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IEA-R1 RESEARCH REACTOR: OPERATIONAL LIFE EXTENSION AND CONSIDERATIONS REGARDING FUTURE DECOMMISSIONING

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ABSTRACT

The IEA-R1 reactor is a pool type research reactor moderated and cooled by light water and uses graphite and beryllium reflectors. The reactor is located at the Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP), in the city of São Paulo, Brazil. It is the oldest research reactor in the southern hemisphere and one of the oldest of this kind in the world. The first criticality of the reactor was obtained on September 16, 1957. Given the fact that Brazil does not have yet a definitive radioactive waste repository and a national policy establishing rules for the spent fuel storage, the institutions which operate the research reactors for more than 50 years in the country have searched internal solutions for continued operation. This paper describes the spent fuel assemblies and radioactive waste management process for the IEA-R1 reactor and the refurbishment and modernization program adopted to extend its lifetime. Some considerations about the future decommissioning of the reactor are also discussed which, in my opinion, might help the operating organization to make decisions about financial, legal and technical aspects of the decommissioning procedures in a time frame of 10-15 years

1. INTRODUCTION

About 810 research reactors have been constructed worldwide to date, with some 20 more under construction or planned. Of these, about 287 are in operation and about 524 are shutdown and at various stages of decommissioning [1].

Table 1. Statistics of Research Reactors (RR´s)

Status	Number of RR´s
Operating	287
Shutdown	114
Decommissioned	410
Under construction	10
Planned	10
Unknown	1
Total	**832**

From the information given in the table 1 it is possible to observe that the number of shut down/decommissioned reactors now far exceeds that of operational ones. According to International Atomic Energy Agency (IAEA), since 1990s the number of research reactors in operation has decreased considerably. There are many reasons to shutdown and decommission facilities:

- obsolete technology or process;
- lack of business need or support for continued operation;
- licensing and regulatory changes;
- incidents and accidents;
- political and operational constraints;
- change of site use and stakeholder pressure.

This trend has been clearly visible for a number of years and there are no signs of its reversal. This inevitably calls for more attention to be given to decommissioning and dismantling of these older research reactors by IAEA and countries with operating nuclear reactors. As a consequence of this concern there is a growing emergence of companies specialized in the decommissioning business all over the world.

Over 70 research reactors operating until 2006 are already 40 years old and will become likely candidates for decommissioning in the near future. A general regulatory trend today is to encourage the completion of decommissioning of research reactors as soon as possible after final shutdown to ensure the unrestrictive use for other activities (table 2).

Table 2. Decommissioning status of shutdown reactors

1. Planned for decommissioning (shutdown)	
1.1 to unrestricted use	4
1.2 to safe enclosure	2
1.3 unknown/undecided	18
2. In the process of decommissioning	
2.1 to unrestricted use	55
2.2 to safe enclosure	29
2.3 unknown/undecided	44
3. Decommissioning completed	
3.1 to unrestricted use	207
3.2 to safe enclosure	26
3.3 unknown/undecided	4
4. Decommissioning unknown	
4.1 unknown	45

2. IEA-R1 RESEARCH REACTOR

The Brazilian research reactor IEA-R1 at the Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo, is being used for basic and applied research in nuclear and neutron physics and chemistry as well as for radioisotopes production for medical and industrial applications. IEA-R1 is the largest research reactor in Brazil, with a maximum power rating of 5 MWth. Constructed by Babcock & Wilcox (B&W) the reactor achieved its first criticality on September 16, 1957. Although designed to operate at 5 MW the reactor operated at only 2 MW until mid-eighties on an operational cycle of 8 hours a day, 5 days a week. The power level as well as operational schedule has been changed gradually. The reactor currently operates at 3.5 MW_{th} with a 64-hour cycle per week.

According to the International Atomic Energy Agency (IAEA) [1] most of the research reactors with age of more than 40 years have been closed worldwide, others such as the IEA-R1 have undergone upgrades and modernizations as described in section 2.1 resulting in its life extensions. On the other hand the spent fuel assemblies and radioactive waste management have been the major issues for many research reactor operators during its reactor operation and after shutdown. Sections 2.2 and 2.3 describe respectively, the IEA-R1 spent fuel and radioactive waste management at IPEN.

2.1. Reactor Modernization

The IEA-R1 reactor modernization program and refurbishment of its systems and components started in early 1970 when several modifications were introduced in the basic structure of the reactor particularly those related with the reactor safety improvement in order to upgrade the reactor power. Some of these modifications are listed below:

- Modification of the ventilation system (1971)
- Installation of a second heat exchanger, a new cooling tower and a new electrical system with the installation of diesel power generators (1974)
- Installation of a new reactor control console (1976)
- Replacement of ceramic lining of the reactor pool with stainless steel (1978)
- Substitution of control rods of the type CB_4 with fourchette type (Cd,In,Ag) (1979)
- Separation of hot and cold areas and construction of isolation chambers for the access to the reactor building and reactor hall and reconstruction of the secondary cooling tower (1987)
- Major maintenance job in the old cooling tower, change of pipe lines, installation of new air conditioning and exhaust system, new fire-detection and fire-fighting equipment like smoke detectors, sprinklers, hydrants and a digital data acquisition system to monitor all the reactor parameters (1996)
- Installation of an emergency spray core cooling system, four isolation valves in the Primary Cooling System to prevent accidental drainage of the pool water, substitution of some instruments in the control room and replacement of area and duct radiation monitors (1997)
- New water treatment and purification system and the replacement of four reactor control rods (2003/4)

Fifty years of experience in operation of the IEA-R1 reactor has shown that continuous modernization and refurbishment program is very important to maintain the reactor utilization index high. Implantation of an integrated management system including quality assurance, safety culture and environmental consciousness is essential for reactor operation, maintenance and irradiation services. This can help a great deal in elevating the self esteem and a sense of collective responsibility in the reactor staff. Planning, efficient management and continuous improvement are the key words in a quality management system.

2.2. Spent Fuel Management

Since its startup the reactor had about 240 core configuration changes and used around 200 fuel assemblies (table 3). It is possible to analyze the reactor fuel utilization history in terms of four cycles:

- The first cycle corresponds to the first core of the reactor (1957). It was composed of U-Al alloy fuel with 20wt% enrichment, having 19 curved fuel plates produced by B&W. These fuel assemblies failed at the early stages of the reactor operation, due to pitting corrosion caused by the brazing flux used to fix the fuel plates to the support plates and were replaced, in 1958, by new ones, also produced by B&W. They were identical to the earlier ones but brazing was not used for assembling;

- The second cycle corresponds to a complete substitution of the core in 1968. Fuel made with U-Al alloy, 93 wt% enrichment, having 18 flat fuel plates were bought from UNC (USA). At this time the core was converted from LEU to HEU.

- The third cycle is characterized by the restriction of HEU fuel supply. IPEN bought, from NUKEM (Germany) in 1981, 5 fuel element assemblies of UAl_x-Al dispersion type, with 20wt% enrichment and having 18 flat fuel plates per fuel element assembly.

- The fourth cycle began in 1982, with a decision of IPEN to fabricate its own fuel elements and to replace, gradually, the high burn up HEU fuels in the core.

Table 3. Fuel Element Assemblies of IEA-R1 Research Reactor

NUMBER OF ELEMENTS	*ENRICHMENT (W/O U-235)*	*FABRICATION*	*PRESENT LOCATION*
40 (1957)	20 (UAl)	USA	USA
39 (1958)	20 (UAl)	USA	USA
29 (1968)	93 (UAl)	USA	USA
04 (1968)	93 (UAl)	CERCA	USA
10 (1968)	93 (UAl)	USA	USA
05 (1981)	20 (UAl_x-Al)	NUKEM	USA
77(1982)	20 (U_3O_8Al)/ (U_3Si_2Al)	BRAZIL	33 USA 20 wet storage 24 reactor core

The spent fuel assemblies of the IEA-R1 have been stored at the wet storage located at the reactor pool compartment. In this compartment, there are seven racks made of stainless steel and fixed on the walls of the pool at a depth sufficient to provide adequate shielding. In addition, there are two stainless steel and four aluminum racks, located at the bottom of the pool. The total storage capacity of the facility is for 156 assemblies.

In 1999 the racks were almost full, however based on the US policy to accept (Research Reactor Spent Nuclear Fuel Acceptance Program) the MTR fuel assemblies originally enriched in the United States, IPEN negotiated with DOE (Department of Energy/USA) and returned 127 spent fuel assemblies (SFA) in 1999 and additional 33 assemblies in 2007 [2].

According to the newly proposed operation schedule (4 to 5 MW, 120 hrs per week), 18 to 20 assemblies will be burnt up annually. Currently, 43 storage positions are occupied and in 7-10 years the wet storage facility at the reactor will therefore be full.

In order to discuss a regional strategy for the management of the spent fuel from the research reactors of the Latin America that have the same problem of storage of spent fuel assemblies, a regional project “Management of Spent Fuel from Research Reactors” was approved by IAEA to define specific conditions for operational and interim storage of the spent fuel for each specific research reactor, and to establish forms of regional cooperation for final disposal of the spent fuels. IPEN opted to consider the possibility to design and develop a dual-purpose cask, for transport and storage of 21 IEA-R1 SFA. Such cask is being developed as part of the regional project and can be used as a backup to extend the storage capacity of the wet storage facility and to store the spent fuel assemblies after the reactor shutdown during the decommissioning stage [3].

2.3. Radioactive Waste Management

The irradiated material and others previously replaced equipment are stored in the reactor pool, dry storage, or sent to the Radioactive Waste Laboratory (LRR) located at IPEN-CNEN/SP. As the reactor has been operating since 1957, many of the original equipment and systems such as the pool water treatment and purification system, heat exchanger, ceramic lining of the reactor pool, pneumatic irradiation system had to be replaced or refurbished and most of the waste material was transported and stored at LRR. However, it is important to mention that this Laboratory does not have the capacity to handle and store large activated and/or contaminated pieces of equipment which will have to be removed from the reactor at the time its decommissioning. This kind of waste encompasses large volumes and activities and it will be necessary to construct an appropriate plant to receive it and make detailed inventory of the material and develop procedures to store them safely. Since these matters involve large sums of money as well as trained personnel a plan for future decommissioning has to start well ahead of time. Experience from other reactors in the world which have undergone decommissioning shows that planning should be started at lest a decade before the actual decommissioning. Issues such as legal aspects, funding, (which may run in to several millions of dollars) site selection for storage of contaminated components and technical manpower necessary, need to be discussed with the operator institution and other appropriate authorities.

4. CONCLUSIONS

The reactor modernization program and refurbishment adopted by IPEN has been very important to increase the operation time of the reactor as much as possible however, sometime in the future (may be 10-15 years from now) the reactor may have to be shutdown as the refurbishing may no longer be cost effective and there will be necessity of its decommissioning. It is very important for the facility to discuss the possibility of the reactor shutdown in the future and about the necessity of have a decommissioning plan that should contain the possible options as well as the necessary trained manpower and funding needed.

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