Associação Brasileira de Energia Nuclear – ABEN
2019 International Nuclear Atlantic Conference - INAC 2019
Santos, SP, Brazil, October 21-25, 2019

Agência Brasileira do ISBN
ISBN 978-85-99141-08-3

FUTURE CHALLENGES FOR IPEN/MB-01 NUCLEAR RESEARCH REACTOR

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ABSTRACT

Along the last 30 years, the IPEN/MB-01 research reactor (RR) played a key role in the Brazilian Nuclear Program development. In more than 3,660 sessions it was possible to develop several research experiments, train new operators for the Brazilian nuclear power plants (NPP) and form hundreds of new human resources for nuclear area. Nowadays a new core is under deployment in the facility to prototype the Brazilian Multipurpose Research Reactor (RMB) core project. Several challenges, technical and managerial, are being overcome to fulfill the task, so this paper presents the future challenges for the next 30 years of operation, regarding measures to improve the RR utilization. It is expected to attract more students each year, receive researches from abroad, improve the contact with other RRs around the world to exchange experience in safe operation, maintenance and management system and improve the contacts with Brazilian and Latin America universities. In the same way several experiments are planned to be performed, including those related to the NEA/OECD International Benchmark and those related to the undergraduate and graduate courses.

1. INTRODUCTION

The IPEN/MB-01 Nuclear Research Reactor belongs to the so called “zero power” class of nuclear reactors. It is a genuinely Brazilian reactor as the conception, design and construction was totally performed in the country. It is located at Nuclear and Energy Research Institute (IPEN-CNEN/SP) and its first criticality occurred on November of 1988. Figure 1 shows the reactor building.

The facility was designed to be a very flexible structure, so it is possible to set several different core configurations to be analyzed in a wide perspective. As the rating power is 100W it is possible to simulate a nuclear power reactor, in scale, with no need of a complex heat removal system.

Nowadays, the facility is under a core replacement process. The first one has been used for the last 30 years and the new one is going to be used to prototype, and validate, the Brazilian Multipurpose RR core (RMB).

The first core had a structure of 28 x 26 fuel rods containing 52 $U0_2$ pellets, in each rod, performing 4,3% of enrichment. The rod structure is constructed using stainless-steel AISI-304.

There were 2 groups of 12 safety rods and more 2 groups of 12 control rods, responsible for the reactivity control and reactor shutdown. All the control rods are made using a composition of Ag-In-Cd with an austenitic stainless-steel cladding and are inserted in the reactor core through specific guide tubes. In the other hand, the safety rods are made using B_4C and were kept outside the core during regular operation. It is important to highlight that just 1 control or safety rod are capable to shut down the reactor, providing a great safety operation margin.

Figure 1 – View of IPEN/MB-01 reactor building.

In the Figure 2 is possible to observe the first reactor core, including the safety and control rods. In the same Figure is possible to identify the tubes along the core where the nuclear instrumentation has been installed.

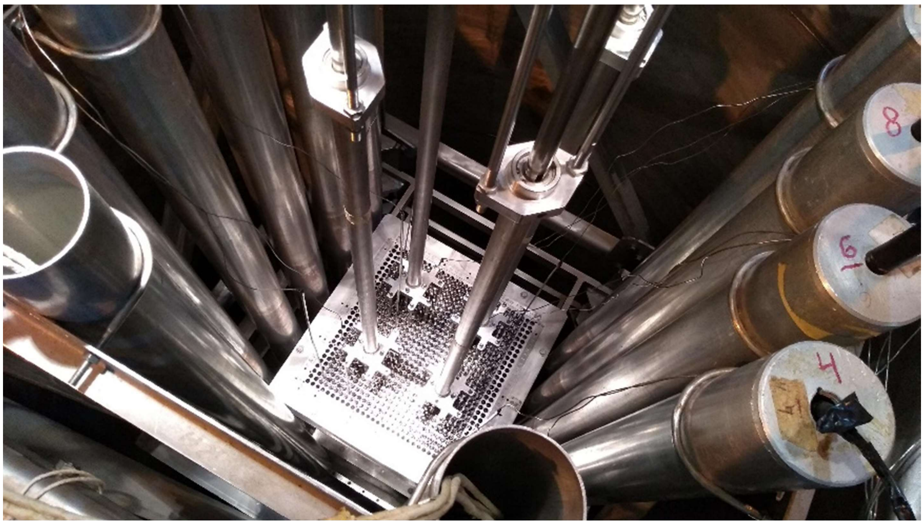


Figure 2 – First core, including the fuel rods, safety/control rods and nuclear instrumentation tubes.

2. REACTOR UTILIZATION DURING THE LAST 30 YEARS

Along the last 30 years, the IPEN/MB-01 RR played a key role in the Brazilian Nuclear Program development. It was 3,663 sessions, 20 students a year (average), 10 different experiments a year (average), which could provide dozens of new operators and professionals (undergraduate and graduate levels) in nuclear area.

In this context the IPEN/MB-01 facility has been used as a full-scale facility to evaluate the performance of different cores and optimize its project. It allowed the measurement of several nuclear parameters, such as reactivity, neutron flux distribution, power, reaction rates, among others, providing nuclear data to the reactor physics sector and computational code validation.

Furthermore, it allowed the validation of reactor physics methodology and nuclear data associated performing several NEA/OECD benchmark experiments and providing data to its database.

Another great contribution of the facility is related to the training process to form new operators for Brazilian NPPs and Research Reactors. Along the years more than 40 new operators were formed for RR and about 50 operators for NPP. Usually, the training course for new RR operators take about 2 years, including theoretical classes (nuclear physics, reactor physics, radiation detection, radiological protection and others), reactor systems (water supply, HVAC, compressed air, nuclear instrumentation and others) and reactor operation (operating procedures, safety systems, emergency systems, core management, fuel handling and storage and others). In the other hand the NPP operator’s training course takes about 3 weeks, as it is just a part of a very comprehensive training program. At the facility they have classes about the facility, they perform about 7 different experiments and participate in the reactor operation. All the activities and experiments are reported as part of the training course.

Besides the formation of new operators, the facility made a great contribution in the development of human resources through undergraduate and graduate courses and projects with Brazilian universities. In average it was performed more than 100 session per year with 20 students (BSc, MSc, PhD or Post-Doctoral) each year.

Finally, IPEN/MB-01 facility played a key role in the experience acquisition regarding the management of nuclear facilities, considering safety operation, proper maintenance, accounting and control of nuclear material, physical and radiological protection, and others aspects. In this context it contributed to preserve the nuclear knowledge acquired during the last 30 years.

3. CHALLENGES FOR THE NEXT 30 YEARS

The very first challenge that are still in place is the commissioning process of the new core. Nowadays it is clear that we have lost part of the knowledge (and experience) developed during the last years. It is particularly visible about some details of the facility or equipment that are not handled during regular activities. One example can be the mechanical couplings along the control rod drive mechanisms (CRDM) or couplings among the structure that holds the core and the CRDM or the shock absorber. Of course, it is possible to find all the details in the reactor documentation, but in some cases, it takes a long time.

Another great challenge, and somehow related to the first one, is the aging of the Brazilian nuclear workforce. The particular situation of IPEN/MB-01 is critical because, nowadays, there are just 2 senior operators available and both of them have conditions to retire at any moment. There is one operator whose training started in 2013 (license issued in 2014) with great knowledge of the facility and several hours of operation. Another operator is under training and going to be fully formed as soon as the new core start to operate. Another point to be considered is the retirement of the most active researchers at the facility. It is predicted to occur by the end of 2019. In the same way is important to highlight that the staff responsible to keep the facility, and the reactor itself, running (maintenance, experimental, radiological protection) are going to retire in, not more than, 3 years.

In the reactor utilization point of view one challenge to be overcome is to reestablish the connection with some stakeholders. It is known that most of the Brazilian Universities are facing the same aging situation described above. In this scenario some activities performed with researches from others Institutions are not in place anymore. One consequence is the reduction in the number of students effectively using the facility.

Considering the regular maintenance aspects, the challenge is to keep the facility running using equipment and elements from its original project. Presently, it is getting harder to find several parts. The solution is being to buy and storage several spare parts, but it is known it cannot be a good strategy for electronic parts, for example. For the next years this issue is going to be more sensitive as the natural aging of the components are going to be more and more significant.

A related aspect is the instrumentation upgrade, which includes both nuclear and process. As an example, it is possible to highlight the ventilation system, water supply system, water treatment, air conditioning, heater, fire protection and others auxiliary systems of the facility. As it is 30 years old, most of these systems need to be refurbished. According to the procurement process and some financial constraints a major planning needs to be performed including all the Institution levels to properly address all the needs for the next years.

Analyzing the challenges described 3 different major areas have been identified. The first one is related to the replenishment of the workforce, before most of the knowledge were lost, the second is about improve the reactor utilization because there is no sense to have a reactor properly running with a low level of utilization. The last topic regards the facility upgrade, which just can be done with a suitable staff number and enough knowledge and experience. Thus, these 3 topics are the basis to define actions to be developed and address the future challenges of the IPEN/MB-01 RR.

4. ACTIONS TO OVERCOME THE FUTURE CHALLENGES

To face and overcome the future challenges of IPEN/MB-01 RR it is under preparation a specific Strategic Plan (SP). This document has a vital rule to assure an efficient and well managed utilization of the RR, as it provides information for a sustainable operation and investment justification (refurbishment or expansion). During this development it is been used a specific Technical Report from IAEA, called Strategic Planning for Research Reactors [1], as a model and guide for the SP preparation.

With a proper methodology is possible to identify all the reactor's stackeholders and address their needs aiming a proper utilization and sustainability of the facility.

Moreover, to address all the issues regarding the future challenges it was considered the Strategic Orientations Plan 2019-2022 from the Brazilian Nuclear Energy Commission (CNEN) [2]. This document defines general guidelines for "Research, Development and Innovation" and "Human Resources Development", so this information was considered during the development of Strategic Actions to face the future challenges.

Considering the methodology presented in [1], the guidelines defined in [2] and the experience acquired during the years it was possible to analyze the present and potential capabilities of the reactor, the existing and potential stackeholders (and their needs) in the utilization point of view. Then, considering the scenario (staff and budget) of the reactor some major objectives has been defined.

These major objectives have been divided into 4 main areas. The first one is Education, then Training, Research and Managerial. For each area few specific objectives have been defined considering the "SMART" criteria (Specific, Measurable, Achievable, Relevant, Timely), so it will be possible to accomplish the task (at first), follow up it and measure (with key performance indicators) its development and effectiveness.

It is important to highlight that this paper do not intend to present the whole Strategic Plan, as, for example, the Strategic Analysis (SWOT analysis – strengths, weaknesses, opportunities and threats) is not presented here.

Thus, the specific objectives are presented below.

4.1. Education

4.1.1. Technical information tours

Include the IPEN/MB-01 facility in the institutional regular visitation system (weekly basis). The main idea is to receive students from all over the country in a regular basis. In average the Institute receives more than 1200 visitors per year (most of them are students and teachers). To accomplish the task, it will be prepared a guide to perform the visitations and guarantee a homogeneous tour and presentation to the visitors. This topic will expand the social rule of the reactor allowing the society to gather information about how a nuclear reactor works and its importance to the society.

4.1.2. Internet reactor laboratory (IRL)

In 2015 IAEA has created the IRL programme. It provides a powerful tool to students and technical staff of countries that don't have a RR to participate in live reactor experiments. This tool can link a host reactor with a classroom in any other place with an internet connection [3, 4].

In this context the main objective is to establish this kind of tool at IPEN/MB-01 facility. This initiative will collaborate in many aspects to bring professionals to the facility. First, bringing professional from other countries (and IAEA) to share experiences regarding others IRL projects. Then, bringing new researches and new students to the facility regarding the development and deployment of the IRL project. Once it is successfully concluded it will contribute to increase the utilization of the IPEN/MB-01 RR, as it will be available for a much greater number of students.

4.2. Training

4.2.1. New RR operators training courses

To overcome the challenge related to the staff retirement it is imperative to form, at least, 3 new senior operators in the facility. This particular item has great importance as the process to form new staff and transfer the knowledge to them takes time. Usually, it is necessary about 1,5 years to form a senior operator for the facility [5].

As the candidates for new operators has been already identified the training course is about to be deployed. It is important to highlight that it must take place very soon because it needs to be done before the retirement of the last existing senior operator.

4.2.2. New NPP operators training courses

During the last 30 years it was offered several training courses to form new operators to the Brazilian NPPs.

So, the goal here is to continue offering a proper training course to the NPP and to accomplish this goal it is necessary to update all the training course material as the new core are being put in place.

4.3. Research

4.3.1. Provide access to researchers from outside

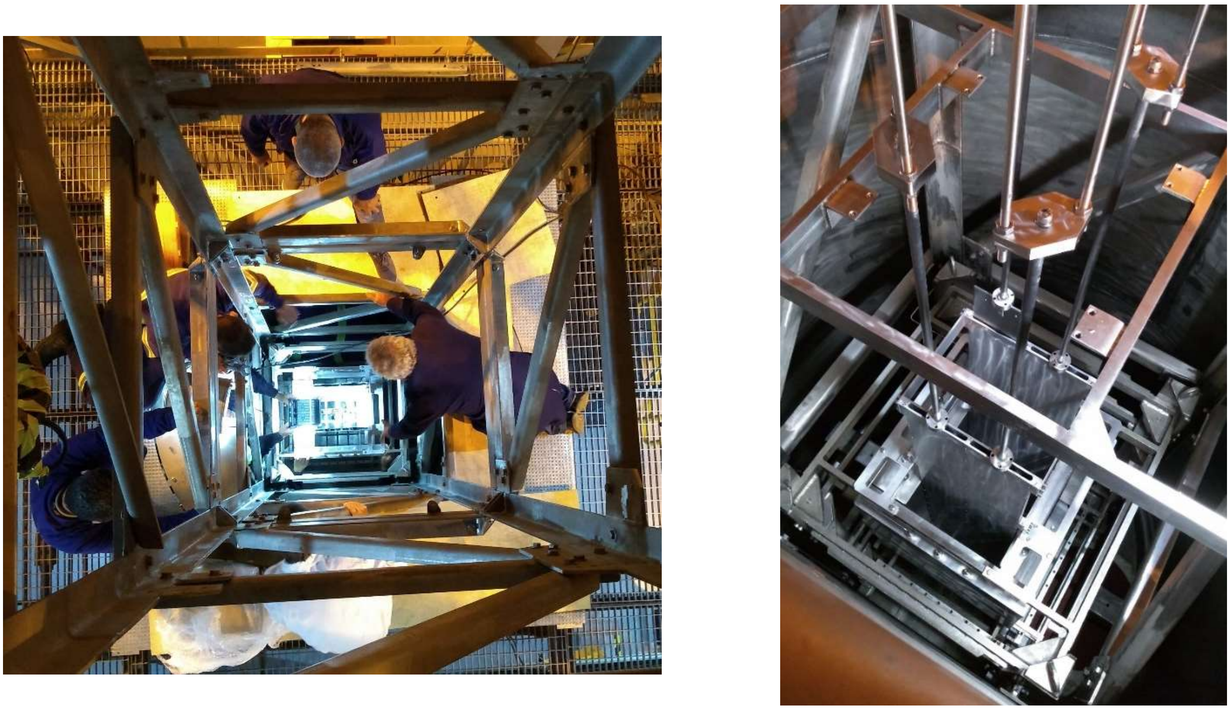
It is imperative to create conditions to bring researchers from outside the local Institute. Escola Politécnica of the University of São Paulo (The Engineering School) is the closest place to start conversations and initiate cooperations through agreements. In this context the IPEN/MB-01 RR can play a key role in the development of projects and offer a multidisciplinary nuclear laboratory to the Engineering School, as they have great interest in Nuclear Area [6]. At least, another 3 different Universities located in São Paulo are part of a list do be contacted to initiate conversations.

4.3.2. Provide access to researchers from inside

In the next 5 years most of the Institute's staff are going to retire. Among those who are not going to retire it was verified it is a consensus that the RR is a great multidisciplinary laboratory and could aggregate those professionals. It is known that the organizational environment does not enhance internal cooperation among the professionals, so in this context the main goal is to create strategies to facilitate the entrance of them to collaborate with the facility. In this way the first strategy to be implemented consists in specifics technical tours through the facility followed by presentations of the main nuclear and auxiliary systems to those professionals. It is known that a great number of employees, inside the institute, have knowledge and practical experience in industrial facilities and their systems.

4.3.3. Experimental validation of RMB core

This activity is going to play a key role in the RMB core development in order to obtain experimental support and validate the calculation methods used in the core project and that is the reason why CNEN has decided to prototype the RMB core. To accomplish this task, it is imperative to form new human resources and new operators (item 4.2.1). A strategy to design and perform all the necessary experiments needs to be done to support the RMB commissioning phase. Figure 3 presents the core replacement activities and the new core itself.



(a) (b)

Figure 3 – (a) Activities regarding the core replacement and (b) the new core structure.

4.3.4. Expand the number of experiments performed

Along the last years 8 different experiments have been performed (gamma spectrometry, flux measurement (NAA), power measurement (NAA), reactor tour and criticalization, criticality prediction, control rod calibration, temperature coefficient measurement, void coefficient measurement and power measurement through neutron noise). Using the Research Reactor Database (RRDB) [7] and a specific IAEA Training Course Series document [8] it will be possible to analyze several experiments performed in similar facilities around the world. The development and deployment of new experiments can bring new professionals and students to the facility, contributing to increase the reactor utilization.

4.4. Management of the facility

4.4.1. Improve the communication with others RRs

The communication with others facilities are going to be improved as they can actively contribute to exchange experience in safe operation, maintenance and management system. It is a fact that we can learn a lot with the staff from other places, as they have different constraints, clients, experiments and staff background. This communication is going to be done, primarily, with the Brazilian RR and then expanded to other countries. One strategy, for the Brazilian RR, is to promote regular meetings and an active channel to exchange information. To accomplish the task, it will be used all the existing staff network, as it is usual their participation in international events, like IAEA ones.

4.4.2. General upgrade

To overcome the challenge of facility obsolescence one strategy is to establish cooperation agreements with the Instrumentation Service (Nuclear Engineering Division) from Nuclear Engineering Institute (IEN/CNEN), which is another CNEN Institute. This strategy is in accordance with the CNEN’s Strategic Orientation Plan [2] as it promotes an integration among the several Institutions, putting the workforce of different Institutions together. In particular, IEN Institute played a key role in the reactor commissioning 30 years ago. Nowadays, there is another opportunity to reestablish this cooperation through a general upgrade, regarding the instrumentation of several nuclear and auxiliary systems.

4.4.3. Specific web portal

The development of a specific web portal for the IPEN/MB-01 RR can contribute to increase the visibility of the facility. It can act as support tool in the finding process for new researchers, students and visitors. It can actively contribute to increase the reactor utilization.

5. CONCLUSIONS

According to the challenges that are already in place and those that IPEN/MB-01 are going to face in the near future it is imperative to develop a comprehensive Strategic Planning to handle the future constraints. The main threat is related to the workforce aging as the absence of a well trained staff is going to jeopardize the development of the facility and its sustainable utilization.

In this context a strategy will be to form new operators as soon as possible and create a proper environment to put several professionals (and students) together in a multidisciplinary laboratory, the IPEN/MB-01 RR. The success of this endeavor is vital to justify the future activities of the facility.

As soon as the Strategic Planning is concluded a new paper can be issued to share the experience in performing this in-depth study.

ACKNOWLEDGMENTS

Special thanks to Hugo Landim (IPEN/MB-01 operator), Julian Shorto (IPEN staff), Marcos Santana (IEN staff), Renato França (IPEN staff), Rogerio Jerez (IPEN/MB-01 senior operator) and Silvio Menzel (IPEN staff) for the great contributions and ideas along the last year regarding the future of the IPEN/MB-01 facility.

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