OPERATION AND EXPLOITATION OF THE REACTOR

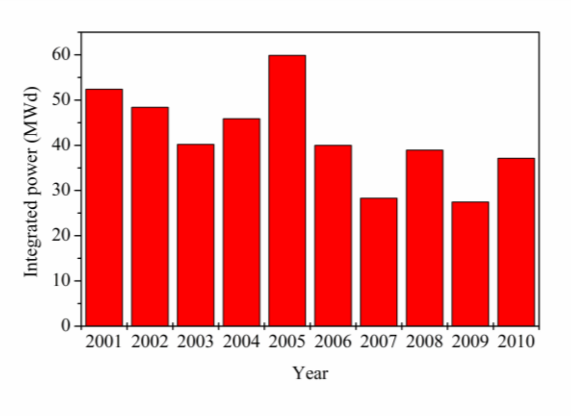
José Gonçalves Marques

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 Tomography Radiation effects Dosimetry and detector development Education and training	29.7 21.8 17.9 5.3 <0.1
UCQR	NAA Isotope Production	8.1 0.6
Univ. Lisboa	Isotope Production	13.8
IVIA	Radiation Effects	1.8
UPV	Isotope Production	0.9
IPFN	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. Neutron tomography was recently started in the RPI and already accounted for more than 20% of the reactor utilization in 2010. The integrated power in 2010 increased when compared with 2009, as shown in the figure below, where it is visible that 2005 continues to be the year with more activity.



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

J.G. MARQUES, Princ.
N.P. BARRADAS, Princ. (85%)
D. BEASLEY, Aux., (Contract)
A.C. FERNANDES, Aux. (Contract)
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A. KLING, Aux. (85%)
M.A.S. PEREIRA, Aux. (Contract)
A.R. RAMOS WAHL, Aux. (85%)

Reactor Operators

J.A.M. RIBEIRO
J.C. ROXO
N. SERROTE
R. SANTOS

Technical Personnel

F.B. GOMES
R. POMBO
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Students

M.A.F. COSTA, PhD Student, UNL, FCT grant

Collaborators

T. GIRARD, CFNUL
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Neutron Tomography at the RPI

M. A. Stanojev Pereira, 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. The characterization of the prototype installed under project "Neutron Tomography at the Portuguese Research Reactor" (POCI/FIS/59287/2004) funded by FCT was finished and the setup was used to image historical tiles within project RADIART (PTDC/HIS-HEC/101756/2008) of the UQCR/ITN.

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 was installed in the horizontal access of the thermal column and is thus limited to a parallel beam with 5 cm diameter. During 2010 the characterization of the installation was finished. In the present conditions, the best irradiation time is 7 minutes and the spatial resolution in the current conditions is 323 μm.

Even if the present conditions are not optimal, the setup started being used to image real objects, namely ceramic tiles within the RADIART project. Tiles are an important component of the cultural heritage in Portugal. They are composed of a ceramic base covered by a vitreous glaze which provides an impermeable glassy and brilliant surface. The porosity and permeability of the ceramic body are in the origin of the deterioration of ancient tiles. The main goal of these studies is to obtain information on the porosity of the tiles and how water can ingress and contribute to the degradation of the tile.

Figure 1 shows images of the fragment of a XVII century tile, imaged with conventional photography and with neutron tomography. The fragment was inspected in two distinct conditions: dried and moistened. For the first condition it was dried at room temperature for several days and a set of 200 individual images obtained in angular steps of 0.9º was taken. As can be seen, except for some dark spots, the sample shows homogeneity in terms of neutron transmission. For the second condition, the tile was partially immersed in water for some hours before irradiation and, as before, 200 individual images were taken. The water inside the tile is clearly visible by the darker regions of the image and the variations in water concentration are also easily visible by the gray level fluctuation in the image.

It is expected that the current setup will be transferred to a neutron beam line with a high neutron flux, with a parallel and a divergent beam, to increase the imaging area up to 30 cm by 30 cm, reduce the acquisition time and obtain images with better quality.

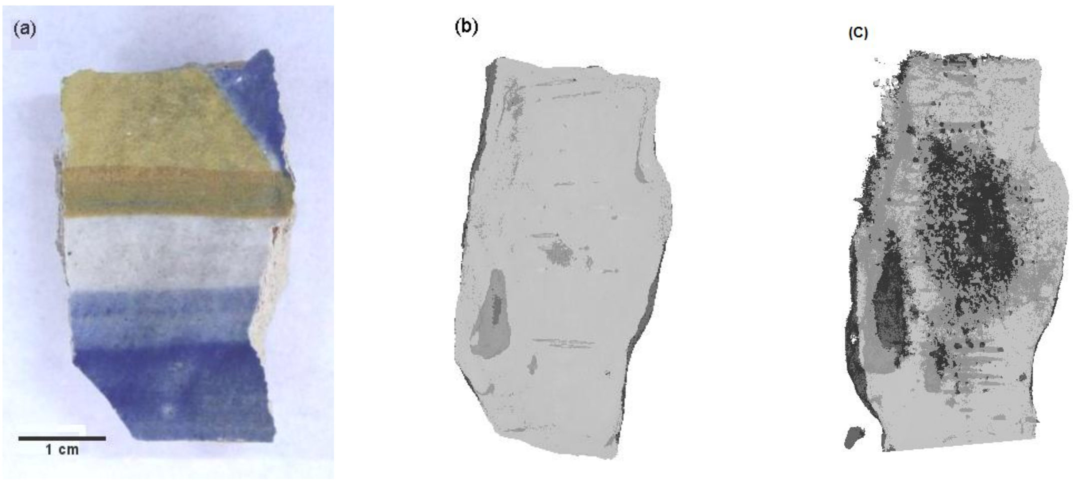
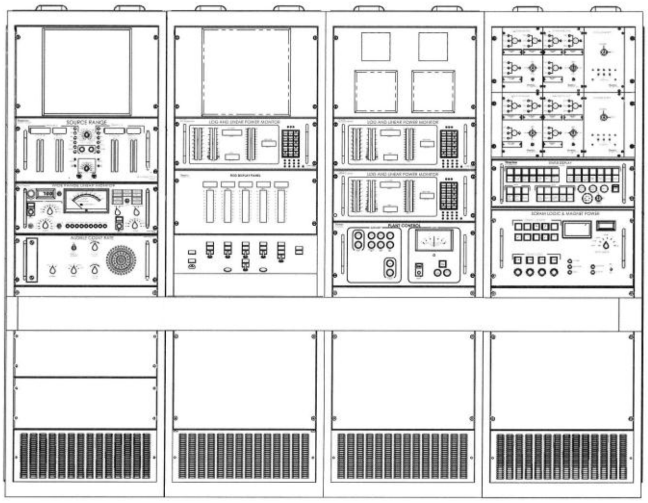


Fig 1. Fragment of a XVII century tile with (a) conventional photography, (b) neutron tomography of the dry fragment, (c) neutron tomography of the wet fragment.

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 modules made at the then Laboratory for Nuclear Physics and Energy. The replacement of obsolete and hard-to-maintain modules was initiated in the late nineties but the project for the 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. The final shipment of analogic modules manufactured by Thermo Electron and GammaMetrics (USA) was received in early 2010. The console is being assembled next to the control room, with more than thirty modules received over five years. It is expected that the replacement can be done in 2011 once the tests are finished and regulatory permission is obtained.



Improvement of the RPI Radiation Protection Monitoring
A. Kling, A. R. Ramos, J. G. Marques

The monitoring of the radiation levels in the interior of the reactor hall and of radioactive gaseous effluents is of high importance for the safe operation of a research reactor. During the year 2010 the main focus was a further modernization of the monitoring within the reactor hall. The existing aging real-time noble gas monitor (Merlin-Gerin CAG-141) was replaced by a modern Mirion NGM204L monitoring system. The new system uses semiconductor detectors for the measurement of β- and γ-activity in the air allowing a wide range of activity concentration values and an easy calibration to a reference isotope (Kr-85 in our case). Also, new Si-detector based gamma radiation monitors (Mirion GIM204) were acquired and installed. The new monitors have a lower measurable minimum dose rate (0.01µSv/h) than the Merlin-Gerin C/IEP51 ionization chambers (1µSv/h) installed more than twenty years ago. During the test operation it was observed that the dose rates measured by the new monitors are significantly lower showing a more realistic situation. Both new radiation monitoring systems are fully compatible with the Merlin-Gerin RAMSYS data acquisition software used for most of the other monitoring system allowing an easier processing of the registered data.

Radiation Tolerance of Wireless Devices
I. López [1], J.A. Agapito [1], F. Franco [1], S. Gaillot [2], J. G. Marques

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. The use of wireless systems in nuclear installations is very attractive, as cabling is nearly reduced to zero, provided the devices can operate without significant degradation in radiation environments. Previous irradiations in the fast neutron facility of RPI and in the industrial Co-60 unit at ITN were focused on pt100 temperature sensors from Omega. Although these survived fast neutron fluences up to $4x10^{12}$ n/cm^2 without measurable degradation, they showed degradation after a gamma dose of 200 Gy and were destroyed above 600 Gy. Since these sensors are highly integrated it was not possible to identify at which doses the different components were failing. In 2010 we irradiated wireless modules from Cypress (CYWM6935) and from Texas Instruments (CC2530). Their behavior under gamma irradiation was better than the one of the devices previously tested. However, the microprocessors were destroyed above 500 Gy, while other critical components such as logic gates, flash memories and multiplexers survived at least until 1 kGy. These results, a priori, restrict the use of wireless devices to 'soft' radiation environments.

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Software for Monitoring the Reactor Instrumentation and Control Systems

D. Beasley, J.G. Marques

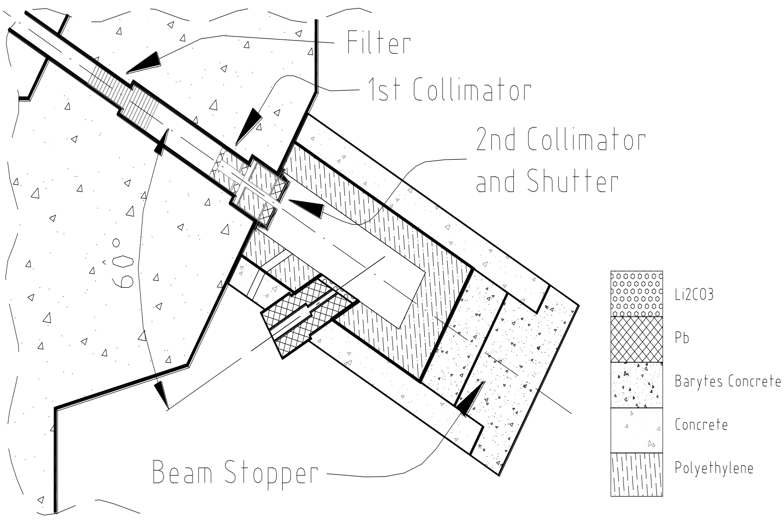
The new control system of the RPI will use paperless recorders from Yokogawa for data display in the operators' console. Although the control system is completely based on analog modules, the Yokogawa recorders when used as data acquisition platforms provide many of the advantages of a digital control system, at a fraction of the cost. LabView was used to develop dedicated software that can be run on multiple computers. The functions implemented include:

- Display operational variables (e.g., reactor power, temperature in cooling circuits) in custom-made screens, or from stored data.
- Automatic generation of daily log files and reports.
- Novel warning of any unusual behavior before triggering of conventional alarms, by analyzing data trends and comparison with normal data.

Monte Carlo Modeling of Modifications to the Epithermal Neutron Beam Line

D. Beasley, J.G. Marques

A beam irradiation facility with a neutron spectrum rich in the thermal and epithermal components was built ten years ago in the RPI. This facility was designed for multiple applications and for this reason it was provided with two openings with 2 cm and 5 cm diameter and the possibility of cutting the thermal component with a Cd filter. Multi-elemental 'Prompt Gamma Neutron Activation Analysis' (PGNAA) using a HPGe detector will now be implemented in this line. However, the high gamma background prohibits PGNAA in the current configuration. An MCNP model of the beamline was built, using realistic neutron and gamma components from the reactor core. Several modifications to the general arrangement and to the neutron and gamma filters were studied. A new design of a sample chamber extending from the current chamber was modeled and the new flux, signal to noise ratio and expected count rate were determined.



The SIMPLE Dark Matter Search Project

M. Felizardo, T.A. Girard[1], T. Morlat[1], A.C. Fernandes, F. Giuliani[2], A.R. Ramos, J.G. Marques, M. Auguste[3], D. Boyer[3], A. Cavaillou[3], C. Sudre[3], J. Poupeney[3], H.S. Miley[4], R.F. Payne[4], J. Puibasset[5]

Project activity in 2010 centered on the completion of the Stage 1, and execution of the Stage 2, measurements of the 30 kgd measurement in the underground site (Laboratoire Souterrain Bas Bruit, LSBB). Shielding improvements between the two stages consisted of the addition of a 10cm thickness of PE below the detector water bath, and completion of the wood base to a full 20cm. These were implemented in new MCNP simulations, resulting in a neutron background estimate of 0.22 evt/kgd. Stage 1 was completed on 5 February, yielding a 14.1 kgd exposure the results of which have been published in Phys. Rev. Lett. and constitute the world's most restrictive exclusion of a SD WIMP-proton coupling to date. Stage 2, completed 22 July, preliminary analysis of the data yields zero candidate WIMP events for the 10.1 kgd exposure, and new spin-dependent exclusion contours surpassing that of the Stage 1 results. A publication of the Stage 2 results is in preparation.

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