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Abstract

- The Egyptian Atomic Energy Authority (EAEA) owns a new material testing research reactor (MTR) called ETRR-2. This reactor was commissioned in 1997 and is a swimming pool type using plate type Fuel elements with 20% enrichment. It is cooled and moderated by light water and uses beryllium as a reflector. Its maximum thermal power is 22 MW, with maximum thermal neutron flux of 2.7xl014 n/cm2/s and can be operated up to one cycle, around 18 days, for the high fluence necessary for applying long irradiations for peaceful utilization and a wide range of applications. The reactor is a multipurpose utilization, containing different facilities for applying neutron activation analysis (NAA), radioisotope production (e.g., Ir-131, Co-60, P-32, Mo-99, etc.), neutron transmutation doping (NTD) of silicon ingots of 12.5 cm diameter and 30 cm in length, neutron radiography education for university students, research for scientists, and training for new operators.
- Also, the reactor is equipped with 26 positions for in-core irradiation with high fluence positions, two radial beam ports, two tangential beam ports and a thermal column. The reactor has special hot cells for material testing under irradiation conditions. We can apply the impact tests, tensile strength tests, and other material characterization for irradiated samples which can be used in different industrial applications, nuclear power plants and fusion reactors.
- The strategic and business plan for reactor utilization and collaborations with national and regional partners was updated. Also, several design modifications for the NTD facility to irradiate larger silicon ingots was implemented. In this paper we will present the different current and future activities for peaceful utilization of the ETRR-2 reactor, stressing on the benefits of material irradiation testing and characterization at high neutron fluxes and high fluence.

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.

1- INTRODUCTION

- The human resource category includes public information. Training and education and 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 irradiaition 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 the intermediate and higher powered research reactors.

1 - INTRODUCTION

- In this paper we will stress on the current status and potential capabilities of the Egyptian Research Reactor (ETRR-2).

2. R.R Utilization Matrix:

1. 2.Low Thermal Flux Reactor:

- Flux < 10^{13} n/cm^2.s.
- Potential Radio- isotopes, Na^{24}, P^{32}, Cl^{38}, Mn^{56}, Ar^{41}, Cu^{64} and Au^{198}.

2.2.Medium Thermal Flux Reactor:

- Flux: (10^{13} – 10^{14} n/cm2.s)
- Potential R.I, Y^{90}, Mo^{99}, I^{125}, I^{131}, and Xe^{133}.

2. R.R Utilization Matrix:

2.3.High Thermal Flux Reactor:

- Flux > 10^{14} , n/cm2.s
- Potential R.I, C^{14}, S^{35}, Cr^{51}, Co^{60}, Sr^{89}, Sm^{153}, Yb^{169}, Tm^{170} and Ir^{192}.

2.4.Fast Flux Reactors:

- Fast flux in the reactor is necessary for production of some isotopes like K^{40} (n,p) Ar^{41}, so it is necessary to reduce the thermal neutrons by shielding with Cd or B.
- Samples for there irradiations are individually wrapped in fail. It is important to define the flux values at in-core irradiation positions.

3- Current Status of R.Rs in Egypt and Potential Capabilities.

- **Egypt Owns Two Research Reactors:-**

  3.1. The first Research Reactor ETRR-1:

  – The first one was built by Soviet union, and went critical in 1960, with full power 2.0MW and maximum thermal flux $2.5x10^{13}$ $n/cm^2.s$. The Reactor places under tank type, the fuel element designed with 10% enrichment, its uses light water as a coolant, moderator and reflector. The reactor equipped with 8 vertical channel for samples irradiation to produce radio – isotopes, and 9 horizontal channels for applying beam experiments. Starting from 1987, a plan was placed for modernization and life extension of the reactor in cooperation partially with IAEA through technical cooperation projects.

3 - Current Status of R.Rs in Egypt and Potential Capabilities.

- The reactor still operating until now, the main utilization are:-

1. Neutron time of flight experiment.
2. Neutron Diffraction.
3. Neutron Scattering.
4. Shielding Research.
5. Computerized Neutron tomography.
6. Production of I-131 and P-32 for medical purposes.
7. Irradiation of samples (Geological, …).
8. Education & Training for university students.
9. Simulator training and transient analysis for Nuclear Reactors.

3 - Current Status of R.Rs in Egypt and Potential Capabilities.

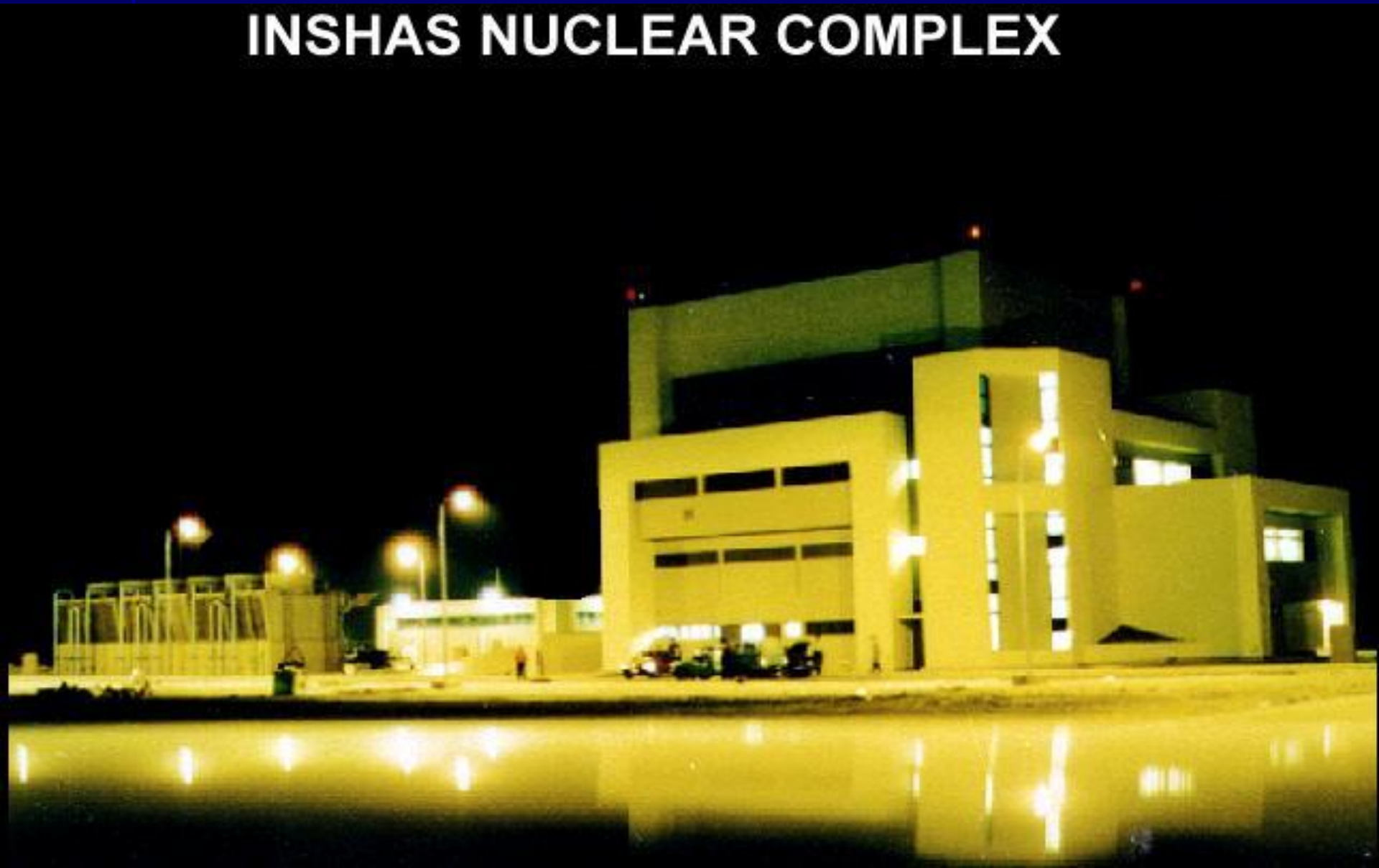
- **3.2. The Second Research Reactor ETRR-2:**

The Egypt Second Research Reactor (ETRR-2), also called the Multipurpose Reactor (MPR), is located at the Inshas Nuclear Center of the Egypt Atomic Energy Authority about 60 Km from Cairo. The reactor power is a 22MW,and the maximum thermal flux $2.7x10^{14}$ $n/cm^2.s$. light water moderated. And cooled, open-pool reactor designed and manufactured by INVAP, a company in Argentina. The reactor is designed to be used in a wide variety of fields including neutron physics, materials science, and boron capture therapy. The facility was constructed and commissioned through the 1990 with initial criticality on November 27, 1997. Full power (22 MW) operations occurred on March 11, 1998.

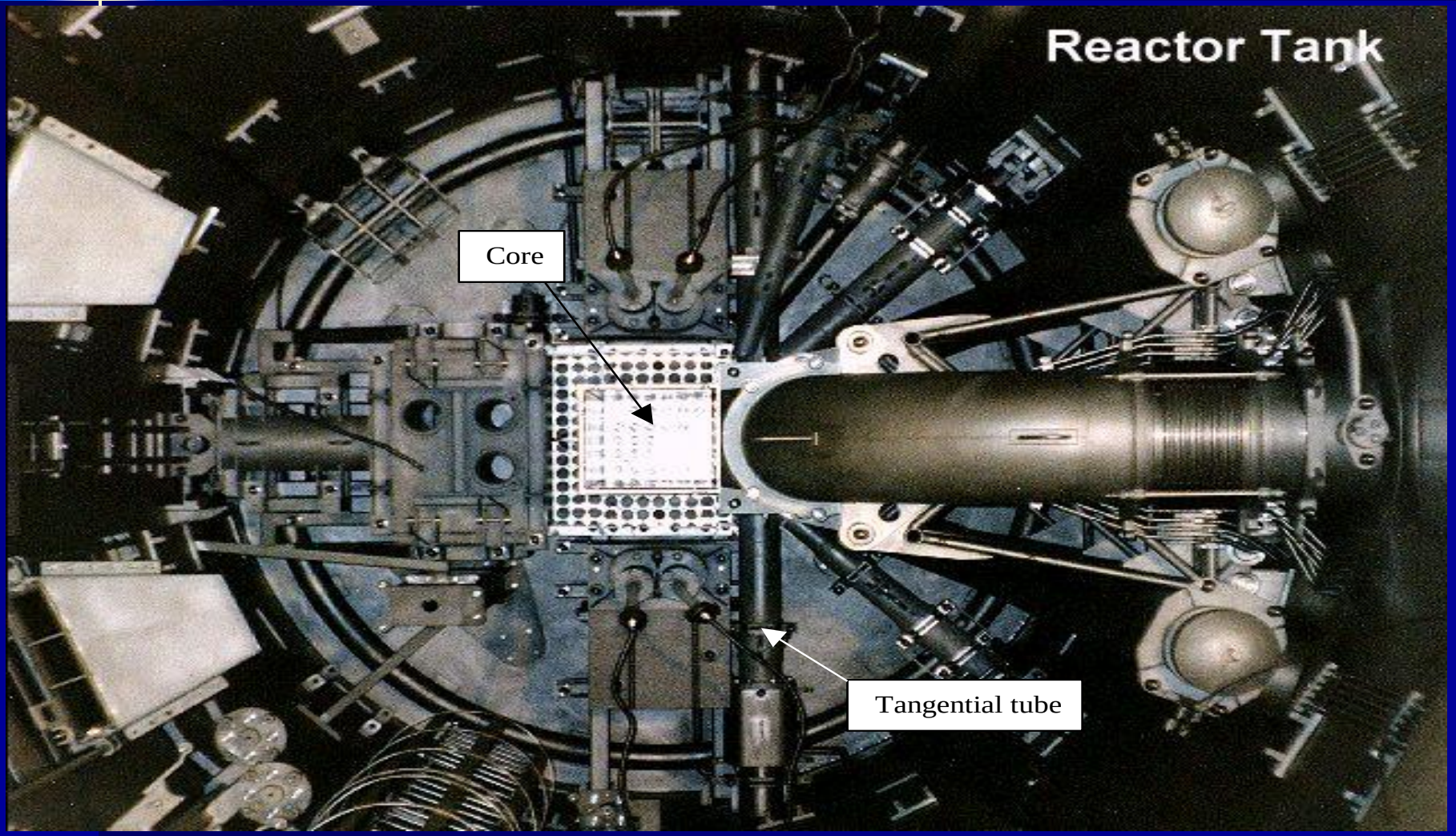
Research and Industrial Capabilities of the ETRR-2

- 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.

Facilities

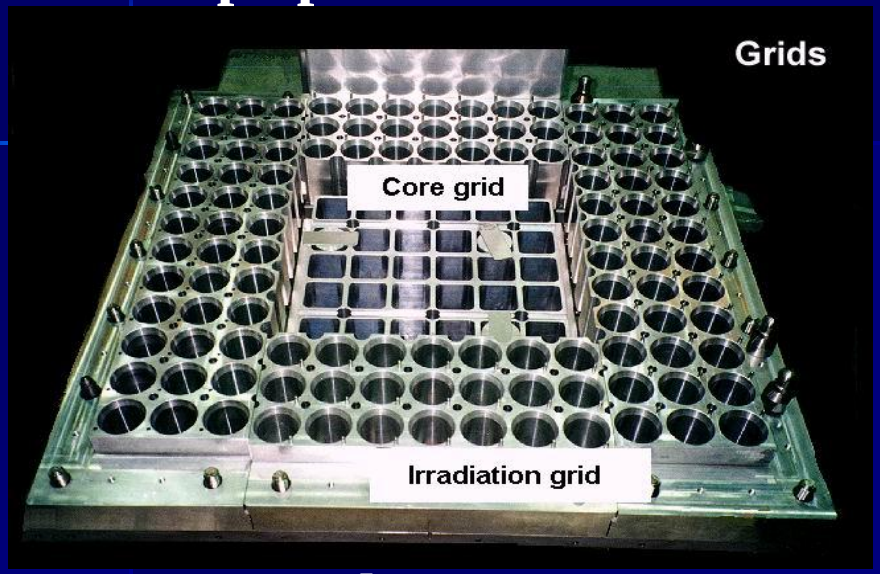


Facilities



The Facilities

1-Isotope production

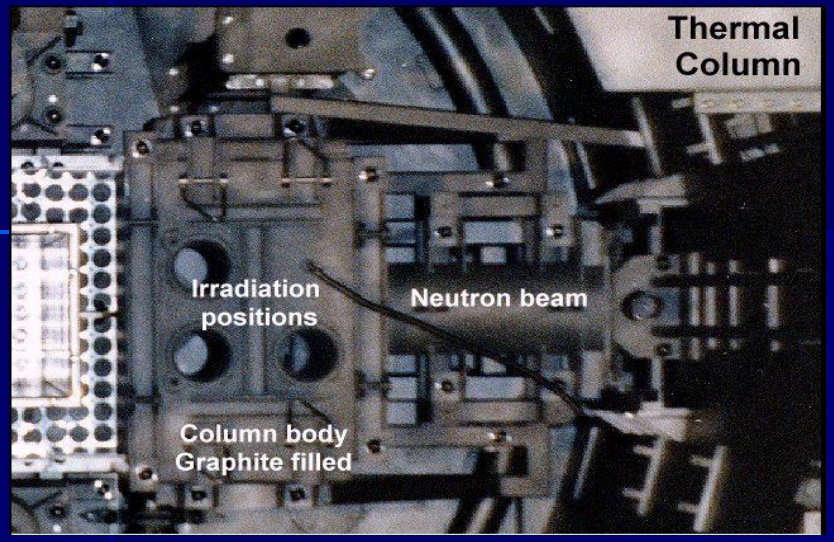


2-Gem stones Production

3-Beam Tubes

4-Semiconductor Production

5- NTD Facility



6- Pneumatic Tubes (INAA)

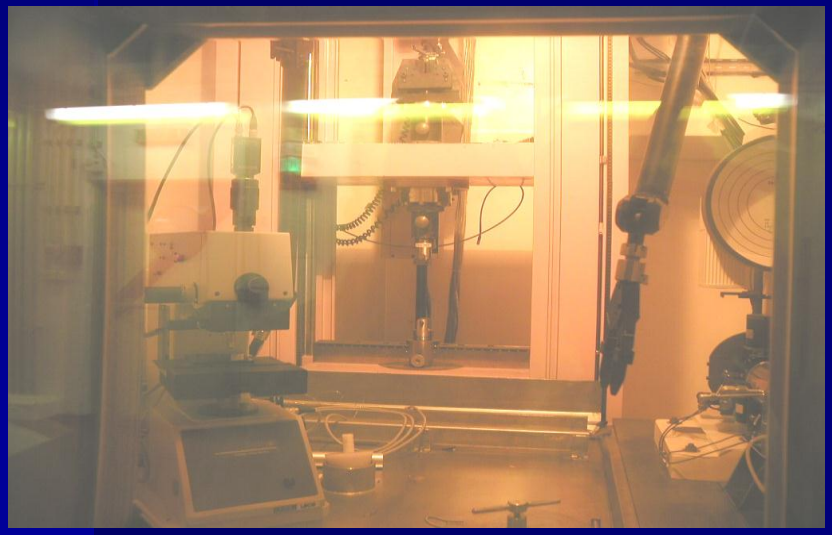
7- NAA Lab.

8- Neutron Radiography

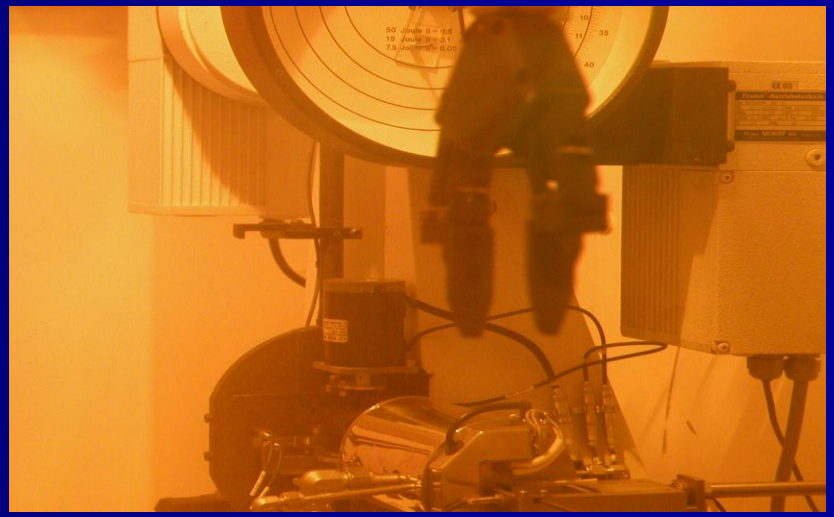
9- Underwater Neutron Radiography

10- Material Testing Cell

11- Impact Machine



12- Micro Hardness Tester



4 - Future Prospects for R.Rs Utilization

- **Mission:**
  - The Egyptian Atomic Energy Authority, 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.
- **Marketing strategy:**
  - The potential customers of EAEA research reactors, 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 affect the price of the products.

4 - Future Prospects for R.Rs Utilization

The main items of our plan to sustain the RRs utilization are:

1. 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.
2. 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

4 - Future Prospects for R.Rs Utilization

3.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.

4.Applying QA/QC programs and ISO Accreditation for all reactor services and NAA Lab.

5.Production of special radio isotopes for medical and industrial uses (e.g., Mo-99, Cr-51, Ir-192, I-125).

6.Continues training and re-training for manpower development.

7.Income generation from irradiation services.

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

4 - Future Prospects for R.Rs Utilization

- **Current Status of Mo-99 Production at ETRR-2 Reactor and Prospects for International experts**

ETRR-2 Capabilities

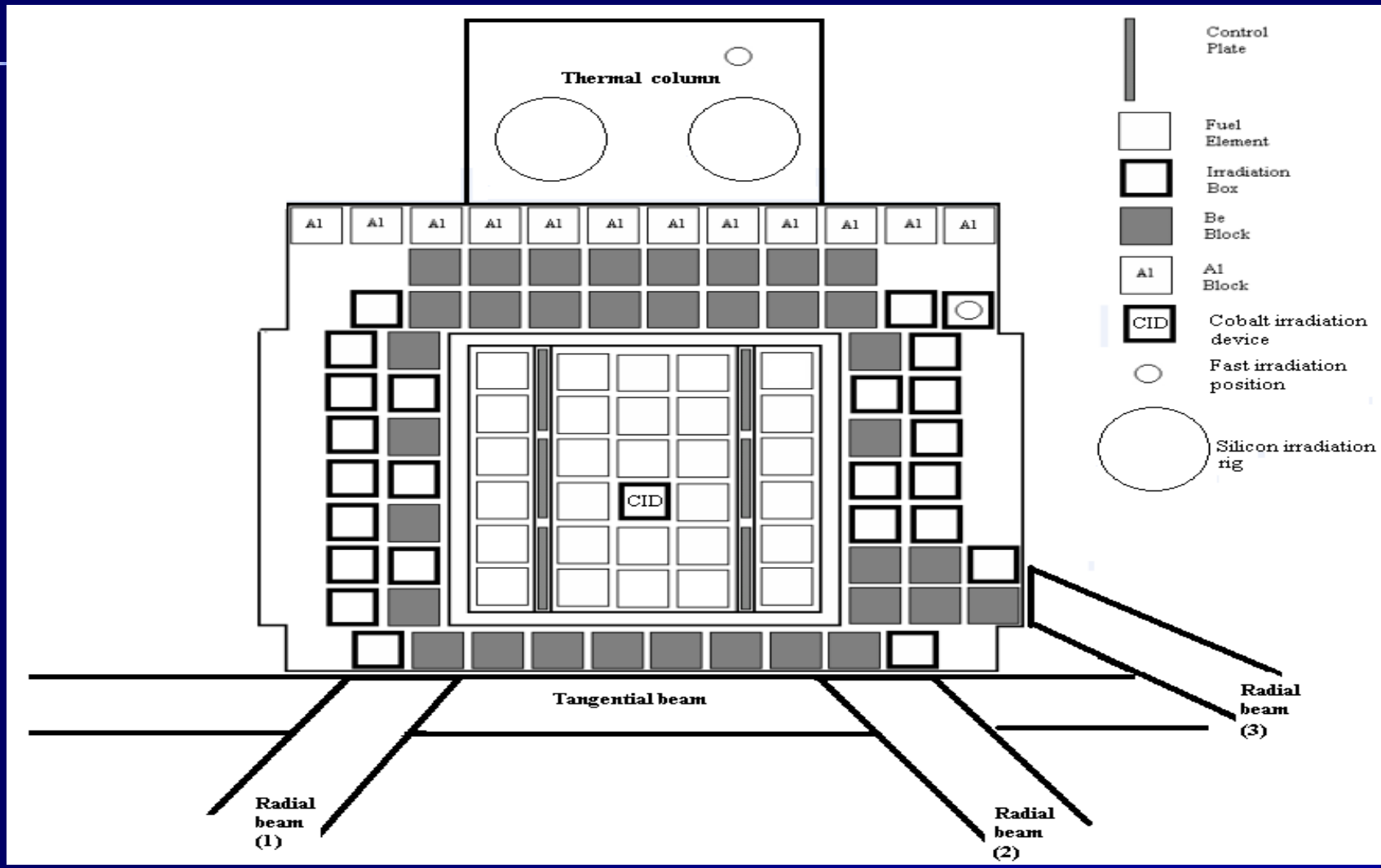
- ETRR-2 is a Material Testing Reactor (MTR), open pool type, 22 MW Power, of variable core arrangement, cooled and moderated by light water , with Be blocks reflectors.
- The main utilization aspects on the ETRR-2 design are:
- - Its flexible arrangement irradiation positions and potential for modification to meet the requirements of the utilization;
- - Free access of reactor personnel and experimentalists during reactor operation at full power.

ETRR-2 Capabilities

- ETRR-2 is a multipurpose reactor, several irradiation and production facilities have been installed for:
  - Sample irradiation and Radio Isotope (RI) production (I-131, I-125, Cr-51, Ir-192, and Co-60);
  - Neutron Activation Analysis (NAA);
  - Neutron Transmutation Doping (NTD);

- For each irradiation facility, there are special irradiation box /device and operational tools and procedures for handling and transportation.

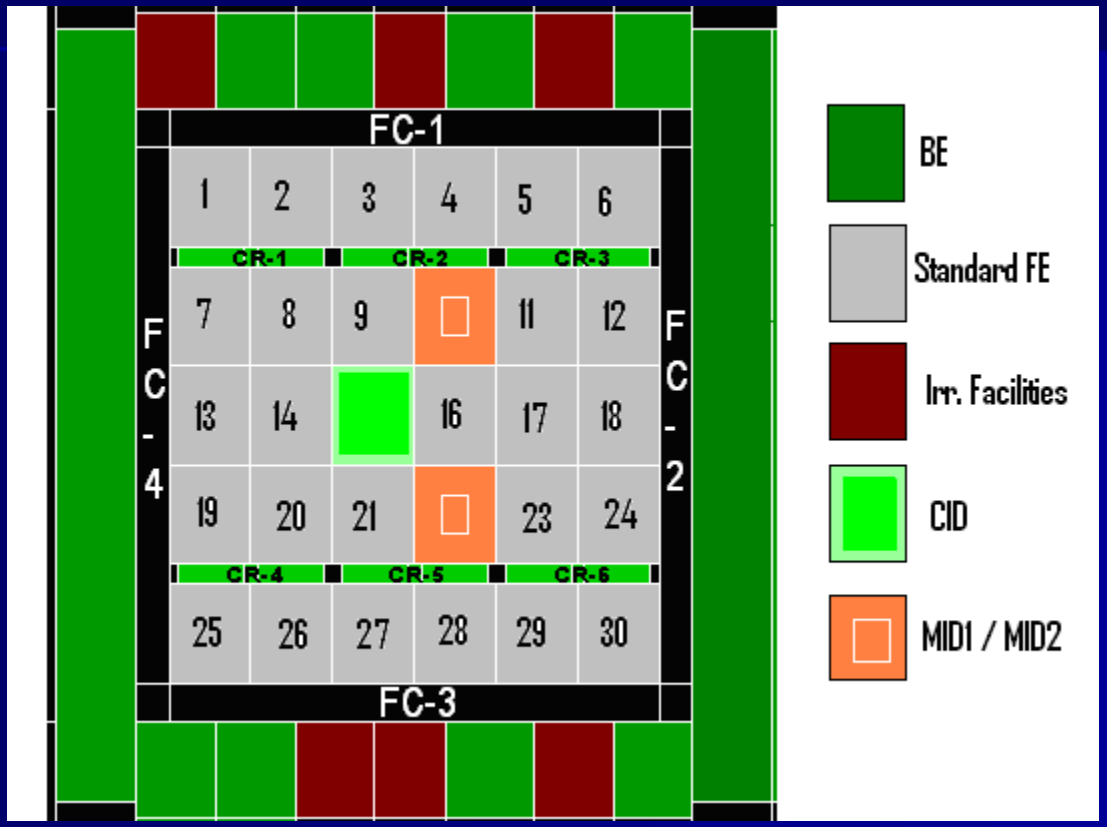
Irradiation Facilities



ETRR-2 Capabilities

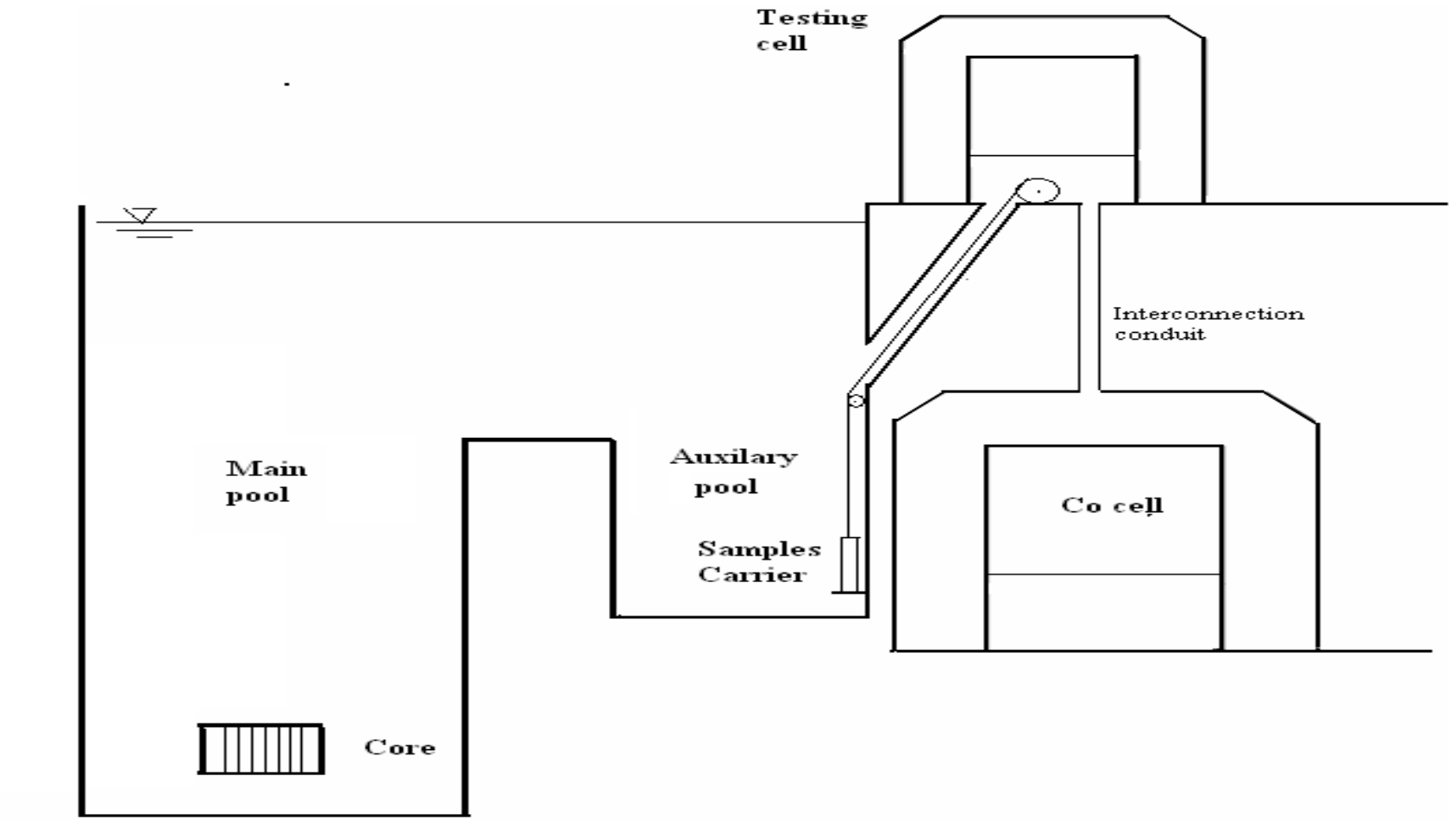
- Two irradiation boxes and will be placed inside the core for the purpose of Mo-99 production replacing two fuel elements.
- in-core irradiation has the advantage of no special cooling or irradiation loop is required
- hot cells will be modified to be used in Mo-99 targets loading / unloading and loading in a shield

Irradiation Facilities



Planned in-core irradiation positions for Mo-99 production

ETRR-2 capabilities



Hot cells for Mo-99 Targets loading/ unloading

ETRR-2 capabilities

Local Technical support infrastructure

- National center 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 radio isotope.
- Local experience for exporting radio isotopes including safer transportation according to international regulation

Status of Production of Mo-99 by Neutron Activation

This project is going on in cooperation with Chinese experts.

Achievements:

- A revised work plan for production of Mo-99 by neutron activation was finalized.
- Based on these plans and actual status the following items were implemented:

- **The neutronic and thermal hydraulic analysis were finalized.**
- **The irradiation target (Mo-98) capsule , shielded container and handling procedures were finalized.**
- **The processing steps together with QA and procedures were finalized.**

Status of Production of Mo-99 by Neutrons Activation

- **The new hot cells for this project were tested and approved from regulatory body.**
- **The SAR was reviewed from regulatory body.**
- **The operating staff were trained on the processing of Mo-99 to produce Tc-99 in medical form.**
- **The hot testing and commissioning is expected to be started in cooperation with Chinese experts in Nov. 2009.**

Status of Production of Mo-99 from Fission of LEU Targets

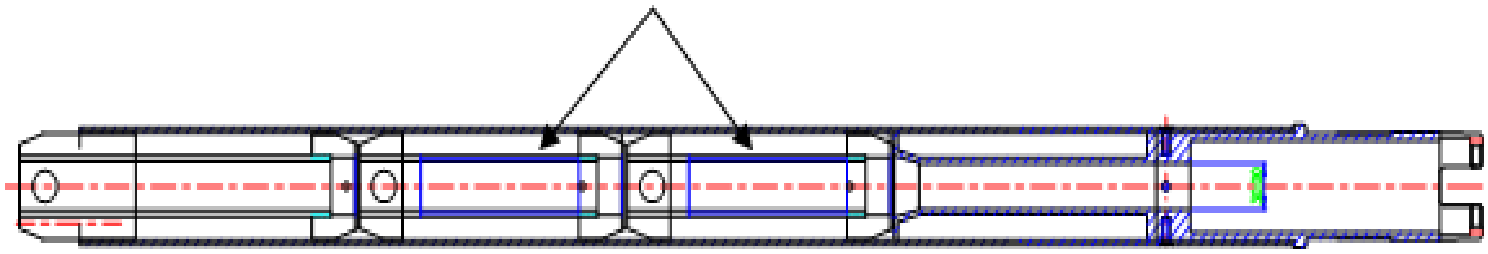
- The project of Mo-99 production from LEU targets is going on in cooperation with IN*VA*P
- Irradiation Facilities modifications
- The LEU targets specifications were identified and targets were supplied.
- The design and manufacturing of Mo-99 targets irradiation box was completed .
- The in-core irradiation 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 with the reactor operating limits and conditions.
- An expert mission from the safety section of IAEA was requested to support the review of the safety documentation of Mo-99 production .

Status of Production of Mo-99 from Fission of LEU Targets

Irradiation boxes:

- **A special in-core irradiation boxes have been designed and manufactured for irradiation of the uranium targets for fission Mo-99 production**
- **A testing loop was used to verify the irradiation box engineering.**

Two targets holders



In-core irradiation box

Status of Production of Mo-99 from Fission of LEU Targets

Processing Facilities:

- **The training on the processing steps for production plant were completed in Argentina.**
- **The handling rout for the irradiated targets from the reactor to the radio-isotope production facility was defined.**
- **Initial review of the updated safety Analysis Report was reviewed**
- **All necessary cold tests in the hot cells were finalized.**
- **Hot commissioning is expected to be started by the end of 2009.**
- **After commissioning starting production 2009, to cover the needs of national hospitals.**

Plan for commissioning of M0-99 production facilities

- 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 RPF.
- The test will consist in characterization of the core and verification that the core conditions remain within acceptable criteria when irradiation boxes for Mo-99 production are placed inside the core.
- Half power irradiation of Mo-99 production targets will be performed as hot start-up of tasks and tests for irradiation facilities commissioning.
- One full power irradiation of Mo-99 production targets will be performed to finalize commissioning and tests of irradiation facilities at ETRR-2.

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 E14): reactor startup;
- Day 6: reactor shutdown. Irradiation boxes are removed from core and placed in pool for cooling;
- Day 8: same as Day 1
- Day 13: same as Day

... Etc

- Cooling time is 24 hours
- Target processing takes 18 hours
- Weakly Production is two patches 500 Ci each on fixed days of the weak and two days apart

Local Technical support infrastructure

Local Technical support infrastructure

- National center 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 radio isotope.
- Local experience for exporting radio isotopes including safer transportation according to international regulation

Prospects for international cooperation

EAEA can supply part of the Mo-99 generators regional or international market

reliable supply of this Mo-99 generators by ETRR-2 needs:

- Secure reactor fuel and Mo-99 targets supply necessary for long operation

- technical assistance including spar parts and consumable material supply

-Collaboration with other reactors producing Mo-99 (puck up, experience and technology transfer, marketing ,…

- Enough number of trained operators to support long operation.

5. Services and Collaboration

- Collaborations between Egyptian R.Rs for better utilization can be achieved with countries which not having R.Rs, this activity is important for social benefit, information exchange, services marketing and income generation. The modes of collaboration are:-

5 - Services and Collaboration

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.

  -To improve the reactor products with market nodes.

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 5",6" and length 30cm.
- Irradiation services to produces, I-131, C0-60, P-32.

5- Services and Collaboration

- Implementation of INAA, NAA for geological, foodstuff , biological and environmental samples.
- Simulation training.
- O-J-T.
- Software training (e.g. MNCT) code, 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-camera.
- Maintenance of gamma-camera and radiation protection devices.

5- Services and Collaboration

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.
- Common research and scientific publications.

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