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Dipartimento Innovazione

RADIATION TECHNOLOGY FACILITIES OPERATING AT THE ITALIAN ENEA-CASACCIA RESEARCH CENTER

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ENEA - Dipartimento Innovazione
Centro Ricerche Casaccia,Roma

Work presented at the "First International Symposium on Nuclear and related techniques in Agriculture, Industry, Health and Environment (NURT 1997)

October 28-30, 1997 - La Habana, Cuba

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RIASSUNTO

Il Centro Ricerca ENEA della Casaccia, situato a 20 km circa da Roma, è il maggiore centro di ricerca tecnologica italiano, con oltre 2000 ricercatori impegnati in numerosi campi di ricerca avanzata (materiali, energia, ambiente, etc.).
Nell'ambito delle tecnologie di irraggiamento, sono presenti e pienamente funzionanti presso il C.R.Casaccia tre principali impianti: un reattore termico TRIGA Mark II da 1 MW (RC-1); un reattore-sorgente veloce da 5 kW (TAPIRO); un impianto di irraggiamento a Cobalto-60 da 3.7×10^{15} Bq (CALLIOPE).
I principali programmi di R&S condotti riguardano la produzione di radioisotopi e radiotraccianti di utlizzo in campo medico, la radiografia neutronica, l'analisi per attivazione neutronica, l'analisi del danno da radiazioni, la diffrattometria neutronica, il trattamento di derrate alimentari, i processi di reticolazione polimerica, il trattamento di rifiuti (tossico-nocivi, chimici, ospedalieri).
Il presente lavoro fornisce una descrizione tecnica degli impianti, nonché indicazioni sui principali programmi condotti attualmente presso tali impianti.

ABSTRACT

The ENEA Casaccia Research Center, 20 km far from Rome, is the main Italian technological research Center, with more than 2000 scientists involved in several advanced research fields (materials, energy, environment, etc.).
Within the frame of radiation technology, three main facilities are in service at full power at the Casaccia Research Center: a 1 MW TRIGA Mark II reactor (RC-1); a 5 kW fast source reactor (TAPIRO); a 3.7×10^{15} Bq Cobalt-60 irradiation plant (CALLIOPE).
Main R&D programmes carried out regard medical radioisotopes and radiotrackers production, neutron radiography, neutron activation analysis, radiation damage analysis, neutron diffractometry, foodstuffs treatment, crosslinking processes, wastes (hazardous, chemical, hospital) processing.
The paper provides a features description of utilized facilities and reports main present carried out projects.

INTRODUCTION

ENEA (formerly "Italian National Agency for New Technology, Energy and the Environment") is the main governmental Italian agency responsible for the scientific and technological research in the field of advanced materials, innovative technologies and processes, energy saving, energy advanced production methods, environmental surveying, monitoring and safeguarding, new waste treatment processes, etc..
The Agency, having a total staff of around 4000, is presently operating throughout Italy with nine major research centers and a number of smaller facilities. The main research center is the C.R. Casaccia, 20 km far from Rome, where activities are carried out from more than 2000 scientists. Since early sixties, numerous research programs regarding radiation technology applications (materials, foodstuffs, wastes, ND-analyses, etc.), are performed at the C.R. Casaccia, utilizing the neutron and gamma facilities represented by the TRIGA MarkII Reactor, the TAPIRO fast source Reactor and the CALLIOPE Cobalt-60 gamma Plant.

TRIGA "RC-1" NUCLEAR REACTOR

The TRIGA Mark II nuclear reactor, named "RC-1", was built in the early sixties from GENERAL ATOMIC (now G.A. TECHNOLOGIES), with original start-up maximum power of 100 kW, increased by the ENEA staff to 1 MW in 1963.

The TRIGA RC-1 is a pool heterogeneous-homogeneous thermal reactor having a core contained in an aluminum vessel and placed inside a cylindrical graphite reflector, bounded with lead shielding. The biological shield is provided by ordinary concrete having mean thickness of 2.2 m. Demineralized natural water, filling the vessel, ensures the functions of neutron moderator, cooling mean and first biological shield.
Nuclear fuel is an assembly of ZrH (zirconium hydride) and Uranium (ternary alloy) cylindrical rods having 8.5% in weight of U enriched at 20% in ^{235}U. Each single rod mean weight is limited to 3.4 kg and the corresponding ^{235}U content is 38 g.
Neutrons moderation is assured by the combined effect of cooling water and the ZrH of the alloy, being the last one responsible of the prompt high negative temperature coefficient, representing a relevant self safe system. Fuel elements cladding (stainless steel, 0.5 mm as thickness and 36.3 mm as diameter) includes the top and bottom graphite reflector (about 88 mm each in length). The cylindrical compact core, including 106 fuel rods elements, shows an overall diameter of 500 mm. Exceeding reactivity reaches about 2$ (~1400 pcm).
Reactor control is ensured by four rods: two shims and one safety fueled follower rods, and one regulation rod. The chain reaction start-up is provided by an Am-Be neutrons source.
Produced thermal power is removed by natural water circulation through a suitable thermohydraulic loop comprehending heat exchangers and cooling towers.
Table 1 reports the main features of the reactor, whose horizontal section is shown in Fig.1.
Neutrons extraction and neutrons/gamma irradiation activities are performed by some suitable locations and channels.

Table 1 - TRIGA RC-1 general features

REACTOR TYPE	pool type, thermal heterogeneous-homogeneous
MAX. LICENSED POWER	1 MW
MAX NEUTRON THERMAL FLUX	$2.7 \cdot 10^{13}$ n cm^2s^{-1} (central thimble - Cd ratio: 1.73) $2.6 \cdot 10^{9}$ n cm^2s^{-1} (thermalizing column - Cd ratio: > 250)
MAX GAMMA DOSE RATE	1.03 MGy/h (central thimble)
COOLING SYSTEM	natural water circulation + heat exchanger
CORE	106 elements (ZrH-U alloy) about 4.5 kg of ^{235}U
CONTROL RODS	3 boron carbide shims, 1 safety fuel follower 1 boron carbide regulation rod
IRRADIATION FACILITIES	• 1 rotating rack (vertical, 40 samples allowed) • 5 radial channels • 1 pneumatic transfer system (rabbit) • 1 piercing channel • 1 horizontal thermal column • 1 vertical thermalizing column

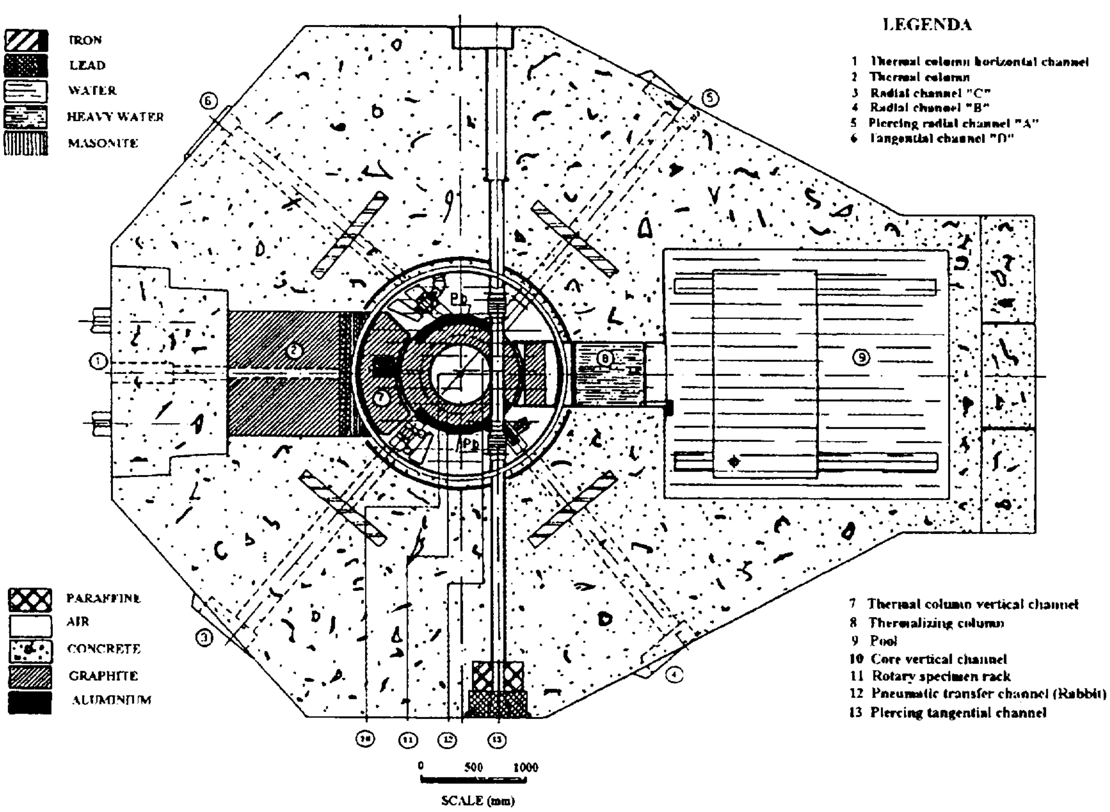

Fig. 1 - TRIGA Reactor horizontal section

At present the main activities carried out are:

- neutron irradiation for radiotrackers production and activation analysis. In particular, in collaboration with some roman Hospitals, radioisotopes for medical purposes are in production as ^{18}F, ^{90}Y, ^{65}Cu, used for diagnostic and therapy in oncology field. A process to recover ^{89}Sr from urine of cancer sick has been developed together S. Eugenio roman hospital;
- neutron spectroscopy and diffraction, in magnetic systems, liquid and amorphous substances devoted to new detectors for use in high energy physics research, in cooperation with some Italian University;
- neutron radiography and tomography, developing, in collaboration with Physics Department of University of Bologna - I, an advanced neutron computed tomography equipped with news types of detectors based on scintillating optical fibers.

Several R&D activities have been carried along over 30 years of operation, mainly with reference, in the past, to the basic and applied research support to foreseen peaceful national development of nuclear power plants for electricity production.

"TAPIRO" FAST SOURCE REACTOR

The "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.

Fuel is a metal alloy of 98.5% in weight of U, fully enriched at 93.8% in ^{235}U, with 1.5% in weight of Mo. Critical mass is 21.46 kg.

The nominal thermal power is 5 kW and the maximum neutron flux is $4 \cdot 10^{12}$ n/cm^{2}s.

Table 2 summarizes main reactor features and Fig.2 shows reactor longitudinal section.

Channels of various dimension and with different neutron spectra are distributed around the core.

The large thermal column is manufactured by graphite blocks, suitable to be removed and replaced with experimental assemblies for any research purpose.

The main activities performed are:

- damage study on aerospatial electrical components and monocrystals detectors used in high energy physics research;
- preliminary study to adapt neutron reactor spectra for application in Boron Neutron Capture Therapy (BNCT) to evaluate neutron dose deposition on human head phantom.

Table 2 - TAPIRO general features

REACTOR TYPE	fast source
MAX. THERMAL POWER	5 kW
MAX NEUTRON FLUX	$2.2 \cdot 10^{12}$ n cm^2 s^{-1}
MAX GAMMA DOSE RATE	20 kGy/h
COOLING SYSTEM	forced He + heat exchanger
CORE	U metal alloy (U 98.5%, Mo 1.5%) enrichment: 93.5% in ^{235}U critical mass: 21.46 kg
CONTROL RODS	• 2 shims • 2 safety • 1 regulation
SHUTDOWN SYSTEM	core and reflector separation
IRRADIATION FACILITIES	• 1 irradiation cavity • 2 radial channels • 1 piercing channel • 1 horizontal channel • 1 vertical channel • 1 thermal column

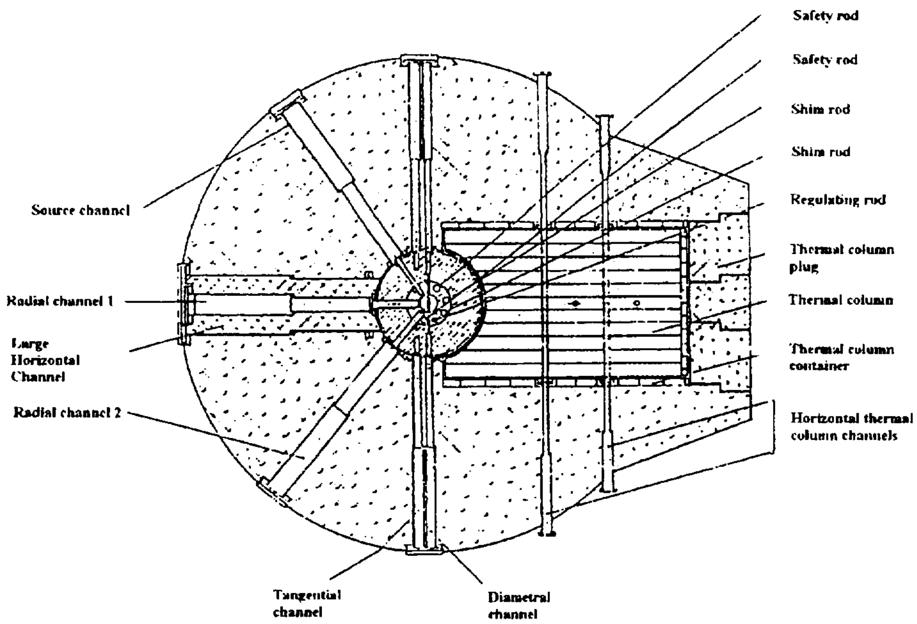

Fig. 2 - TAPIRO Reactor horizontal section

"CALLIOPE" GAMMA RADIATION PLANT

The "CALLIOPE" irradiation plant was built in the late sixties (previous name was "Agrigamma") in order to carry out R&D programs focused on agricultural product treatment by radiation (i.e. seeds stimulation, foodstuffs shelf-life prolongation, etc.); differently, from early eighties the plant has been deeply involved also in radiation processing research on industrial materials (e.g. cables polymerization), wastes processing (hospital/airport wastes sterilization, sludges decontamination), as well as in testing and characterization of materials to be utilized in hostile environment (nuclear plants, aerospace, etc.).
On February 1989 Calliope got from the Italian Ministry of Industry the highest level of functioning license for similar plants.
The Calliope plant is a pool-type irradiation facility equipped with a Cobalt-60 gamma source in a large volume shielded cell. The present source rack is cylindrical geometry type with Co-60 pencils arranged along the rack circumference (Tab.3 summarizes main plant features).
The main plant sections (see Fig.3) are: the irradiation cell with access maze, the storage pool, the materials transport system, auxiliary systems (ventilation, water purification, etc.) and safety/security systems (radiation monitoring, fire extinguishing, earthquake monitoring, etc.).
The irradiation cell biological protection shielding material is ordinary concrete (thickness till 180 cm) with baritic concrete inserts in critical points, in order to avoid radiation streaming due to ducts, voids, etc.
On the cell roof a suitable hatch-huge crane system allows the loading/unloading operations of radioactive materials during source recharge procedures.
A lead glass window, lodged in a steel armor inserted in the concrete wall of the control room, allows direct sight inspection of irradiation processes in the cell inner.
The storage water pool dimensions are 2.0x4.5x8.0 meters and two separate source emergency storage wells, closed by two shielded corks, are foreseen on the bottom of the pool.
The main activities so far carried out at the plant have been devoted to some specific experimental activities, set-up and small scale industrial demonstration of processes with good prospects for future industrial applications.
On some occasions, service activities have also been performed, mainly in cases of very limited flowrates and specific as well as non-standard irradiation conditions.
Among the activities performed, meaningful industrial fall-out could be assigned to the following processes:

- set up of crosslinking and grafting processes referred to ethylene-propylene co-polymers;
- experimental study of irradiated crystals (e.g. $PbWO_4$) in order to characterize radiation damage mainly with reference to optical properties;
- liquid and solid waste treatment: wastewater from industrial plants (e.g. COD reduction of wastes coming from textile dyeing, printing and finishing plants (5-20 kGy)), effluents from the municipal network (disinfection from coliform bacteria (0.8-1 kGy) and streptococci bacteria (3-4 kGy)) and hospital/airport waste sterilization (25-35 kGy);
- set up of SIT (Sterile Insect Technique) processes (against Medfly or white-fly) having an industrial approach to the design of different irradiation phases (collecting, counting,

packaging, irradiation, storage) and taking into account the possibility of a specific irradiator suitable design;

- foodstuffs treatment: a large number of product have been irradiated, mainly with reference to chicken products for microbiological restoration purpose and wheat/pasta products for decontamination-disinfestation processes set up;
- other processes like: aerospace or nuclear materials testing and qualification as industrial service, gemstone color enhancement by radiation/heating (mainly in colorless topaz stones in order to obtain a blue color), etc.

Tab.3 - CALLIOPE Plant main features:

Radioactive source	Co-60, SS double encapsulated with damp storage
Source geometry	cylindrical rack, with radioisotope pencils placed on two levels of external rack surface
Emitted radiation	2 gamma photons emitted in coincidence (100%)
Photons Energy	1.173 and 1.332 MeV (average 1.25 MeV)
Max. licensed activity	$3.x10^{15}$ Bq (= 100,000 Ci)
Max. dose rate	20 kGy/h (along the rack longitudinal axis)

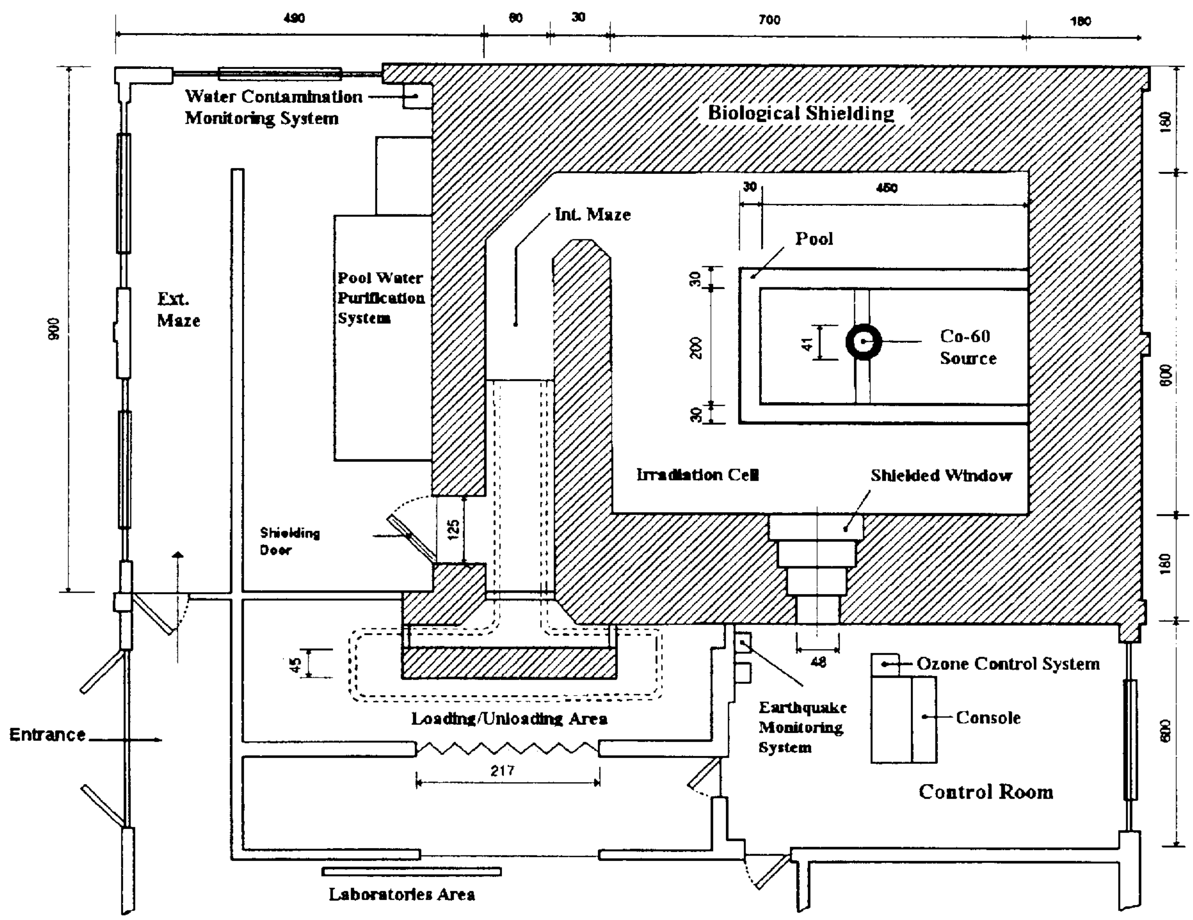

Fig. 3 - CALLIOPE Plant lay out (dim. in cm)

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