THE UTILIZATION OF IPR-R1 TRIGA NUCLEAR RESEARCH REACTOR FOR EDUCATIONAL PURPOSES IN BRAZIL

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ABSTRACT

The Nuclear Technology Development Centre (CDTN), a research institute of the Brazilian Nuclear Energy Commission (CNEN), offers the Training Course for Research Reactor Operator (CTORP). This course is offered since 1974 and about 250 workers were certificated by CDTN. The CTORP is a three-week practical training course using the IPR-R1 TRIGA reactor which emphasizes basic nuclear reactor neutronic principles. Subjects such as the neutron multiplication factor, criticality, reactivity worth, period, poisoning, delayed neutrons and control rods are discussed in such a manner that even someone not familiar with reactor physics and kinetics can easily follow it. A few equations are used and several tables and graphs illustrate the text. A proposal to expand the training activities at the IPR-R1 TRIGA reactor is presented here, in order to meet the current demand for education and training in the nuclear area. Research projects programs would be created in the postgraduate course at CDTN. In addition to the normal reactor physics topics addressed by CTORP, new items as thermal hydraulic and instrumentation should be added and discussed in more detail. Among the new items that should be studied, may be cited: reactor thermal power calibration, fuel and water temperatures, heat transfer, fuel thermal conductivity, temperature coefficients, Design Basis Accident, etc. Validation and verification of modern neutronic and thermal-fluid dynamics computer code, such: Monte Carlo, WIMS, RELAP and CFX. Theoretical and experimental burn-up calculations and an introduction to reactor control and safety system based on the microprocessor.

1. Introduction

Rising concerns about global warming and energy security have spurred a revival of interest in nuclear energy, leading to a “nuclear power renaissance” in countries the world over. In Brazil, the nuclear renaissance can be seen in the completion of construction of its third nuclear power plant and in the government's decision to design and build the Brazilian Multipurpose research Reactor (RMB). The role of nuclear energy in Brazil is complementary to others sources. Presently two NPP are in operation (Angra 1 and 2) with a total of 2000 MW_e that accounts for the generation of approximately 3% of electric power consumed in Brazil. A third unity (Angra 3) is under construction. Even though with such relatively small nuclear park, Brazil has one of the biggest word nuclear resources, being the sixth natural uranium resource in the world and has a fuel cycle industry capable to provide fuel elements.

Brazil has four research reactors in operation: the MB-01, a 0.1 kW critical facility; the IEA-R1, a 5 MW pool type reactor; the Argonauta, a 500 W Argonaut type reactor and the IPR-R1, a 100 kW TRIGA Mark I type reactor. They were constructed mainly for using in nuclear research, education and radioisotope production. The Nuclear Technology Development Centre (CDTN) offers the Training Course for Research Reactor Operator (CTORP) using the IPR-R1 TRIGA reactor [1]. This paper describes the Brazilian experience in application of CTORP and presents a proposal to expand the training activities at the IPR-R1 reactor, in order to meet the current demand for education and training in the nuclear area.

2. The IPR-R1 reactor

The IPR-R1 TRIGA reactor at Belo Horizonte is a typical TRIGA Mark I light-water and open pool type reactor. The fuel elements in the reactor core are cooled by water natural convection. The heat removal capability of this process is great enough for safety reasons at the current maximum 250 kW power level configuration. However, a heat removal system is provided for removing heat from the reactor pool water. The basic parameter which allows TRIGA reactors to operate safely during either steady-state or transient conditions is the prompt negative temperature coefficient associated with the TRIGA fuel and core design. This temperature coefficient allows great freedom in steady state and transient operations. The IPR-R1 was designed for training in reactor operation, neutronic and thermal-hydraulic researches and isotope production, but has been used practically only for characterization of samples by neutron activation analysis technique. Figure 1 shows two photographs of the pool and the core with the reactor in operation.

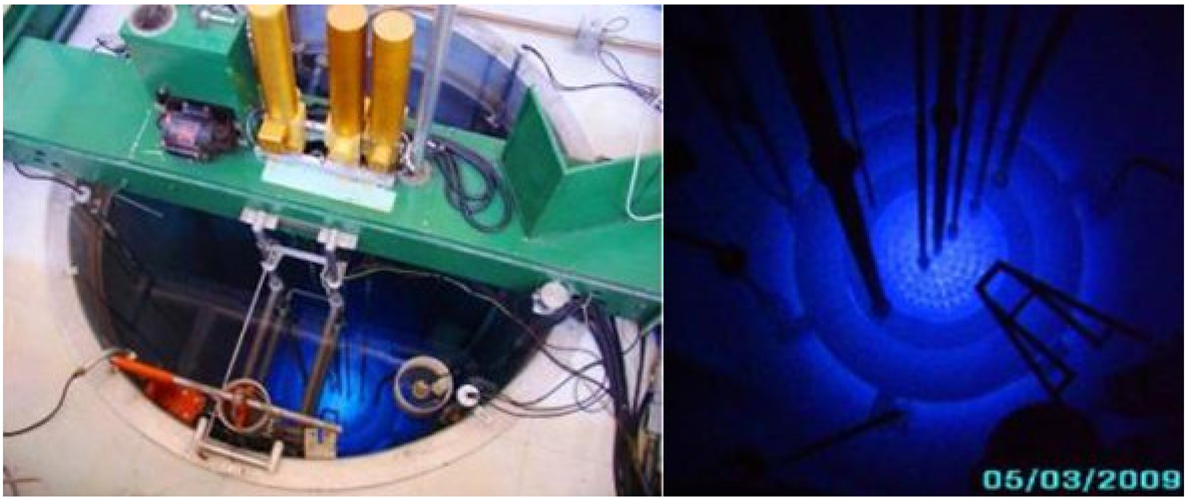

Figure 1. The IPR-R1 TRIGA nuclear reactor

3. The Operator Training Course on Research Reactors (CTORP)

One of the requirements for the commissioning of the Angra 1 Power Station, the first Nuclear Power Plant in Brazil, was the training program for future nuclear reactor operators [2]. In general, training programs in countries with experience in the nuclear area included training in research reactors operation or in reactor simulators [3], [4]. Among all the Brazilian research reactors, the IPR-R1 TRIGA was chosen to be the most appropriate for operators training. In the middle seventies, the Operator Training Course on Research Reactors CTORP [1] was structured with the aim of filling part of the reactor operators training for Angra 1, which started its commercial operation in 1985. Since then, CTORP has been given 25 times and has certified around 250 professionals for the Brazilian nuclear sector.

The content of this training program was first drawn by experts from the Nuclear Utilities Services Corporation, an American company, working in behalf of FURNAS, the reactor operator, together with Brazilian staff from the Radioactive Research Institute – IPR (later its name changed to Nuclear Technology Development Centre – CDTN). During several days, the requirements for the training program were quoted with the experimental installations available at CDTN, and adaptations were provided, either to adjust the texts to the existing equipment or to make them match the practical character intended for the training.

The CTORP is a three-week practical training course using the IPR-R1 TRIGA reactor which emphasizes basic nuclear reactor neutronic principles. Subjects such as the neutron multiplication factor, criticality, reactivity worth, period, poisoning, delayed neutrons and control rods are discussed in such a manner that even someone not familiar with reactor physics and kinetics can easily follow it. The experiments are divided into three categories: Reactor Experiments, Laboratory Experiments and Radiological Protection Experiments. The CTORP is applied indiscriminately to professionals with high school and also with higher levels. For this reason, this course avoids the application of differential and integral calculus, using only elementary mathematics. A few equations are used and several tables and graphs illustrate the text. This approach does not diminish the level of the course. The physical concepts which could be masked by a more elaborate mathematical treatment are better understood and assimilated by the trainees. Additional requirements of the program for the first applications were that the operators had some experience in the operation of thermal power stations and that they should get in advance the written description of the experiments to be made at the TRIGA research reactor of CDTN. During the practical classes, special attention is given to each trainee to participate effectively in the experiment, and everyone in the class is expected to participate in the discussions.

After the first week and the second one, the trainees do written tests to measure their progress in learning the fundamental principles. At the end of the three week course a written and an oral examination will be administrate to each student to evaluated the overall knowledge of the student at the end of the program. The practical test is necessarily applied by two experts who did not teach in the course. This procedure aims to avoid any prejudgment that could occur due to the student-teacher interaction during the course.

The final evaluation of the trainees is done on the basis of individual questionnaires, partial tests and final exams. Approval is given to trainees who obtain final grade equal or greater than 70 %. Another important point in the philosophy of this course is the student-instructor relationship. It is our intention to treat all students as equals, regardless of their company position or academic background. Further, although the students will perform many startups and other operations on the reactor control console, it is essential to remember that the licensed reactor Senior Operator is fully responsible for the reactor at all times and no action affecting the reactor shall be performed without his knowledge and consent.

The CTORP so far has been applied 25 times, and about 250 trainees received Research Reactor Operator certificates. The efficiency and success of the course have been confirmed over the years by the good performance of the workers in the later stages of the training program.

4 Proposal for a program in reactor technology using the IPR-R1 TRIGA

Nuclear Technology Development Centre (CDTN) was the first nuclear research institute in Brazil. In the sixties there was the pioneer project conducted by a research group called Thorium Group. The aim of the project was development a thorium fueled reactor. This project realized several progresses in conceptual design (fuel technology, reactor physics, thermal hydraulics, reactor vessel and materials). With the decision of the Brazilian Government to build a Westinghouse PWR (Angra1) in a turn key bases, the Thorium Group discontinued the activities in the early seventies. However, the human power and knowledge developed under the frame work of this initiative were very useful for the future Brazilian nuclear program [5]. Until the late 80s CDTN provided reactor technical support for Brazilian nuclear power plants.

During the last decade there was a recovery of several areas of research in CDTN research institute, leading to the creation of the Postgraduate Program in Science and Technology of Radiation, Minerals and Materials. In the course programme there isn't nuclear reactor technology. With the conclusion of Angra 3, the design and construction of the RMB and the resumption of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology.

It is proposed here the expansion of training activities in the IPR-R1 TRIGA reactor. Research projects programs would be created in the CDTN postgraduate program. CDTN is now an academic environment and it is an ideal place for reactor operation education. Students of the postgraduate course at CDTN, not an expert in nuclear energy, would be practice on reactor technology, enabling them to know the terminology referring to this field and to follow the renaissance of this area.

In order to perform a research program and training in postgraduate students, using the IPR-R1 reactor, is in progress the update of its instrumentation for monitoring of operational parameters. The new system would be microprocessor based, and would utilize large LCD displays that are typical of state-of-the-art control rooms. So, the graduates would find the same type of control system of a typical reactor control room.

A digital system is being developed to monitor, store and simulate the behavior of operating parameters. Figure 2 shows two user-friend interface of the system, in two computer video screens. In the foreground can be seen the calibration curve of a control rod. The graphical interfaces will provide greater reliability and transparency in IPR-R1 TRIGA reactors operations. Besides allowing online reactor parameters visualization and transmission through the internet or in the networks, the data can be stored and made available for exercises.

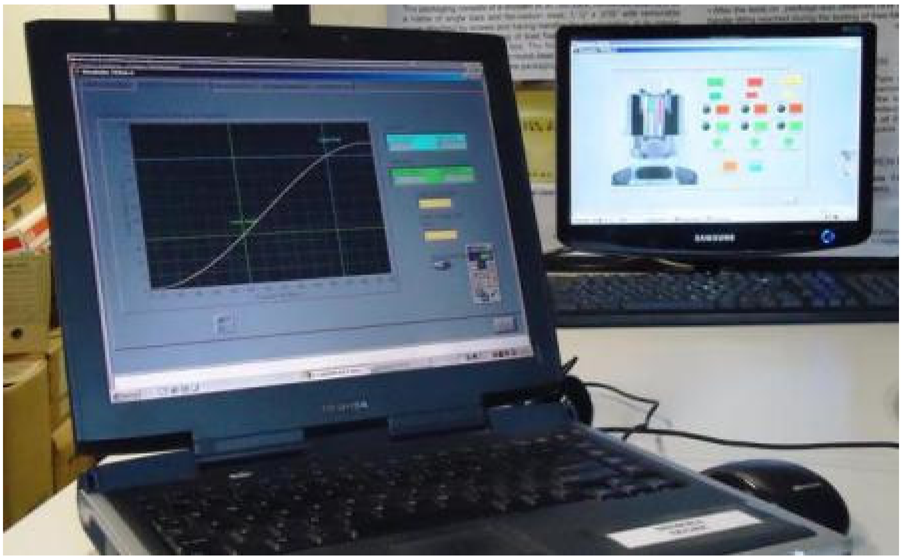

Figure 2. Digital system for simulation of IPR-R1 TRIGA neutronic parameters

In addition to the normal neutronic and radiation protection topics addressed by CTORP, new items as thermal hydraulic and instrumentation should be added and discussed in more detail, mainly in the postgraduate program at CDTN. Among the new items that should be studied, may be cited:

- Validation and verification of reactor physics and kinetics computer codes, such as: MCNP, WIMS-D and TRIGLAV-W.

- Validation and verification of thermal-fluid dynamics computer codes, such as RELAP and CFX.
- Development of codes, including coupling of neutronic and thermal-hydraulic codes.
- Calculation of various research reactor physics parameters and models.
- Basics of burn-up calculations and experiments.
- Core optimization.
- Safety requirements, strategic planning and IAEA standards for research reactors.
- Design Basis Accident (DBA).
- Reactor thermal power calibrations and heat transfer.
- Fuel and water temperatures, and heat transfer.
- Reactor instrumentation, digital control and safety system based on the microprocessor.

5. Conclusions

With the revival of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology. The IPR-R1 TRIGA research reactor at Nuclear Technology Development Center (CDTN) was used in the past for education, particularly for the needs of the Brazilian nuclear power plants operators training. This paper proposed the expansion of training activities at the IPR-R1 reactor. Research projects programs would be created in the postgraduate course at CDTN. In addition to the normal neutronic topics addressed by CTORP course, new fields as thermal hydraulic and instrumentation should be added and discussed in more detail. In order to perform a research program and training using the IPR-R1 reactor is needed the update its instrumentation for control of operational parameters.

6. Acknowledgements

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6. References

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