UTILIZATION OF ETRR-2 AND COLLABORATION

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1. INTRODUCTION

Owners and operators of many research reactors are finding that their facilities are not being utilized as fully as they might wish. Perhaps the original mission of the reactor has been accomplished, or a particular analysis is now performed better in other ways. Therefore, many research reactor owners and operators recognize that there is a need to develop a strategic plan for long-term sustainability including the marketing of their facilities. An important first element in writing a strategic plan is to evaluate the current and potential capabilities of the reactor.

The purpose of this paper is to assist in providing some factual and advisory information with respect to all of the current applications of research reactors. Each facility owner and operator will be able to assess whether or not a new application is feasible with the reactor, and what will be required to develop capability in that application.

Applications fall into the following categories: human resource development, irradiations and extracted beam work. The human resource category includes public information. Training and education can be accomplished by any reactor.

Irradiation applications involve inserting material into the reactor to induce radioactivity for analytical purposes to produce radioisotopes or to induce radiation damage effects. Almost all reactors can utilize some irradiation applications, but as the reactor flux gets higher the range or potential uses gets larger.

Beam work usually includes using neutron beams outside of the reactor for a variety of analytical purposes. Because of the magnitude of the fluxes needed at some distance from the core, most beam work can only be performed by intermediate and high powered research reactors. In this paper we will stress the current status and potential capabilities of the Egyptian Research Reactor (ETRR-2).

2. RR UTILIZATION MATRIX

2.1. Low thermal flux reactor

— Flux $<10^{13}$ $cm^{-2}s^{-1}$; and
— Potential radioisotopes: ^{24}Na, ^{32}P, ^{l38}C, ^{56}Mn, ^{41}Ar, ^{64}Cu and ^{198}Au.

2.2. Medium thermal flux reactor

— Flux: (10^{13}–10^{14} $cm^{-2}s^{-1}$); and
— Potential RI: ^{90}Y, ^{99}Mo, ^{125}I, ^{131}I and ^{133}Xe.

2.3. High thermal flux reactor

— Flux $>10^{14}$ $cm^{-2}s^{-1}$; and
— Potential RI: ^{14}C, ^{35}S, ^{51}Cr, ^{60}Co, ^{89}Sr, ^{153}Sm, ^{169}Yb, ^{170}Tm and ^{192}Ir.

2.4. Fast flux reactors

Fast flux in the reactor is necessary for production of some isotopes like K40 (n,p) Ar41, so it is necessary to reduce the thermal neutrons by shielding with Cd or B. Samples for irradiation are individually wrapped in foil. It is important to define the flux values at in-core irradiation positions.

3. CURRENT STATUS OF EGYPT'S TWO RRS AND POTENTIAL CAPABILITIES

3.1. The first research reactor ETRR-1

The first one was built by the Soviet Union and went critical in 1960, with a power rating of 2.0 MW and a maximum thermal flux of 2.5×1013 cm-2s-1. The reactor is classified as a tank type, with fuel elements designed for 10% enrichment. It uses light water as a coolant, moderator and reflector. The reactor equipped with 8 vertical channels for sample irradiation to produce radioisotopes, and 9 horizontal channels for applying beam experiments. Starting in 1987, a plan was established for modernization and life extension of the reactor in cooperation partially with the IAEA through technical cooperation projects. The reactor still operating presently, its main utilization areas are:

- Neutron time of flight experiment;
- Neutron diffraction;
- Neutron scattering;
- Shielding research;
- Computerized neutron tomography;
- Production of ^{131}I and ^{32}P for medical purposes;
- Irradiation of samples (Geological, etc.);
- Education and training for university students; and
- Simulator training and transient analysis for nuclear reactors.

3.2. The second research reactor ETRR-2

The Egypt Second Research Reactor (ETRR-2), also called the Multipurpose Reactor (MPR), is located at the Inshas Nuclear Centre of the EEAEA about 60 km from Cairo. The maximum reactor power is 22 MW and the maximum thermal flux 2.7×10^{14} $cm^{-2}s^{-1}$. Light water moderated and cooled, this open pool reactor was designed and manufactured by INVAP of Argentina. The reactor was designed to be used in a wide variety of fields including neutron physics, materials science and boron capture therapy. Construction began in 1990, and the facility achieved initial criticality on 27 November 1997. Initial full power (22 MW) operations occurred on 11 March 1998.

3.2.1. Research and industrial capabilities of ETRR-2

The ETRR-2 facility seems to incorporate many lessons from previous research reactor designs and utilization programs. INVAP and EAEA had clearly evaluated and envisioned the potential usage of the facility based on experiences and international studies concerning the use of medium flux. The key aspect of the ETRR-2 design is its flexibility and potential for modification to harmonize with the requirements of the utilization. ETRR-2 is a Material Testing Reactor (MTR), open pool type, with 22 MW of power, and a variable core arrangement. It is cooled and moderated by light water with Be blocks as reflectors. The main utilization aspects on the ETRR-2 design are its flexible arrangement of irradiation positions, potential for modification to meet the requirements of the utilization and free access of reactor and experiment personnel to the facilities during reactor operation at full power. ETRR-2 is a multipurpose reactor with several irradiation and production facilities that have been installed for sample irradiation, RI production (e.g., ^{131}I, ^{125}I, ^{51}Cr, ^{192}Ir, and ^{60}Co), NAA and NTD. For each irradiation facility, there is a special irradiation box or device, operational tools and procedures for handling and transportation.

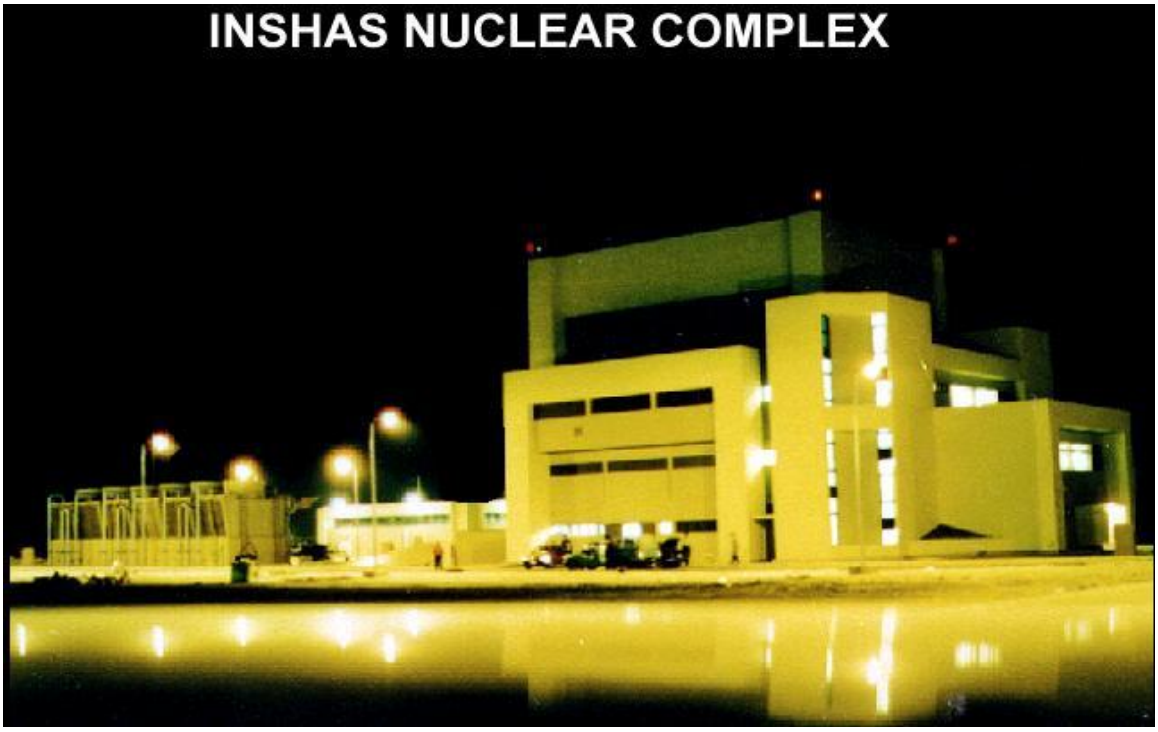


Fig. 1. Inshas Nuclear Complex at night.

3.2.2. Irradiation facilities

Two irradiation boxes and will be placed inside the core for the purpose of ^{99}Mo production replacing two fuel elements. In-core irradiation has the advantage of requiring no special cooling or irradiation loop. Hot cells will be modified for the use of ^{99}Mo targets and their loading and unloading. Loading takes place in a shielded container.

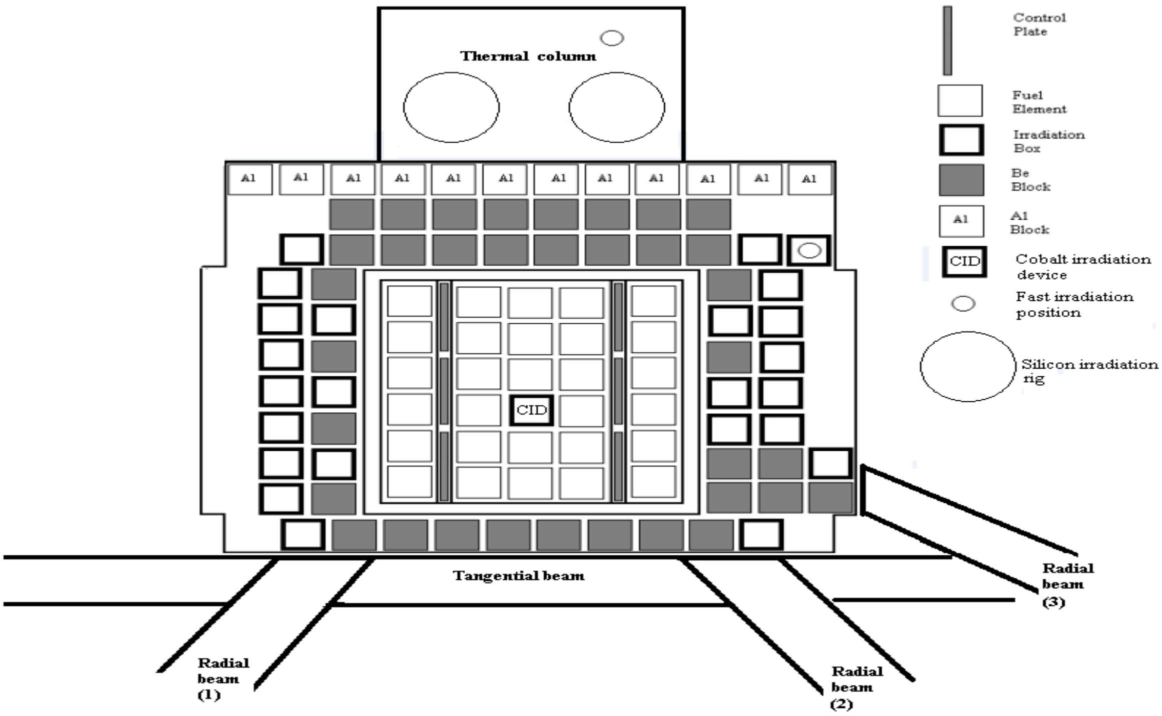


Fig. 2. Irradiation devices of the ETRR-2.

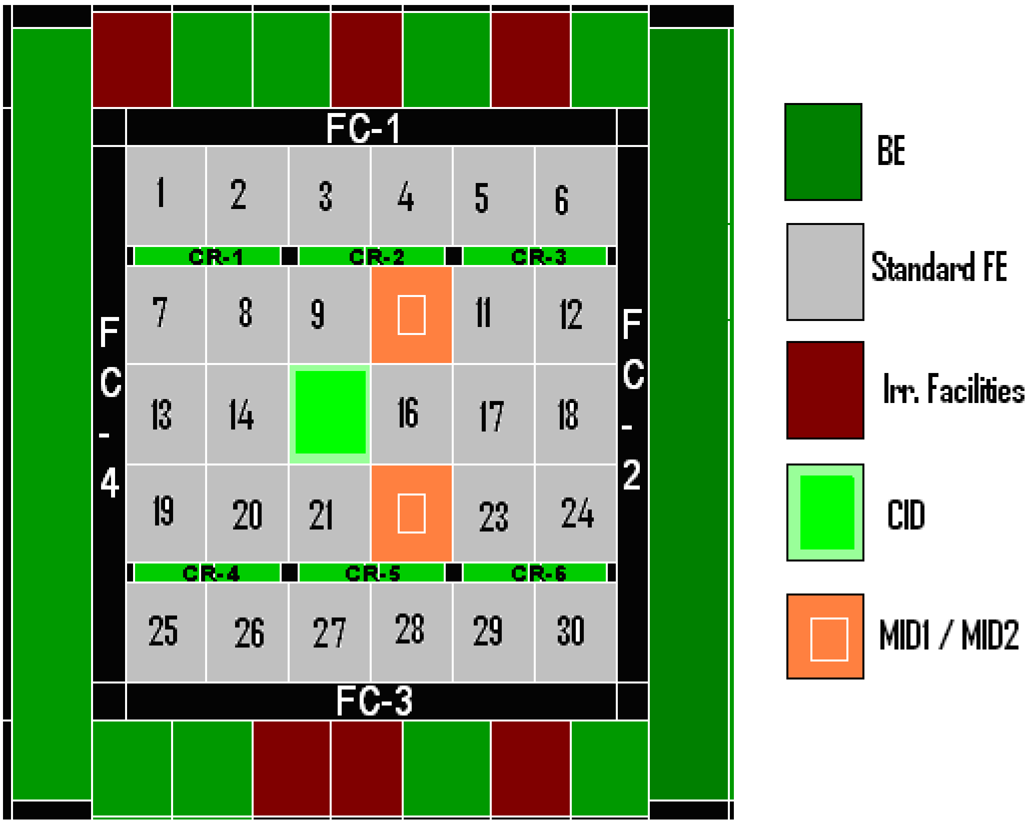


Fig. 3. Planned in-core irradiation positions for ^{99}Mo production.

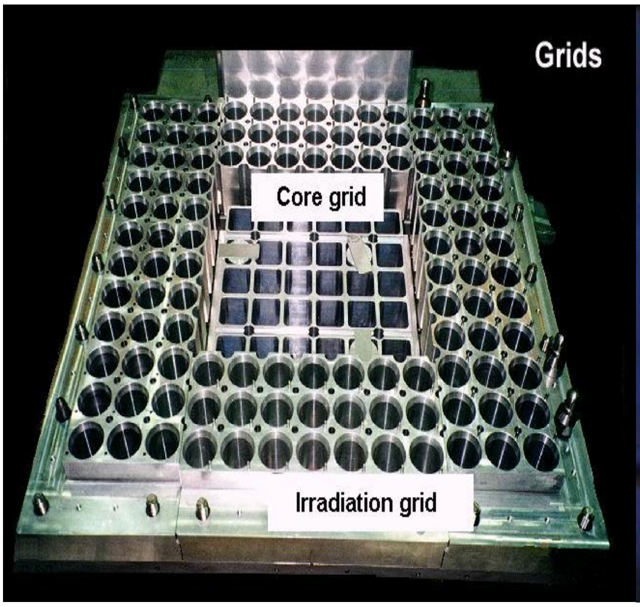


Fig. 4. Isotope production. *Fig. 5. Gemstones production.*

Fig. 6. Beam tubes. *Fig. 7. Semiconductor production.*

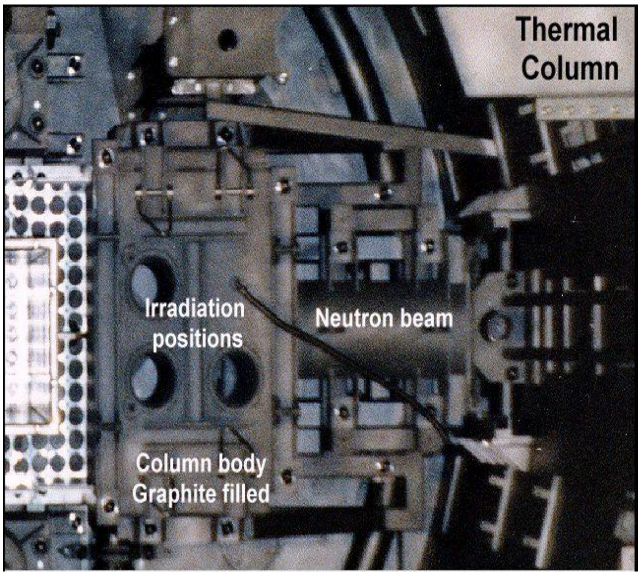


Fig. 8. NTD facility.

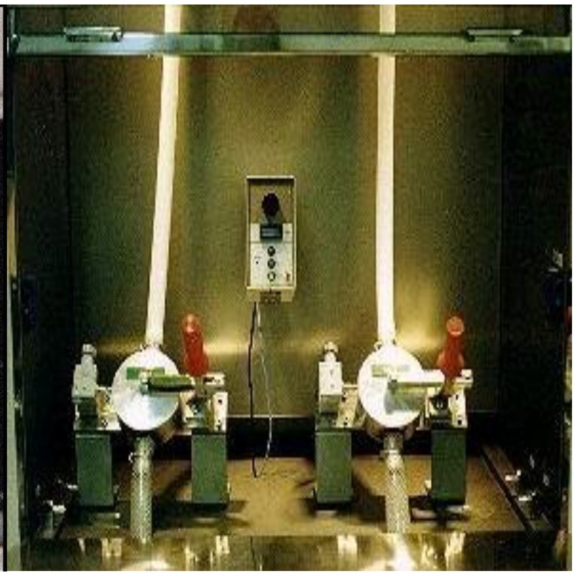


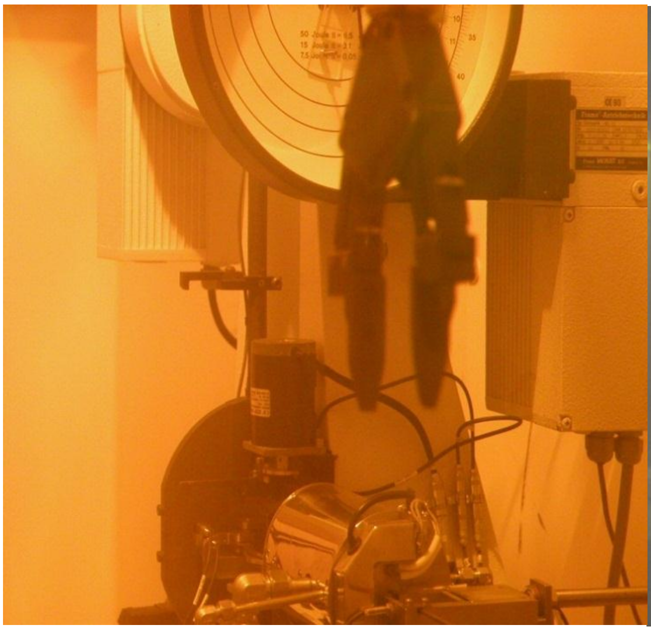
Fig. 9. Pneumatic tubes (INAA).

Fig. 10. NAA lab.

Fig. 11. Neutron radiography.

Fig. 12. Underwater neutron radiography

Fig. 13. Material testing cell.



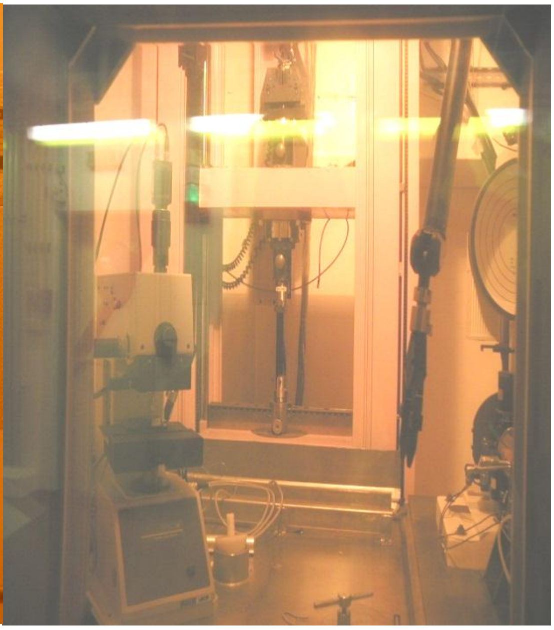


Fig. 14. Impact machine.

Fig. 15. Micro hardness tester.

3.2.3. Status of production of ^{99}Mo by neutron activation

This project is going on in cooperation with Chinese experts. Its achievements to date are:

- A revised work plan for production of ^{99}Mo by neutron activation was finalized;
- The neutronic and thermal hydraulic analyses were finalized;
- The irradiation target (^{98}Mo) capsule, shielded container and handling procedures were finalized;
- The processing steps with QA and procedures were finalized.The new hot cells for this project were tested and approved by the regulatory body;
- The Safety Analysis Report (SAR) was reviewed by the regulatory body;
- The operating staff was trained on the processing of ^{99}Mo to produce ^{99m}Tc in medical form; and
- Hot testing and commissioning is expected to be started in cooperation with Chinese experts in November 2009.

3.2.4. Status of production of ^{99}Mo by LEU fission

The project of ^{99}Mo production from LEU targets is ongoing in cooperation with INVAP. Hot commissioning is expected to be started by the end of 2009, and after commissioning, RI production is intended to cover the needs of national hospitals. Irradiation and processing facilities required some modifications, which are detailed below:

- LEU target specifications were identified, and targets were supplied;
- The design and manufacturing of ^{99}Motargets irradiation box was completed;
- The in-core irradiation positions at ETRR-2 reactor were defined;
- The neutronic, thermal hydraulics and core management strategy were completed using the necessary codes, which achieves the safety of irradiation within the reactor operating limits and conditions;
- An expert mission from the Nuclear Safety Department of the IAEA was requested to support the review of the safety documentation of ^{99}Mo production;
- Training on the processing steps for the production plant were completed in Argentina;
- The handling route for the irradiated targets from the reactor to the radioisotope production facility was defined;
- Initial review of the updated SAR was completed; and
- All necessary cold tests in the hot cells were finalized.

3.2.5. Plan for commissioning of ^{99}Mo production facilities

The irradiation plan for commissioning describes the planned activities and targets irradiations to perform the commissioning tests for the irradiation facilities at ETRR-2, and then irradiated targets will be supplied to the Radioisotope Production Facility. The test will consist of characterization of the core and verification that the core conditions remain within acceptable criteria when irradiation boxes for ^{99}Mo production are placed inside the core.

Half power irradiation of ^{99}Mo production targets will be performed during hot start up tests for irradiation facilities commissioning.

One full power irradiation of ^{99}Mo production targets will be performed to finalize commissioning and tests of the irradiation facilities at ETRR-2.

3.2.6. Production plan

The irradiation and removal schedule is simple and follows the reactor cycle (10–15 days). An example is as follows:

- Day 1: Two irradiation boxes with target plates are loaded into two positions in the core (average thermal flux is 2.06×10^{14}); reactor startup also;
- Day 6: reactor shutdown. Irradiation boxes are removed from core and placed in pool for cooling;
- Day 8: same as Day 1;
- Cooling time is 24 hours;
- Target processing takes 18 hours; and
- Weekly production is two batches of 500 Ci each on fixed days of the week and two days apart.

4. FUTURE PROSPECTS FOR RR UTILIZATION

4.1. Mission

EAEA, in order to sustain and improve the utilization of its ETRR-2 reactor, will develop and market high quality services and products, mainly radioisotopes, to the nuclear medicine community, local and petroleum industry. Initially, EAEA will focus on the Egyptian market and will look to expand its market, according to the strategies outlined in this plan.

4.2. Marketing strategy

The potential customers of EAEA RRs include public and private hospitals, nuclear medical researchers and industry. Pharmaceutical companies and distribution agents are also potential customers. The market is penetrated by other foreign companies, which affects the price of the products.

The main items of our plan to sustain RR utilization are:

- Development of business plans and marketing of reactor services;
- Development of a plan for each reactor facility;
- Creation and promotion of local, national, regional market for each reactor facility;
- Ensure long-term sustainability of reactor utilization;
- Resolution of inhabiting safety or operational issues;
- Solving all the safety related issues;
- Getting the reactor fully and continuously operable with high level of safety;
- Assurance of the availability of the fuel necessary for the reactor operation;
- Putting all the reactor facilities fully operational, solving all the related operational issues;
- Applying the periodic maintenance and repair for reactor systems;
- Applying the requirements of the regulatory body for safe operation and utilization;
- Development of the reactor facilities to harmonize the requirements of the local and international market;
- Development of NTD facility;
- Installation of small angle neutron scattering (SANS) facility for industrial application and material sciences;
- Development of the static neutron radiography to be real time;
- Applying QA/QC programmes and ISO accreditation for all reactor services and the NAA Lab;
- Production of special radioisotopes for medical and industrial uses (e.g., ^{99}Mo, ^{51}Cr, ^{192}Ir, ^{125}I);
- Continuous training and re-training for manpower development;
- Income generation from irradiation services; and

- Collaboration and exchange information and experience with Arab and African countries, through:
  - Networking and bilateral cooperation;
  - Conferences and forums;
  - Workshops, training activities, expert mission and fellowships; and
  - Sharing in research projects and proficiency exercises organized by IAEA or by TCDC.

4.3. Local technical support infrastructure

- National Centre for Nuclear Safety and Radiation Control (NCNSRC) for safety review , licensing, and inspection;
- Waste management center for liquid and solid waste treatment and disposal;
- National organization of health for certification of medical used radioisotope; and
- Local experience for exporting radioisotopes including safer transportation according to international regulation.

5. SERVICES AND COLLABORATION

Collaboration between Egyptian RRs for better utilization can be achieved with countries that do not have a reactor. This activity is important for social benefit, information exchange, services marketing and income generation.

5.1. Objectives

The main objectives of collaboration with consumers are:

- To maximize the use of ETRR-2 reactor for regional benefit;
- To generate income in order to help subsidize the operation and maintenance of reactor;
- To exchange information, knowledge and experience; and
- To improve the reactor products with market nodes.

5.2. Services

The services which can be given are:

- Beam tube experiments (Neutron time of flight, neutron tomography, neutron radiography);
- Irradiation of silicon ingots with diameters of 5” or 6” and length of 30 cm;
- Irradiation services to produce ^{131}I, ^{60}Co, ^{32}P;
- Implementation of INAA, NAA for geological, foodstuff, biological and environmental samples;
- Simulation training;
- On-the-job training;
- Software training (e.g., MNCT), particularly for the MTR package;
- Training and workshops activities in the field of, radiation protection, QA/QC, fuel management, core calculations and calculations necessary for utilization and isotope production;
- Manufacture of irradiation boxes;
- Installation of sealed sources in gamma cameras; and
- Maintenance of gamma cameras and radiation protection devices.

5.3. Modes of collaboration

- Networking within various field of utilization and technology;
- Technical cooperation projects;
- Conferences, training courses, workshops, expert missions and scientific visits;
- Students training;
- Experimental facilities sharing;
- Software training; and
- Common research and scientific publications.