ENEA Thermal and Fast Research Reactors utilization for R&D activities at Casaccia Center


ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development
C.R. CASACCIA
Via Anguillarese, 301, 00123 S. MARIA DI GALERIA (ROMA) ITALY
mario.carta@enea.it, massimo.sepielli@enea.it
1. TRIGA RC-1 reactor

2. TAPIRO reactor

3. Final comments
We are here
We are here
TRIGA RC-1 Reactor
<table>
<thead>
<tr>
<th><strong>Reactor</strong></th>
<th>Triga Mark II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactor Name</strong></td>
<td>ENEA RC-1</td>
</tr>
<tr>
<td><strong>Site</strong></td>
<td>C.R. Casaccia Rome</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>1 MW</td>
</tr>
<tr>
<td><strong>Construction (100 kW)</strong></td>
<td>1960</td>
</tr>
<tr>
<td><strong>Upgrade (1 MW)</strong></td>
<td>1967</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
<td>Uranium – ZrH alloy (8.5% Wt U)</td>
</tr>
<tr>
<td><strong>Enrichment</strong></td>
<td>20 % $^{235}$U</td>
</tr>
<tr>
<td><strong>Moderator</strong></td>
<td>H$_2$O, ZrH</td>
</tr>
<tr>
<td><strong>Coolant</strong></td>
<td>Demineralized water in natural convection</td>
</tr>
</tbody>
</table>
## TRIGA RC-1 Reactor

### TRIGA RC-1 Main Features - 2

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reflector</strong></td>
<td>Graphite</td>
</tr>
<tr>
<td><strong>Control rods</strong></td>
<td>#3 B(_4)C Fuel Follower</td>
</tr>
<tr>
<td></td>
<td>#1 B(_4)C Regulating Rod</td>
</tr>
<tr>
<td><strong>Fuel Clad</strong></td>
<td>SS – Clad (0.5 mm thickness)</td>
</tr>
<tr>
<td><strong>U – 235 per fuel element</strong></td>
<td>~ 38 g (fresh)</td>
</tr>
<tr>
<td><strong>U – 235 loaded</strong></td>
<td>~ 3400 g</td>
</tr>
<tr>
<td><strong>Max burn-up allowed</strong></td>
<td>35 %</td>
</tr>
<tr>
<td><strong>Max Neutron Flux (Central Thimble)</strong></td>
<td>~ $2.7 \times 10^{13}$ n/cm(^2).s</td>
</tr>
</tbody>
</table>
Horizontal Section
TRIGA RC-1 Reactor

Experimental channels
**TRIGA RC-1 Reactor**

**Standard Core Configuration**

- **Standard Fuel Elements** (N=106)
- **Fuel Follower Control Rod** (N=3)
- **Boron Carbide Control Rod** (N=1)
- **Instrumented Elements** (N=3)
- **Graphite** (N=11)
- **Neutron Source** (N=1)
- **Central Thimble** (Air or Water)
- **Rabbit**
TRIGA RC-1 Reactor

TRADE epopee (2000 ÷ 2006)

SC3 (~ -5000 pcm)
pre-TRADE Experimental Benchmark

M. Carta, N. Burgio, V. Peluso, R. Rosa, A. Santagata (ENEA)
C. Jammes (CEA)
M. Martina (Politecnico di Torino)
T. Sasa, T. Sugawara (JAEA)

IAEA Coordinated Research Project
“Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems (ADS)”
coordinated by A. Stanculescu → S. Monti (IAEA)
Irradiation studies in neutron thermal field.

Neutron Radiography & Tomography.

Neutron Activation Analysis.

Radioisotopes production for medical applications.

Reactor modeling: reconstruction of the current fuel burnup level.

Formulation of a Strategic Planning.

Education & Training.
TRIGA RC-1 Staff
TAPIRO Reactor

- Fast source reactor
- Based on the concept of AFSR (Argonne Fast Source Reactor - Idaho Falls)
- Designed by ENEA’s staff
- Start-up: 1971
TAPIRO Reactor

Fixed Core

Mov. Core

Diametral Channel
## TAPIRO Reactor

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CORE</strong></td>
<td>Cylindrical: diameter 125.8 mm</td>
</tr>
<tr>
<td></td>
<td>height 109.5 mm (2/3 fixed – 1/3 mobile)</td>
</tr>
<tr>
<td><strong>FUEL</strong></td>
<td>Uranium-molybdenum alloy (98.5% U – 1.5% Mo)</td>
</tr>
<tr>
<td></td>
<td>Density: 18.5 g cm(^{-3})</td>
</tr>
<tr>
<td></td>
<td>Enrichment: 93.5% U(^{235})</td>
</tr>
<tr>
<td></td>
<td>Operative mass: 22107.42 g/U(^{235})</td>
</tr>
<tr>
<td><strong>CLADDING</strong></td>
<td>Stainless steel: thick 0.5 mm</td>
</tr>
<tr>
<td><strong>REFLECTOR</strong></td>
<td>Cylindrical Inner Reflector: diameter 348 mm</td>
</tr>
<tr>
<td></td>
<td>Outer Reflector: diameter 800 mm</td>
</tr>
<tr>
<td></td>
<td>Overall Height: 700 mm</td>
</tr>
<tr>
<td></td>
<td>Material: Copper</td>
</tr>
<tr>
<td></td>
<td>Weight: 2600 kg</td>
</tr>
</tbody>
</table>
TAPIRO Reactor
The TAPIRO Reactor diagram shows the 235U Core, Copper Reflector, and Radial Channel 1. The reactor's neutron fluxes are given as:

- \( \Phi \approx 2 \times 10^{10} \text{ n/cm}^2 \cdot \text{s} @ 5 \text{ kW} \)
- \( \Phi \approx 5 \times 10^{11} \text{ n/cm}^2 \cdot \text{s} @ 5 \text{ kW} \)
- \( \Phi \approx 3 \times 10^{12} \text{ n/cm}^2 \cdot \text{s} @ 5 \text{ kW} \)
I must state that I am not aware of any permanent nuclear reactor system that, despite its a-priori complexity, has ever been so comprehensively characterized neutronically, over so large and steep a range of neutron field variation, over so complete an energetic domain and to the accuracy levels defended here.

A. Fabry, NEUTRONIC CHARACTERIZATION OF THE TAPIRO FAST-NEUTRON SOURCE REACTOR
What has been done in the past...

The TAPIRO neutronic characterization 1983-1986

Benchmark-Field Referencing

\[ \Phi_{i,k}^{EQ} = \frac{C_{i,k}}{C_i, \chi_{25}} \Phi_{\chi_{25}} \]

TAPIRO

Flux Transfer

MOL - \( \Sigma \Sigma \)

NBS (USA)
Bilateral agreement ENEA - SCK•CEN Mol

Direct integral experimental link between the standard (fission spectrum) and the Tapiro core center neutron field shows impressive spectral similitude above 1 MeV, a fact which allows to turn the second system into a true benchmark facility.

This is the only fast neutron benchmark in Western Europe displaying neutron fluxes as high as $10^{12} \text{ cm}^{-2} \text{ s}^{-1}$, a feature making it ideally suited for routine Benchmark Field Referencing within the Community.

A. Fabry, NEUTRONIC CHARACTERIZATION OF THE TAPIRO FAST-NEUTRON SOURCE REACTOR
(not exhaustive list, casual order)

APD (Avalanche PhotoDiodes) irradiation in support of CMS (Compact Muon Solenoid – LHC – CERN) experiences

M. Angelone, A. Festinesi, G. Rosi, F. Cavallari, M. Diemoz, E. Longo, G. Organtini; Neutron flux Measurement at Tapiro fast reactor for APD’s Irradiation fluence evaluation; CMS NOTE 1998/060

MDT (Monitored Drift Tubes) irradiation in support of ATLAS (LHC – CERN) experiences


SPND (Self Powered Neutron Detectors) irradiation in support of ITER experiences

M. Angelone, A. Klix; Self Powered Neutron Detectors; Final report on Task 3.1.1 - F4E-2010-GRT-056-02 (ES-AC) on Nuclear Data Studies/Experiments in Support of TBM Activities

Piezoceramic motor irradiation in support of ITER experiences

M. Pillon et al.; Study of the response of a piezoceramic motor irradiated in a fast reactor up to a neutron fluence of 2.77E+17 n/cm2; 28th Symposium on Fusion Technology (SOFT 2014), San Sebastián, Spain, 29th September 3rd October 2014
What can be done in the future (support to GEN IV systems)

Propagation experiences → Correlation analysis TAPIRO ↔ Reference

Irradiation and propagation experiences → Nuclear data

What can be done in the future (support to GEN IV systems)

Consistent Data Assimilation methodology(*)

Linking the integral data experiment results to basic nuclear parameters employed by evaluators to generate ENDF/B point energy files in order to improve them.

- Sensitivity of cross sections to the perturbation of the reaction model parameters (EMPIRE code).

\[
\frac{\Delta R}{\Delta p_k} = \sum_j \frac{\Delta R}{\Delta \sigma_j} \times \frac{\Delta \sigma_j}{\Delta p_k}
\]

- Sensitivity coefficients (adjoint technique) of integral reactor parameters to the cross section variations (ERANOS code).

(*) G. Palmiotti, M. Salvatores, H. Hiruta, M. Herman, P. Oblozinsky, M. T. Pigni; USE OF COVARIANCE MATRICES IN A CONSISTENT (MULTISCALE) DATA ASSIMILATION FOR IMPROVEMENT OF BASIC NUCLEAR PARAMETERS IN NUCLEAR REACTOR APPLICATIONS: FROM METERS TO FEMTOMETERS; International Conference on Nuclear Data for Science and Technology 2010
Images “about” TAPIRO
A strong team!

Orlando

Carlos
Final comments

➢ TRIGA RC-1 and TAPIRO are, until today, significant resources in the context of scientific and applied research in Italy, and they are a necessary infrastructure to support research institutions and Universities.

➢ TRIGA RC-1 is involved in various applied research fields like irradiation studies in neutron thermal field, Neutron Activation Analysis, radioisotopes production studies (participation to a call in H2020), Education & Training.

➢ TAPIRO is a “qualitative” (not “quantitative” as in the current fashion) powerful tool to investigate in a well characterized neutron field (a so called standard field) the properties of the matter under neutron irradiation.

➢ In the context of international collaborations (in particular IAEA sponsored collaborations), both TRIGA RC-1 and TAPIRO reactors are involved in different working groups devoted to utilization, operation and maintenance of research reactors.
Bariloche, 14 November 2014
Thank you for your attention!