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Future Perspectives for Neutron Beam Utilization in Brazil

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The production of radioisotopes in the Brazilian research reactors has a limited capacity leading to a high dependence on external supply. In order to overcome this issue and due to the high age of these research reactors, in 2010 the Brazilian Nuclear Commission decided to develop a new research reactor for radioisotope production, nuclear materials and fuel irradiation testing and neutron beam science. Regarding the last purpose, the Brazilian Multipurpose Reactor (RMB) has been designed to provide thermal and cold neutron beams using neutron guides to transport neutrons to a large hall of instruments. This article describes the main characteristics of the RMB project.

Introduction

Brazil has four research reactors (RR) in operation: IEA-R1, a 5 MW pool type RR; IPR-R1, a 100 kW TRIGA type RR; ARGONAUTA, a 500 W Argonaut type RR, and IPEN/MB-01, a 100 W critical facility. The first three were constructed in the 1950s and 1960s for teaching, training, and nuclear research, and for many years they were the basic infrastructure for the Brazilian nuclear developing program. The last, IPEN/

MB-01, is the result of a national project developed specifically for qualification of reactor physics. Considering the relatively low power of Brazilian research reactors, with exception of IEA-R1, none of the other reactors are appropriate for regular radioisotope production, and even IEA-R1 has a limited capacity. As a consequence, the Mo-99 needed to attend Brazilian nuclear medicine services has been imported. Because of the high dependence on external supply, the international Mo-99 supply crisis that occurred in 2008–2009 significantly affected Brazilian nuclear medicine services, and in 2010 the Brazilian Nuclear Commission decided to build a new research reactor. The new reactor named RMB (Brazilian Multipurpose Reactor) will be a 30 MW open pool type reactor, using low enriched uranium fuel. The facility will be the center of a new nuclear research institute, to be built about 100 kilometers from São Paulo city, in the southeast part of Brazil. Besides producing radioisotopes for medical application, the complex will have several facilities, to use thermal and cold neutron beams; to produce radioisotopes for several applications; to perform neutron activation analysis; and to

perform irradiation tests of materials and fuels. The neutron beam facilities are foreseen as a national laboratory in complement to the Brazilian Synchrotron Light Laboratory (LNLS).

Description of the reactor

RMB is a MTR open pool type reactor that uses heavy water and beryllium as reflector, and light water as moderator and cooling fluid. The power of the reactor is 30 MW, and its main requirements, established during the feasibility study, are: radioisotope production to attend national demand beyond 2020; production of thermal and cold neutron beams for research and application in several areas; development of materials and nuclear fuels; neutron activation analysis; and silicon transmutation doping.

The reactor core is a 5×5 matrix, containing 23 MTR fuel elements, and leaving two positions available for materials irradiation tests. Each fuel element has 21 plates made of low enriched (19.75%) uranium silicide-aluminum dispersion fuel (U_3Si_2 -Al) clad with aluminum. Three sides of the core are surrounded by a reflector vessel, filled

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with heavy water that acts as reflector for the neutrons produced in the core. The reflection on the fourth side is done with the utilization of removable beryllium blocks inside a box of regular water. The core is designed to have a cycle length of 28 days.

Reflector vessel

The reflector vessel is made of zircaloy, and it is installed in the bottom of the reactor pool, about 10.5 meters below water surface level. Filled with heavy water, it has an internal diameter equal to 2.6 meters and an internal height equal to 1.0 meter. It has 5 positions for silicon neutron transmutation doping; 14 positions for pneumatic irradiation; 20 positions for bulk irradiation; one cold neutron source; 2 cold neutron beam tubes; 2 thermal beam tubes, 1 thermal neutron beam tube for neutronography and one position for fuel irradiation testing, where up to 2 rigs can be installed simultaneously.

At least ten of the bulk irradiation positions in the reflector vessel can be used to irradiate rigs with low enriched fuel targets to produce Mo-99.

Reactor and service pools

The reactor pool is a 5.1 meters diameter, 14 meters high cylindrical tank made of stainless steel, filled with water up to the 12.6 meters level. It houses the reflector vessel, a small spent fuel storage rack, with capacity to store up to 32 fuel elements; the bundles of tubes used for pneumatic irradiation; the internal piping that form the inlet and outlet of the primary and pool cooling systems; nuclear and process instrumentation; auxiliary support and mechanical structures, and the water inventory, required for the pool cooling system to perform its functions.

Adjacent to the reactor pool there is the service pool, a 9.0 meters high rectangular stainless steel structure, with maximum water level equal to 7.6 meters. The service pool houses a spent fuel storage rack with capacity for up to 600 spent fuel elements (enough for ten years of operation); and many other devices needed for normal operation of the facility. The service pool is connected to the reactor pool by a transfer channel.

To comply with the requirement to allow the interim storage, for at

least 100 years of all spent nuclear fuel used in the reactor; a building, named “Spent Fuel Storage Building,” was designed adjacent to the reactor building. This building, which can be accessed directly from the reactor building, will have two additional pools, one for temporary wet storage of the spent fuel used in the reactor, and the other for handling and dismantling rigs that were used for material and fuel irradiation tests.

The two pools of the spent fuel storage building plus the reactor pool and the service pool, these latter two located in the reactor building, form a stainless steel structure embedded in a concrete block. Three hot cells located in the reactor building and one hot cell in the spent fuel storage building complement the concrete block.

The research and production nucleus

The reactor and spent fuel storage buildings are the center of what is called the “research and production nucleus” (Figure 1), which includes a radioisotope production facility and three laboratories: one for research utilizing neutron beams;

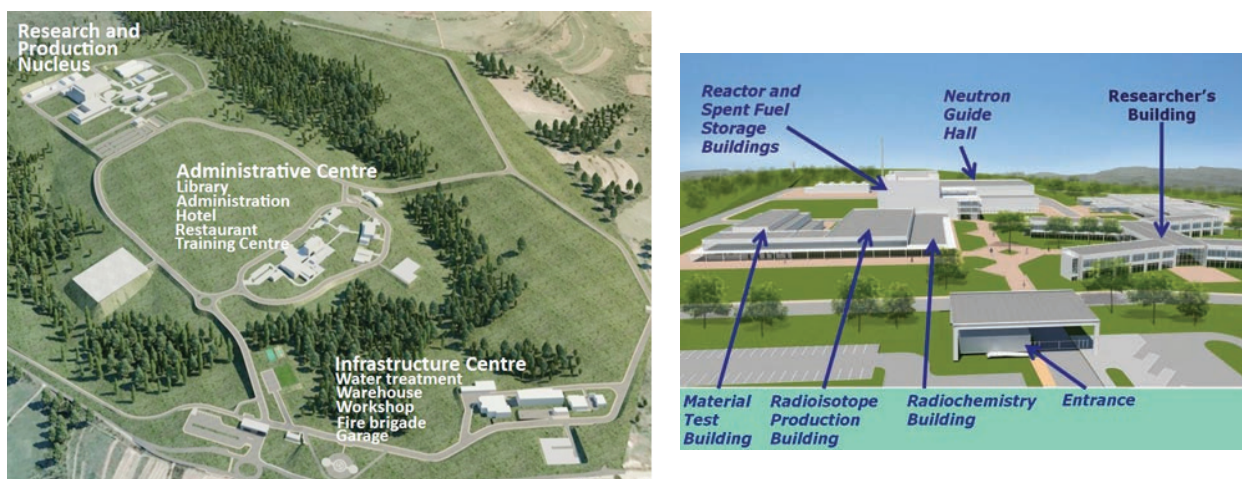


Figure 1. RMB Research Centre schematic view (left). Research and Production Nucleus architecture layout (right).

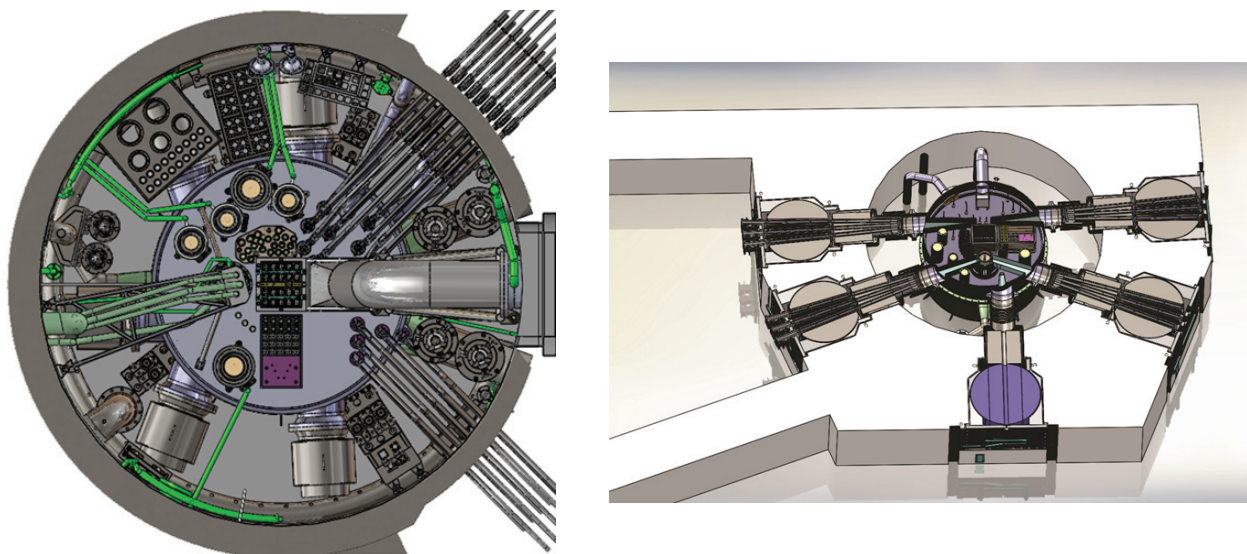


Figure 2. RMB Reactor tank scheme (left). Neutron beam tubes scheme (right).

one for neutron activation analysis; and the third one for post irradiation analysis of irradiated materials and nuclear fuels.

The neutron beams laboratory will have lines of thermal and cold neutrons for experiments involving different neutron beam techniques like diffraction, small angle scattering, reflection and others; as well as other methods like neutronography and prompt gamma activation analysis.

The radiochemistry laboratory will have two pneumatic connections to receive long life irradiated samples, plus five pneumatic tubes connected directly to the reflector vessel, for cyclic irradiations of short life products and delayed neutron activation analysis.

Seven more facilities complement the research and production nu-

cleus, the reactor auxiliary building, the cooling tower complex, the electrical supply and distribution building, a radioactive waste management facility, a workshop, an operator's support building, and a researcher's building.

Neutron beam utilization

In the RMB, the thermal and the cold neutron beams will be generated inside the reflector vessel by the neutrons thermalized by the heavy water (D_2O) at room temperature and a cold neutron source composed by a cryogenic cylinder of approximately 17 liters, containing liquefied D_2 at a temperature of 24 K, respectively. The thermalized neutrons will be extracted by three thermal neutron beam tubes and two cold neutron beam tubes (Figure 2). Inside each beam tube it

will be possible to install three neutron guides with an angular separation of 3 degrees between each other. These neutron guides will be extended in order to transport the beams to an experimental hall of instruments named Neutron Guide Hall (NGH) where it is planned to install up to 18 neutron scattering instruments.

In the initial stage the intent is to implement only two neutron guides for thermal neutrons and another two for cold neutrons. Based on the Brazilian Synchrotron Light Laboratory (LNLS) users community demand and studies still in progress, it was suggested to install two diffractometers (one high-resolution and one high-intensity), a small-angle neutron scattering (SANS) and a neutronography instrument in a thermal beam tube at reactor face, during this first stage.