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***Link to IAEA Research Reactors Data** Base:* [TRIGA]

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1 General information and technical data of TRIGA RC-1 reactor

The TRIGA RC-1 nuclear research reactor (Training Research isotopes General Atomic Reactor Casaccia 1) is a source of thermal neutrons.

TRIGA RC-1 (Fig. 1) was built in 1960 in its first version with 100 kW power as part of the U.S. Atom for Peace initiative. In 1967 its power was upgraded to 1 MW based on the ENEA staff design.

The TRIGA RC-1 core consists of an annular structure immersed in water which serves as primary coolant (Fig. 2). The core is arranged in a honeycomb-like array forming an annulus with seven coaxial cylindrical rings of fuel elements.

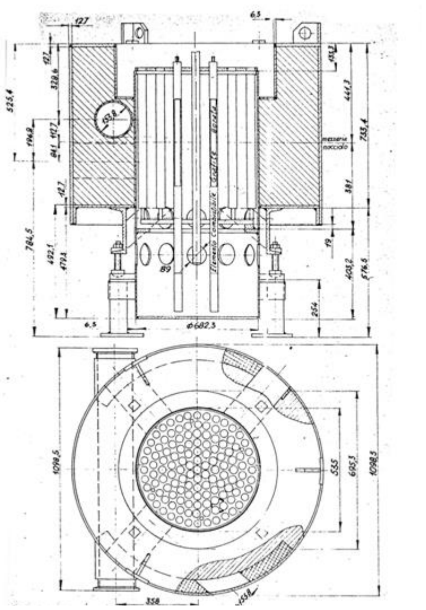

Fig. 2
Schematic view of the reactor assembly.

Fig. 1 - TRIGA RC-1 reactor.

A typical core loading is shown in Fig. 3. The reactor's main features are:

- Maximum power: 1 MW;
- Maximum neutron flux: 2.7 10^{13} n·cm^{-2}· s^{-1};
- Core cooling by natural convection;
- Irradiation facilities:
  - 1 Central Channel;
  - 40 Positions in rotating rack;
  - 1 Pneumatic transfer system ("Rabbit”);
  - 1 Loop for irradiations of liquids;
  - 1 Thermal Column;
  - 1 Thermalizing Column;

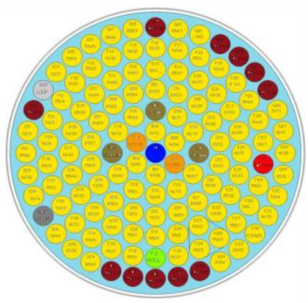

Fig. 3 - TRIGA RC-1 core.

- 6 Horizontal neutron channels;
- Irradiation cavity in the core (3 el. space);
- Irradiation cavity in the Thermal Column inside the reactor pool.

In Tab. 1 are shown the main characteristics of the core.

Core	Cylindrical diameter	535mm
	Height	670mm
Fuel	Type	Uranium – ZrH alloy (8.5% Wt U)
	Enrichment	20 % ^{235}U
	Moderator	H_2O, ZrH
	Coolant	Demineralized water in natural convection
Control Rods	Type	n°3 B_4C Fuel Follower n°1 B_4C Regulating Rod
Reflector	Cylindrical Inner Reflector diameter	543 mm
	Outer Reflector Diameter	1098.5 mm
	Overall Height	733.4 mm
	Radial thickness	214mm
	Material	Graphite

Tab. 1 – Characteristics of the TRIGA RC-1 core.

2 Experimental facilities

A global view of the TRIGA RC-1 experimental facilities is shown in Figs. 4 and 5, while in Tab. 2 are shown their main characteristics.

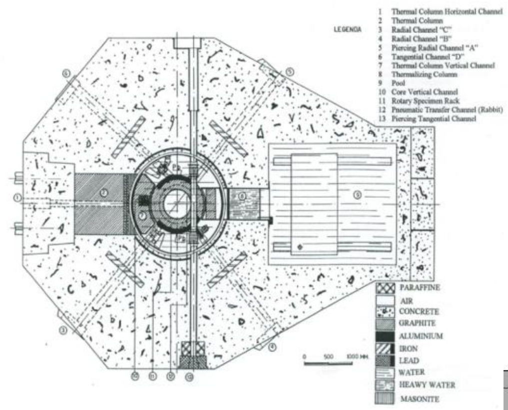

Fig. 4 - Irradiations facilities.

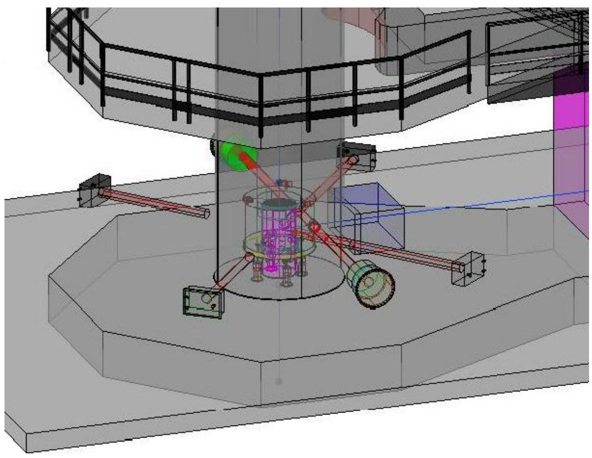

Fig. 5 - Radial neutron channels.

EXPERIMENTAL FACILITY	THERMAL FLUX $n/(cm^2 \cdot s)$	R_{Cd}[1]	SHAPE	DIMENSIONS (mm) UNLESS DIFFERENTLY SPECIFIED
A - Radial Channel	$4.8 \cdot 10^{12}$ (*)	~ 2.2	CYLINDER	Ø INT. = 152
B - Radial Channel	$4.3 \cdot 10^{10}$ (*)	~ 3	CYLINDER	Ø INT. = 152
C - Radial Channel	$4.3 \cdot 10^{10}$ (*)	~ 3	CYLINDER	Ø INT. = 152
D – Tangential Channel	$5.4 \cdot 10^{10}$ (*)	10.4	CYLINDER	Ø INT. = 152
Piercing Tangential Channel	$1.1 \cdot 10^{6}$ (**)	1.8	CYLINDER	Ø INT. = 180
Thermal Column Horizontal Channel	$2.2 \cdot 10^{6}$ (**)	3.8	CYLINDER	Ø INT. = 40
Thermal Column Vertical Channel (with plug of graphite)	$1.9 \cdot 10^{10}$	4.3	SQUARE	SIDE = 100
Thermal Column Vertical Channel (without cap of graphite)	$4.2 \cdot 10^{9}$	~ 4	SQUARE	SIDE = 100
Central thimble	$2.68 \cdot 10^{13}$	1.7	CYLINDER "S" SHAPED	Ø INT. = 34.04
Thermalizing Column	$1.3 \cdot 10^{8}$ (**)	> 100	PARALLELEPIPED	608 x 608 x 155
Rotary Specimen Rack	$2.0 \cdot 10^{12}$	2.7	CYLINDER "S" SHAPED	Ø INT. = 32
Removable grid cavity	$1.25 \cdot 10^{13}$	2.2	TRIANGULAR PRISM	L = 75~ h = 650
RABBIT (Pneumatic transfer tube)	$5.1 \cdot 10^{12}$	2.0	CYLINDER	Ø INT.. = 14 Ø INT. TUBE = 27
Loop for irradiation of liquids	$\sim 5.0 \cdot 10^{12}$		CYLINDER	V ~ 150 ml

Tab. 2 - TRIGA RC-1 experimental locations main characteristics.

(*) – Measured inside the horizontal channel

(**) – Measured at the exit of the horizontal channel

[1] R_{CD} = Cadmium ratio. This is an index of the degree of thermalization of the neutron flux. R_{CD} ranges from 1 (flux not thermalized) to values >>1, proportionally to the degree of thermalization of the neutron flux.

3 TRIGA RC-1 in the field of the applied research

3.1 *Materials irradiation in thermal spectrum*

An experimental facility can be used for irradiations in thermal spectrum. It is a Plexiglas cylindrical (diameter 170 mm, length 330 mm) waterproof cavity (Figs. 6-7) that can be moved in the water and placed in front of the thermalizing column neutron beam, deeply in the shielded tank. The cylinder it's equipped also with a tube allowing the connection of the cavity, by wires or cables, with the external of the pool. It's possible to introduce a wide variety of objects: from gold foils to ampule or others containers of sufficient dimensions to test irradiation effects on various materials. It is provided with a positioning system to facilitate operations.

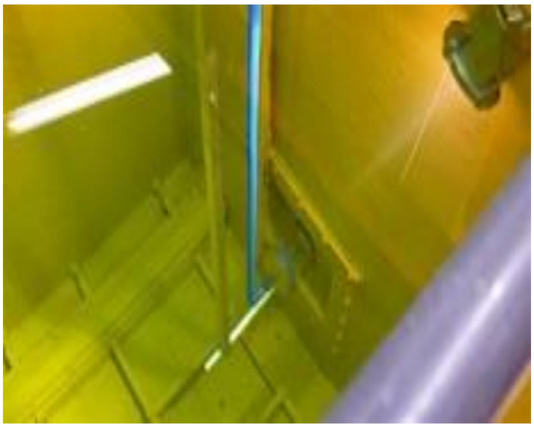

Fig. 6 - Cavity position in the pool in correspondence of the thermalizing column.

Fig. 7 - Detail of the cavity.

3.2 *Neutron radiography and tomography*

Neutron fluxes provided by the thermal column and the piercing tangential channel are used to obtain a radiography image of objects and, with a time dependent image acquisition, a tomography reconstruction of such objects. The device is composed by:

- A mechanical support able to rotate and translate objects so that the operator can reach the optimal exposition to the neutron flux;
- A neutron converter provided with efficiency parameters;
- A system equipped with an optical system used to focus the light produced;
- A CCD camera connected with an acquisition and analysis system composed by hardware and software;
- A software tool for tomography reconstruction.

3.3 *Isotopes for medicine*

TRIGA RC-1 reactor has been used for the preparation of isotopes for nuclear medicine. ^{18}F has been produced irradiating $LiNO_3$ by $^{16}O(t,n)^{18}F$ reaction using tritons from $^{6}Li(n,t)$ ^{4}He reaction. The produced ^{18}F has been efficiently purified, and used for the synthesis of ^{18}F-FGD medical grade, in a semi-automatic synthesis apparatus.

The reactor has also been used for the preparation of the isotope ^{166}Ho, by starting from ^{165}Ho; the obtained ^{166}Ho was employed for the synthesis of different therapeutic carriers, and used in the experimental therapy of human patients in solid tumors. An international patent on the technique has been filed.

Actually a new original facility is under installation, devoted to the preparation of isotopes of clinical interest in therapy and diagnostics, (^{131}I, ^{133}Xe, ^{99}Mo).

3.4 Isotopes for industry

TRIGA RC-1 reactor has been used for the characterization and follows up of industrial processes. In one application radioactive ^{198}Au has been prepared by neutron irradiation and dissolved in molten aluminium of industrial electrowinning cells. The follow up of isotopic ^{198}Au dilution allowed a complete study of mass balance, and the optimization of efficiency electrolysis parameters of the industrial cells.

In a second application ^{133}Xe prepared by neutron irradiation was used as a gaseous tracer in the process of coke preparation. The system has been applied in industrial coke oven process, and allowed a precise monitoring of temperature set point for industrial continuous coke preparation. An international patent on the technique has also been granted.

3.5 Neutron activation analysis

Neutron Activation Analysis (NAA) has been widely employed by means of TRIGA RC-1 reactor since 1963.

In the TRIGA RC-1 reactor NAA is mainly performed by pile irradiations using either a vertical channel passing through the core center (Central Thimble), a second vertical channel characterized by a pneumatic tube to transfer the irradiated samples (Rabbit), a rotating rack with forty holes for samples introduction (Lazy Susan), and a water pool, separated from the reactor core, with a thermalizing thickness of D^2O (Thermalizing column).

Gamma spectrometry measurements are performed by mean of HPGe detectors supplied from Canberra and ORTEC, equipped with adequate instrumentation and software. The laboratory is also equipped with an anti-coincidence measurement system utilizing a NaI 12 inches diameter ×12 inches length annular single crystal Bicron detector characterized by a relevant spectral background reduction. Another useful detector is constituted by an HPGe planar detector with high efficiency in measuring x and γ rays of energy < 100 keV and for XRF counting.

By exploiting the instrumental analysis (INAA) potentials it is possible to study analytically and determine, either by thermal, epithermal, or fast neutrons, or by the radiochemical separation, the majority of the macro constituents, minor constituents, trace, and ultra-trace elements in a very wide set of matrices and materials. The samples that may be analyzed and the applications of the INAA range from alloys to soils; from sediments and suspended matter to the atmospheric particulate matter; from archaeological materials to detector materials used in the field of elementary particles; from radiotracers to the execution of forensic studies.

Fig. 8 - Experimental apparatus for Neutron Activation Analysis.

3.6 Radiological characterization

During the last years the activities carried out at the TRIGA RC-1 Reactor by Nuclear Materials Characterization Laboratory's personnel has been aimed to the radiological characterization of drums containing wastes produced in the routine activities of the plant.

The characterization was carried out using mobile equipment:

ISOCS (In Situ Object Counting System): radiological characterization system for assaying objects of any shape and nature containing ϒ-emitting radionuclides; the measurement system operates with a Germanium detector, whose response to a series of point sources or distributed in predefined arrays was characterized using Monte Carlo codes.

Portable Multi-Channel, equipped with neutron probe and gamma radiation detector. This instrument is characterized by high accuracy and speed in response and was used for preliminary inspections of the drums.

4 Design and manufacturing of experimental devices and measurement systems

TRIGA RC-1 is part of a laboratory that has a section devoted to design and manufacture experimental devices (mechanicals, hydraulics and electronics). Some examples are:

- Neutron collimators;
- Channel shutters;
- Irradiation devices;
- Optical bench for neutron imaging;
- "Ad hoc" Hydraulics loops;
- Ancillary systems for experiments;
- Electronic control panels;
- Devices for Neutron Activation Analysis.

Some relevant examples of R&D experiences occurred in the last ten years:

- Test and utilization of a special instrumentable TRIGA RC-1 fuel element;
- Multiplication factors measurements by means of D-T tubes;
- Investigation by neutron tomography and a volumetric 3D display of archaeological samples;
- Neutron imaging tests of archaeological samples;
- Neutron imaging tests of electronic/mechanical equipment;
- Neutron imaging tests of biological samples;
- Environmental (neutron/gamma) tests of electronic components;
- Design and characterization of neutron collimators;
- Tests and development of innovative neutron detectors;
- Irradiations and neutron activation of many kind of solid/liquid samples for several purposes;
- Developing of a digital console for control rooms parameters supervision.

5 Use of the reactor in the field of education and personnel training

- Teaching for University students:
  - Introduction to calculation tools for reactor analysis (Monte Carlo and Deterministic codes);
  - Introduction to experimental measurements.

- Personnel training:
  - Training of plant personnel for the attainment of the certificates for the plant operation;
  - Permanent training for operation and maintenance of the plant;
  - Training of operators active in the nuclear field (Qualified experts, Firefighters, Soldiers etc…).