Some essential features of the TAPIRO Fast-Neutron Source Reactor

located at ENEA-CRE Casaccia (Rome)

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Abstract

TAPIRO is a fast neutron source reactor operating at CASACCIA Research Center since 1971. The project, entirely developed by ENEA's staff, is based on the general concept of AFSR (Argonne Fast Source Reactor - Idaho Falls).

The reactor is equipped with a homogeneous cylindrical core having 6.29 cm as radius and 10.87 cm as height; cladding is provided by stainless steel (0.5 mm thickness) placed on a cylindrical copper reflector having (30 cm as thickness). All components assembled in a stainless steel tank, are placed inside a near spherical borated concrete shielding system having 1.75 m as thickness. Channels of various dimension and with different neutron spectra are distributed around the core. A large thermal column is manufactured by graphite blocks, suitable to be removed and replaced with experimental assemblies for any research purpose.

The TAPIRO possibilities for reactor experiments with energies up to 1.35 MeV will be illustrated.

REACTOR LAYOUT

The TAPIRO reactor, located in the ENEA Casaccia Centre near Rome, is a highly enriched uranium-235 fast neutron facility. Since 1971, it has been used for fast reactor shielding experiments, biological effects of fast neutrons, etc. A sketch of the reactor is shown in Figures 1 and 2. The nominal power is 5 kW (thermal) and the core (with central neutron fluence rate of 4×10^{12} n · cm^{-2} · s^{-1}) is cooled by helium. The reactor cylindrical core (12.58 cm diameter and 10.87 cm height) is made of 93.5 % enriched uranium metal in a uranium-molybdenum alloy (98.5 % U, 1.5 % Mo in weight) and is totally reflected by copper; it is made by two overlapped cylindrical blocks: the upper one is fixed to the reactor structure whereas the lower one is movable and can drop in order to rapidly shut-down the system. The reactivity control is achieved by adjustment of the core neutron leakage from the reflector.

The copper reflector (cylindrical-shaped) is divided into two concentric zones: the inner zone, up to 17.4 cm radius, and the outer zone up to 40.0 cm. radius. The height of the reflector is 72.0 cm. A 60° sector of the external copper reflector is removable allowing insertion of fissile spectral conversion zones feeding the thermal column.

The reactor is surrounded by borate concrete shielding about 170 cm thick.

Four experimental channels take place within the system: three different channels at the reactor midplane and one tangential (to the top edge of the core) channel. One midplane channel crosses over the core allowing measures of small samples (internal diameter of the channel in correspondence of the core ≈ 1 cm) in an almost pure U-235 fission spectrum.

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A large experimental cavity, labeled thermal column (parallelepiped 110 × 110 × 160 cm), is present within the shield zone. The maximum depth available for the epithermal column is 160 cm (distance from the external surface of the reflector), reserved for filter/moderator materials.

NEUTRONICS

At the full nominal reactor power, the total core integrated neutron source strength is of $\approx 3\times10^{14}$ n/s. Such an integrated neutron source strength provides a total neutron fluence rate of $\approx 4\times10^{12}$ $n \cdot cm^{-2} \cdot s^{-1}$ at the core center ($\approx 8\times10^{11}$ $n \cdot cm^{-2} \cdot s^{-1}$ > 1.35 MeV estimated by calculation) and a total neutron fluence rate of $\approx 1.5\times10^{10}$ $n \cdot cm^{-2} \cdot s^{-1}$ ($\approx 4\times10^{7}$ $n \cdot cm^{-2} \cdot s^{-1}$ > 1.35 MeV estimated by calculation) at the entrance of the thermal column.

A large array of spectral shapes is available throughout the system.

ACTIVITIES IN PROGRESS UP-TODAY

Actually, the reactor team (1 Director + 1 Supervisors + 1 trainee Operator + 1 Technician) drives the TAPIRO reactor in order to support R&D activities in the following fields:

- Materials: Characterization of N-16 counters devoted to monitoring functions in eastern Europe power plants. Neutron radiation damage on lead tungstate single crystals, APD's (Avalanche Photo Diodes) and optical flats in the frame of the ECOLE electromagnetic calorimeter design (CERN LHC-Large Hadron Collider Project). Neutron radiation influence on airspace electronic components (silicon based). Radiography and sectional radiography in the field of non-destructive analysis techniques.
- Radiology: BNCT (Boron Neutron Capture Therapy) and, in general, neutron radiation effects on cancerous cells [1].

FUTURE ACTIVITIES

SUPPORT TO ACCELERATOR-DRIVEN SYSTEM R&D

The TAPIRO source reactor provides a rich variety of relevant reference neutron spectra, with reasonably high neutron fluence rate (ranging from 10^{12} $n \cdot cm^{-2} \cdot s^{-1}$ at the core center to 10^{10} $n \cdot cm^{-2} \cdot s^{-1}$ within the thermal column). The natural capabilities of the system, conceived as a neutron source producer, consider its application in the field of the neutronic characterization of neutron source fed components.

- Different patterns of neutron field available in the system allow investigations of selected phenomena (like radiation damage) under a large variety of fluence and spectrum conditions.
- Static and dynamic neutron flux regimes may be employed in order to perform parametric studies on ADS prototypical fuel components inserted within the reactor thermal column (eventually fed by an auxiliary spectral converter zone).
- Steady neutron flux conditions may be employed to analyze, for example, the influence of fuel/Pb ratio on neutronic behavior of fuel-lead matrices.

- Dynamic neutron flux conditions, achievable by dropping the lower movable portion of the TAPIRO core, may reproduce absolute reactivity measurement conditions relative to source-jerk techniques.

BLANKET EXPERIMENTS

Benchmark experiments are possible on the fast source reactor TAPIRO in order to validate the neutronic codes for studying systems characterized by significant spectral changes within the core and blanket, as is the case for HTGR and fast systems. The experiments would consist in detection traverses in graphite and lead columns, starting from near external reflector boundary, where a sector of the outer copper reflector can be removed obtaining a very hard neutron spectrum. In experiments along the graphite column the spectrum gradually softens up to thermal values, whereas in experiments along the lead column the spectrum softens from hard to epithermal ones. Different materials would be interposed, such as U-nat, Pb, Fe, etc. to reproduce spectrum transition conditions at interface points between regions with different compositions. Activation foils would be used for analysis with threshold energies in the fast, intermediate and epithermal regions. The activity measurement performed by quantitative gamma spectrometry will allow the detection of the neutron flux and spectral properties in a suitable number of energy groups for each of the given sets of control points. Other detection techniques, such as those utilizing fission chambers, would also be considered.

Analogous experiments on TAPIRO were performed in the early 70's for studying the propagation of neutrons along the axis of a large sodium tank inserted in place of the graphite column. It was a measurement campaign made in collaboration with CEA Cadarache within the fast reactor program and had a similar purpose, i.e., that of testing the ability of neutronic codes to reproduce the measured quantities. Those experimental data are now included in the NEA documentation within the International Reactor Physics Experiment Evaluation Project (IRPhEP [2]).

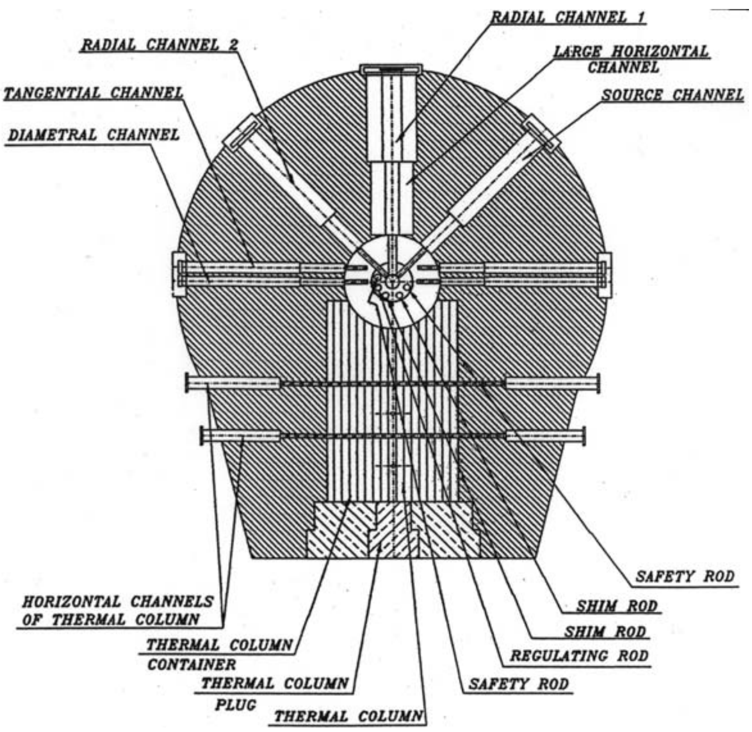

Figure 1 – TAPIRO Horizontal Section

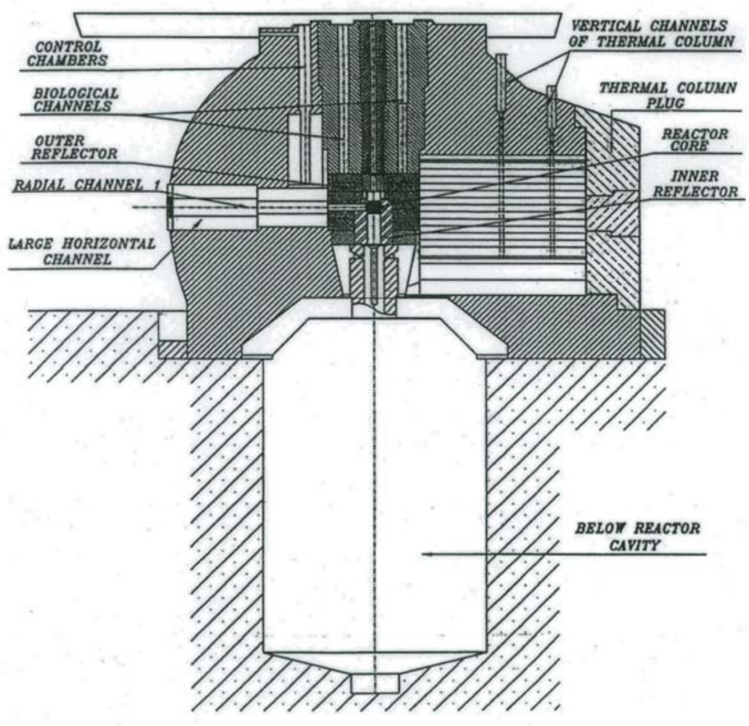

Figure 2 – TAPIRO Vertical Section

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