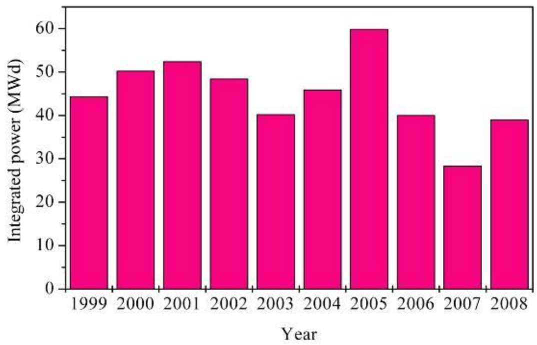
OPERATION AND EXPLOITATION OF THE REACTOR, DOSIMETRY (RPI) AND REACTOR CALCULATIONS

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 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 activities in 2008 were clearly dominated by the return of the highly enriched uranium (HEU) fuel to the USA. This was a complex task, started in January with the evaluation of bids for the supply of a transport cask and only concluded in the late summer when the fuel arrived finally arrived in the USA. Regarding new setups, a prototype setup for neutron tomography became operational this year, once the initial problems were solved.



The main users of the reactor are described in the Table below. External users accounted for more than 50% of the use of the reactor in 2008.

User	Area	Time (%)
URSN	NAA	20.0
	Dosimetry and detector development	10.3
	Radiation effects	1.5
	Education and training	0.4
	Other	0.9
UCQR	NAA	11.5
	Isotope Production	0.6
UPSR	Isotope Production	1.8
UFA	Neutron scattering	0.4
Univ. Lisboa	Isotope Production	17.8
IVIA	Radiation Effects	0.4
Univ. Bona	Isotope Production	34.4

The figure to the left indicates the integrated power produced by the RPI in the last 10 years. The year of 2008 marked the conclusion of the "conversion and return" process, which led to significant periods without reactor operation. A recovery is already visible, in both the integrated power (39 MWd in 2008 vs. 28 MWd in 2007) and total irradiation time (1394 h in 2008 vs. 1256 h in 2007).

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Return of HEU fuel from the RPI to the USA

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

Objectives

Return to the United States in the summer of 2008 of fresh and irradiated Highly Enriched Uranium (HEU) fuel assemblies from the Portuguese Research Reactor (RPI). The shipment of the fuel assemblies was the last step within IAEA's Technical Cooperation project POR4016, which covered also the core conversion to Low Enriched Uranium (LEU) fuel in 2007.

Results

The RPI was commissioned in 1961 with LEU fuel. However, it was later converted to HEU fuel. The HEU fuel was delivered to the RPI in the summer of 1974 but only started being used in 1990, at a time when a significant number of reactors was instead being converted to LEU, for non-proliferation reasons.

Fig 1. Loading into the TN-MTR transport cask of an irradiated (top) and a fresh fuel assembly (bottom).

In 1999 Portugal declared its interest to participate in the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program of the Department of Energy (DOE) of the USA. A commitment was then made to stop using HEU fuel after May 12, 2006, convert the core of the reactor to LEU and return all HEU until May 12, 2009.

The core conversion to LEU fuel was done within IAEA's Technical Cooperation project POR4016 with financial support of the USA and Portuguese governments. An extension on the use of HEU until May 31, 2007 was granted by DOE, in order to minimize the downtime of the reactor. The actual conversion was completed in October 2007.

TN International, an AREVA NC subsidiary, was selected as supplier of the transport cask and services by the IAEA, as a result of an international call for bids within project POR4016.

TN International provided an integrated package, which included a TN-MTR transport cask, a transfer cask for transport of individual assemblies from the reactor's pool to the TN-MTR cask, and technical assistance during loading. Limitations on the floor loading of the reactor building and on the capacity of the crane prevented the placement and loading of the TN-MTR transport cask inside the containment building. The cask was thus placed outside, under permanent surveillance, in a support structure built around it. The irradiated assemblies were discharged from the transfer cask in a small water basin placed on top of the TN-MTR cask, as shown in Fig. 1 (top). Fresh, non-irradiated, assemblies were loaded by hand into the same cask, as shown in Fig. 1 (bottom). The loading of the transport cask was made within three working days; three additional days were required to complete the radiological tests, close the cask, dry its interior and place the TN-MTR inside a standard 20 feet ISO container.

The transport to the USA was done by a ship under contract with DOE.

Published work

J.G. Marques, N.P. Barradas, A. Kling, A.R. Ramos, C. Anne, V. Garcia, Return of HEU Fuel from the Portuguese Research Reactor, *Proc. Int. Meeting on Reduced Enrichment for Research and Test Reactors, Washington, USA, Argonne National Laboratory, Paper 11-2.*

New Beam Filter for the Fast Irradiation Facility of the RPI

M. Lubrano[1], A.C. Fernandes, J.G. Marques

The performance of electronic components under irradiation is a concern for the nuclear industry, and both the space and the high-energy physics communities. In many situations the use of radiation hard components is not an option due to the high costs involved and standard components are used instead. However, the use of such components complicates the radiation hardness assurance. Only testing can give an indication on the radiation tolerance of the component and indicate which malfunctions can occur in a radiation environment. A fast neutron irradiation facility was implemented in the RPI in the year 2000 and was extensively used for qualification of electronic components for the LHC facility at CERN. The same facility will be used within the MTR Integrated Infrastructure Initiative (FP6) to test components for the Jules Horowitz Reactor, to be erected in Cadarache, France. A study of the modifications to be introduced in the neutron and gamma filter to adapt it to the new needs was performed as the subject of an internship of the "Génie Atomique" course of INSTN. A MCNP model of the current facility was built and qualified with measurements. A new composition for the filter was found and will be used in an update of the safety analysis report.

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Implementation of ASTM Standard E1855-04 in the RPI

M. Sargedas, J.P. Santos, A.C. Fernandes, J.G. Marques

The core conversion to LEU fuel performed in late 2007 changed significantly the neutron and gamma spectra in the fast neutron gamma facility of the RPI used for the qualification of electronic components. A full characterization of the facility was done combining MCNP calculations with conventional dosimetry techniques for neutrons and photons. At the same time, a new technique for fast neutron dosimetry was implemented using the variation of the small current gain of NPN transistors (reference 2N2222) under neutron irradiation, following ASTM standard E1855-04. A correction for the effects of the simultaneous gamma irradiation was done through separate irradiations in the ^{60}Co irradiation facility of ITN. A good agreement was found between the different techniques to obtain the "1 MeV equivalent" fluence, as specified in ASTM standard E722-04, which is commonly used to compare irradiations performed in different installations. Procedures for the application of standard E1855 at fast neutron irradiation facility at the RPI were drafted.

Neutron Tomography at the RPI

A. Rico, J.G. Marques

Neutron radiography is a well established non-destructive analysis method. 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 less than one minute, even for modest neutron fluxes of the order of 10^5 n/cm2/s. A prototype setup for neutron tomography was implemented in the horizontal access of the thermal column of the RPI. The prototype includes a ZnS:Ag scintillator screen, a FingerLakes CCD camera with fast readout and a rotary table where the object is placed in front of the beam. Full control of the setup is done through a custom-made MATLAB application. It is expected that this setup will be transferred to a neutron beam line, using a divergent beam, which will improve the resolution and increase the imaging area.

New Acoustic Instrumentation for Superheated Droplet Detectors

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The application of Superheated Droplet Detectors (SDDs) in dark matter searches by the SIMPLE project, as well as neutron dosimetry and spectrometry at the Portuguese Research Reactor, uses an acoustic instrumentation sensitive to the shock wave generated by the bubble nucleation of the refrigerant droplets. Previous instrumentation relied on the use of a low-cost piezoelectric transducer, which was generally unable to provide discrimination between true bubble nucleation events and background noise events common to SDDs, including microleaks, fractures and trapped nitrogen gas. The development of a new instrumentation (high-quality electret microphone and adaptive electronics) was shown to provide this discrimination capacity through a reduced noise level and distinct fast Fourier transforms of the event registration. The performance demonstrates a factor 10 reduction in noise compared with the previous transducer instrumentation. The spatial localization of an event through an array of sensors was also initiated. Locating an event can automatically reject those that fail to satisfy prescribed criteria related to their nature or origin. This was accomplished in a two step procedure: event validation and localization. Results yielded resolutions of ~1.21 mm^2 with a 90% confidence level.

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The SIMPLE Dark Matter Search Project

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With a new 30 kg exposure measurement finally approved in April, the remainder of 2008 has been spent in preparations and acquisitions necessary to the measurement, which involves 15x 2% superheated droplet detectors (SDDs) equipped with new acoustic-background discriminating instrumentation, to be installed in a 700 liter temperature-regulating water bath, surrounded by 25 tons of water shielding, sited 500 m below ground for background suppression. Dr. Morlat returned to SIMPLE from PICASSO with a 5 year research position under the FCT “Ciência 2007” program; now temporarily located at the project site at “Laboratoire Souterrain Bas Bruit” (LSBB) near Apt (France), she oversaw the safety recertification of the hyperbaric chamber, extensive cleanroom cleaning, temperature controller testing, and input of a new high capacity bi-distiller.

Locally, apart from the R&D of new instrumentation (reported elsewhere), construction of the required 15 channel DAQ, and preliminary R&D of a new “big droplet detector” which remains in progress, the results of a preliminary CF3I SDD measurement were finalized, again indicating a significantly increased sensitivity of the superheated liquid technique over the more traditional (cryogenic, noble liquid, scintillator) in such searches. In December, an LSBB mission was effected to assess the experiment development and readiness for the initiation of the 200 day measurement which is now scheduled for January 2009.

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Radiological Shielding Calculations for the Optimization of Spent Fuel Loading

A. Kling, J. G. Marques

For the shipment of the spent fuel of the Portuguese Research Reactor (RPI) the fuel assemblies had to be transferred from the reactor pool to the transport cask using a transfer cask. Since some of them had a significantly shorter cooling time than in the last shipment new calculations for the determination of the expected dose rates at the transfer cask and the transport cask surface were necessary to minimize radiation exposure of the staff. The radionuclide inventory of each fuel assembly was estimated using the ORIGEN code which served as input for the shielding calculations. Since Monte Carlo calculations for photon shielding calculations with thick lead shielding are very time consuming the MicroShield code, which uses analytical methods, was employed. The results showed that the highest dose rates to be expected at the side walls of the transfer cask were in the order of 2 mSv/h in good agreement with the maximum measured value of 1.2 mSv/h. Due to the short exposure time and the distance kept to the side walls of the transfer cask these values were considered as acceptable. The maximum photon dose rate at the fully loaded transport cask at contact was calculated to be 2.8 μSv/h (measured 3.0 μSv/h), which was far below the permitted dose rate of 2 mSv/h.