Two fast transport pneumatic tubes are available for fast irradiation samples for the use in NAA applications. The system has two positions of irradiation. One position in the reflector area with thermal flux of $9 \times 10^{13}$ n/cm$^2$.sec and the other position being in the thermal column with thermal flux of $2 \times 10^{11}$ n/cm$^2$.sec (see Fig.1).

NAA lab is provided with high efficiency detection systems for elemental analysis of irradiated samples. Environmental, geological, and biological samples could be analyzed for different applications at the NAA labs with the provided detection systems. The lab contributes to the reactor routine measurements of pools water samples, etc.
2.4. Neutron Transmutation Doping TND
Neutron transmutation doping facilities at ETRR-2 consist of two irradiation rigs located in the thermal column for silicon irradiation (see Fig. 1). Theses rigs are capable of irradiating up to 28 cm long five-inch diameter ingot (127 mm) with axial resistively variation in the product less than 5 %. Labs of post irradiation tests and measurements are also included. The existing silicon irradiation rigs should be modified to meet the customer requirements for larger size ingots.

2.5. Neutron radiography Facilities
Radiography Facility mounted in front of a beam radial tube (tube1 in Fig.1) with proper shielding and samples handling mechanisms.
- Beam port flux about 3.0 x10^7 n/cm2.sec;
- L= 3315 mm;
- D= 30 mm.

Underwater Neutron Radiography Facility for irradiated samples non-destructive tests is installed at radial beam tube (tube 3 in Fig 1) housed at the main pool.
- Beam port thermal flux bout 1.8 10^9 n/cm2/sec
- L= 1377 mm
- D= 40 mm

2.6 Thermal Column
Thermal column and connected shielded room with access control are dedicated for BNCT application.

![Fig. 3. ETRR-2 irradiation facilities with modifications](image)
3. Future Prospects for ETRR-2 Utilization

The main items of future plan to sustain the RR utilization are:

- Development of the existing facilities to increase the utilization and harmonize with the market requirements:
  - Upgrading of the NTD facilities;
  - Introduce irradiation facilities for Mo-99 production;
  - Installation of small angle neutron scattering (SANS) facility;
  - Development of the static neutron radiography to be real-time to allow for more applications.
- Accreditation for NAA Lab and implantation of K$_0$ method and Large Sample Activation Analysis (LSAA).
- Production of radio isotopes (I-131, I-125, Cr-51, Ir-192).
- Continues training and re-training for manpower development to support longer time operation.
- Collaboration and exchange information and experience with regional countries.

3.1. Upgrading of silicon transmutation doping facilities

It is possible to introduce modifications to the existing silicon irradiation rig to irradiate six-inch diameter silicon ingots instead of dismantling it and constructing a new rig in the same place. The existing aluminum container (about 15 mm thick) in the irradiation rig can be substituted with another one of appropriate thickness (3 mm) and inner diameter sufficient to accommodate six-inch diameter. A simple design of new aluminum container has been completed as well as manufacturing of one new container for the purpose of irradiation tests and commissioning. The new container can irradiate two six-inch ingot instead of one 5-inch ingot in old five-inch container. Irradiation tests and commissioning of the upgraded facility are in progress.

The outer positions in the irradiation grid could be made available for irradiation of 8-inch ingots and more six-inch diameter. An example of new proposed silicon irradiation positions is shown in Fig 3. In case there is no much demand for 8-inch size the same rig can be also used to irradiate more six-inch diameter. A simple irradiation rig design similar to the one used in IEA-R1 research reactor [3] is suggested to be adapted in ETRR-2.

3.2. In-core Mo-99 productions

Low Enriched Uranium-aluminum plates will be irradiated in the reactor core in special dedicated irradiation boxes to produce 1000 Ci of Mo-99 per week. The existing in-core irradiation box for Co-60 production will remain in the new core design. Two irradiation boxes will be placed inside the core for the purpose of Mo-99 production replacing two fuel elements as shown in Fig. 3.

Each irradiation box contains two target holders where the targets are loaded. The loading operation is performed inside of testing cell, and then target holders are transferred to the auxiliary pool to be assembled in irradiation box. Irradiation boxes are transferred from auxiliary pool to the reactor core for irradiation. The in core irradiation has the advantage of no special cooling or irradiation loop is required. The irradiation boxes will be loaded into or removed from the core while the reactor is shut down. In-core irradiation for Mo-99 production is performed in RA3 research reactor [4].
Once reached the irradiation time, each irradiation box is removed with the operational tool from the core. Once cooled, the irradiation box is transferred to the auxiliary pool where it is disassembled under water. Targets holders are transported from the auxiliary pool to the testing cell using the sample carrier. Inside the testing cell, plates are transferred to the target containers and sent to the cobalt cell using the correspondent interconnection conduit. The target containers are loaded in the shielded container previously entered into the cobalt cell and send to RI Production Facilities (see Fig. 2).

3.3. Installation of SANS
ETRR-2 has appropriate design of the beam tubes and optimal conditions for installation of 2 or 3 scattering instruments. It is possible to start with an instrument of intermediate level IAEA will support a first SANS for applications in materials science and engineering.

4. Services and Collaboration
Better utilization can be also achieved by collaboration with countries having no RR and other RR institutes. The modes of collaboration are to maximize the use of ETRR-2 for regional benefit and improve the reactor products and services and exchange experience.

4.1. Services which can be provided
- Neutron radiography
- Irradiation of silicon ingots with diameters five and 6-inche diameter and length of 28 cm.
- Irradiation services to produces, I-131, I-125, Co-60,....
- NAA for geological, foodstuff, biological, and environmental samples.
- On the job training
- Training on calculation codes (e.g. MCNP code, MTR- Package,...)
- Training and workshops activities in the field of, radiation protection, core calculations ,and isotope production

4.3. Modes of Collaboration:
- Networking and bilateral co-operation;
- Technical cooperation projects;
- Conferences and forum;
- Meetings , training activates , workshops, expert mission and scientific visits;
- Experimental facilities sharing;
- Common research and scientific publications;
- Participation in research projects.

5. Conclusions
The main utilization aspect of ETRR-2 design is its flexible irradiation positions and potential for modification to harmonize with the requirements of the utilization. Effective utilization of ETRR-2 facilities can be achieved through (i) development of an effective and updated utilization plan, (ii) manpower development to support longer time of operation, (iii) implementation of necessary modifications, which incorporate experience of similar research reactor designs and utilization and indicant simple design, (iv) AEA Technical cooperation activities, and (v) collaboration with other RR centers and sharing services.
REFERENCES