JORDAN RESEARCH AND TRAINING REACTOR UTILIZATION FACILITIES

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1. INTRODUCTION

The building and construction of a research and test reactor is a gigantic step towards establishing a nuclear power programme in Jordan and a landmark of its nuclear technology infrastructure. The reactor will become the focal point for a National Nuclear Technology Center (NTC) that is intended to play the primary role in educating the upcoming generations of nuclear engineers and scientists in Jordan [1], and provide irradiation services in support of the Jordanian industrial, agricultural and health/medical infrastructure [2].

The Jordan Research and Training Reactor (JRTR) will be located in Ramtha approximately 70 km north of Amman, within the Jordan University of Science and Technology (JUST) campus, one of the largest universities in Jordan. With about 20 000 students from more than 50 nations, the university is home to the only Nuclear Engineering Department (NED) in Jordan [3]. Currently, Jordan serves as a regional educational centre, a medical hub for the Middle East and a supplier of know-how in the various areas of education, engineering and science. It is anticipated that the established NTC will support these efforts and complement and solidify the objective of instituting nuclear energy as a viable option for fulfilling the Jordanian electricity and water needs in the 21st century

2. JRTR DESCRIPTION

Jordan Research and Training Reactor (JRTR) is a multipurpose isotope production, research and training reactor, with a designed power of 5 MW upgradable to 10 MW. It is light water moderated and cooled open-tank-in-pool type reactor; the core (shown in Figure 1) consists of 18 MTR plate type fuel assemblies, surrounded by beryllium and graphite reflector blocks. The core is flexible and can be reconfigured by replacing the fuel assemblies with beryllium blocks and vice versa.

The fuel is MTR plate type, aluminum clad, 19.75% enriched uranium silicide (U_3Si_2) dispersed in an aluminum matrix. The nominal fuel loading is 18 fuel assemblies containing 7.0 kg of ^{235}U, and each assembly is a bundle of 21 fuel plates. The operating cycle is 50 days. When one fuel assembly is reloaded; the average discharge burn-up is 70%.

The compact core design is optimized to produce the highest thermal neutron fluxes at in-core and external irradiation facilities. The maximum in-core thermal-flux-to-power ratio is 2.9×10^{13} cm^{-2}s^{-1}MW^{-1}, producing a maximum thermal flux of 1.45×10^{14} cm^{-2}s^{-1}, and the maximum external thermal flux to power ratio is 1.4×10^{13} cm^{-2}s^{-1}MW^{-1} producing a maximum thermal flux of 6.78×10^{13} cm^{-2}s^{-1}.

Forced convection cooling is used to cool the reactor under normal operating conditions. The coolant flows downward at a rate of 146 kg/s, with an inlet temperature of around 35°C and exits the core with an outlet temperature of 44.2°C. The average heat flux is 17.3 W/cm^2, with a maximum of 51.9 W/cm^2, and the power peaking factor is 2.54 [4].

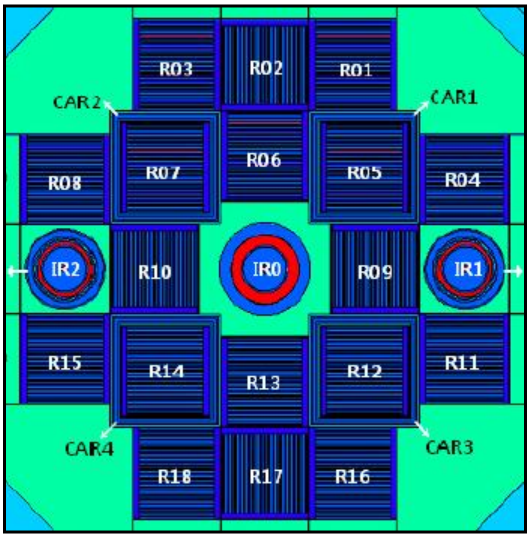

Fig. 1. JRTR Core showing the fuel assemblies and beryllium blocks.

3. UTILIZATION FACILITIES

JRTR is designed to be utilized in three main areas: education and training, advanced nuclear research, and commercial and industrial services centered on radioisotopes production. To carry out these functions the JRTR is equipped with 30 vertical experimental facilities (VXF), 4 beam ports and 1 thermal column. The location and layout of the facilities is shown in Figure 2.

3.1 Educating and training

The reactor is designed to include laboratories and classrooms that will support the establishment of a nuclear reactor school for educating and training students in disciplines like nuclear engineering, reactor physics, radiochemistry, nuclear technology, radiation protection, and other related scientific fields where classroom instruction and laboratory experiments will be related in a very practical and realistic manner to the actual operation of the reactor. Nuclear engineering problems of shielding, criticality, control rod aspects, temperature feedback, and reactivity will be demonstrated using the reactor, providing students with an enormously valuable experience. In addition to the reactor building the center will have a two story building consisting of four classrooms, an auditorium, and a visitor’s gallery.

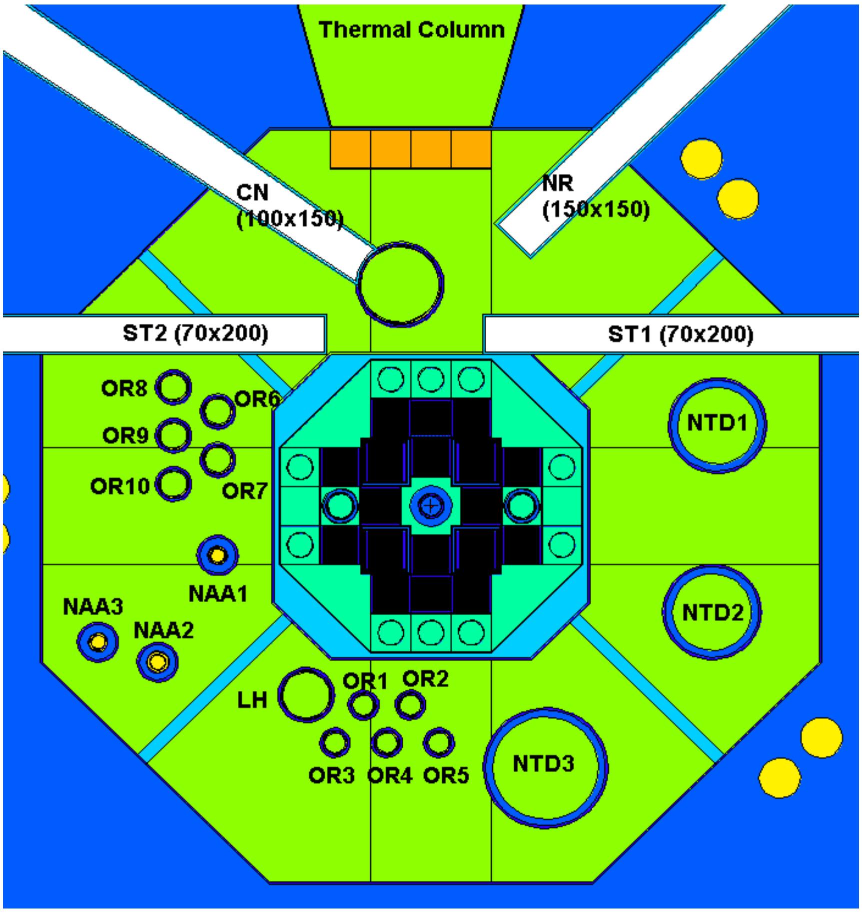

Fig. 2. JRTR utilization facilities layout.

3.2 Neutron activation analysis (NAA)

Radio-analytical techniques such as NAA are one of the most used applications in research reactors. JRTR is designed with three vertical experimental facilities (VXF) dedicated for NAA, each equipped with pneumatic transfer systems (PTS), and a laboratory equipped with a gamma spectroscopy neutron detection system for specimen preparation, irradiation control, measurement, and storage as shown in Figure 3.

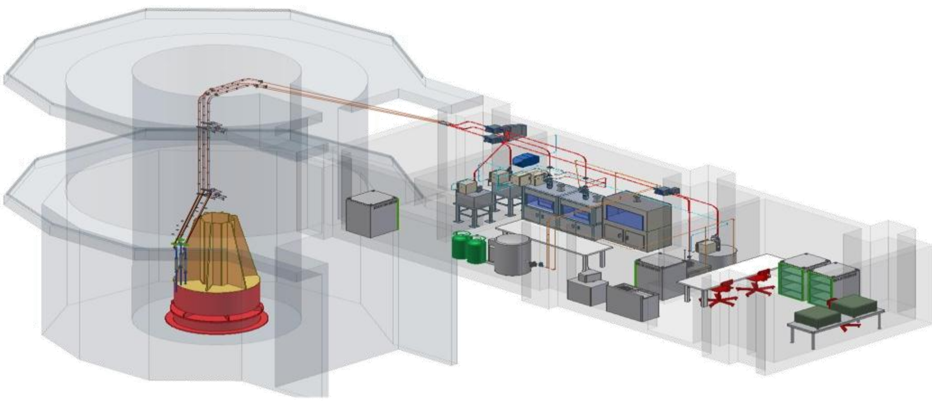

Fig. 3. Neutron activation analysis facility.

3.3 Neutron transmutation doping (NTD)

The superiority of NTD technology over other doping techniques lays in the high homogeneity of the doping profile. When a silicon ingot (^{30}Si) is irradiated in the reactor, it absorbs neutrons, and the product is unstable (^{31}Si) nuclei, which are transmuted into a phosphorus (^{31}P) nucleus by changing a neutron in the ^{31}P nucleus into a proton as shown in the Figure 4. The JRTR is designed with 3 vertical experimental facilities (VXF) dedicated for NTD, 2 (NTD1&2) for commercial service of 5 and 6 inch silicon ingots, and 1 (NTD3) for commercial service of 8 inch silicon ingots. The average thermal flux at the irradiation facilities is 1.4×10^{13} $cm^{-2}s^{-1}$ and they can accommodate ingot of 50 cm in length.

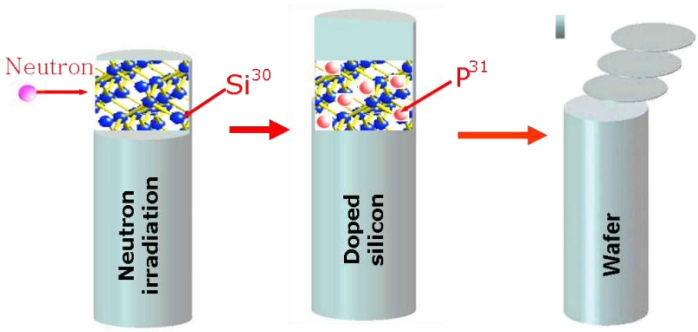

Fig. 4. Neutron transmutation doping reaction by neutron.

3.4 Radioisotopes production

JRTR has the capability to produce a significant number of radioisotopes, but only three will be produced in the initial phase at the startup of the reactor. Two major radioisotopes (^{131}I and ^{192}Ir) for their economic viability, and one (^{99}Tc) for its social impact, will be produced. The JRTR radioisotope production (RIP) facilities will have three banks equipped with eight Hot Cells for processing and production of these isotopes.

The first bank consisting of two hot cells is designed for the production of ^{192}Ir radiography sources. The production capacity of ^{192}Ir sources in the core is estimated at 2 200 Ci/month. The second bank consisting of four hot cells, and a glove box is designed for the production of ^{131}I. The production capacity of ^{131}I in the core is estimated at 20 Ci/week. $^{99}Mo/^{99m}Tc$ will be produced utilizing the (n, γ) reaction.

3.5 Neutron beam ports

The JRTR is designed with four horizontal beam ports, and one thermal column as shown in *FIG. 5*. One tangential cylindrical port (NR), is designed for neutron radiography, 2 tangential rectangular ports for neutron science applications and research, and 1 radial rectangular port is designed to host a cold neutron source (CNS).

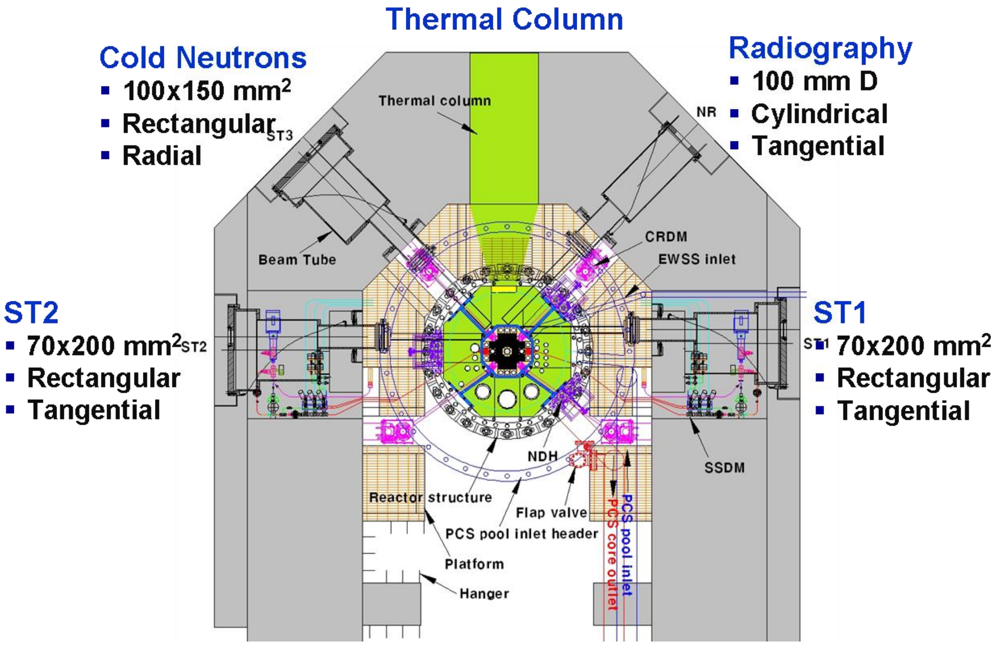

Fig. 5. JRTR neutron beam ports.

4. CONCLUSION

JRTR is Jordan's world class research reactor, which will be playing the primary role in the development of the infrastructure necessary for a nuclear programme and the introduction of nuclear power as part of the energy mix in Jordan. The reactor is scheduled to be completed and commissioned in March 2015, allowing no less than five years before the introduction of Jordan's first nuclear power plant; a period necessary for building and qualifying indigenous human resources and developing the necessary nuclear infrastructure.

JRTR's high performance and diversified utilization facilities will fulfill a critical role in the production of radioisotopes and neutron beams for scientific and commercial uses necessary to support Jordan's educational, health, environmental, industrial and national security objectives.

5. References

[1] XOUBI, N., "Proposal of a nuclear reactor at Jordan University of Science & Technology", JUST/NE/2007-103, Jordan University of Science and Technology, Irbid, (2007).

[2] XOUBI, N., "Request for proposals for the design and construction of research and training reactor", Jordan Atomic Energy Commission, Amman (2009).

[3] XOUBI, N., "Development of nuclear engineering education in Jordan", International Conference on Knowledge Management in Nuclear Facilities, Vienna, 2007, International Atomic Energy Agency, Vienna (2007).

[4] KOREA ATOMIC ENERGY RESEARCH INSTITUTE, DAEWOO, Technical Proposal for the Design and Construction of Research and Training Reactor, Korea Atomic Energy Research Institute, Daejeon (2009).