Future Applications of Neutron Beam Instruments for Jordan Research and Training Reactor (JRTR)

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1. Introduction

Jordan Research and Training Reactor (JRTR) is a 5 MW_{th}, open-pool type, with a maximum thermal flux of $1.7x10^{14}$ n/cm^2.sec [1]. JRTR was designed to achieve a wide range of purposes such as; Neutron Activation Analysis (NAA), material irradiations, Radioisotope Production (RI) as well as to provide the gluttony regional market with a well-trained manpower in various nuclear fields. This article highlights one of the most important objectives of JRTR to make Jordan the center of nuclear and material research by exploiting the advantages of Neutron Beam Instruments and their various applications.

2. General Characteristics of JRTR Beam Tubes

JRTR encompasses a featured experimental hall with four beam tubes, two of which are aligned tangential to the core named Standard Thermal tubes (ST1) and (ST2), where the other tubes are aligned by different angles with the core and are planned for to be Neutron Radiography tube (NR) and Cold Neutron tube (CN). In addition, JRTR has a vertical hole designed to be utilized as a Cold Neutron Source (CNS) as shown in Fig. 1.

Table I: JRTR Beam Tube Specifications [1,2]

Beam Tube ID	Beam nose (wide x height) (mm)	Calculated Thermal flux at Beam nose (n/cm^2.s)	Remarks
ST1	70 x 200	4.8 x 10^{13}	Thermal Neutron
ST2	70 x 200	4.5 x 10^{13}	Thermal Neutron
NR	150 in diameter	2.7 x 10^{13}	Thermal Neutron
CN	100 x 150	2.9 x 10^{13}	Cold Neutron

3. Future Phases & Applications

The possible future facilities of the JRTR neutron beam instruments and their expected applications are outlined in this section. The suggested plan for the installation of these instruments can be discriminated in two phases, as follows.

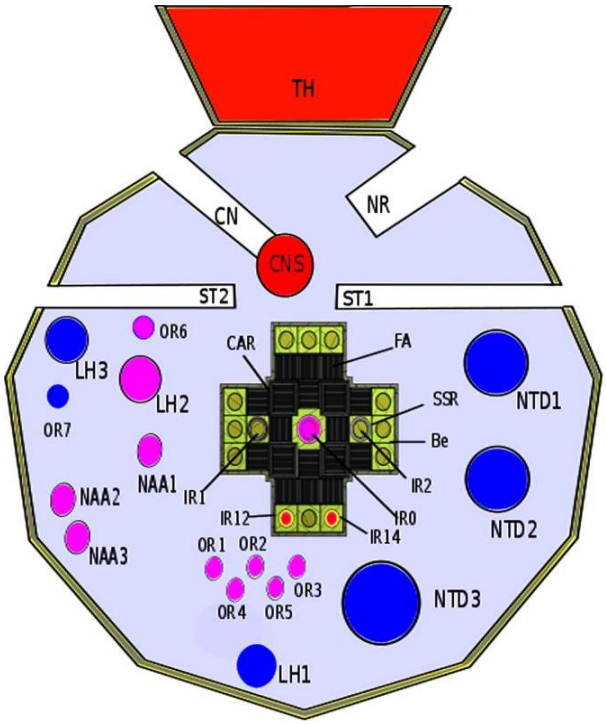

Fig. 1. JRTR core configuration top view with Beam Tube position; FA: Fuel Assembly, SSR: Second Shutdown Rod, CAR: Control Absorber Rod, Be: Beryllium Reflector, IR0: Central Flux Trap, IR1-14: Irradiation Holes, NTD1-3: Neutron Transmutation Doping, NAA1-3: Neutron Activation Analysis, LH1-3: Large Irradiation Hole, OR1-7: Outer Region irradiation holes, ST1,2: Standard Beam Tubes, CNS: Cold Neutron Source, NR: Neutron Imaging, TH: Thermal Column, Pink Color: Aluminum Plug, Blue Color: Water Filled [1].

3.1 Current Phase

This stage includes the design and the installation of the High Resolution Powder Diffractometer (HRPD) on ST1 tube and the Neutron Radiography Facility (NRF) on NR tube, see Fig.2.

There are many conditions and options will be taken into consideration in order to design the most proper HRPD instrument for JRTR. These conditions can be summarized as follows; the HRPD's intended applications, the possible neutron intensity at sample position, the required monochromator characteristics

including the types of crystals (PG, Ge, Cu, Si), the mosaic angles β as well as the different Bragg angles θ_M and the resulted monochromatic wavelength, also the need to implement a high resolution neutron detection system such as He-3 Proportional detectors.

All of these options permit the JRTR to utilize the wide variety of applications of HRPD that comprise the determination of magnetic properties of matter, studying complex crystal structures and investigation of the material phase transitions under various environmental conditions. All of these applications are related to different research areas such as; Ionic conductor, materials for lithium ion batteries, oxygen conductors, ferroelectrics, hydrogen storage materials, super alloys, superconductors, minerals and geological studies [2,3].

On the other side, the neutron radiography facility is expected to support Jordan and the Middle East region in various research fields, such as geology and soil physics, investigating of complex mechanical parts, studies on nuclear fuel and cladding, determination of hydrogenous material, 2-D and 3-D sample structure imaging, non-destructive study of biological samples. [4].

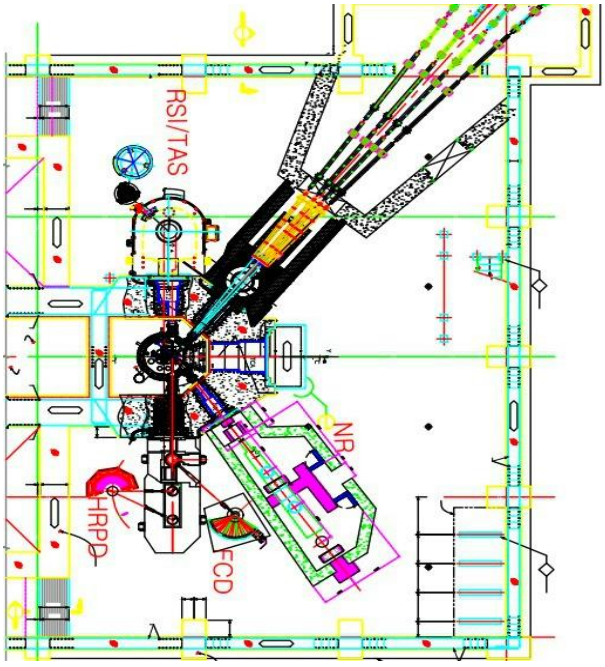

Fig. 2. The possible Layout of Neutron Beam Instruments of ST1, ST2, and NR tubes at JRTR [4].

3.2 Future Phase

In addition to the current phase, JRTR plans to utilize the ST2 tube and the CN tube in future, where these two tubes are able to be attached with a various kinds of instruments with numerous applications as described in Table II & III.

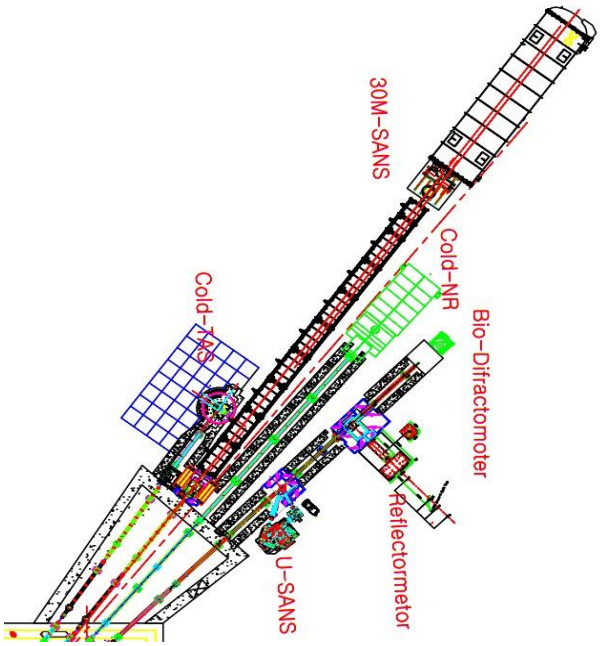

Fig. 3. The possible Layout of Neutron Beam Instruments of CN tube at JRTR [4].

Table II: Possible Neutron Beam Instruments at ST2 tube in Future Phase at JRTR [2,4].

Instrument	Applications
RSI*	investigate the internal and residual stress on materials including the static and fatigue load
M-TAS**	understand the atomic, molecular and magnetic excitations in condensed matter

*RSI: Residual Stress Instrument
**M-TAS: Multi-purpose Triple Axes Spectrometer

Table III: Possible Neutron Beam Instruments at CN tube in Future Phase at JRTR [2,4].

Instrument	Applications
SANS*	Determination of atomic and magnetic structures of single crystals, Crystallographic Texture, large scale structure determination (polymers, biological molecules and magnetic domain)
Ultra SANS	Micro & Nano Structures (cracks, bacteria, clays, polymers ...etc.)
Cold TAS	Atomic-scale & phonon dynamic
Bio-Diffractometer	crystallography of macromolecules such as protein and enzymes
Reflectometer	Study surfaces, complex fluids, buried interfaces, magnetic films and multilayered structures
30M SANS	Nano-structure Studies, lens option
Cold Radiography	Dark field image for (such as tiny and sophisticated mechanical parts, water distribution in plants ... etc.)

*SANS: Small Angle Neutron Scattering Instrument.

4. Conclusion

The JRTR has a featured characteristics and specifications which will support Jordan to establish its own nuclear program, especially with well-trained manpower. The future applications of Neutron Beam Instruments for JRTR looks very promising and fruitful, and while JRTR is continuing to achieve these Applications Jordan will be absolutely the center of nuclear and material research in Middle East. In addition, Jordan will play a main role in developing the peaceful uses of nuclear technology in Middle East, which will encourage other countries to follow Jordan. In summary, JRTR is expected to make a scientific revolution in Jordan and other regional countries which will push the industrial sectors to high advanced levels.

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