THE PORTUGUESE RESEARCH REACTOR: A TOOL FOR THE NEXT CENTURY*

A.J.G. RAMALHO, J.G. MARQUES, F.M. CARDEIRA
Instituto Tecnológico e Nuclear,
Sacavém, Portugal

Abstract

A short presentation is made of the Portuguese Research Reactor utilisation, its problems and the solutions found. Starting with the initial calibration and experiments the routine operation at full power follows. The problems then encountered which drove to the refurbishment are referred. The present status of the system is then presented and from that conclusions for the future are derived.

1. THE INITIAL YEARS

The Portuguese Research Reactor (RPI) is owned by "Instituto Tecnológico e Nuclear", which is the 3rd generation of the main national organisation for Nuclear Activities in the country. In a large extent the decision for its construction was, as in various other countries, a consequence of the "Atoms for Peace" programme launched by the U.S. president D. Eisenhower.

The initial criticality of the reactor was achieved in April 25, 1961 and the full power was reached one year latter after a detailed calibration of the reactor at low power. At the initiation of the calibration work all the neutron detectors were kept in the low position used during the initial startup, i.e., close to the reactor core, where they were indicating a power of 4 W. Once the mapping of the core was done the true power was determined to be 1.48W. This was the starting point for the power rise up to full power.

As the control equipment supplied was all based in vacuum tubes and electro-mechanical relays it was decided from the outset that the system should be upgraded and changed to transistors and electronic logic. Among the first actions taken was therefore the decision to have a young engineer trained in electronics for reactor control. The choice was Eng. João Batista Menezes and the place of training the "Centre d'Études Nucléaires de Saclay" where he went for a period of three years. There most of the ideas that he applied latter were gained.

In less than two years after the full power was reached a leak in the heat exchanger (a full aluminium piece, with the secondary water running in four passes in the tubes and the demineralised water from the pool in the shell) was found. The leakage developed to the point that by the summer of 1964 it was clear that plugging tubes to stop the leakage would be impossible. Work to obtain a stainless steel heat exchanger was initiated but the replacement only occurred in 1966.

By then it was the piping of the demineraliser circuit that developed leakage. All this piping was totally embedded in the concrete of the pool wall and the water entering or leaving the circuit would run through gutters, one along the North side of the pool wall and the other along the South side. The inlet gutter was risen about 5 cm above the level of the outlet. This installation was very nice from the aesthetics and principle points of view but the selection of the materials was clearly inadequate. All the embedded circuits were replaced by PVC tubing running outside the pool walls.

*This paper is dedicated to the memory of Eng. João Batista Menezes who was a major driving force behind most of the work reported here. Eng. Menezes was a staff member of the RPI since the beginning and the Director of the Reactor Department in the last years of his life.

2. ROUTINE OPERATION AT 1 MW

Due to the above events and to the absence of strong groups needing irradiations, only a limited amount of operation at 1 MW was conducted up to the end of 1966.

By that time the work on the replacement of the control system was initiated under the direct leadership of Eng. João B. Menezes. This work was particularly interesting and useful to train several young electronic engineers in this area. The development and test of the equipment took up to 1972 but the actual replacement was performed in a short period of time, approximately one and a half months in the summer of that year.

In essence the modification replaced not only the vacuum tubes and electro-mechanical relays but also the safety philosophy. In effect the system was originally composed of five channels, start up, linear and automatic control, log-N and period and two safety channels, having as neutron sensors, respectively, a fission chamber, two compensated ionisation chambers and two uncompensated ionisation chambers. The useful range of the safety channels was only above 100kW.

In the new system the two uncompensated ionisation chambers were replaced by compensated ones and a start up and a linear channel maintained while three log-N and power channel were introduced for both period and power safety, with a two out of three coincidence philosophy to initiate the safety actions. This clearly reduced the number of the spurious "scram" initiated by period. Also the substitution of electro-mechanical relays by semiconductor logic circuits reduced appreciably the frequency of spurious alarms; it is to be noted that a few relays were retained in the cases where it was not considered safe to use transistors only.

At this time a thermal power channel was also added. This has been a very useful feature as the small size of the core makes the neutron detectors sensitive to the control rod position.

By the end of the sixties came the US offer to sell the leased uranium, including the possibility of buying new charges of fully enriched uranium. Work was then initiated to study the advantages of the HEU option and the conclusion reached led to the decision of buying this type of fuel. The fabricator GULF was selected and the new HEU fuel was received in 1974.

The reactor reached the peak of its operation at full power in 1971 delivering slightly more than 100 MWd and was then running regularly at 1 MW with good expectations of improving its usage. By 1976 a trend to reduce the operation at full power developed which by the beginning of 1981 settled in with the development of leakage in the primary system (except in the pump room all the piping of the primary circuit was embedded either in the bottom of the pool or in the floor) which forced going to low power operation (i.e., up to 100 kW).

At this time a strong push for the refurbishment of the machine developed. This was driven by internal forces, in which Eng. João B. Menezes was a key element, supported by an intense and interesting collaboration with the "Centre d'Études Nucleaires de Grenoble". In this collaboration a series of studies addressing various aspects of possible actions to be taken were made, including:

— Studies of fully enriched cores;
— Addition of a beryllium reflector;
— Core cooling conditions for powers up to 10 MW;
— Shielding calculations for powers up to 10 MW.

Among the conclusions and recommendations addressing an eventual increase in power, one can refer:

- Existing shielding was adequate up to 5 MW;
- An hold up tank would be necessary;
- Piping diameter should be increased;
- For operation at 10 MW it would be convenient to have a fixed core and improve the shielding.

3. REFURBISHMENT OF 1987-1989

The dominant reason for the refurbishment of 1987-1989 [1] was the operability of the reactor at full power which would entail the replacement of the piping of the primary circuit. This would imply interferences with the pool structure where falling of tiles of the lining had been occurring. Therefore a replacement of the lining was necessary. As the most affected portion of the pool was the stall it was decided to make a complete stainless steel lining of this section of the pool side and still keep tiles in the other section. This implied the removal of all the structures from inside the pool and the construction of a storage vessel for the irradiated fuel that, at the time of the refurbishment, was already exhausted. The vessel was monitored continuously and its water was circulated through the demineraliser.

The new stainless steel primary circuit piping which is capable of handling the cooling of up to 10 MW runs inside the pool and still allows for the operation of the reactor in either section of the pool. An hold up tank was not included, although provision for its installation was made.

At the level of the secondary circuit difficulties had been experienced with the circulation pump and also with the location of cooling tower where part of the free space initially free around it had been used for offices and laboratories. The cooling tower was then substituted and repositioned from the South to the West side of the building.

At the level of the core and reactor control some changes were also made, namely:

- Introduction of a fully enriched core;
- Introduction of a Be reflector;
- Replacement of the control rod drives as well as of the boron carbide control rods by Cd, stainless steel lined, ones (it is noted that the boron carbide rods have experienced swollen in various reactors which have made them stick inside the control elements this causing the assemblies to be risen from their position even if this is essentially prevented by the guide tubes anchored in the shock absorbers and in the control rod driving mechanisms);
- The magnets were also replaced from under water to out of water. This has reduced significantly the problems with the magnets, several of which had been rewired and had the contact switches replaced.

The refurbishment work for which a significant support was received from the IAEA through the Technical Co-operation Program took place between 1987 and the beginning of 1990 and was terminated with the first criticality of the new core, which occurred on January 18, 1990.

Preservation of the building and pool structures has always been an important consideration. In this context repainting was also performed at this time; then as now the system looks much younger than its real age.

4. PRESENT STATUS

Looking at the installation as it is today one can derive the conclusion that it is there to stay. In effect the maintenance performed makes the pool and building look as it was several years in the past. The control and auxiliary system do not show major problems even if there are, certainly, things needing to be done. The ventilation system had the filters replaced recently and the blowers seem ok but the air conditioning is calling for some substitutions. The control system is working but it is relatively old and its improvement will be an interesting job for another new group of young people.

Regarding the utilisation of the reactor, Figure 1 shows, for this decade, the number of irradiations performed annually and time of reactor operation that they implied. One notes that after the considerable reduction in of the number of irradiations occurring between 93 and 96 the recovery was initiated in 1997.

It is particularly rewarding to note the performance of the current year in which up to the middle of June the number of irradiations already exceeded the previous year. In confirmation of this tendency we notice signals that are emerging, namely that:

- The installation of a double axis neutron diffractometer is taking place in beam tube E1 [2];
- A number of components for the small angle neutron scattering system to be installed in the through tube is inside the building [3];
- The preparation of beam tube D1 to give an epithermal neutron beam is under way;
- In sequence to irradiations performed this year [4] work has been initiated to create a fast neutron beam in the beam tube E4;
- The time-of-flight spectrometer, installed in tube D3, is being used for demonstration and training;
- The activities in the general area of BNCT [5] are under way with irradiations of cells being performed in the vertical access of the thermal column and the installation referred above for tube D1;
- Irradiations to produce short lived radioisotopes have been performed and the interest on them seems to be growing [6, 7];
- The activation analysis programme, which still is the major use of the reactor, is being maintained.

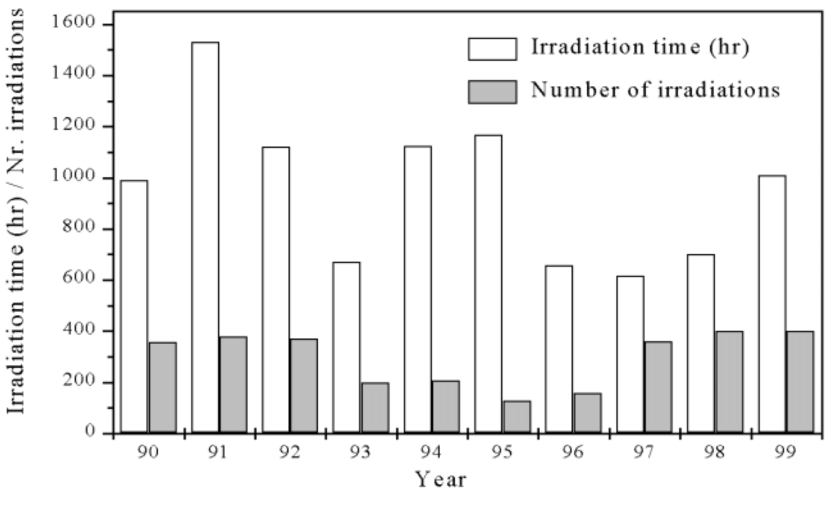

FIG. 1. Utilization of the Portuguese Research Reactor in the present decade. The data for 1999 includes only irradiations performed in the first semester.

The presently foreseen arrangement of the equipment around the experimental area in the first floor of the reactor is shown schematically in Fig. 2. This will bring most of the available beam tubes into use.

One can also see some new blood coming in both for the groups of the reactor operators and, more decisive, of the researchers.

At present the reactor is running five days a week from 9 a.m. to 12 p.m., i.e., in a two-shift per day basis; in the case of need we can make the same operation time continuously. At this stage a new group of operators is about to complete its training programme and it is planned to increase the number of reactor operators to a point allowing for continuous operation on a weekly basis.

Regarding the fuel, it needs to be referred that all irradiated fuel from the original loads was recently returned to the U.S. [8]. Concerning the fuel existing in the installation we note that with the present rate of consumption it will allow for the operation until 2006, i.e., to the end of the period covered by the U.S. acceptance program under the ROD of May 1996.

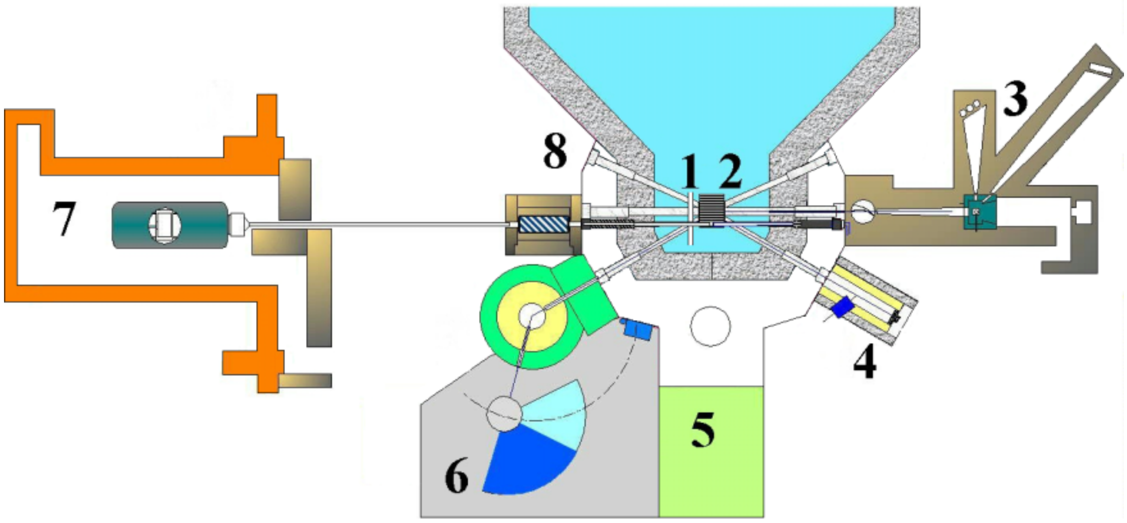

FIG. 2. Arrangement of experimental equipment in the Portuguese Research Reactor: (1) rabbit system, (2) core, (3) time-of-flight spectrometer, (4) facility for epithermal neutron beam, (5) thermal column, (6) double-axis neutron diffractometer, (7) small angle neutron diffractometer, (8) facility for fast neutron beam.

5. THE FUTURE

As the year 2006 approaches it is essential to think on what comes next. It is clear that if the operation of the reactor expands, as the actual trend indicates, the period for which fuel is available is reduced. This will precipitate decisions on the acquisition of new fuel, which has to be of the LEU type. It is also convenient for the return of the spent fuel to the U.S., as it will give more room for this operation.

In looking ahead, one recognises that the existing factors strongly point for the continuation of the project well in the coming century. In effect, a commitment to the rejuvenescence of people, both as reactor operators and researchers, a larger utilisation, the good conditions of the installation, the pre-existing conditions for an increase in power to compensate for the change in fuel type, and a diversification of the utilization are guarantees of success.

The immediate plans are:

— Improve the control system, replacing obsolete components and planning for a new system with more intense computer controlled functions to still improve the safety of the system;

— Review former studies on the increase of power, both at the level of neutron flux and thermohydraulics;
— Start planing all the modifications so that the down time of the reactor is reduced as much as possible.

Certainly one important element of the future usage goes to the increase of acceptability of the nuclear activities in general and, in this context, activities dealing with human health need to be given high priority this are, inter alia, production of short lived isotopes for medical applications or BNCT.

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