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Education and Training on Critical Facility Stand

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ABSTRACT

Training is one of the most important tools for acquiring and maintaining the competency required for various categories of personnel working in the nuclear field. In this context, the Tajora Nuclear Research Center uses the research reactor as well as the Critical Facility Stand as the main tool to ensure a practical and comprehensive understanding of nuclear reactor physics, principles, and operation. The Critical Facility Stand is a 100-watt reactor of the tank type that uses water as a moderator for neutrons and enriches uranium by 19.7% [1]. A Critical Facility Stand Core is a replica of the Main Reactor Core IRT-1 (10 MW$_{th}$), which is used as a support facility for the Main Reactor in training new operators as well as conducting experiments for university students. The core training modules focus on topics related to operation and safety in a nuclear facility, radiation protection, nuclear analytical techniques and their applications, quality assurance of nuclear facilities, and management. That is, thanks to the experience gained in operating and managing the reactor. This paper will discuss the role of the Critical Facility Stand in training new operators of the main reactor, university students, and, the procedures that followed.

1. INTRODUCTION

Tajora Nuclear Research Center (TNRC) was established in 1977. It has been operating since 1980 under the umbrella of the Libyan Atomic Energy Establishment (LAEE) as an institution concerned with nuclear sciences, where its main function is to transfer and develop nuclear sciences in the State of Libya, which is the house of expertise in the nuclear field.

The Tajora Nuclear Research Center houses a 10 MW nuclear research reactor that reached criticality in 1983 with 19.7% [1] low enrichment uranium as a neutron source for the production of radioactive isotopes for medical, agricultural, and industrial applications. The research reactor uses light water as a coolant and moderator, beryllium as a reflector, and boron carbide as a control rod.

In addition to the critical facility stand with a capacity of 100 watts, the first criticality was in 1982, which is a mock-up of the core of the main reactor (research reactor 10 MW$_{th}$), and it is the main tool for training the new operators of the main reactor as well as conducting experiments for the students of the Nuclear Engineering Department at the University of Tripoli (established in 1978, which was equipped with laboratories and educational means to prepare and conduct experiments for students) as well as cooperation with international organizations such as the International Atomic Energy Agency (IAEA) and the Arab Atomic Energy Agency (AAEA).

2. The Critical Facility. [1]

The Critical Assembly of the Critical Facility is a physical model of a reactor (mock-up), designed primarily for experiments carried out with a view to:

- modeling the reactor core load and studying its physics;
- Preparation and optimization of experimental facilities installed in the reactor core.

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Besides, the critical facility may be used:

- to study the parameters of uranium-water lattices of power reactors;
- Fulfilling practice exercises on a thermal column;
- Training and probation of reactor engineer operators.
- Student experiments lab.

The Critical Assembly (Reactor Physical Model) is designed for a rated heat power of 1 watt and a maximum heat power of 100 watts and is arranged in the aluminum tank, which is 2 meters in diameter and approximately 4.5 meters high. The tank is mounted on a separate box and is filled with demineralized water (20 c° to 45c°). The box walls are 1.5 meters thick and made from conventional concrete with a density of 2.3 g/cm³ they provide a sufficient biological shield for the Critical Assembly.

The reflector of the critical assembly (Reactor Physical Model) is a replica of the Main Reactor reflector and is essentially a set of stationary beryllium blocks enclosed in an aluminum vessel and forming a cavity that accommodates fuel assemblies as shown in Figure 1.

The Critical Facility incorporates a graphite thermal column. The first stage of the column adjacent directly to the reflector face is arranged within the critical assembly tank. The second and third stages are located outside the tank, in the box's concrete wall.

To ensure reliable monitoring of the chain reaction, starting with installing the first fuel assemblies into the critical assembly, provide a neutron source (Californium-252) of 10^6 n/sec. It is arranged in one of the replaceable beryllium units.

The power level of the critical assembly is monitored via six independent channels of equipment set within the range of 10^{-7} to 9.9×10^2 watts [1]:

- Three channels with fission chambers (channels SR1, SR2, and SR3) allow monitoring from 1.0×10^{-7} to $1.0x\ 10^{-1}$ w [1].
- Three channels with ionization chambers (WR1, WR2, and WR3) allow monitoring in the range of $1.0x10^{-3}$ to 9.9×10^2 w [1].

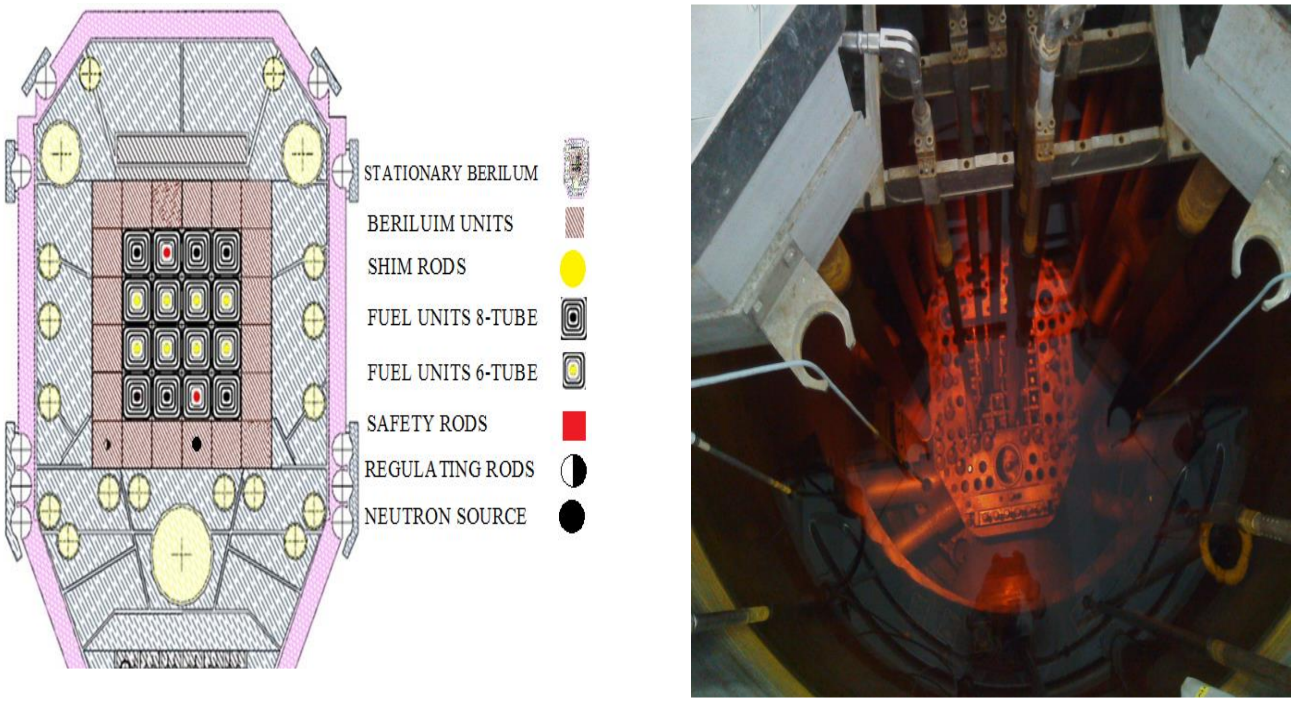
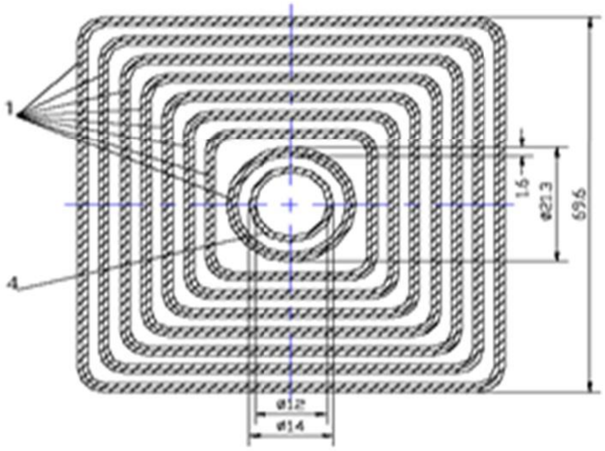


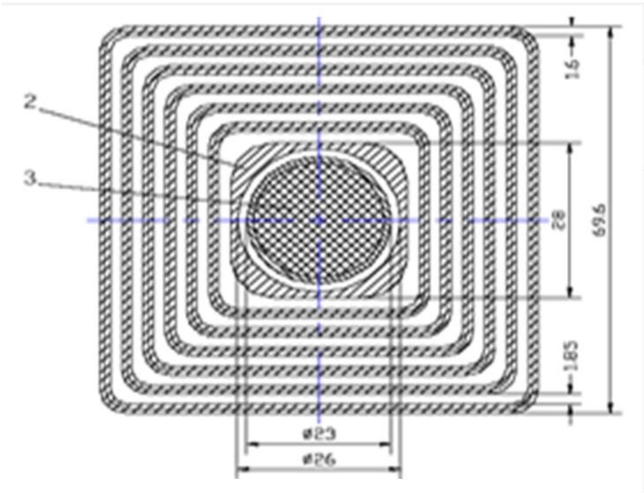
Fig. (1): Core configuration of Critical Facility

3. FUEL

The type IRT-4M 8-tube and 6-tube fuel assemblies shown in Figure.2 with the uranium-235 used in the reactor physical model are arranged on a supporting aluminum alloy lattice at a pitch of 71.5 mm in the same way as in the main reactor.



8 Tube Fuel Assembly



6 Tube fuel Assembly

Fig. (2): Fuel assembly shape at Critical Facility

4. CONTROL AND SAFETY FEATURES [1]

The control and safety system of the critical facility permits remote control of the chain reaction from the critical facility operator's desk:

- The control is effected through eight compensating organs (shim rods), Fig.2 each with its own drive, and one manual regulating rod. The absorbing portion of the rods is 600 mm long and made from boron carbide. All the rods have individual drives. The shim and regulating rods are withdrawn from the critical assembly core in steps.
- Two safety rods, fig. 1, are used for starting up and shutting down the reactor made from boron carbide, depending on the position of the safety rods up or down.
- Additional protection of the critical facility is provided by draining demineralized water (moderator) from the critical assembly tank through the quick dump valve. The dump valve can be opened with the help of the quick- drain buttons located in the critical facility hall and on the operator's desk.

5. CRITICAL FACILITY TEAM [2]

Since 1984, the critical facility has been used to carry out training tasks for new operators (Critical Facility, Main Reactor) and Department of Nuclear Engineering students teaching at the University of Tripoli.

The work team consists of purely national engineers, whereas the work team consists of:

- One of the conditions for appointing the scientific supervisor for experiments and the manager of the critical facility is that be a nuclear engineer with high qualifications and excellent knowledge in reactor physics and engineering.
- One of the conditions for assuming the position of shift head and control physicist is that be a nuclear engineer with high qualifications and experience in the field of operating the critical facility for at least one year and pass the examinations for filling the position.
- One of the conditions for assuming the position of a critical facility operating engineer is that be a nuclear engineer and have practical training in operating the critical facility for at least three months.
- Among the conditions for assuming the position of an engineer responsible for the control and safety system (CSS) in the critical facility is knowledge in the field of electronic engineering, training in the maintenance and operation of (CSS) for no less than six months, and passing special exams to fill this position.
- Among the conditions for assuming, the position of a mechanic or radiation protection officer (RPO) in the critical facility is sufficient

knowledge in the field of specialization, practical experience of not less than three months, and passing exams to fill the position.

The TNRC employs and trains a select number of new employees and students from the department of nuclear engineering each year to become fully qualified and licensed reactor operators.

The training combines lectures, demonstrations, and experiments. Review of radiation protection procedures and regulations; theory and use of alpha, beta, gamma, and neutron detectors; applications in dosimetry and gamma-ray spectroscopy.

6. OPERATOR TRAINING [3]

The training process involves gaining broad and deep knowledge of the reactor systems, how they affect each other, and the operation of the reactor.

Trainees spend three months reading about the reactor systems to help them understand how everything is connected. When the trainee has gained sufficient knowledge of the critical facility, they start to operate it under direct supervision from the shift head.

Trainees learn to operate the critical facility by performing startups, shutdowns, and power manipulations. Learning how quickly the reactor responds to control movement can only be gained through practice.

Once the trainee has demonstrated the ability to operate the critical facility, including responding appropriately to abnormal conditions, the trainee applies for a license. The exam is conducted through an interview, a tour of the critical facility, and a critical facility startup. If the trainee passes the exam, then becomes licensed. If the operator moves to the main reactor, must become re-licensed for the main reactor.

A critical facility operator may choose to upgrade their license to a shift head or control physicist license. This requires additional operating experience, training, and another exam.

7. COURSES & LABS

To complete a bachelor's degree in the Department of Nuclear Engineering at the University of Tripoli, the TNRC provides the Critical Facility as well as the Main Reactor for students to conduct the nuclear lab. It allows students to link between the theoretical and the practical aspects. The program consists of several experiments that last for five weeks Table.1.

Table (1): Material of reactor physics laboratory exercise at Critical Facility

No	Topics
1	Introduction to reactor operation
2	Building up critical mass
3	Reaching Criticality
4	Regulating Rod Calibration
5	Control Rods (Shim and Safety rods) Calibration
6	Reactivity Worth of Fuel Assembly (8-tube, 6-tube)
7	Flux Mapping of the Core (Thermal Neutron Flux)

Students gain some ideas about reactor operation. Students gain a deeper understanding of reactor operation by raising and lowering the energy level, and evaluating the worth of all components at critical assembly, as shown in Figures. 4 and 5, where the students calculate the reactivity worth of components. Every two years, the TNRC hosts around 14 students for the program Figure 3 shows the inside of the control room where the parameters of the reactor can be followed on a supervision screen.

Fig. (3): Control Desck of Critical Facility

Through the Undergraduate Research Opportunities Program, can collaborate with research scholars or faculty during the summer or during the academic year.

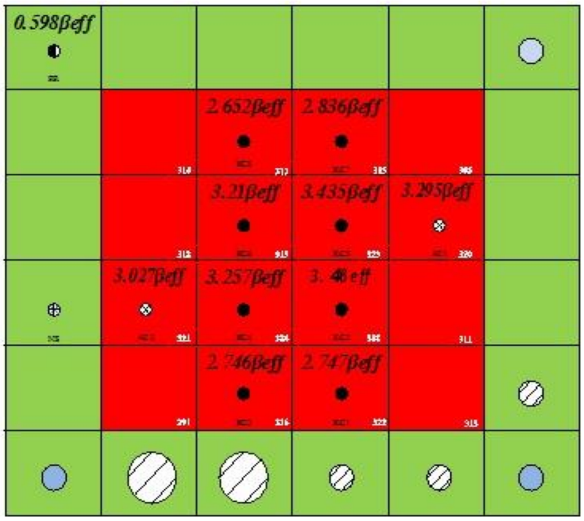


Fig. (4): worth of CR, RR, SR

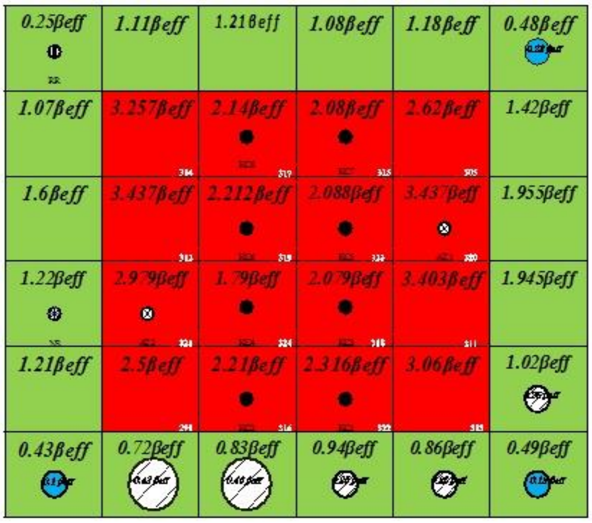


Fig. (5): worth of fuel Assembly, and Beryllium unit

8. CONCLUSION

The training courses of a real nuclear facility are the only way students can approach and understand how different subjects are taken into account to ensure the safe operation of a nuclear facility. Learn how to follow, respect, and apply all regulations.

The feedback from the students shows that practical exercises, as well as hands-on reactor operation, are very efficient in going deep inside the understanding of the theoretical courses in reactor physics.

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