Operation and Exploitation of the Reactor, Dosimetry (RPI) and Reactor Calculations

José Gonçalves Marques

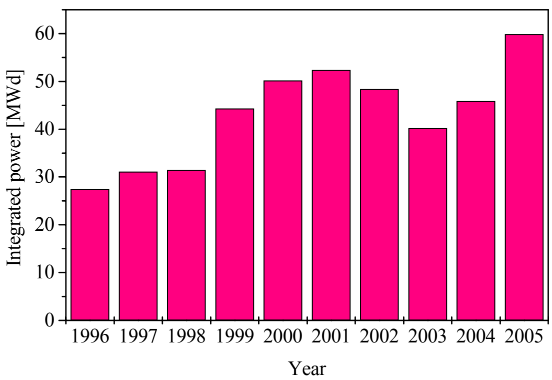
The main objective of the Operation and Exploitation of the Portuguese Research Reactor (RPI) is to be able to satisfy the users' needs while conducting all tasks with the assurance that the reactor is operated in a safe and reliable manner. The year 2005 was a transition year, with some research projects near completion and others just starting.

The laboratory for fabrication of Superheated Droplet Detectors installed in 2004 is now in full use. Three new research projects are using this laboratory.

The Emission Channelling/Blocking Setup is now operational and its optimization is underway, within the scope of a PhD thesis.

The programme for testing of electronic components under fast neutron irradiation for LHC/CERN is near completion. A PhD thesis was presented in the Complutense University of Madrid.

Two projects for installation of setups for neutron tomography and for Perturbed Angular Correlations using short lived isotopes started in late 2005.



The operation of the reactor requires the calculation of parameters such as effective multiplication, control rod worth and safety parameters. An intensive activity in this field has continued, in order to prepare the core conversion to low enriched fuel. A feasibility study for conversion to high density U_3Si_2-Al fuel was done with assistance from the Argonne National Laboratory (USA). No significant loss of performance of the reactor is expected after the core conversion.

The main users of the reactor are described in the Table. The main activity in 2005 was Neutron Activation Analysis (NAA), to users in the Reactor and Chemistry (33%), followed by Isotope Production (30%) and the study of radiation effects in materials and seeds (21%). Isotope production again increased by about 60% from last year and more than doubled relatively to 2004.

User	Area	Time (%)
RPI	NAA	25.0
	Dosimetry and Test of Detectors	7.5
	Other (training, etc)	0.1
Physics	Radiation Effects	18.8
	Neutron Scattering	8.5
Chemistry	NAA	8.0
	Isotope Production	3.8
DPRSN	Isotope Production	3.7
Univ. Lisboa	Isotope Production	20.4
CERN	Radiation Effects	1.8
LIP/Lisbon	Isotope Production	1.5
Univ. Coimbra	Isotope Production	0.8
IVIA	Radiation Effects	0.1

The figure indicates the integrated power produced by the RPI in the last 10 years. A clear increase is seen since 1999, reflecting an increase in its use. The integrated power for 2004 was 60 MWd, about 30% higher than last year and the highest value since 1979. On average, 1.8 irradiations were performed at the same time.

Research Team

Researchers

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N. P. BARRADAS, Aux. (95%)
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Core Conversion of the RPI to LEU Fuel: Feasibility Study

J.G. Marques, N.P.Barradas, A.R. Ramos, J.G. Stevens[1], E.E. Feldman[1], J.A. Stillman[1], J.E. Matos[1]

Objectives

The core conversion of the Portuguese Research Reactor (RPI) to Low Enriched Uranium (LEU) fuel will be performed within IAEA's Technical Cooperation project POR/4/016. This project was approved in the end of 2004 and will have financial support of the US and Portuguese governments. As a first step to the core conversion, a joint feasibility study [1] was made by ITN and the RERTR program at Argonne National Laboratory.

Results

LEU uranium silicide (U_3Si_2-Al) dispersion fuel with a uranium density of 4.8 g/cm^3 was selected because of its widespread use in research reactors and for the relatively large number of manufacturers.

The study was done for two assembly designs with the same number of plates (18) as the HEU standard assembly. The first design (LEU-1) had the same geometry as the HEU design and a ^{235}U loading of 320 g for the standard assembly. The second design (LEU-2) is identical to the first one, except that the fuel meat thickness was increased to 0.6 mm from 0.5 mm, increasing the ^{235}U content to 376 g. Besides establishing the safety margins of the new core, the feasibility study also had a goal of minimizing the number of assemblies required for 10 years of operation of the RPI, or an equivalent 500 MW•d integrated power.

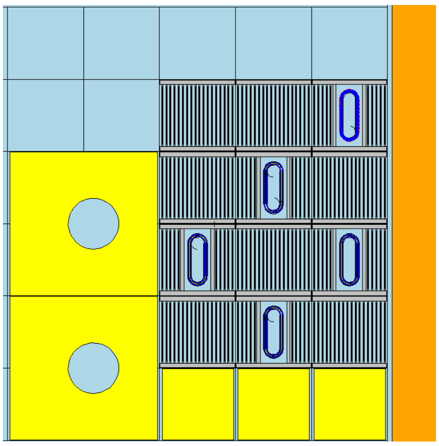

Fig 1. *MCNP model of RPI's core configuration P1/2 selected as reference.*

The original MCNP Monte Carlo model of the RPI made at ITN for dosimetry studies was modified at ANL to perform the conversion calculations. Relevant experimental data for the HEU cores were reproduced using this model, thus establishing its credibility. While the performance of cores using the LEU-1 design was found to be very similar to the ones of the corresponding HEU cores, the use of LEU-2 assemblies was found to reduce the required number of assemblies from 17 down to 13.

Preliminary values for the thermal-hydraulic safety margins for the HEU fuel design and two LEU fuel designs were determined using the PLTEMP code developed at ANL. Detailed MCNP calculations with the control rods at their critical positions were examined to determine the location of the peak power density in the core. All cores were found to have acceptable safety margins.

The LEU core conversion will not require changes to the control rods, control rod drive mechanisms, the instrumentation and control system, or other reactor components except for the fuel.

The operational and safety analyses for conversion of the core are planned to be completed around March 2006 and the documentation to support the request for licensing the new core will be submitted around June 2006. It is expected that the licensing process will be completed before the end of 2006, when the LEU fuel is anticipated to arrive at the reactor. The HEU fuel, regardless of its irradiation status, will be returned to the US before May 2009.

Published or in press work

1. J.G. Marques, N.P. Barradas, A.R. Ramos, J.G. Stevens, E.E. Feldman, J.A. Stillman, J.E. Matos, Core Conversion of the Portuguese Research Reactor: First Results, *Proc. Int. Meeting on Reduced Enrichment for Research and Test Reactors,* Boston, 2005, Argonne National Laboratory, Paper 16-1.

[1]RERTR Program, Argonne National Laboratory Argonne, IL USA 60439

Fast Neutron Irradiation of Electronic Circuits for the LHC/CERN
J.G. Marques, A.C. Fernandes, J.A. Agapito[1], F.J. Franco[1], Y. Zong[1], J. Casas-Cubillos[2]

Temperature measurement is a key issue in the LHC facility at CERN, as it will be used to regulate the cooling of the superconductor magnets. The signal conditioners for cryogenic thermometry are expected to receive a fast neutron fluence of the order of $2x10^{13}$ n/cm^2 during a 10 year period, as well as a gamma dose of 500 Gy, and this can affect the operation of the commercial circuits used in their construction. The operating conditions of these circuits are simulated using a fast neutron irradiation facility built in the RPI in 2000. On-line measurements of properties of the circuits and components are performed before, during and after irradiation and stand-by periods, to evaluate the irradiation damages as well as possible annealing effects. A PhD thesis (F.J. Franco) was presented in the Universidad Complutense de Madrid with work done in the previous years. The irradiations will continue in 2006 with the test of more components in statistically significant amounts, as well as prototypes of the final circuit boards, as they become available.

1 Universidad Complutense de Madrid.
2 CERN, LHC/ACR Division.

Monitoring of Airborne Effluents in the RPI Stack Exhaust and Assessment of their Radiological Impact
A. Kling

The monitoring of airborne radioactive effluents is of high importance for the safe operation of a research reactor and the determination of its radiological impact. In the existing monitoring system (AIRMON-91) all aerosols are stopped by a paper filter before entering the iodine detection channel allowing only to detect elemental ^{131}I in the effluents. Since ^{131}I bound to aerosols could represent a significant contribution to the dose received by members of the public an additional monitoring system (Merlin-Gerin IM201S) capable of the detection of the total ^{131}I release has been installed is now fully operational.
A further important issue was to estimate the annual doses delivered to the public due to the release of airborne radioactive effluents from the RPI stack. The source term was based on measured airborne radioactivity release data for 2003 (^{41}Ar, ^{131}I and aerosols). In addition, the ^{3}H and ^{14}C releases were calculated based on information on their concentration in the reactor pool water and evaporation rates. For the calculation of the radiological impact the code PC-CREAM was used. In order to obtain a conservative estimate of the dose rates unfavourable meteorological conditions were assumed. The results show that for children and adults the radiation dose is vastly dominated by the effect of ^{41}Ar while for infants the contributions due to ^{41}Ar and ^{131}I are about equally important. The dose rates for all three age groups (infants, children and adults) are, even at the shortest calculable distance (300 m), more than two orders of magnitude below the limit of 1 mSv/a established by law.

Development of Superheated Droplet Detectors for Neutron Dosimetry and Spectrometry Applications
A. R. Ramos, M. Felizardo, T. Morlat[1], J. G. Marques, F. Giuliani[1], A. Fernandes, T. A. Girard[1]

This project proposes to study the fabrication and use of SDDs based on ecologically sound, easily manipulated halocarbons such as Octofluoropropane (C3F8), Octofluorocyclobutane (C4F8) and Hexafluoropropylene (C3F6). The chemistry of these particular halocarbons will be investigated. Particular emphasis will be put on strategies for increased detector shelf life: a) chemical: increased gel matrix stability (by adding reagents to increase the gel fracture energy, e.g. agarose) and droplet stability (by adding surfactants); b) physical (repressurization of detectors). The manufactured SDDs will be tested and calibrated using the neutron beam facilities of the Portuguese Research Reactor (RPI). After calibration, the SDDs developed will be tested for use as neutron spectrometers. Finally the detector dosimetric performance will be experimentally evaluated in comparison with thermoluminescent dosimeters based on lithium fluoride, calcium sulphate and alumina. This project is funded by FCT under contract POCTI/FIS/55930/2004. Development of new quasi-monochromatic beams for installation in the E4 tube began in 2005 and the geometries for the main filters (Si+Ti and Si+S filter) have been studied.

1 Centro de Física Nuclear da Universidade de Lisboa.

Installation and Testing of the Emission Channeling Experiment

P. Marques, A. Kling, J. G. Marques

Emission channeling is a powerful tool for the investigation of structural properties of crystalline materials. In contrast to the classical method using radioactive probe atoms incorporated in the lattice, the set-up at RPI uses charged particles arising from thermal neutron induced nuclear reactions, e.g. ^{6}Li(n,τ)α. Channeled particles leaving the crystal are detected by a two-dimensional position sensitive detector located about 60 cm from the target. In the course of the set-up installation one of the main tasks during 2005 was the thorough testing and optimization of the various parameters available in the data acquisition and read-out system. For this purpose sources with different α-emitters were used in order to determine the optimum operational conditions for the detector and the data acquisition system as well as to perform the energy calibration. First two-dimensional patterns were obtained by putting collimators in front of the sources. A further task was to adapt the beam-line D1 in order to host the reaction chamber of the emission channeling set-up. It has been assured that all features of the radiological protection of the beam line stayed intact. Additional lead and lithium carbonate shielding placed at the set-up itself improved the protection of sensitive components located inside the reaction chamber (detector, preamplifier electronics).

Development of a CF3I SDD for Spin-Independent Dark Matter Searches

T. Morlat[1], M. Felizardo, A. R. Ramos, J.G. Marques, F. Giuliani, T. A. Girard[1]

This project proposes the R&D of a superheated droplet detector (SDD) based on trifluoroiodomethane (CF3I) for implementation by the SIMPLE project in searches for spin-independent dark matter, complementing the project's current search activity for spin-dependent dark matter with pentafluorochloroethane (C_2ClF_5). The reason for the refrigerant change is the necessity of a heavy target component, since the spin-independent WIMP-nucleon cross section varies with A^2. The R&D involves the investigation of methods for density-matching the device gel matrix with the refrigerant, the development of an experimental protocol within the P-T phase diagram of both refrigerant and gel which will result in a homogeneous dispersion of small refrigerant droplets within the colloid, and the fabrication of a device prototype for characterizations and response testing with alpha's and neutrons. The project is supported by FCT under contract POCI/FP/63407/2005.

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Dosimetry of Mixed Radiation Fields with Paired Dosemeters

A. C. Fernandes, J. P. Santos, C. Oliveira, J. G. Marques, L. Santos, V. Cardoso, E. Novák[1], M. Osvay[2]

Mixed-field dosimetry is frequently performed using paired detectors, with one of them practically insensitive to neutrons and the other one with similar sensitivities to photons and neutrons. In the frame of EURATOM project no. FIR-CT2003-40157, twin chambers (Mg(Ar) and TE(TE)) and thermoluminescent (TL) dosemeters (TLD700 and TLD100) were used for dose measurements at a zero-power WWER model at the NRI (Nuclear Research Institute Řež plc., Czech Republic). The results obtained by the two methods were consistent, both among themselves and in comparison with reference data provided by NRI.

New TL materials were investigated for the purpose of mixed-field dosimetry. The neutron response of undoped and Cu-doped LTB (Lithium Tetraborate) crystals produced at NASU (Institute of Electron Physics, Uzhgorod, Ukraine) was studied via radiations at the thermal column of the Portuguese Research Reactor and compared with standard commercial phosphors. The undoped LTB has a low photon sensitivity (10 times lower than TLD100), but the doping increases its sensitivity by a factor of 44. In spite of the fact that undoped LTB has a low photon sensitivity, it is more sensitive to thermal neutrons than the doped material by a factor of 5. Although a significant sensitivity loss was observed for the undoped LTB after neutron irradiations (50% sensitivity decrease after 2×10^{12} cm^{-2} neutron fluence), the application of undoped/doped LTB pairs is promising for mixed-field dosimetry at lower neutron doses, using doped and undoped LTB as photon and neutron dosemeters, respectively.

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