OPERATION AND EXPLOITATION OF THE REACTOR

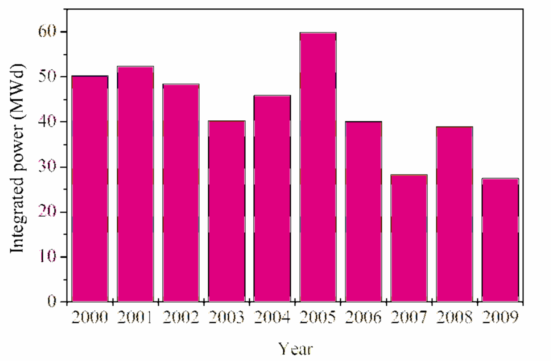
José Gonçalves Marques

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 by a highly competent and motivated staff. The implementation of such objectives demands a variety of activities, some of which are repetitive in objective and variable in content, while others address specific aspects of the same end situation.

The main users of the reactor are described in the Table below.

User	Area	Time (%)
URSN	NAA	46.3
	Dosimetry and detector development	7.5
	Radiation effects	2.4
	Education and training	5.0
	Other	1.2
UCQR	NAA	21.3
	Isotope Production	1.9
Univ. Lisboa	Isotope Production	10.7
IVIA	Radiation Effects	3.0
LIP/Lisboa	Isotope Production	0.6
Univ. Coimbra	Isotope Production	0.1

The largest sustained activity supported by the RPI is neutron activation analysis (NAA) in the URSN and UCQR Research Units of ITN. Most other activities suffer large fluctuations – e.g., education and training is very dependent on the number of students that attend courses that use the reactor in practical sessions. The integrated power in 2009 decreased when compared with 2008, as shown in the figure below, even if in absolute terms the use for NAA increased slightly.



The recent hiring of two researchers for the Operation team, under the *Ciência 2008* initiative, allowed to start an internal program to implement or optimize new techniques, such as neutron tomography and prompt gamma neutron activation analysis, as well as assess the status of experimental setups that had reduced use in the last years and that have the potential to attract new users in a sustained way.

Research Team

Researchers

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Neutron Tomography at the RPI

M.A.S. Pereira, A. Rico, J.G. Marques

Objectives

The objective of this work is to have a neutron tomography setup with an image size of 30 by 30 cm for research and industrial applications at the Portuguese Research Reactor. Significant improvements were made during 2009 to the prototype developed under project "Neutron Tomography at the Portuguese Research Reactor" (POCI/FIS/59287/2004) funded by FCT.

Results

Neutron radiography is a well known non-destructive technique. Compared with X-rays, neutrons have as specific advantages a high interaction probability with hydrogen and a lower attenuation in several heavy elements which are "black" for X-rays. Tomography requires a reasonably high number of 2D images in digital form of the observed object rotated over 180 degrees related to its central axis. With modern CCD cameras it is possible to obtain 2D images in a few minutes, even for modest neutron fluxes of 10^5 n/cm^2/s.

A prototype setup for neutron tomography was implemented in the RPI under project POCI/FIS/59287/2004, funded by FCT. The prototype uses a ZnS:Ag scintillator screen, a FingerLakes CCD camera with fast readout, a Nikon 50 mm/f1.4 lens, and a rotary table where the object is placed in front of the beam. The CCD camera is cooled down to -20 C by Peltier effect. Full control of the setup is done through a custom-made MATLAB application. Images are processed and displayed using the software packages VGStudioMax 2 (Volume Graphics GmbH, Germany) and Octopus (University of Ghent, Belgium).

The prototype was installed in the horizontal access of the thermal column and is thus limited to a parallel beam with 5 cm diameter. During 2009 the neutron and gamma shielding to the CCD camera and the lens were improved, allowing much longer exposures without significant damage to the optics and electronics. Several improvements were made to the MATLAB software application, in order to follow the cooling cycles. The spatial resolution was measured with a standard procedure using Ga foils to be 0.35 mm; it can be further improved using a divergent beam.

Figure 1 shows projections, obtained from a full 3D reconstruction, of a common BIC lighter, with an opaque plastic frame, obtained with the current setup. The level of fluid inside the lighter is clearly visible, as are the plastic pieces under the metallic components on top of the lighter. This setup will soon be used to image historical tiles within project RADIART (PTDC/HIS-HEC/101756/2008) of the UQCR/ITN.

It is expected that the current setup will be transferred to a neutron beam line, using a divergent beam, which will increase the imaging area up to 30 cm by 30 cm, in order to be able to image larger objects.

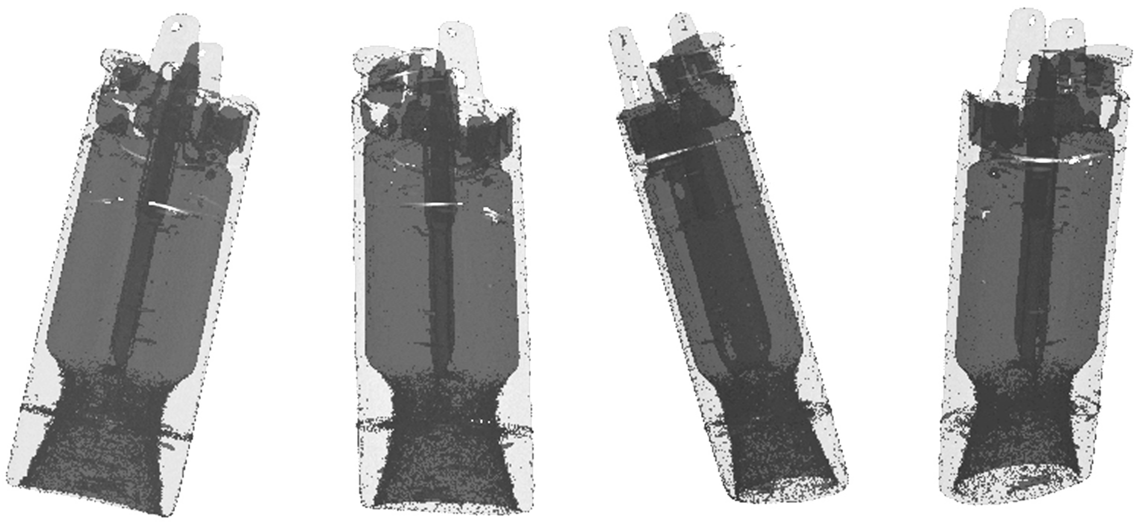
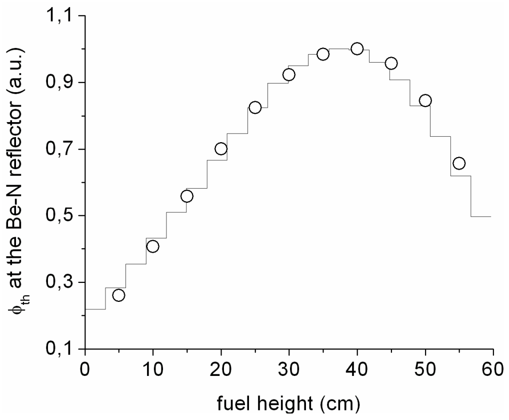


Fig.1 Selected 2D projections taken from a 3D image of a BIC plastic lighter obtained using the neutron tomography setup of the RPI.

MCNP Calculation of Neutron Fluence Rates at the RPI Core

A.C. Fernandes, J.P. Santos, J.G. Marques, A. Kling, A. R. Ramos, N. P. Barradas

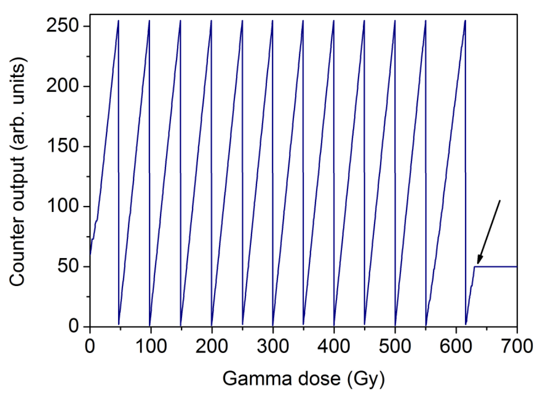
Measured thermal (ϕ_{th}), epithermal and fast (ϕ_f) neutron fluence rates and vertical fluence profiles at various positions of the RPI core grid at low burnup conditions were compared with the results of a core model developed with the MCNP5 Monte Carlo code in the criticality mode. The discrepancy between measured and calculated detector responses at 15 cm below core mid-height (where the maximum fluence rate occurs) was generally smaller than 15%. Concerning neutron fluence rates, an agreement better than 85% was also achieved for ϕ_f and ϕ_{th}. The latter case required to apply proper corrections to measurements in the fuel assemblies that include the temperature of the Maxwellian distribution, estimated with the assistance of the MCNP model. In contrast with previous MCNP models for the HEU core, where assemblies at high burnup were used, the present model has allowed to calculate correctly the absolute value of the neutron fluence rates (discarding the need to normalize the calculations to measurements at some points) and the vertical profiles along the whole fuel height (strong discrepancies were observed before, due to a vertically varying burnup).



Radiation Tolerance of Wireless Devices

J.G. Marques, S. Gaillot [1]

The performance of electronic components and systems under irradiation is a concern for the nuclear industry, the space community and the high-energy physics community. Wireless industrial process sensors became recently available in the market. Their use in nuclear installations is very attractive, as cabling is nearly reduced to zero, provided they can operate without significant degradation in radiation environments. Several wireless pt100 sensors manufactured by Omega (www.omega.co.uk) were irradiated in the fast neutron facility of the RPI and in the ^{60}Co UTR facility, within the scope of the European Integrated Infrastructure Initiative MTR-I3, coordinated by CEA/Cadarache. The target fast neutron fluence and gamma dose defined by CEA were $1x10^{10}$ n/cm^2 and 15 kGy. The wireless pt100 sensors survived fast neutron fluences up to $4x10^{12}$ n/cm^2, without measurable degradation. On the other hand severe degradation was observed under gamma irradiation for doses above 200 Gy, followed by destruction of the devices above 600 Gy. The performance under radiation of the Omega wireless sensors as available in the market is thus not good enough. Post-mortem examinations of the damaged devices suggest a re-engineering of the power supplies will be necessary for a better performance.



[1]CEA, Cadarache, France.

Improvement of Automatic Data Processing for the Radiological Protection of the RPI

A. Kling, D. Beasley, J.G. Marques

For a safe operation of the RPI a thorough and a state-of-the-art radiological control is required. During the year 2009 the main focus in this area lay on the improvement of the automatic processing which is necessary to manage the steadily increasing number of radiological data. A main issue was to eliminate the manual sorting of radiological data according to reactor power levels required for their detailed analysis for reporting. For this purpose existing analysis software has been modified in order to associate the values from a recently installed computerized recording of reactor power level with the data from all automatic radiological control recording systems. Further, an automatic conversion and processing software for the radiological data from measurements with portable instruments (documented daily by the radiation protection technicians in a standardized electronic form) has been developed which can provide processed data for any desired time span.

The SIMPLE Dark Matter Search Project

M. Felizardo, TA Girard [1], T. Morlat [1], A.C. Fernandes, F. Giuliani [1], A.R. Ramos, J.G. Marques, M. Auguste [2], D. Boyer [2], A. Cavaillou [2], C. Sudre [2], J. Poupeney [2], H.S. Miley [3], R.F. Payne [3]

The majority of project activity in 2009 centered on the final preparations for a 30 kgd measurement in the underground site, "Laboratoire Souterrain Bas Bruit" (France), including the installation of a 50-75cm thick water shield surrounding the detector water bath (comprising 8 ton in total), and the complete 16 channels of signal and pressure DAQ. Various improvements to the overall system were also made, including:

- Replacement of its freon injection system;
- Installation of two radon monitors; this led to the subsequent discovery of significantly higher than expected levels in the vicinity of the experiment (400-1000 Bq/m^3), which was addressed by removing the sound baffles on the GESA ventilation ducts, and increasing the duct flow to 0.2 m/s;
- Execution of various MCNP simulations of the on-detector field neutron, using radio-assays of the GESA 30 cm thick concrete walls, indicating a background rate of 1-4 evt/kgd with 50 cm water shielding.

The 16 SDDs were freon-injected and installed from 25 October to 15 November. The measurement has been running since, and already surpassed the 3 kgd measurement goal of PTDC/FIS/57834/2004 by nearly a factor 5, (which was not achieved as a result of funding receipt delays and the unilateral project termination by FCT in June 2008). At the time of this report, the run has achieved a 13 kgd exposure with an accumulated event rate of 7.3 evts/kgd, constituting a factor 25 improvement over that of the 14 kgd PICASSO, and a factor ~ 90 improvement relative to the 52 kgd COUPP. The preliminary results indicate the world's most restrictive exclusion of a SD WIMP-proton coupling to date, and confirm the competiveness of the superheated liquid approach in the search for SI couplings. A publication of these results is in preparation.

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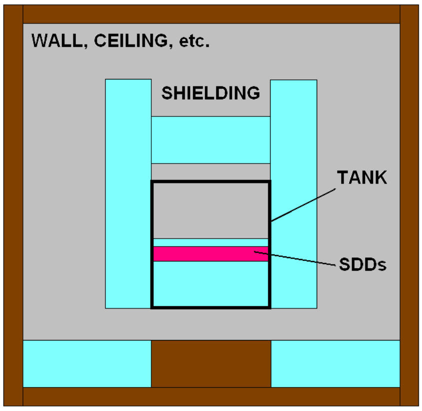
Shielding Calculations for the SIMPLE Experiment

A.C. Fernandes, M. Felizardo, T. A. Girard [1], A.R. Ramos, T. Morlat [1], A. Kling, J.G. Marques

The natural shielding provided by the "Laboratoire Souterrain Bas Bruit" (France) underground facility for the assessment of the background signal of the superheated droplet detectors (SDDs) of SIMPLE was reinforced with a water shell surrounding the detector water bath. The dimensions of the water shielding leading to an acceptable event rate less than 10 evt/kgd were determined using the MCNP5 Monte Carlo code. The radiation source was defined on the basis of measured uranium and thorium contents of the materials used in the walls of the facility. The simplified geometrical model neglected the curvature of the ceiling, the floor structure and the irregular wall thickness. The results have shown that the radiation background can be reduced 3 orders of magnitude, down to ~1 evt/kgd, using 50 cm of water around the SDDs. Initial measurements using the proposed shielding configuration indicate that an event rate of 8 evt/kgd has been obtained.



[1] Centro de Física Nuclear da Universidade de Lisboa, Lisbon.

Preparation for Replacement of the Instrumentation and Control of the RPI

J.G. Marques

The current instrumentation and control system of the RPI was installed in 1972. Its core results from a combination of analog modules of the Multibloc series of Merlin-Gerin (France) with home-made modules. The replacement of obsolete and hard-to-maintain systems was started in the late nineties but the project for complete replacement of the instrumentation and control system could only be started once it was decided that the RPI would be converted to low-enriched fuel and continue operating after 2006. Standard reactor control modules were manufactured by GammaMetrics (USA), which has a long experience in this area with both research and power reactors. Preliminary engineering projects were made at ITN during late 2008 and 2009 for RPI-specific modules such as the safety interlocks using a combination of high reliability CMOS and conventional relay logic. This approach, one step ahead of simply defining the specifications as a customer, allowed both a decrease in the overall costs and a detailed knowledge of the new system.