THE RMB PROJECT – TECHNICAL AND MANAGEMENT DEVELOPMENT STATUS

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Abstract. The Brazilian Nuclear Energy Commission (CNEN) decided to construct a new research reactor, named RMB (Brazilian Multipurpose Reactor). This reactor will be part of a new nuclear research center, to be built on a site about 100 kilometers from São Paulo city, in the southeast part of Brazil. It is a 30 MW open pool-type research reactor using low enriched uranium fuel, and several associated facilities and laboratories in order to produce radioisotopes for medical and industrial use; to use thermal and cold neutron beams in scientific and technological research; to perform neutron activation analysis; and to perform materials and fuel irradiation tests. This project started in September 2008 and is nowadays at the development stage before construction. This article presents updated information on the technical design and the safety features regarding the reactor and the overall installation. It also presents an update on the nowadays overall development status of the RMB project and lessons learned related to the complexity of the project management.
Key Words: research reactor project, research reactor utilization, research reactor management.

1. 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. Considering the relatively low power of Brazilian research reactors, with exception of IEA-R1, none of the other reactors is appropriate for regular radioisotope production, and even IEA-R1 has a limited capacity, and the majority of the radioisotopes for the Brazilian nuclear medicine demand has been imported. Due to the complete dependence on external supply, the 2008/2009 international Mo-99 supply's crisis affected significantly the Brazilian nuclear medicine services, and this vulnerable condition supported, in 2010, the decision of the Brazilian Nuclear Energy Commission (CNEN) to build a new research reactor named Brazilian Multipurpose Reactor (RMB). The RR is a 30 MW open pool-type research reactor using low enriched uranium fuel, and several associated facilities and laboratories in order to produce radioisotopes for medical and industrial use; to use thermal and cold neutron beams in scientific and technological research; to perform neutron activation analysis; and to perform materials and fuel irradiation tests. This project started in September 2008 and is nowadays at the designing stage before construction. Due to the necessity to produce radioisotopes for medical use and to give flexibility to researchers, the RMB reactor is designed to operate 24 hours per day, and an availability of more than 80% yearly. The reactor conceptual design was developed by the CNEN institutes. The basic and detailed engineering designs were developed by INVAP and the Brazilians engineering companies INTERTECHNE and AMAZUL. Directorate of Research and Development, responsible for the research institutes of CNEN, is the technical coordinator office to verify and to prepare licensing documentation of the project and will be the operator organization as well. RMB is an MTR open pool-type reactor that uses beryllium and heavy water as a reflector, and light water as a moderator and cooling fluid. Its main requirements were established by CNEN technicians during the feasibility study and the conceptual design. The reactor core is a 5 X 5 matrix, containing 23 plate-type fuel elements, and leaving 2 positions available for materials irradiation tests. Each fuel element has 21 fuel plates made of low enriched (19.75 wt%) uranium silicide-aluminum dispersion fuel (U_3Si_2-Al) with aluminum cladding. Three sides of the core are surrounded by a reflector vessel, filled 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 33 days. With this core characteristics the reactor accomplishes with its main utilization tasks as to: extract neutron beams (thermal and cold) for scattering, diffraction and neutrongraphy, to produce radioisotopes, to perform silicon doping, to test materials under neutron irradiation fields, to test nuclear fuel samples under irradiation, to perform neutron activation analysis and to activate materials.

RMB will be part of a new CNEN´s nuclear research and production center. The new site infrastructure shall consider in its design and construction not only the needs of the reactor and its complementary laboratories but also the needs of future facilities and laboratories. As a new nuclear center, it is necessary to have all the environmental and nuclear site licenses issued by the competent authorities adding more time and effort for the project development. References [1] to [7] present the RMB project in a detailed manner.

2. PROJECT DEVELOPMENT STATUS

The RMB project management organization set the life cycle into three phases: phase 1- Implementation; phase 2- operation; and phase 3- decommissioning. Today the RMB project is in the implementation phase with the following steps: (i) site setup; (ii) conceptual design; (iii) basic (or preliminary) engineering design; (iv) detailed (or executive) engineering design; (v) procurement and contracts; (vi) construction; (vii) fuel assembly development and manufacture; (viii) nuclear and environmental licensing; and (ix) commissioning. For each step, there are management plans and resources allocated. There is also a strong interaction within the engineering steps and the licensing needs. Steps (v), (vi) and (ix) did not initiate yet. The following items will present the status of each step that has initiated.

2.1. Site Setup

The new site is located in Iperó County, São Paulo State, 110 kilometers west from São Paulo city, in the southeast part of Brazil. The RMB Center site has an area of about 2.04 million square meters. 60% of this area was federally owned and given to CNEN, and 40% of this area was privately owned and expropriated by the Government of the State of São Paulo in benefit to the RMB project.

Many preliminary actions were performed to characterize the site as topography; ground survey; meteorological tower installed; and a pre-operational radiological environment monitoring plan is under regular execution.

A small information center is already installed on the site, allowing receiving visitors to explain the project and to show the landscape of the new nuclear center.

In June 2018, in a solemnity with the presence of the President of Brazil, it was laid the foundation stone of the RMB Project. *(see Fig.1)*

A small office for the construction step is already installed on the site.

Fig. 1. RMB Site

2.2. Conceptual Engineering Design

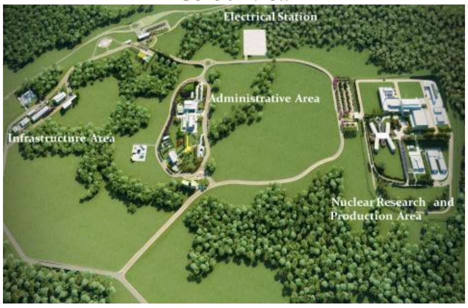
Starting in September 2008, CNEN Institute technicians developed the conceptual engineering design of the research reactor, laboratories, main facilities, and site infrastructure. IPEN – Energy and Nuclear Research Institute of CNEN, located in São Paulo, is the most involved research institute with the RMB work and project management as the technicians' experience and IPEN infrastructure were the main sources for the RMB project.

2.3. Basic Engineering Design

In 2010, CNEN and the Argentinean Atomic Commission (CNEA) decided to adopt, for the new research reactors of Brazil (RMB) and Argentina (RA10), the conceptual model of the OPAL research reactor based on INVAP´s design. For the Brazilian RMB research reactor, in addition to radioisotope production and neutron beam utilization, CNEN established two other design requirements, as decided in the conceptual engineering design. The first one was the capability to test fuels and materials for the Brazilian nuclear power program, and the second was the requirement to have the necessary infrastructure to allow the interim storage, for at least 100 years, of all spent nuclear fuel used in the reactor. The Ministry of Science, Technology and Innovation (MCTI) granted CNEN with financial resources for the RMB project basic engineering design. This allowed, in 2012, the signature of a contract with INTERTECHNE, a Brazilian company, to develop the engineering work for the preliminary design phase of all buildings, facilities, and infrastructure of the new center. *(See Fig.2)* In

2013 CNEN signed a contract with INVAP for the work related to the basic engineering of the reactor and connected systems. Both contracts ended in November 2014. Almost seven thousand engineering documents were produced up to this point of implementation by both engineering companies.

General view



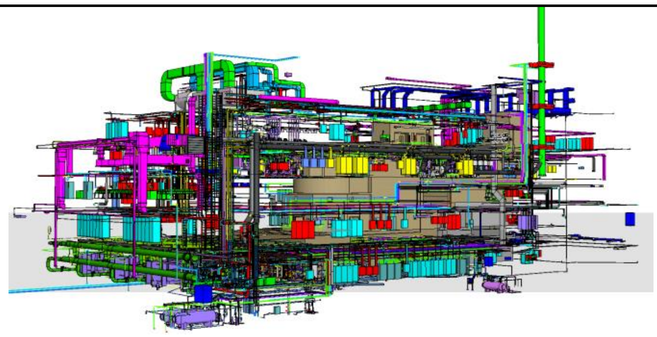
NRPA view

1 – NRPA Entrance
2 – Researchers Bld.
3 – Workshop Bld.
4 – Waste Processing and Storage Bld.
5 –Electrical Supply Bld.
6 – Cooling Towers
7 –Reactor Auxiliary Bld.
8 – Reactor Bld.
9 – Spent Fuel Bld.
10 – Post Irradiation Lab.
11 – Radioisotope Processing Bld.
12 – Radiochemistry Lab.
13 – Operator Support Bld.
14 – Neutron Beam Lab

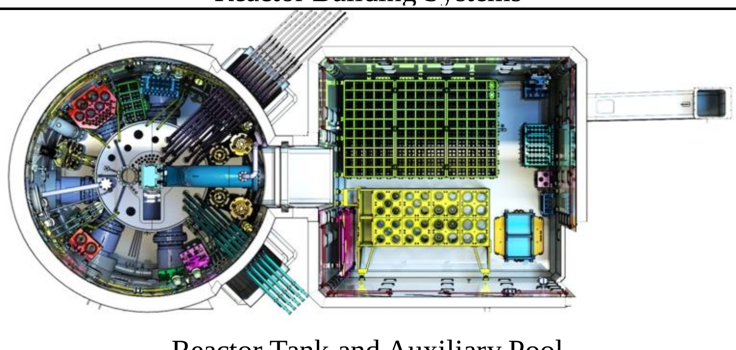
Fig. 2. Engineering view of RMB nuclear research center

2.4. Detailed Engineering Design

The MCTI granted CNEN with financial resources for the detailed engineering design of the RMB research reactor facility in the Nuclear Research and Production Area (NRPA) *(See Fig.2)*. This means the reactor building, the spent fuel building, the reactor auxiliary building, cooling towers, electrical supply building, operator support building, and the neutron beam laboratory. The effort for this work complies with more than 70 working packages encompassing all the structures, systems, and components (SSC), and more than one million man-hours of engineering work. For this engineering work, two companies were contracted. INVAP, from Argentina, for the nuclear SSC and AMAZUL, from Brazil, for the conventional SSC which includes civil and electrical engineering works. CNEN is the project coordinator and AMAZUL is the integration leader with INVAP. Almost 8 thousand engineering documents have been planned and prepared by these companies for this project step. (*See Fig.3*)



Reactor Building Systems



Reactor Tank and Auxiliary Pool

Reactor Tank

Fig. 3. Examples from detailed engineering design

Detailed design of other buildings, laboratories, and infrastructure of the RMB project will be done along with the contracts of the construction step.

2.5. Fuel Assembly Development and Fabrication

The MCTI granted CNEN with financial resources for the fuel assembly development and improvement of the existing fabrication infrastructure. Brazil has the technology for uranium enrichment by ultracentrifuge method and has the technology for producing fuel for research and power reactors. The RMB fuel cycle management system has developed a coordinated project to establish an infrastructure for producing fuel assemblies for the reactor operation, and uranium targets for Mo-99 production. The goals of this coordinated project were: (i) to have a centrifuge cascade enriching uranium up to 20 wt% with the capacity to supply RMB yearly needs; (ii) to upgraded the CNEN existing infrastructure to produce nuclear fuel assemblies and uranium targets for the RMB yearly needs; (iii) to produce a set of fuel assemblies for a real RMB mockup core at the IPEN/MB-01 Critical Facility of CNEN. As a result of this coordinated project, the following actions were done: (i) The Navy Technological Center in São Paulo (CTMSP) upgraded a uranium centrifuge cascade, at its Isotope Enrichment Laboratory, for working exclusively to RMB RR. This cascade is already commissioned and can yearly produce the 20% enriched uranium (UF_6) in the quantities as needed by RMB; (ii) The Nuclear Fuel Center (CCN) of the Energy and Nuclear Research Institute (IPEN) of the CNEN, in São Paulo, has upgraded its infrastructure to attend RMB needs exclusively. The CCN upgraded all systems related to UF_6 conversion to metallic uranium, the production of uranium alloys, the preparation of powders and briquettes, plates rolling and fuel assembly, and quality control laboratories. As results of this upgrading, many innovative processes were developed and some patents generated; (iii) The CCN produced 19 fuel assemblies of U_3Si_2-Al dispersion fuel, with the same design of RMB project. The fuel design incorporates discrete burnable poison as needed by RMB design. These fuel assemblies were loaded at the IPEN/MB-01, Critical Facility of IPEN/CNEN-SP, for simulating the RMB core. Some of these fuel assemblies can be disassembled for modifying internal devices to benchmark reactor physics analysis. The infrastructure developed in this coordinated project is ready for attending RMB needs for continuous operation in terms of fuel assemblies and uranium targets for Mo-99 production.

2.6. Environmental License

The environmental licensing process started in 2011. MRS, a Brazilian Company, prepared the Environmental Impact Assessment (EIA) for the RMB center. IBAMA (Environment Regulatory Authority) analyzed and approved the RMB EIA. CNEN sponsored three public hearings in two cities near the RMB site (Iperó and Sorocaba), and São Paulo city. IBAMA has awarded RMB Project with the first environmental license (Initial License) in May 2015. CNEN has already prepared the environmental plans (EP) for the IBAMA installation license authorization. With this license, it will be possible to initiate the field infrastructure actions for the construction step. A total of 24 EPs were prepared and sent to IBAMA for approval. These EPs are: environmental management plan; environmental program for construction; noise monitoring and control program; particulate matter monitoring and control program; erosion process monitoring and control program; liquid waste management program - installation phase; solid waste management program - installation phase; surface water quality monitoring program; degraded areas recovery program; groundwater quality monitoring program; liquid waste management program - operation phase; solid waste management program - operation phase; flora management and conservation program; Rescue, management and conservation program for terrestrial and aquatic fauna; signaling program;

road system impact mitigation program; environmental education program for construction workers; environmental education program for the local community; program for strengthening public and private infrastructure; local workforce training program; social communication program; archaeological prospecting and heritage education program; labor demobilization plan

RMB Project got also the license for using the water from a river located near the site for the cooling towers operational needs, and water from the underground for human use.

2.7. Nuclear License

The nuclear licensing process started in 2012. CNEN’s Institutes technicians did the Site Evaluation Report (SER). The Nuclear License Authority (DRS/CNEN - Directorate of Radioprotection and Safety of CNEN) analyzed the SER and approved it. The DRS/CNEN awarded RMB Project with the Site License in January 2015. CNEN’s Institutes technicians did the Preliminary Safety Analysis Report (PSAR) of the RMB research reactor. This was given to DRS/CNEN in December 2018 and now is under analysis. If approved by DRS/CNEN, RMB will be awarded with the reactor construction license. *(See Fig.4)*

CNEN’s Institutes technicians are now preparing the Final Safety Analysis Report (FSAR) to ask DRS/CNEN for the reactor operating license. INVAP and AMAZUL develop the input analyses along the reactor detailed design step.

Fig. 4. RMB Preliminary safety analysis report (PSAR)

3. MANAGEMENT REMARKS

Since 2015 the Brazilian Government did change the presidents three times. This political command change did impact the economy of the country and the investments in the area of science and technology. The RMB project suffered by these political changes in its budgetary plans and construction development. The project did not have new money in these last four years, but the government did maintain the financial resources for the work already contracted during the year 2014. One relevant fact to RMB was the creation of the Brazilian Nuclear Program Development Committee (CDPNB). This is a government committee chaired by eleven Brazilian ministries. The CDPNB gave priority attention to the RMB Project and has brought the Ministry of Health to give financial support for the construction step of the project. With this support, the future perspective for the RMB financial issue solution has increased to a level that is almost warranted the beginning of the construction in the next years. An important decision of the CDPNB was to couple the RMB construction to the

Nuclear Medicine utilization improvement in the country, so that is why the Ministry of Healthy will give real support to the RMB project.

A new research reactor project, together with the infrastructure development of a new research center, gives an important challenge to the researchers and technicians in charge of them due to the complexity of matters and issues involved. Nevertheless, due to economic and governmental matters, the financial resource given to the project did not reflect the budgetary needs. This has imposed restrictions on the management of the project, and it was only possible to develop some steps (work packages) at once instead of an integral work, as a normal EPC process.

4. CONCLUSION

The RMB Project, having a 30 MW research reactor, is developed since 2008. and its engineering design is well developed. The fuel assembly production was solved through the construction of a dedicated enrichment cascade and a fuel assembly producing installation upgrade. This infrastructure is ready and able to produce all the needs for RMB continuous operation. The environmental and nuclear licensing are under development as needed. The budgetary financing issue of the project is under consolidation within the Government, including both the Ministry of Science and Technology and the Ministry of Health. It is foreseen the beginning of the construction steps for the next two years.

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