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Neutron imaging researches and applications in Brazilian research reactors: challenges and trends

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In Brazil, we have three research reactors with neutron extractor devices: 1) IEA-R1, at the Nuclear and Energetic Research Institute, in São Paulo; 2) IPR-R1, at the Nuclear Technology Development Centre, in Belo Horizonte; and 3) Argonauta, at the Nuclear Engineering Institute, in Rio de Janeiro. These facilities have been used for neutron imaging for more than 40 years, resulting in several technical reports, scientific papers, M.Sc. dissertations and Ph.D. thesis. In most of the cases, neutron imaging was used for testing and analyses of different kind of materials.
At IEA-R1 Research Reactor, neutron imaging is an important research area, by using direct conversion (gadolinium plates) as indirect conversion (dysprosium plates). Neutron flow features of IEA-R1 at 2MW are: thermal flux of $3\times106n/cm^2.s$; thermal to epithermal ratio of 5:7, cadmium rate of 150; n/γ ratio of $5\times10^5n/cm^2.mrem$; beam diameter of 20 cm. Neutron imaging has been used here to materials inspection and testing. Recently, real neutron imaging experiments have been carried out for inspection of samples in motion.
At Argonauta Research Reactor, neutron imaging radiography has been carried out since 1972. Nowadays, Electronic Imaging Systems (EIS) offer real time inspection of samples, allowing dynamic events observation as well the inspection of a great number of samples per time unit. At 360W power, the characteristics of the Argonauta neutron facility are: thermal flux of $4,46\times10^5n/cm^2.s$; L/D ratio of 70; n/γ ratio of $3\times10^6n/cm^2.mrem$; average energy of 30 MeV. The real time neutron imaging applications includes drugs and explosives identification and localization, as well as materials testing for aircraft industry.
At IPR-R1 Research Reactor, the first studies on neutron extractor installation were developed in 70´s, but only in 1987 this device was assembled and tested. It was used a vertical extractor, where samples were mounted in a box containing a photographic film and a gadolinium plate, placed at 3,62m from the reactor core, under a thermal flux of $1,68\times10^6n/cm^2.s$ (at 100kW power) and beam diameter of 10cm. This facility was used to examine several objects of different materials. Images obtained by neutron imaging were compared to X-ray imaging, as a way to identify in which cases we could use neutron or X-ray imaging.
At this moment, a multipurpose reactor is under construction in Brazil, with expectation to be in operation before 2023. It will offer 13 neutron beams, where 7 of them will be in thermal neutron spectrum with energies between 10 to 100 MeV and 6 beams in cold neutrons spectrum with energies lower than 10 MeV. This new reactor will have a neutron extractor device with only one thermal neutron beam dedicated to neutron imaging. These thermal neutrons will be collected directly from the reflector tank by optimized neutrons extractors to assure the desired amplification factor at the samples position.
In order to face the new challenges of radiopharmaceutical production and material testing as well as neutron activation and neutrongraphy, the operation of the multipurpose reactor will offer a higher thermal neutron flux and physical installations specially designed for neutron imaging. This new facility and the experience acquired by more than 40 years of neutron imaging researches will improve the Brazilian capabilities in development of new research areas, applications and materials testing by neutron imaging.

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