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REPORT

"AGEING MANAGEMENT SELF-ASSESSMENT REPORT OF THE  
IPEN IEA-R1 REACTOR "

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CIENCIA Y LA TECNOLOGIA NUCLEARES EN  
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## 1. INTRODUCTION

Since its first start-up, 41 years ago, the IEA-R1 research reactor has been operating regularly and it has undergone many reforms and upgrading.

Presently, the main reactor utilization are: radioisotopes productions like Samarium and Iridium, Silicon doping, neutron scattering experiments, activation analysis, neutrongraphy and operators training. A major increase in reactor utilization is planned for next two years and these include: Molybdenum production via capture for Tc-99 generators, gems irradiation, I-131 production and irradiation of fuel and ferritic steels in special devices.

In order to reach a reasonable level of safety, reliability an availability the following activities are to be implemented:

- Systematic Ageing Management
- On-line Monitoring and Diagnosis
- Better Core Management
- Better Quality Assurance Program
- Replacement of key components and systems

The first items will be conducted through this Arcal project and this present report is the result of the phase of this project where a systematic self-assessment based on IAEA guidelines will be reported in a separated reported.

The improvement of the quality assurance program is being carried out through a contract with a third party company.

Many upgrades and replacements are planned for the next two years such as: full core with  $U_3Si_2$  fuel elements, introduction of Beryllium reflectors and Molybdenum irradiator, and replacement of key aged components.



## 2. BRIEF IEA-R1 REACTOR HISTORY

### 2.1 INTRODUCTION

The IEA-R1 reactor is pool a type, light water moderated and graphite reflected research reactor located at the Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP), in the city of São Paulo, Brazil. The reactor was designed and built by Babcock & Wilcox Co. in accordance with specification furnished by the Brazilian Nuclear Energy Commission and financed by the U.S. "Atoms for Peace" program.

The first start-up was on September 16<sup>th</sup>, 1957, being the first criticality achieved in the Southern hemisphere. Although designed to operate at 5 MW, this reactor operated until 1997 at a power level of 2 MW mainly for basic and applied research, as well as in experimental production of radioisotopes for medicine, industry and life sciences applications. Due to the recent growth of radioisotope demand in Brazil in the eighties for medical diagnosis and therapies, IPEN had decided since that time to increase the reactor power level to 5 MW and to operate the reactor continuously. To achieve this goal, it was necessary to perform some systems modifications and introduce new safety systems as the Emergency Core Cooling System-ECCS in order to obtain the licensing from Brazilian Regulatory Authority.

Due to the licensing authorities demands and in order to accomplish the reactor safety and quality requirements it was prepared a new Safety Analysis Report (SAR) that resulted in new construction direction and safety requirements for the IEA-R1 reactor. In addition, it is being implemented a revised Quality Assurance Program.

In general, these new criteria are listed below: [9]

- Defence in depth
- Safety requirements on design and construction
- Safety limits on design
- List of safety functions
- Reliability and availability on systems safety related
- Quality Assurance Program
- Radiological shielding
- Physical protection
- Commissioning
- Emergency Plan

On balance, the upgrade of IEA-R1 reactor from 2 to 5 MW resulted in the introduction of new safety items and new components to assure the safety requirements stated in the SAR. These changes are listed in the item 2.3.

## 2.2 BRIEF DESCRIPTION OF THE IEA-R1 RESEARCH REACTOR [12][14][17]

### 2.2.1 Reactor Building and Structure

The reactor pool is constructed using ordinary concrete except for the lower portion barytes concrete was used to enhance radiation shielding. It is fully lined inside with stainless steel. The pool is 9.5 m deep, 3.0 m wide, 13.7 m long, and has a total volume of 272 m<sup>3</sup>. The pool has a removable gate that can separate and isolate the reactor-operating compartment from the storage compartment. The volume of the side that normally contains the reactor is 159 m<sup>3</sup>.

The reactor building has 2000 m<sup>2</sup> divided into 5 floors:

- Basement: machine room with the primary and secondary pumps and pipes, heat exchangers, water treatment and retreatment systems;
- 1<sup>st</sup> floor: experimental floor (physical experiments and dry storage);
- 2<sup>nd</sup> floor: air conditioning and ventilation system;
- 3<sup>rd</sup> floor: control room and reactor hall;
- 4<sup>th</sup> floor: normal and emergency exhaust system.

The pool has four bottom penetrations: a 0.305 m diameter primary coolant system exit directly under the core, a 0.305 m diameter primary return line, a sealed pneumatic tube system penetration spool and a 0.1016 m diameter water retreatment line. Ten beam tubes penetrate the walls in the normal reactor operating position and two beam tubes penetrate the walls in the thermal column operating position.

### 2.2.2 Core

The reactor core is composed by 21 standard and 4 control fuel elements in a 5 x 5 array placed on a aluminium grid plate with 80 holes. The remainder grid positions are filled by reflector elements and experimental devices. Four neutron monitors are positioned above the top of the reflector elements. The grid plate is suspended from a movable bridge that spans the width of the pool and can be positioned in three position. In the main position, the grid plate is at the center of focus of the beam tubes ( six 6", two 8" and one 6" through port tube) above the header of the primary coolant loop. The second position is between a thermal column made up of graphite blocks placed inside a rectangular steel box and two 6" beam tubes. The maximum operating power at this position is 100 kW. The third position is at the storage compartment where no operation is permitted and it is used only for operating compartment maintenance.

The reactor is fuelled with Materials Testing Reactor (MTR) type fuel elements. Two types of elements, standard and control, are used. The fuel meat is uranium oxide (U<sub>3</sub>O<sub>8</sub>) dispersed in 1060 aluminium. Fuel element's structural material is 6262 T6 aluminium.

Standard elements contain 18 flat fuel plates and overall length of 873 mm and a horizontal profile of 76.1 mm x 79.76 mm. Overall fuel plate length is 625 mm. Active length is 590 mm and active width is 60.35 mm. A standard element contains approximately 214 gm U<sup>235</sup> with 20% enrichment. Total mass of a standard fuel element is 5.5 kg.

Control elements, contain 12 flat fuel plates, 142 gm of U<sup>235</sup>, and have a total mass of 7.3 kg. Control elements have an overall length of 1,419 mm. The active portion of the element is similar to the active portion of a standard element. The extra length provides



a guide for the control rod and includes slots for handling the element because it has no handling bale. Safety rods and the regulating rod consist of two thin blades attached to a piston and drive extension. The active portion of the blades is silver (80 %) - Indium (15 %) - cadmium (5 %).

The control rods are positioned by drive motors located at the top of the reactor bridge. The rod drive system is interlocked to permit only one rod to be moved at a time. Rod extensions are attached to the drives by electromagnets located above the surface of the pool. A scram signal de-energizes the magnets allowing the rods to fall into the core by gravity.

### **2.2.3 Instrumentation, control and safety system**

Monitoring instruments associated with the reactor core are: (1) two non-compensated ion chambers, Safety 1 and Safety 2; (2) one wide range fission chamber; (3) one compensated ion chamber, linear level; (4) core differential pressure measurement device; and (5) thermocouples for measuring coolant temperature at inlet and outlet.

During a start-up, when power level is below 500 kw, the fission chamber will initiate a reactor scram at a period of 12 seconds or less. The period scram is interlocked out of operation at powers above 500 kw. The fission chamber and Safety 1 and Safety 2 initiate high power scrams at 5.25 MW (105 %) using a 2-out-of-3 logic scheme. This allows for a 5 % instrument error and assures that true power does not exceed 5.5 MW. The linear level compensated ion chamber provides feedback for an automatic reactor power control system.

The coolant temperatures are measured by thermocouples, one located approximately a meter directly above the core and the other within a well in the primary coolant piping at the core exit at the bottom of the pool. Core differential temperature is used as the measure of reactor thermal power. Neutron detectors are adjusted to the power level corresponding to the core differential temperature.

A nitrogen-16 (N-16) channel is installed. The detector is positioned on the primary coolant piping between the core exit and the nitrogen-16 decay tank. The N-16 detector is independent of the rod shadow effects seen by the other power monitors. The present response fluctuates by approximately 5 %, so it cannot be used as an absolute measure of power.

Protection systems are those devices and interlocks that automatically shut the reactor down when a process variable exceeds a pre-set value. The principal protection system instruments are: (1) Safety channels 1, 2, and 3; (2) Core exit temperature; (3) Reactor period; (4) Core differential pressure; (5) Primary coolant flow; (6) Primary pump electric supply; (7) Safety and control rods; (8) Area radiation monitors; (9) Duct radiation monitors; and (10) Pool level.

Safety systems act to keep the reactor core submerged in water during accidents that cause loss of primary coolant from the reactor pool. The two safety systems are: (1) Emergency Core Cooling System (ECCS) and (2) Reactor Pool Isolation Valves (RPIV).

### **2.2.4 Primary coolant system**

The primary coolant pumps drive the pool water downward through the reactor core into a reducing cone (hopper) that is attached under the core grid. Twelve inch (0.305 m) diameter, stainless steel, primary coolant piping passes through the pool floor directly



under the core grid. A sliding convection valve or header (essentially a concentric tube within the primary pipe) is raised upward under forced circulation regime and lowers downward for natural circulation. Once raised, it is held in place by a differential pressure between the flow path within the header (lower pressure) and the pool. At a flow rate of about 800 gpm, the header will drop of its own weight. During natural circulation, flow enters the bottom of the grid and flows upward through the core.

The primary flow path is from the core to a 27.2 m<sup>3</sup> nitrogen-16 decay tank. At the normal flow rate of 681.3 m<sup>3</sup>/hr (3,000 gpm), primary coolant is held up for 144 seconds to permit seven second half life N<sup>16</sup> decay. From the decay tank, coolant flows to identical, 57 KW centrifugal pumps. During normal operation, one pump is on line. Each pump has a flywheel that maintains primary flow for 80 seconds to permit some decay in residual reactor power following a loss of electric power. From the pump, primary coolant flows through the tubes of one of two tube-and-shell heat exchangers, past a flow orifice, and hence back through the floor of the pool and into a diffuser pipe in the bottom of the pool that ensures optimum mixing with the bulk pool water

Both the primary coolant line from the pool and the return line to the pool have redundant, motor operated isolation valves; one is a gate valve, the other is a ball valve. All four valves are automatically closed if pool level drops by -40 cm from full level.

### **2.2.5 Secondary coolant system**

Secondary coolant is pumped from the shell side of the on-line heat exchanger, through the on-line pump, through the on-line cooling tower, through a flow orifice, and back to the heat exchanger. Normal secondary flow rate is approximately 590 m<sup>3</sup>/hr (1,700 gpm).

### **2.2.6 Auxiliary systems**

#### **(a) Systems for control of radioactive effluents**

The installed systems that prevent the uncontrolled release of radioactive airborne and liquid effluents from the facility to the environment, in addition to the fuel plate cladding, are: (1) Emergency Exhaust System; (2) Pool Floor Ventilation Isolation; and (3) Retention Tank Drain System.

#### **(b) Ventilation system**

The ventilation system is divided between potentially radioactive (hot) areas and non-radioactive (cold) areas. The hot areas include the pool floor, the beam tube floor, and the reactor basement. The cold areas include the control room, corridors and stairways, and offices and laboratories within the reactor confinement. Air is supplied to both areas from a common intake and supply fan. The cold areas are maintained at a negative pressure relative to atmospheric pressure by use of dampers and exhaust fans. By use of larger exhaust fans, the hot areas are maintained at a negative pressure relative to the cold areas. Each area exhausts through its own exhaust flow system to individual stacks on the roof of the facility at elevations approximately 22 m above ground level.



The hot exhaust system has a normal and an emergency exhaust path. The normal path contains an absolute filter only. The emergency path contains a dehumidifier, an air heater, and a sequence of absolute, charcoal, and absolute filters. There are four duct monitors in the hot exhaust system; one on the pool floor, one on the beam tube floor that also services the basement, one in the air handling room just before the split between the normal and emergency exhaust paths, and one at the base of the hot exhaust stack. If the pool floor monitor and the air handling room monitor simultaneously reach an alarm level, dampers switch the hot exhaust from the normal to the emergency path and recirculation within the building is secured.

### (c) Electric distribution system

The electric distribution system is categorized as Normal, Essential, and Vital:

- **Normal** system is the off-site electrical supply that is delivered to the site. Under normal circumstances, all electrical power to the site is provided by the normal supply.

- **Essential** system is provided for important loads throughout the facility. The essential system consists of two diesel generators, one at 220 V and the other at 440 V. If normal power supply is lost, there is a 10 second period during which essential electricity is lost while the diesels start and go on line.

- **Vital** system is provided for those loads that are deemed vital to reactor safety. A 220 V diesel generator provides power to the reactor control console and to the ECCS solenoid valves. A 440 V diesel generator provides power to the primary coolant pumps and to the primary coolant isolation valves. Both the 220 V and 440 V system are non-interruptible (No-Break). On loss of normal electricity to the 220 V system, a battery with a DC to AC converter maintains power until the diesel can start and go on line. The 440 V generator is normally driven by an electric motor. On loss of normal power supply, an electromagnetic clutch to the motor is disengaged, and a flywheel maintains voltage until the diesel drive has time to start and come on line.

### (d) Irradiation facilities

In the reactor core operating compartment are found several irradiation facilities:

- Inside the grid plate:

**EIRA** – Water Cooled Irradiation Element, used to irradiate tellurium, sulphur, metallic gold, organic and mineral matter, etc, inside 8 aluminium capsules with DIA=3/4" and h=70 mm fitted in an aluminium tube;

**EIGRA** – Water Cooled Graphite Irradiation Element, used to irradiate tellurium, samarium, etc, inside 24 capsules as described above, fitted in a rectangular aluminium profile;

**CICON** – Irradiation Loop for Miniplates. Closed loop, with cooling, monitoring and control system for irradiation of fuel miniplates;

**EIX** – Water Cooled Irradiation Element, used to irradiate 2 pressurised capsules of xenon to produce  $^{125}\text{I}$ ;

**EIF** – Similar to EIGRA, used to irradiate Iridium wires to be used in "in situ" cancer therapy;

**EIS** – Silicon Irradiation Element, used to irradiate silicon crystals;



- Outside the grid plate (pneumatic system):

This irradiation system is installed adjacent to main core position. This system can work with irradiation times from 1 second up to 20 minutes for the dispatching and returning of the rabbit to two receiving laboratories located outside the reactor building in the Radiochemistry Division.

- Beam holes:

Each beam hole can accommodate three different types of plugs. There are sample plugs inside which it is possible to irradiate huge samples near of core; electrical plugs for experiments requiring fluid pipes or wires; collimating plug which allows the withdrawal of a neutron beam of 1.5" diameter.

### **2.2.7 Emergency core cooling system (ECCS)**

The ECCS is a gravity driven spray nozzles system and it activated when pool level fall down 450 cm below the full level. The system has redundant 75 m<sup>3</sup> water storage tanks. Piping systems from each tank enter the reactor building where flow from each system is initiated by redundant, parallel solenoid valves.

One set of solenoids is within the reactor confinement, which will activate but may not be accessible in the event of a LOCA (Loss Of Coolant Accident), and the other is outside the confinement and is accessible at all times. Just up stream of the solenoids are regulating valves that can be adjusted to produce the desired flow rate of 3 m<sup>3</sup>/hr. The redundant ECCS systems join together into a single pipe just before entering the pool.

The single line descends behind the reactor tower and forms a "U" behind and around the sides of the tower above the core. There are seven spray nozzles, each with an opening 4.3 mm in diameter.

## 2.3 MAIN MODIFICATIONS, REFORMS AND UPGRADING [12] [13]

Since its start-up in 1957, the IEA-R1 research reactor has been modified for several reasons such as replacement of aged structures and components, upgrading of systems, structures and components following new technologies and tendencies, and adequacy to safety codes and standards that have changed during the years.

The main modifications up to 1995 are listed below:

- 1971: - Changes in reactor building ventilation system.
- 1974: - Duplication of the primary coolant system to redundancy;  
- Introduction of flywheels on the primary centrifugal pumps;  
- Installation of a N<sup>16</sup> decay tank to reduce operational dose;  
- Upgrade of the electric distribution system with the installation of emergency diesel-generators.
- 1976: - Replacement of the original instrumentation and control operation console;  
- Replacement of the original control drive mechanism;  
- Changes in the pneumatic system in order to obtain a better flux homogenisation in the irradiation position, and replacement of the aluminium by steel in the tubes.
- 1978: - Replacement of the original ceramic liner of the pool walls by steel liner;  
- Installation of a auxiliary bypass system for emergency water supply.
- 1987: - Separation of the reactor building internal area into radiological hot and cold rooms;  
- Introduction of access chambers;  
- Introduction of vertical duct for irradiated material transfer;  
- Installation of a new cooling towers;  
- Main maintenance of the emergency generators.
- 1991: - Construction of a radiation shielding for the resins columns in the pool water purification and treatment system.
- 1995: - Power Upgrade from 2MW to 5MW

In the middle of nineties, in order to partially nationalise the production of the imported radioisotopes, mainly <sup>99</sup>Mo, was taken the decision to modernise and upgrade the power of the IEA-R1 from 2 to 5 MW and to change its operational cycle from 8 hours a day to continuous operation. Also the conversion to LEU, which had began in the eighties, was completed and in September 16, 1997, 40 years after its first criticality, the reactor operated with 5 MW and with a core configuration of 25 Brazilian made LEU fuel elements.

The modifications which were done to operate the reactor at 5 MW, are those related with safety and ageing, as the introduction of a passive spray system for emergency cooling, and isolation valves of primary system, and the complete check, maintenance and, in some cases, components replacement in all reactor systems such as the secondary



reactor cooling system, the fire system, the ventilation system, the electrical system, the instrumentation and control, and radiation monitoring system.

Besides these modification it was necessary to prepare a new Safety Analysis Report, a review of the Emergency, Irradiation Protection, and Security Plans, as well as a Quality Assurance Program in order to satisfy safety and regulation codes and standards required by the licensing authority - CNEN(Brazilian Nuclear Energy Commission.)

To accomplish safety requirements demanded by the Brazilian Regulatory Authority (CNEN) to power upgrade of IEA-R1, a set of actions were made which consist mainly with the adequacy of old systems and design of new ones, involving engineering, analysis, safety evaluation and licensing. The most representatives are:

**Reactor Core:** The Core configuration was changed from mixed (IHEU,LEU) 5x6 array to a LEU 5x5. The new core configuration provides thermal fluxes of magnitude  $5 \times 10^{13}$  n/cm<sup>2</sup>.s. Also a Be irradiator was bought from CERCA and is going to be used to produce <sup>99</sup>Mo in the center of the core.

**Primary Coolant System:** Four isolation ball and gate type valves type ball and gate electrically actuated were installed at the inlet and outlet of the primary piping to isolate the reactor pool within one minute in a case of primary system piping break (LOCA). Pumps also had components, changed due ageing and are monitored in operation by a new Vibration Monitoring System.

**Secondary Coolant System:** The cooling towers were checked and all secondary piping completely replaced due to corrosion. The new piping were installed above the ground to facilitate inspection.

**Spent fuel wet storage:** Two new Aluminium set of racks were installed to increase the spent fuel storage capacity.

**Fire System:** A new detection and fire extinguisher system was installed covering all areas of risk, according to evaluation previously performed.

**Heating, Ventilation and Air Conditioning (HVAC) System):** A new system was installed with the separation of reactor building into two distinct and isolated areas (cold and hot) in respect to radiation exposition. The cold area will be completely free of radioactivity contamination risk. A new battery of filters, shutoff dampers, fan coils, blowers, isolated air ducts and instruments were installed.

**Electrical System:** New power control panels were provided to distribute power from the main switch gear and emergency generators directly to a set of consumers and motor control center. All wiring was checked, revised, and distributed into new cable trays, making possible the isolation of instrumentation and power cables for the new systems.

**Instrumentation and Control:** Improvements were made in the reactor protection system and in safety related instrumentation. New interlocks using 2 out 3 logic were implemented, specially to drive primary circuit isolation and emergency core cooling system valves using pool level signals from new level sensors as initialising events. Interlock to protect core against power excursion at lower power level was also installed. Also new panels were installed in the control room, and in the emergency room for the new systems and radiation protection systems.



**Radiation Monitoring System:** Old monitors were replaced and new gaseous effluent monitors were installed. Also new panels in the control room were installed.

**Emergency Core Cooling System (ECCS):** It is a fully passive system, employing two redundant trains with four automatic valves designed to work in fail safe concept, spraying water directly from reservoirs into uncovered reactor core, and avoiding fuel element melting. ECCS was designed to continuous operation during 26 hours after reactor shutdown.

## 2.4 AGEING MANAGEMENT EXPERIENCE

The reactor IEA-R1 ageing is a problem that has been noticed and pointed out for a long time by the technical staff involved in the management and operation of the reactor. In order to deal with this problem several actions has been taken. In early nineties, in order to understand and manage the ageing problem and to extend the life of the components and systems, some technicians was put in charge to elaborate a plan to manage the ageing problem. The modifications listed in the previous item 2.3, particularly ECCS, shows the preoccupation with the degradation of the reactor systems and components which demanded several reforms and replacements.

While conducting huge modifications in order to upgrade the reactor, a plan of testing and inspection was elaborated to assess ageing management and some safety requirements of SAR. Although this plan is being presented as the Ageing Management Program it does not consider all ageing aspects of the reactor IEA-R1 neither uses appropriate tools or implement a complete Ageing Management Program. From this program results a list of important items to be tested and inspected but not a comprehensive profile of all tasks to manage the ageing problem.

In addition to the upgrading process, it is important to notice that some other actions related to ageing were performed even though they have not resulted in modifications or replacements as listed in the last paragraph of item 2.3. Some ageing management studies examples are listed below: [15]

**Core support structure:** The main portion of the core support structure frame was checked considering the fatigue and radiation damage as ageing stressors. The evaluation results showed that there was no need for modification or replacement.

**Seismic qualification of building, structures and components:** To accomplish with the applicable recent safety codes and standards, a seismic qualification of building, structures and components had to be presented to the Regulatory Authority (CNEN). A seismic evaluation of the reactor site, based on seismic risk, was done and showed that the seismic level is so small that no additional seismic qualification was required.

**Concrete ageing:** Inspections were performed to check if there were damages to the reactor building and pool concrete. No faults were detected.

**Pool wall steel liner:** Nor leak problem was detected based on visual inspection neither in the leak rate of the drain system of the pool wall liner.

The following items are a brief description and brief history of some programs and plans to management the reactor which gave us some experience in ageing manage using operational management of the reactor installation and facilities.

## 2.4.1 MAINTENANCE

Since its start-up the IEA-R1 reactor has had several different maintenance approaches. Up to the seventies there was no dedicated group in charge of maintenance on IEA-R1 reactor. The maintenance was carried out by specific groups inside IPEN functional structure, managed and allocated by the reactor Operation Division only when the reactor presented some problem. In the second half of that decade, until early eighties, some groups of maintenance were created inside the Operation Division, for example: group of water treatment, group of electronic, etc; but there was not a dedicated group of maintenance working in an integrated manner.

In early eighties organisational changes at the Institute lead to the transfer of a large group of scientists and technicians from others divisions to the reactor directorate, allowing the reorganisation of the maintenance with specialised staff dedicated to maintain the reactor and its facilities. Maintenance Program was implemented and some activities were organised in routines that have to be performed by the operation group and maintenance group.

In the beginning of the nineties, due to of changes in the organisation of the Institute and other factors, this staff was dismantled. Since then these activities has been carried out by reactor Operation Division, which execute the routines established in the Maintenance Program. The Division of Reactor Operation has been in charged of conducting the maintenance of the reactor and its facilities but there was no dedicated group to carry out and to plan the maintenance of the reactor. In addition, the operation group is in charge to execute some activities of the Testing and Inspection Program.

Recently, to achieve a better organisational structure to operate the reactor continuously at full 5MW and to manage adequately the ageing, the IEA- R1 reactor management was restructured. A new division named Division of Technical Support and Maintenance was created. This division main tasks are:

- Maintenance
- Specialised Repairs
- Core Management
- Water Treatment and Re-treatment
- Continuing Modernisation
- Implement the Ageing Program

Regarding the Maintenance Program, which is being revised, a corrective maintenance record procedure is in use and it generates bimonthly reports about executed services and the procedures can be checked in attachment 5.2(b). In attachment 5.1(a) and 5.1 (b) are showed two examples of the compilation of the maintenance carried out in two systems, primary system and beam holes, important to illustrated our ageing analysis in the final item of this report.

To illustrate, it also included in attachment 5.2(c) and 5.2(d) the annual maintenance programming for 1999 and the general preventive maintenance. In either one it is indicated the item considered, the particular procedure to be used and the date to be executed.

The first step to have a good reformulation of the maintenance strategy was done by creating the new Division of the Technical Support and Maintenance, however it is important to think about the objectives of this reorganisation. Vague objectives can make these changes ineffective. In the last thirty years that we have changed the maintenance strategy we have collecting some successes and mistakes having the sole goal to keep the



reactor operation, but recently a new goal was added that is to manage the ageing of the components and systems.

Considering the age of some reactors systems and components, even though renewed and upgraded we have to define the maintenance strategy as the cornerstone of a long life, with safe and smooth operation of the reactor.

Reviewing the reactor maintenance history we can find good material to study and implement a realistic Maintenance Program with the goal to operate the reactor and to do a good ageing management of its components and systems.

#### **2.4.2 DESCRIPTION OF THE TESTING AND INSPECTION PROGRAM**

Previously, the testing and inspections that were conducted had only a routine purpose and they were conducted by the operational staff as part of the normal operation procedures. They had not a systematic approach inside a more general ageing management strategy. There was not a specific document that would plan all the testing and inspections but rather they were scattered inside every maintenance procedures.

As stated before, in mid nineties a specific group was created to assess the reactor ageing management. The first and only result preceded by this group so far is a Testing and Inspection Program which were prepared not only for ageing management but also in part of it to satisfy requirements set forth in the Safety Analysis Report (SAR).

The primary objective of this program is to satisfy commissioning procedures stated in the SAR, which defined the activities, methodologies and periodicity in order to assure safe operation. At the same time, this program would also include ageing management aspects leading to ageing phenomena studies and follow up.

However, although the program was established, as shown in the next page as Table 1 - Testing and Inspection Program - Summary, the actual execution was not properly conducted due in poor participation of the personnel involved.

Analysing the reports that have been generated, we can notice that not all activities were performed and in the cases where activities are executed the results are not adequately registered nor centralised. The information is dispersed and the necessary corrective actions are not always taken. In some cases, abnormal condition are reported and registered in the operation logbook. However this information is not properly analysed.

As stated before, a new Division of Technical Support and Maintenance in the Reactor Department was created to deal with this problem, with a centralised management scheme, which can better supervise and co-ordinate the associated activities in order to implement this program assuring more reliable information and operation.



**TABLE 1 - INSPECTION AND TESTING PLAN SUMMARY [10]**

<b>TASK</b>	<b>COMPONENTS</b>	<b>TEST / INSPECTION</b>	<b>FREQUENCY / STARTED</b>
1	ESNR ( Structure )	Visual	July-98
2	Emergency coolant system	Visual	Bimonthly /July-98
3	Pool liner	Visual	Semesterly / July-98
4	Primary system: piping, Decay tank, pumps, etc	Visual	Annually / July-98
5	Retention tank	Leak Test	Monthly / July-98
6	Fuel elements	Visual Monitoring ( H2O) Sipping Check	Quarterly / September-97 Weekly / Stembro-97 Semesterly / September-97 Annually / September-97
7	Core elements storage	Visual Monitoring (H2O) Sipping	Three years / Set.-97 Weekly / September-97
8	Control Element	Visual Monitoring Sipping Check	Quarterly / September-97 Weekly / September-97 Semesterly / September-97 Annual / September-97
9	Control and Safety rods	Visual Fall Test	Semesterly / September-97 Quarterly / September-97
10	Control rods leader	Visual	Semesterly / September-97
11	Reflectors	Visual	3 years / Setptember.-98
12	Radiation detectors	Full Check; detectors, cabs and connectors replacement	Annually / December / 97
13	Reactor Control Panel	Check and calibration	Safety related Components/Quarterly Others components/ Annually September / 97
14	Containment Irradiation gauges	Check and calibration	Safety related Components/Quarterly Others components/ Annually September / 97
15	Process Instruments	Check and calibration	Annually / September 97
17	Rotative equipment	Monitoring hold on (CVM )	Since January/97
18	Grounding System	Check/ Measuring	2 years / Set. 97
19	Light protection system	Check/ Measuring	2 years / Set. 97
20	Ventilation/exhaust system	Full check	Annual / July/97
21	Water Treatment and re-treatment System	Visual Check Full Check	Visual / test = weekly Full check = annual July/97
22	Pneumatic Irradiation System	Visual check / Full Test Cleaning / Lubrication	Visual / Test = Monthly Cleaning / lubrication = Annual July/97
23	Fire Alarm System	Full Check	Semesterly / July/97
24	Power command panels	Full Check	Annual /July/97



### 2.4.3 RECORDS AND DOCUMENTATION HISTORY

This section describes how the engineering documentation as well as quality assurance, operational, maintenance and inspection data are organised. They are divided in the following groups:

- a) Engineering documents.
- b) Operational and maintenance procedures and records.
- c) Inspection, audit and testing procedures record.

Regarding engineering documents, until 1995, there was not a formal Quality Assurance implemented being all the documents kept under the responsibility of the Operation Division. No formal procedures for emission, classification, identification, approval, revision, distribution, control and archived existed. The documents were archived and organised informally under the responsibility of the Operation Division.

During the power upgrading to 5 MW a formal Quality Assurance Program was partially implemented. All older documents (drawings, manuals, etc.) were not transferred into new system being only rearranged and identified and still under the control of the Operation Division.

However all new produced engineering documents were emitted, approved and controlled under formal procedures stated forth in the Quality Assurance, and most of this documentation is controlled by a QA technician reporting directly to the head of the Reactors Directorate. The present QA was elaborated individually, applying only for the IEA-R1 reactor nor being included the interfaces with the Institute areas. This QA is presently revised to a new institutional framed version considering all interfaces with every Institute areas.

To understand the next consideration is necessary to notice that the operational and maintenance procedures generate the following records:

- Operation shifts record book
- Maintenance and Operation events - Logbook
- Systems maintenance record books.
- Start-up and shutdown check list
- Operational follow-up and reports: monthly and semesterly
- REDO (Abnormal events report)
- CRS (Safety review committee reports or findings)

These documents are controlled by the Operation Supervisor who is responsible to concentrate them and take the necessary actions resultant from the reported events. Except to CRS documents that is archived by the co-ordinator of the committee, all others documents are archived by the Operation Division. One example of these documents is showed in attachment 5.2(a)-REDO, that is an abnormal operational event record report form. Then when an abnormal operational event occurs, the responsible operation leader classifies the occurrence. If it is found to be important to reactor safety he fills a REDO identifying the causes and possible corrective actions, and submit it to the safety committee co-ordinator. The REDO is next analysed by every members of this committee (8 members from related areas) who should issue their findings. The REDO is closed only when all necessary actions were taken.

The system maintenance record book is presently upgraded to be produced as a computer print-out as showed in attachment 5.2(b). Previously, it was recorded in a register book separated by kinds of maintenance executed.

Regarding the inspection, audit and testing procedure records, as described in item 2.4.2, the inspections were not conducted as planned. The records associated with the inspection and testing procedures are not organised in a centralised manner, being filed in individual basis. However, several inspection and testing are carried out during the annually reactor shutdown for core configuration changes and general maintenance activities, and the results and records are concentrated and archived by the Operation Supervisor.

#### **2.4.4 DESCRIPTION OF THE DATA ACQUISITION SYSTEMS (SAD)**

As part of the ageing management effort and in order to improve plant performance, availability, reliability and safety, a plant condition monitoring system is being installed. Nowadays, a data acquisition system is already installed as described below.

The IEA-R1 Data Acquisition System (SAD) has the main objective of monitoring and registering the main reactor operational parameters. The monitoring function is redundant with the Instrumentation and Control panels indications installed in the Reactor Control Room. The SAD is composed by:

- a) Remote station (ER 208)
- b) PC compatible Computer
- c) Printer

The system performs the acquisition and recording of the signals and it presents them through a Man-Machine Interface installed in a PC computer. The DC values of these signals are compared with set points and when these limiting set-points are violated an indication of occurrence is produced. The system can also produce periodic operational reports through the printer.

##### **a) Monitored Variables**

A total of 61 operational variables and parameters are monitored by SAD and they are summarised below:

- a) Temperature variables: total 24.
- b) Flow variables, level and pressure variables: total 6.
- c) Water chemistry variables: total 2.
- d) Radiation variables, area monitoring: total 9.
- e) Radiation variables, ducts and tanks monitoring: total 5.
- f) Nuclear Variables: total 8.
- g) Control and Safety Rods Positions Variables: total 7.
- h) Other possible variables (require field installation, not available yet)



## b) Input/output Signals Characteristics

The remote station ER-208 can receive the following inputs:

- 31 0 to 10 V signals
- 9 signals with 4 to 20 m.A. or 1 to 5 V
- 39 TTL digital signals
- 96 dry contact digital signals (on-off)

The communication between the remote station ER-208 and the computer is performed using serial signal RS-485, the data are presented using ELIPSE software.

The remote station has a data acquisition unit, a signal conditioning unit, power supply and input/output borne.

The computer has a colour monitor and printer, with communication programs and the ELIPSE 21 for DOS 6.22 interface program. It also has a system status checking program. The system is presently fully operational, however, the results are not properly used and analysed by the operation staff.

### 2.4.5 DESCRIPTION OF THE ON-LINE PUMPS VIBRATION MONITORING AND DIAGNOSIS SYSTEM.

In the last revision of the Safety Analysis Report (SAR), to exclude the possibility of occurrence loss of coolant and loss of flow accident caused by malfunction and/or missile generation by the primary pumps fault, it was installed a vibration monitoring and diagnosis system.

So, in order to detect and diagnosis early fault occurrences to prevent potential accidents and to plan a better maintenance, a vibration monitoring and diagnosis system was installed in the primary and secondary loops pumps and in the emergency diesel generator.

The system was manufactured by Brüel and Kjaer and it is composed by 18 accelerometers and 6 thermocouples, pre-amplifiers, a controller unit with A/D converter, multiplexes and data processing and a computer for Man-Machine Interface as well as diagnosis functions using the compass package.

The system continuously acquires data from the sensors and process them comparing the results with adjustable set points to generate alarm. The data can be recorded and generates graphical as well as text reports.

The following are the main functions of the system under stationary and some for transient condition:

- AC/DC Measurements, low pass, band pass, DC.
- Machine histograms and scalar history
- Auto spectral analysis and history
- Campbell analysis
- Bode Diagrams
- Orbit, vector history and X-Y history
- Cepstrum , Envelope spectrum

The PC supports UNIX operating system with PostScript driver, X-Window system and Oracle SQL databases. Direct RS-232, Modem or ETHERNET TCP/IP performs the communication.

### **3. AGEING MANAGEMENT SELF-ASSESSMENT ACCORDING TO THE IAEA GUIDELINES.**

#### **3.1 INTRODUCTION**

In order to implement an effective ageing management in the IEA-R1 reactor a study was done about the methodology to be adopted according with guidelines from IAEA:

- IAEA Services Series - "Guidelines for the Review of Research Reactor Safety."
- IAEA-TECDOC-792 - "Management of Research Reactor Ageing."
- TECHNICAL REPORT 338 - "Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety."

A study of the guidelines from IAEA indicates that the first step in implementing a comprehensive ageing management is to establish a common ground as far as definitions and requirements are concerned. For this purpose we studied and followed the chapters 2 and 3 of the IEA-TECDOC-792 about the followings subjects:

- Definitions and management of ageing
- General safety requirements
- Service condition and ageing
- Physical conditions and ageing mechanisms
- Non-physical conditions and effects
- Current trends and future activities in research on ageing

The next step in the present work was to actually apply the IAEA recommended methodology following the steps listed below which were studied and analysed:

- Selection and categorisation of systems/components/equipment
- Selection of Critical Items
- Ageing surveillance activities: Testing and Inspection Program, Maintenance Program and Monitoring and Diagnosis.
- Data collection and records keeping.
- Proposed Systems to be Monitored and Diagnosed

Regarding the use of information about experience of others research reactors operation, it is expected that in the forthcoming Workshop to be occur in Santiago, Chile, this subject will be discussed with the participation of the other Latin-America reactor operators and mainly with the help of the IAEA experts. From IEA-R1 reactor, the questionnaire recommended by guideline and shown in Appendix III was filled and attached to this presented report as attachment 5.4.

The next steps in the ageing management are the evaluation of the ageing effects and definition of actions to prevent and mitigate their ageing effects to prepare guidelines in order to assure continuous reactor operation and to demonstrate that the present ageing status with a appropriate ageing management is acceptable under safety reviews to attend regulatory authorities. These activities will be developed in a second phase of this ARCAL project.

As a result, the first activities described in the item below were in the direction of implementing an ageing management according to recommendation set above and report the results on selection and categorisation, surveillance activities and record keeping.

### 3.2 AGEING MANAGEMENT ACTIVITIES

According to the methodology proposed by IAEA TECDOC 792, the first activity is to prepare a detailed listing of IEA-R1 systems and components with their classifications. This was done following the example given in the Appendix I, Tables 1.1 and 1.2 of aforementioned document.

A preliminary listing containing a detailed break down of all systems into their components was prepared based on information contained in the Operational Manual and SAR. This listing was analysed by the senior operating staff and the engineering group involved in this project until a final version was defined.

This listing was distributed to be filled individually by the head of the reactor operation department, the head of engineering department, the head of the technical support and maintenance division, the head of the operation division and other senior operators. They were expected to filled the columns with information about whether the components is safety related, replacement easy and ageing mechanism involved, based on criteria defined in table 1.2 of aforementioned document.

Not everyone answered formally. However the replies collected and interviews allowed us to set up meetings to reach a common ground table representing the general consensus.

An important problem occurred regarding the classification of components related to safety. Since according to IEA-R1 reactor SAR which followed strictly criterions and definitions to classify systems and components important to safety satisfy licensing codes while the examples given in IAEA TECDOC 792 and other literatures apparently follow other criteria and definitions for safety related items classification regarding ageing aspects. To avoid having to adopt a particular solution, the associated column was filled taking both criteria into considerations. The nomenclature used is defined in the attachment 5.3(b). In the particular case of IEA-R1 reactor, due to the installation of ECCS, most of the components which were safety related before, became no longer safety related but only functionally important and/or related to the defence in depth concept.

The columns that indicate replacement easy were filled using strictly the criteria contained the attachment 5.3(b) , not using intermediary grading between them to classify the components. We understand the criteria as the following: (A) Impossible to replace independent of cost, technology or time available, (B) Difficult to replace, costly, requires specialised technology and demand long time, (C) Normal to replace depending on usual engineering, low cost and time, (D) Readily to replace, without engineering, low cost and low time.

The ageing mechanisms listed in the last columns were filled without much problems being a consensus that have seen established and matured for sometime, although we have to alert that the mechanisms 10 and 12, as indicated in table 1, was point out in some items but it will be verified and confirmed during next phase of this project.

A survey on existing Testing and Inspection plan being executed was conducted through interviews with the operational staff and the Head of the Operation Division and the Head of the Technical Support and Maintenance Division, and search through available procedures, reports and registers. The result of this survey is reported previously in item 2.4.2 and represent the present status regarding testing and inspection at IEA-R1.

The procedure carried out to self asses the status of maintenance program was quite similar as above, i.e., interviews and documentation search were performed. In this case others technicians who are no longer working actively in maintenance or operation of the reactor were also interviewed. The main conclusions are reported in item 2.4.1.



In order to self assess the status of the documentation and records keeping system we verified the existing procedures, new and old documentation and the archiving system as well as we interviewed not only the personnel above listed but also the staff responsible for the Quality Assurance Program. The result is presented in item 2.4.3.

The next items will analyse the information and data collected during the activities described above.



### 3.3 CRITICAL ITEMS SELECTED FOR AGEING MANAGEMENT

The criteria used to selected critical items was based on the importance of a given item regarding safety relationship and replacement ease. A first grouping was done using the above criteria generating four groups as defined below:

- (a) Y\* and A
- (b) Y\* and B
- (c) Y and A
- (d) Y and B

Inside each of the groups, the items were ordered (sorted) by the number of ageing mechanisms involved, indicated in the parenthesis. Items that were already included in a more important group were not repeated in a lesser important group. The four groups listings and their components are detailed below:

- (a) Y\* and A (5) 160 - Structure
- (4) 001 - Pool Structure
  
- (b) Y\* and B (7) 006 - Header Movement Systems
- (7) 015 - Primary Loop Isolation Valves
- (7) 023 - Standard Fuel Element
- (7) 024 - Control Fuel Element
- (7) 025 - Radiation Element
- (7) 026 - Reflector Elements
- (7) 122 - Beam Holes
- (7) 129 - Dry Material Storage Building
- (6) 004 - Header
- (6) 030 - Core Support Structure
- (6) 117 - Pneumatics Tubes in Pool
- (6) 131 - Crane
- (5) 036 - Magnet
- (5) 037 - Control Rod Mechanism
- (5) 033 - Core Movement System
- (5) 056 - Control panel
- (5) 057- Power panel CP 02
- (5) 058- Nuclear measure channels
- (5) 059- Operation channels - CINC
- (5) 060- Logarithm channel - CF
- (5) 061- Power multiband linear channel - CIC
- (5) 062- Safety channels
- (5) 063- Safety rods
- (5) 064- Control rods
- (5) 065- Regulating rod mechanisms
- (5) 066- SCRAM Circuit
- (5) 067- Fission Chamber
- (5) 068- Compensated Ionisation Chamber
- (5) 069- Non-Compensated Ionisation Chamber



- (5) 070- Recorder
- (5) 071- Preamplifier
- (5) 127 - Pool Gate
- (5) 130 - Storage Tube for Irradiation Material
- (4) 002 - Liner
- (4) 039 - Spray Nozzle
- (3) 038 - Support Structure
- (2) 171 - Control and Inspection Routines
- (2) 172 - Reviews and Assessment
- (1) 165 - Design

(c) Y and A (5) 162 - Biological Shield

- (d) Y and B (7) 007- Primary Circuit Pump - B 101A  
(7) 007- Primary Circuit Pump - B 101A  
(6) 161- Penetration  
(3) 163- Organisation

The pool Structure, the building structure and the biological shielding are the most important items because they are not replaceable. Some items, like the pool gate, the header movement system and the dry material storage, were not usually considered an important item to be monitored, but they showed up as an important ageing related item in this listing. One should notice that the fuel elements were also included as item to be studied even though they are generally considered consumables. This is because our fuel elements are fabricated in Brazil being in the process of qualification and also due to the fact that some of them remains quite a long time in the core.

As far as infrastructure goes one should notice that important items are related to design obsolescence, maintenance program review, updated licensing requirements and the last but not the least, aged organisation structure should also be analysed.

### **3.4 AGEING MANAGEMENT RECOMMENDATIONS**

In view of the selected critical items for ageing management and the self-assessment made on the maintenance program, documentation and records organisation and monitoring and diagnosis systems, the following recommendations for future activities on IEA-R1 reactor ageing management are proposed below.

#### **3.4.1 MAINTENANCE**

- a) Verify if every selected item for ageing management is included in the new revised Maintenance Program.
- b) Analyse whether the maintenance is adequate for the selected item.
- c) Review Maintenance Program accordingly.
- d) Verify if organisational structure, human resources and equipment inside the Institute is adequate to perform the maintenance, particularly by centralising the management.
- e) Enhance predictive maintenance capability.
- f) Organise the history and the records about past maintenance executed and the future record keeping.

#### **3.4.2 TESTING AND INSPECTION PROGRAM**

- a) Verify if every selected items for ageing management are included in the present Testing and Inspection Program as proposed in item 3.3.
- b) Analyse whether the procedures are adequate to test and inspect all ageing mechanisms involved.
- c) Review the Testing and Inspection Program accordingly
- d) Verify if organisational structure, human resources and equipment inside the Institute is adequate to perform the program, particularly by centralising the management of the program.
- e) Organise the Testing and Inspections Program record keeping system.

### 3.4.3 DOCUMENTS AND RECORDS ORGANISATION

- a) Full implementation of the Quality Assurance Procedures
- b) Reorganise the older documents performing at least classification, identification and control.
- c) Centralise the management of the documentation.
- d) Complement or redraw the missing documents.

### 3.4.4 PROPOSED SYSTEMS TO BE MONITORED AND DIAGNOSED

To select items to be monitored and diagnosed we considered the critical ageing management component's list shown in item 3.3 as well as their faults events and maintenance history.

#### a) Primary Pumps Vibration Monitoring and Diagnosis System.

This system was chosen after analysing the critical component list, item 3.3, and detecting that the primary pumps are not only important for safety of the plant but they are also important for the continuous reactor operation. In case the pumps or associated system are inoperative or damaged this can jeopardise the safety and continuous reactor operation.

In addition, reviewing the primary pumps past maintenance history, attachment 5.3.2, one can observe that these pumps present high frequency of corrective maintenance indicating that predictive and preventive maintenance as well as testing and inspection are not effective.

Just to illustrate, in this last month of June, even though the Monitoring System was installed, but not fully operational, the primary pump B had its rotor locked, without any early warning.

As described in item 2.4.5, the primary pumps Vibration Monitoring System is already installed, but many activities should be conducted from now or to fully benefit from its operation:

- I) Completely review and finalise the installation with "commissioning".
- II) Continuous on-line operation of the System generating diagnosis reports.
- III) Training of expert operators for the system.
- IV) Utilisation of this system for experimental purposes, to implement new algorithms like "wavelets", upgrading the system to include capability to monitor and diagnosis the pumps during transients improving the number of faults that can be early detected.

b) IEA-R1 Data Acquisition System (SAD)

To add capability to on-line monitoring and detection of early faulty sensors, equipment and systems, the most effective way is through a plant condition monitoring system.

In order to implement a plant condition monitoring system, the first step was to install a data acquisition system as described in item 2.4.4.

It is foreseen that this system will be upgraded to include artificial intelligence capability through the introduction of a computer program that can detect early faults isolating these faults (such as sensors, actuators and controllers). This method is based on neural-fuzzy techniques.

The next steps in this work will be:

- I) Review and finalise the installation (only SAD) including "commissioning".
- II) Training personnel to operate the system (only SAD).
- III) Continuous on-line operation of the system generating diagnosis report (only SAD).
- IV) Implement and test a new algorithm for fault detection and isolation (FDI)
- V) Utilisation of this system for experimental purposes.



#### 4. COMMENTS AND DISCUSSION ITEMS

- a) Discuss interpretation about the meaning of "important to safety" as used in the TECDOC 752 when confronted with the same term when used in licensing.
- b) Discuss the criteria used for critical items selection as proposed in item 3.3.
- c) Why Operational requirements are not included as part of the criteria for critical items selection.
- d) How and from where data from other reactors operation and ageing management experience can be introduced into this project.
- e) Discuss how the ageing management "culture" can be introduced among engineering, operation, maintenance, etc staff.
- f) Discuss problems related to engineering documentation, data collection and record keeping.
- g) Planning activities for the second phase of the project from August 1999 to November/2000.



## **5. ATTACHMENTS**

### **5.1 MAINTENANCE RECORDS STUDIES EXAMPLES**

- (a) Primary System**
- (b) Beam Holes**

### **5.2 DOCUMENTS**

- (a) Example of the Abnormal Occurrences Document - REDO**
- (b) Example of the Print-out Maintenance Registers Routine**
- (c) Example of Annual (1999) Maintenance of the Reactor IEA-R1**
- (d) Example of General Maintenance Schedule Table**

### **5.3 LIST AND SELF-ASSESSMENT OF COMPONENTS AND SYSTEMS**

- (a) Table 1**
- (b) Table 2**

### **5.4 QUESTIONNAIRE**

- (a) Answered questionnaire about IEA-R1 reactor.**

## 5.1 MAINTENANCE RECORDS STUDIES EXAMPLES [6]

### (a) Primary System

Date	Equipment	Occurrence	Observation
19.08.74	B101 - A/B	Desgaste nas juntas flexíveis das bombas por falta de alinhamento entre as flanges e o volante. Torneamento dos rotores e raqueteamento das sedes dos anéis de vedação. Havia um problema de vedação que foi solucionado.	Também em 20 e 26.08.74.
02.09.74	B101 - A	Retirado o motor para reparos por ruídos nos rolamentos.	
19.09.74	B101 - B	Defeito na bomba.	
27.09.74	B101 - A/B	Instalado o sistema de segurança das bombas e feitos testes.	Até 01.10.74.
11.03.75	B101 - A	Vibração no motor da bomba. Manutenção.	
25.05.75	B101 - B	Lubrificação e alinhamento.	
02.06.75	B101 - A	Queima do transformador da chave compensadora. Troca.	
16.06.75	B101 - A	Alinhamento da flange. Curto-circuito na bobina. Troca.	
22.08.77	Sistema de refrigeração	Lubrificação em todo o sistema de refrigeração.	
23.02.79	Transformador do primário	Removido para reparos o transformador 1-A	
22.05.79	Bóia de alarme	Instalação da bóia de alarme na piscina.	
25.06.79	Pressostato	Instalação do pressostato no sistema de refrigeração.	
02.10.79	Bomba hidráulica	Instalação do transformador de partida na bomba hidráulica.	
09.11.79	Bomba de limpeza do fundo da piscina	Instalação e adaptação de uma bomba para a limpeza do fundo da piscina.	
11.09.80	Trocadores de calor	Troca do trocador de calor novo instalado, pelo velho já reformado e montagem das tubulações.	Até 19.09.80.
11.04.81	Trocadores de calor	Retirada do trocador de calor novo.	Pela Jean Lieutaud.
07.06.81	Trocadores de calor	Instalação do trocador novo.	Pela Jean Lieutaud.
23.10.82	B101 - A	Retirada do rolamento do mancal do volante de inércia.	Também em 04.10.82.
15.12.82	B101 - A	Instalação do volante de inércia.	
05.11.84	Circuito primário	Instalação de válvulas e manômetros.	
23.04.85	B101 - B	Desmontagem da bomba e feita uma lista de peças a serem trocadas.	
02.12.85	B101 - A/B	Instalação da bomba.	
07.04.86	B101 - B	Aquecimento anormal entre a bomba e o mancal.	
28.07.86	B101 - B	Defeito no by-pass (pressostato).	
29.06.87	Caixas do núcleo	Troca das caixas de água do núcleo do reator.	
08.09.87	Bomba hidráulica	Instalação da bomba hidráulica do circuito primário A.	
18.07.88	B101 - A	Troca das gaxetas da bomba.	
26.01.89	Trocador de calor B	Corrosão e encrustação nos espelhos do trocador. Limpeza e troca de juntas.	
02.03.89	B101 - A	Problemas na bomba. Funcionando bomba B.	
17.07.89	B101 - A	Desmontagem da bomba para troca de rolamento.	Também em 18.07.89.
14.03.90	Placa de orifício	Retirada da placa de orifício para manutenção e calibração.	
25.04.91	B101 - A/B	Problema de vibração na bobina dos contadores da bomba B e problema de desalinhamento da bomba A.	Em 29.04.91: nenhuma vibração constatada.
11.09.91	B101 - A	Bomba com rolamento quebrado.	
31.01.92	B101 - A	Retirado relê de tempo da bomba e substituído pelo relê da bomba B101 - B	
17.06.92	B101 - A	Aquecimento anormal no mancal do volante de inércia.	
17.07.92	B101 - B	Troca da gaxeta da bomba.	
13.08.92	B101 - A	Análise de ruídos na bomba para verificação das condições dos rolamentos.	

19.11.92	Micro-switch	Primário em by-pass devido a problemas no micro-switch.	
24.11.92	B101 - A	Problemas na bomba.	
15.01.93	B101 - A	Retirada, para manutenção, da chave geral da bomba do painel do 1o. andar.	Reinstalada em 15.02.93.
15.01.93	B101 - B	Troca da gaxeta da bomba.	
12.04.93	B101 - B	Troca das gaxetas da bomba.	
30.08.93	B101 - A	Troca do supervisor trifásico da chave de partida da bomba.	
03.01.94	B101 - A/B	Troca dos relés térmicos de proteção e dos contatores, principais e auxiliares, da chave de partida dos motores.	
24.01.94	B101 - B	Troca da botoeira "liga/desliga" do motor da bomba.	
28.03.94	B101 - B	Troca da botoeira "liga" do comando do motor da bomba.	
11.04.94	B101 - B	Troca de rolamentos e roletes.	
18.04.94	B101 - A	Troca de rolamentos (NU2311 e 6311), coxins e retentores(01422BR e 00498BR-1)	
05.12.94	B101 - B	Manutenção corretiva no comando da bomba.	
03.01.95	B101 - A/B	Manutenção nos comandos das bombas no painel do 1o. andar.	
20.02.95	B101 - B	Troca do bocal de aspiração.	
15.09.95	B101 - A	Retirada de 1 flange de conexão da bomba com a tubulação do primário.	
20.09.95	B101 - B	Troca das gaxetas da bomba.	
18.12.95	B101	Manutenção na botoeira de comando do motor da bomba.	
21.12.95	B101 - A	Deslocamento do mancal do volante de inércia devido à perda de fixação dos rolamentos do eixo do volante (volta à sua posição original em 18.01.96).	
21.12.95	B101 - A	Término da reforma de bomba pela firma "KSB".	Instalação em 02.01.96
02.01.96	B101 - A	Troca do volante de inércia.	Ver relatório
02.01.96	B101 - A	Início da instalação.	
18.01.96	B101 - A	Desmontagem por problemas e fundida nova peça devido a erro de fundição da bomba	Firma: KSB
02.02.96	B101 - A	Troca do eixo, rolamentos e do corpo da bomba, que apresentou vazamento.	
23.05.96	B101-A	Montado para entrada em operação a partir de 27.05	
13.11.96	TC-B	Ruptura de um tubo deste trocador	Ver relatório
24.02.97	Header	Ruptura da extremidade de ligação entre haste e pistão	
12.05.97	B101-B	Troca dos rolamentos do motor desta bomba (traseiro: N6318 da NSK e dianteiro: NU 318 da NSK)	liberada em 19.06.97
07.97	Válvulas isolamento	Estão sendo preparadas as tubulações que irão receber as 4 válvulas de isolamento da piscina	TECMAN
25/07/97	Válvulas isolamento	colocação do tampão sobre o header para realização da instalação das válvulas de isolamento da piscina	
28.07.07	Válvulas isolamento	Recebimento de 4 válvulas (duas esfera e duas gaveta)	
01.08.97	Tubulação	Retirada a tubulação que vai desde a flange de saída do primário até a VP1	
11/08/97	Válvulas isolamento	Colocado a camisa sobre um dos ramos do difusor para evitar a saída da água da piscina	
11/08/97	Tanque de Decaimento	Corte do sifão junto a parede do prédio do reator para retirada da água da canaleta do primário que sairá da tubulação quando do corte da mesma para rebaixamento	
14/08/97	Válvulas isolamento	Colocado a última camisa sobre um dos ramos do difusor para evitar a saída da água da piscina	
15/08/97	Válvulas isolamento	Após verificar-se que continuava o vazamento através do circuito primário, resolveu-se contratar uma firma de mergulho para retirar o difusor e colocar uma flange cega no local.	Firma TEC-SUB

29/08/97	Válvulas isolamento	As 7horas e 30minutos um mergulhador foi até o fundo da piscina fazer o trabalho acima descrito. A firma TECMAN montou o trecho de tubulação desde a flange do difusor até a válvula de isolamento e com isto liberou a piscina. As 15 horas o mergulhador voltou a piscina para tirar a flange cega e colocar o difusor..	
02/09/97	Válvulas isolamento	Terminado o trecho de tubulação entre flange do header e a primeira válvula gaveta do sistema de isolamento. Com isto, retirou-se a flange cega da piscina e colocou-se o header no local.	
11/09/97	Tubulação	Término da montagem. As juntas da perna quente (duas) até a primeira válvula gaveta são de alumínio e foram preenchidas com silicone. A partir desta válvula, foram colocadas 4 juntas de TEFLON. As juntas da perna fria (duas) até a primeira válvula gaveta são de alumínio sem silicone e apresentam vazamentos. As demais (4) são de alumínio e foram colocado silicone sem controle.	TECMAN
15/09/97	Tubulação	Tentando eliminar o vazamento na flange sob o núcleo, os parafusos de aço inox foram substituídos por de aço carbono para dar maior torque.	
13/10/97	piscina	Foi encontrado borracha de silicone boiando junto a câmara de fissão oriunda das juntas do primário.	
16/10/97	tubulação	As quatro juntas de teflon da perna fria (após a válvula gaveta) foram trocadas por de teflon.	TECMAN
21/11/97	Válvulas isolamento	Após verificar-se que continuava o vazamento através do circuito primário, resolveu-se contratar novamente a firma de mergulho para retirar o difusor e colocar uma flange cega no local.. A firma TECMAN procedeu a substituição das juntas de aço inox por juntas de TEFLON na saída do difusor e na entrada da válvula gaveta.	Firma TEC-SUB e TECMAN
01/04/98	Trocador de calor B	O trocador foi aberto e foram plugueados 6 tubos que apresentavam vazamento para o secundário. O fechamento ocorreu dia 14/05/98	IPEN
29/05/98	Bomba do primário B	Alinhamento	MTM
17/06/99	Bomba do primário A	Alinhamento	MTM

**(b) Beam Holes**

<b>Data</b>	<b>Equipamento</b>	<b>Ocorrência</b>	<b>Observações</b>
11.09.78	BH - 12	Arrumado o ralo próximo ao BH-12.	
11.09.78	BH - 5	Arrumada a válvula de dreno.	
25.09.78	BH - 12	Arrumado vazamento.	
15.01.85	BH's	Troca de 4 válvulas de dreno.	
11.03.85	BH - 11 e 12	Troca das válvulas de dreno.	
12.08.85	BH - 8	Recolocação do colimador que havia sido retirado por causa de vazamentos.	
24.02.86	BH - 4	Reparo de vazamento de água próximo ao BH 4.	
07.04.86	BH - 3	Troca da válvula de drenagem.	
25.08.86	BH - 3	Afastamento do núcleo e reparos no BH - 3.	
04.07.88	BH's	Extensão das mangueiras do BH's.	
27.04.92	Drenagem BH - 10	Troca da mangueira de drenagem do BH 10, por vazamento.	
25.05.92	Mangueiras de drenagem	Troca das braçadeiras das mangueiras de drenagens dos tubos colimadores.	
04.06.92	Drenagem BH - 10	Troca da mangueira de drenagem do BH 10.	
09.11.92	Drenagem BH - 6	Troca da válvula tipo gaveta de dreno do tubo BH 6.	
19.11.92	Drenagem BH - 6	Reparo de um vazamento na linha.	
16.12.92	BH - 6	BH - 6 com vazamento.	
15.01.93	Drenagem BH - 6	Troca de uma luva do sistema de drenagem por vazamento.	
29.03.93	BH - 6	Manutenção do BH - 6.	
27.04.93	BH - 7	Conserto da botoeira do BH - 7.	
08.12.93	BH - 6	Reparos na linha de drenagem do BH 6 por motivos de vazamento.	
14.03.94	BH - 6	Conserto de vazamento.	
01.03.95	BH -12	Troca de um "T" de plástico na linha de dreno do BH 12.	
10.04.95	BH - 3	Troca do tubo colimador do BH 3.	
17.07.95	Sistema de drenagem	Troca de uma conexão do sistema de drenagem dos tubos colimadores.	
15.12.95	BH - 11 e 12	Troca das chaves "push-button" dos BHs do rack pequeno.	
14/09/97	BH's	Visando o aumento de potência de 2 para 5 MW, estão sendo preparados tampões em alumínio para serem colocados na flange externa destes tubos.	TECMAN
27/09/97	BH's	Teste de estanqueidade nos tampões. Maioria com defeito na solda (pressão de teste = 1,5 kg)	operadores
01/10/97	BH's	Solda refeita e passagem no teste	
09/10/97	BH's	Início da montagem das tampas nos BH's. Não foram colocados tampas nos BH's 03, 04 e 10 por serem especiais e BH's fechados.	
21/11/97	BH's	Foram instaladas as três últimas tampas	TECMAN
28/05/99	BH's	Colocada a flange original no BH#14 e cartola	IPEN



## 5.2 (a) Example of the Abnormal Occurrences Document - REDO [6]

IPEN-CNEN/SP  
COORDENADORIA DE REATORES E CIRC. EXPERIMENTAIS  
RELATÓRIO DE EVENTO DE OPERAÇÃO (REDO)

No.:01/98

UNIDADE  
OPERACIONAL:REATOR IEA-R1m

### DESCRIÇÃO DO EVENTO:

No dia 31/03/98, observou-se que o nível de água da piscina do reator IEA-R1m estava baixando de forma irregular. A princípio pensou-se que o nível de evaporação de água poderia ser o responsável pelo fato, uma vez que ao operar a 5 MW, o aumento da temperatura da água da piscina é elevado (até ~36°C). As 14h 20minutos, o supervisor foi avisado que o nível havia baixado cerca de 5 cm em 20 horas. Este valor é o limite máximo indicado nas Especificações Técnicas do reator. Após percorrer a instalação e não localizar a causa do problema, as 15h20min o reator foi desligado.

### AÇÃO TOMADA/TEMPO DE REPARO:

Uma vez que nada de irregular foi encontrado na instalação, após o desligamento foram realizados os seguintes procedimentos:

- dia 31/3, das 17:00 h até 19:00 h foram fechadas as válvulas VP1, VP9 e de isolamento da piscina e verificamos que o nível da piscina permaneceu inalterado. Isto mostrou que não se tratava de problemas relacionados com a evaporação da água da piscina ou infiltrações pelas paredes;
- as 19:00 h as válvulas foram reabertas e o primário ligado. Constatou-se que após 45 minutos, o nível baixara 1,2 cm e após 1 h45 min, - 3,7 cm.
- as 21 h 20 min trocamos de trocador de calor (trocador A pelo B). O circuito primário foi religado com este novo alinhamento e, após 1h 50min, constatamos que o nível da piscina não havia se alterado e isto nos levou a conclusão de que o problema era no trocador de calor B;
- dia 01/04, o trocador B foi aberto e verificamos que pelo menos um tubo estava perfurado.

### TEMPO TOTAL DE PARADA:

Devido a este problema, o reator precisou ser desligado antes do horário previsto e, portanto, deixou de operar por 32 horas à 5 MW. Com o trocador de calor B em manutenção e o A em operação, foi possível religar o reator dia 06/04, como programado.

### CAUSA PROVÁVEL:

Ruptura de um tubo interno do trocador na região de entrada da água do primário. Pelo histórico deste trocador, já estão plugueados 4 tubos na mesma região conforme desenho anexo. O último plugueamento ocorreu em 13/11/96. Nesta ocasião, vários testes e limpeza do trocador foram feitos. Contudo, o tubo que rompeu agora não constava da região de risco mencionada pelo relatório da firma que se responsabilizou pelos testes (o referido Relatório encontra-se na ROI).



CAUSA:

Forte impacto da água do primário sobre os tubos do trocador em local aonde a distância entre os espelhos é superior a 1 metro.

MEDIDAS PREVENTIVAS RECOMENDADAS PARA EVITAR NOVAS OCORRÊNCIAS:

Fazer um estudo visando a colocação de uma tela na entrada da água do primário que aumente a perda de carga e diminua o impacto sobre os tubos do trocador ou, realizar o plugueamento antecipado dos tubos que ficam nesta região.

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SUPERVISOR / OPERADOR

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CHEFE DE DIVISÃO

IPEN-CNEN/SP  
COORDENADORIA DE REATORES E CIRC. EXPERIMENTAIS  
RELATÓRIO DE EVENTO DE OPERAÇÃO (REDO)

PRELIMINAR (8 HORAS)

No.: 01/98

FINAL (24 HORAS)

UNIDADE OPERACIONAL: REATOR IEA-R1m

TÍTULO DO EVENTO: QUEDA DO NÍVEL DE ÁGUA DA PISCINA DO REATOR IEA-R1m

DATA/HORA DO EVENTO: 31/03/98, 15 h 20 min

RELATADO POR: Frajndlich, Roberto

SISTEMA (NOME-SIGLA): Sistema de Resfriamento

COMPONENTE (NOME-No.): Trocador de Calor B

MODO DE OPERAÇÃO DA UNIDADE OPERACIONAL DURANTE O EVENTO	SINTOMA
<input type="checkbox"/> OPERAÇÃO MANUAL <input type="checkbox"/> MANUTENÇÃO <input type="checkbox"/> PARADA <input type="checkbox"/> <input type="checkbox"/> POTENCIA PARCIAL <input type="checkbox"/> <input type="checkbox"/> POTENCIA TOTAL <input type="checkbox"/> <input type="checkbox"/> TESTE <input type="checkbox"/>	<input type="checkbox"/> ALARME-SALA DE CONTROLE <input type="checkbox"/> RUIDO <input type="checkbox"/> ALARME-SALA PROT. RADIOL. <input type="checkbox"/> INDICAÇÃO DE NÍVEL BAIXO <input type="checkbox"/> FUMAÇA/INCÊNDIO <input type="checkbox"/> FUNCIONAMENTO ERRÁTICO <input type="checkbox"/> VAZAMENTO <input type="checkbox"/> COMPONENTE/EQUIPAMENTO SISTEMA PARALISADO <input type="checkbox"/> VIBRAÇÃO <input type="checkbox"/> COMPONENTE/EQUIPAMENTO SISTEMA DANIFICADO

EFEITO NA OPERAÇÃO	MODO DE DESCOBERTA
<input type="checkbox"/> PARALIZAÇÃO TOTAL DA UNIDADE OPERACIONAL <input type="checkbox"/> ISOLAMENTO DO SISTEMA <input type="checkbox"/> PARALIZAÇÃO PARCIAL DA UNIDADE OPERACIONAL <input type="checkbox"/> ISOLAMENTO DO COMPONENTE <input type="checkbox"/> SCRAM MANUAL <input type="checkbox"/> SEM EFEITO NA OPERAÇÃO <input type="checkbox"/> SCRAM AUTOMÁTICO <input type="checkbox"/> LIBERAÇÃO DE RADIOATIVIDADE <input type="checkbox"/> REDUÇÃO DE POTÊNCIA	<input type="checkbox"/> SUPERVISÃO SALA DE CONTROLE <input type="checkbox"/> MANUTENÇÃO PREVENTIVA <input type="checkbox"/> SUPERVISÃO SALA DE EMERGÊNCIA <input type="checkbox"/> MANUTENÇÃO CORRETIVA <input type="checkbox"/> INSPEÇÃO EM OPERAÇÃO <input type="checkbox"/> AVALIAÇÃO PERIÓDICA <input type="checkbox"/> TESTE <input type="checkbox"/> VERIFICAÇÃO EVENTUAL

AÇÃO TOMADA	CAUSA DIRETA	CAUSA BÁSICA
TROCA DE PEÇA DO COMPONENTE	DESGASTE NORMAL	ERRO DO OPERADOR
TROCA DO COMPONENTE	DESGASTE ANORMAL	ERRO DE PROCEDIMENTO
REPARO SEM RETIRAR	CORROSÃO	FALTA DE PROCEDIMENTO
CALIBRAÇÃO/AJUSTAGEM	FADIGA	TRATAMENTO DE ÁGUA
LIMPEZA/LUBRIFICAÇÃO	FRATURA/QUEBRA	FORNECIMENTO
REPARO COM RETIRADA	INCÊNDIO/EXPLOSÃO	FABRICAÇÃO
REPARO DE EMERGÊNCIA	ATERRAMENTO	MONTAGEM
NENHUMA ANÁLISE MAIS PROFUNDA	TENSÃO	MANUTENÇÃO
	CURTO-CIRCUITO	MATERIAL
	GOLPE DE ARIETE	PROJETO
	FALTA DE PROTEÇÃO	FALTA DE PROTEÇÃO



## 5.2(b) Example of the Print-out Maintenance Registers Routine [6]

### ROTINA PARA REGISTRO DE MANUTENÇÕES REATOR IEA - R1

SEÇÃO 0	ÍNDICE	PÁGINA
SEÇÃO 1	PROPÓSITO	0X
SEÇÃO 2	APLICAÇÃO	0X
SEÇÃO 3	DEFINIÇÕES	0X
SEÇÃO 4	RESPONSABILIDADES	0X
SEÇÃO 5	REFERÊNCIAS	0X
SEÇÃO 6	PROCEDIMENTO	
6.1	PRECAUÇÕES	0X
6.2	PROCEDIMENTO PARA O USO DO <i>MS-WORD 6.0</i>	0X
6.3	PROCEDIMENTO INCLUIR MANUTENÇÕES	0X
6.4	PROCEDIMENTO EXCLUIR MANUTENÇÕES	0X
6.5	PROCEDIMENTO ORGANIZAR MANUTENÇÕES	0X
6.6	PROCEDIMENTO IMPRIMIR MANUTENÇÕES	0X



## SEÇÃO 1 PROPÓSITO

Esta rotina tem como finalidade fornecer os procedimentos para o uso do *Sistema de Registro de Manutenções*, das manutenções ocorridas nos sistemas do reator IEA - R1.

## SEÇÃO 2 APLICAÇÃO

Esta rotina é aplicada para toda e qualquer manutenção corretiva nos sistemas do IEA - R1 e registrada no 'Log-Book'. O *Sistema Registro de Manutenções* deve ser atualizado e impresso periodicamente (de 2 em 2 meses).

## SEÇÃO 3 DEFINIÇÕES

O *Sistema Registro de Manutenções* foi catalogado em computador do tipo *IBM-PC* ou compatível, utilizando-se o aplicativo *Word 6.0 para Windows* da *Microsoft*. Os dados são armazenados em disco flexível de 1.44Mb, que deve acompanhar a pasta com os registros impressos. Estes dados estão organizados no disquete da seguinte forma: Os arquivos (todos com extensão *.doc*, de documento *Word 6.0*) contendo as manutenções se encontram no diretório *MANUTENC*, estando este classificado em sub-diretórios, cada um referente a um sistema do reator, nomeados e classificados a seguir:

<i>Nome do Sistema</i>	<i>diretório</i>	<i>Arquivos no diretório</i>
Alimentação Elétrica e Auxiliares	eletrica	instalac.doc ( <i>instalações elétricas</i> ) gerador.doc ( <i>grupo geradores</i> )
Ventilação e Ar Condicionado	ventilac	exnormal.doc ( <i>exaustão normal</i> ) exemergc.doc ( <i>exaustão de emergência</i> ) recircul.doc ( <i>condicionamento de ar</i> )
Instrumentação e Controle	controle	controle.doc
Tratamento e Retratamento de Água	agua	agua.doc
Irradiação de Amostras	irradiac	irradiac.doc
Refrigeração do Reator	refriger	primario.doc ( <i>circuito primário</i> ) secundar.doc ( <i>circuito secundário</i> )
Sustentação e Movimentação do Núcleo	sustenta	sustenta.doc
Ar Comprimido	arcompri	arcompri.doc
Alarmes de Irradiação	alarmirr	alarmirr.doc
Tubos de Irradiação	colimad	colimad.doc
Comunicação	comunica	comunica.doc
Combate à Incêndio	incendio	incendio.doc
Medidores de Vazão, Temperatura e N-16.	n16vaztp	n16vaztp.doc
Iluminação de Emergência	iluemerg	iluemerg.doc
Interligações Auxiliares	interaux	interaux.doc
Sistemas de Apoio	apoio	apoio.doc

## SEÇÃO 4 - RESPONSABILIDADES

Cabe ao operador designado, a responsabilidade sobre a atualização do *Sistema Registro de Manutenções*, feita periodicamente e com base no 'Log-Book', como também a conferência dos dados colhidos.

## SEÇÃO 5 - REFERÊNCIAS

Cabe aqui como consulta apropriada - referente os *softwares* utilizados para a confecção do sistema - os seguintes livros:

- *Microsoft Winword 6.0* - manual do usuário e guia de referencia
- *Microsoft Windows 3.11* - manual do usuário e guia de referência
- *Microsoft DOS 6.22* - manual do usuário e guia de referência
- manual da impressora utilizada para impressão dos registros

## SEÇÃO 6 - PROCEDIMENTOS

### 6.1 - PRECAUÇÕES

Por motivos de segurança deve ser feita uma cópia em disco flexível, após a atualização das manutenções, de todo o diretório MANUTENC localizado no computador da seção. Isto pode ser feito da seguinte maneira:

- através do *MS-DOS*, localizar e entrar no diretório que contém o diretório MANUTENC no disco rígido do computador da seção, através do comando CD c:\[diretório];
- inserir o disco flexível de cópia reserva na unidade apropriada (A: ou B: conforme o caso);
- digitar o seguinte comando: XCOPY \manutenc\\*. \* a:\ /E.

Este disco cópia - juntamente com o *Registro de Manutenções* impresso - deverá permanecer em poder do OSR da seção.

### 6.2 - PROCEDIMENTO PARA O USO DO *MS-WORD 6.0*

Para acessar o *MS-WORD 6.0* o procedimento é o seguinte:

- ao iniciar o computador, no 'prompt' do *MS-DOS*, digitar WIN para acessar o *MS-Windows 3.11*;

- Localizar e acessar o 'grupo de programas' *Ms-Office*; acessar o *MS-WORD 6.0*;
- no menu 'Arquivo' selecionar o item 'Abrir' e localizar o diretório MANUTENC, para o acesso do sistema desejado;
- selecionar o arquivo desejado.

Ao finalizar a atualização de cada arquivo, este deve ser organizado e impresso, como descrito nas seções 6.5 e 6.6.

Para finalizar o procedimento de atualização das manutenções:

- pressionar simultaneamente as teclas ALT e F4; em seguida o operador deverá escolher se deseja ou não gravar as alterações feitas no arquivo;
- para voltar ao *MS-DOS* pressionar novamente as teclas ALT e F4 simultâneas;
- ao final, realizar a cópia de salvaguarda descrita na seção 6.1.

### 6.3 - PROCEDIMENTO INCLUIR MANUTENÇÕES

Para adicionar manutenções ao registro:

- tendo o operador iniciado o *MS-WORD 6.0*, e na presença do arquivo desejado, posicionar o cursor em cima da tabela (sem que texto algum esteja sublinhado);
- no menu 'Tabela' selecionar o item 'Inserir linhas' - disponível apenas quando o cursor está em cima de uma tabela;
- digitar a *Data*, o *Equipamento*, a *Ocorrência* e possíveis *Observações* referentes à manutenção

O operador deve observar se já existe o equipamento a ser incluído com um nome diferente, para que não haja um acúmulo desnecessário de itens.

### 6.4 - PROCEDIMENTO EXCLUIR MANUTENÇÕES

Para excluir manutenções do registro:

- tendo o operador iniciado o *MS-WORD 6.0*, e na presença do arquivo desejado, posicionar o cursor em cima da tabela na linha desejada, e no menu 'Tabela', 'Selecionar Linhas';
- ainda no menu 'Tabela' selecionar o item 'Excluir linhas', e em seguida 'Excluir linha inteira';

### 6.5 - PROCEDIMENTO ORGANIZAR MANUTENÇÕES

Ao finalizar a atualização de cada arquivo, este deve ser organizado da seguinte forma:

- posicionar o cursor sobre a tabela (sem texto sublinhado) e no menu 'Tabela', 'Classificar'.
- no primeiro campo, selecionar *Equipamento* com opção 'crescente'; e no segundo, *Data* com opção 'decrecente';
- o item 'possui linha de título' deve estar selecionado.
- em seguida verificar os extremos da tabela, para detectar possíveis linha espúrias.



#### 6.6 - PROCEDIMENTO IMPRIMIR MANUTENÇÕES

Ao finalizar a organização de cada arquivo, este deve ser impresso e anexado à pasta contendo o *Sistema Registro de Manutenções*:

- no menu 'Arquivo', selecionar 'Imprimir'.
- verificar se as opções de impressora, número de cópias e páginas estão corretas;
- verificar se a impressora se encontra 'pronta';
- acionar o botão de 'OK' para a impressão.







### 5.3 List and Self-assessment of components and systems

#### 5.3(a) TABLE OF IEA-R1 COMPONENTS AND SYSTEMS

SYSTEMS / COMPONENTS	SAFETY RELATED	REPLACEMENT EASE	MECHANISMS
<b>Primary Water Coolant System</b>			
001- Pool/structure	Y-Y*	A	1,5,10,12
002- Liner	Y-Y*	B	1,5,9,12
003- Hopper	Y-M	B	1,5,7,9,10,12
004- Header	Y-Y*(1)	B	1,5,7,9,10,12
005- Diffuser	Y-M	B	1,5,7,9,10,12
006- Header Movement System	Y-M	B	1,4,5,7,9,10,12
007- Primary Circuit Pump - B 101A	Y-M	B	4,5,7,8,9,10,12
008- Primary Circuit Pump - B 101B	Y-M	B	4,5,7,8,9,10,12
009- Inertial Flywheel - Pump 101A	Y-M	C	4,5,7,8,9,10,12
010- Inertial Flywheel - Pump 101B	Y-M	C	4,5,7,8,9,10,12
011- Heat Exchanger TC - A (BW)	Y-M	B	5,7,8,9,10,12
012- Heat Exchanger TC - B (CBA)	Y-M	B	5,7,8,9,10,12
013- Primary Piping	Y-M	B	5,7,8,9,10,12
014- Radioactive retention tank (N16)	Y-M	B	1,5,7,9,10,12
015- Isolation Valves	Y-Y*(1)	B	4,5,7,8,9,10,12
016- Check Valve	Y-M	B	3,5,7,9,10,12
017- Flow Control Valve	Y-M	C	4,5,6,7,8,9,10,12
018- Flow Meter (orifice plate)	Y-M	C	5,7,9,10,12
019- Seals	Y-M	B	1,5,7,9,10,12
020- Valves	Y-M	C	4,5,7,8,9,10,12
<b>Reactor Core</b>			
021- Matrix Plate	Y-Y*	B	1,5,8,9,10,12
022- Matrix Plugs	Y-Y*	C	1,5,8,9,12
023- Standard Fuel Element	Y-Y*	B	1,2,4,5,8,9,12
024- Control Fuel Element	Y-Y*	B	1,2,4,5,8,9,12
025- Radiation Element	Y-Y*	B	1,2,4,5,8,9,12
026- Reflector Elements	Y-Y*	B	1,2,4,5,8,9,12
027- Fission Chamber	Y-Y*	C	1,2,4,5,8,9,10,12
028- Compensated Ion Chamber	Y-Y*	C	1,2,4,5,8,9,10,12
029- Non-Compensated Ion chamber	Y-Y*	C	1,2,4,5,8,9,10,12

<b>SYSTEMS / COMPONENTS</b>	<b>SAFETY RELATED</b>	<b>REPLACEMENT EASE</b>	<b>MECHANISMS</b>
<b>Core Support and Movement System</b>			
030- Core support structure	Y-Y*	B	1,5,8,9,10,12
031- Bridge	Y-M	B	4,7,9,10,12
032- Command panel	Y-M	C	4,8,9,10,12
033- Movement System	Y-Y*(1)	C	4,8,9,10,12
034- Control rod	Y-Y*	C	4,8,9,10,12
035- Safety rod	Y-Y*	C	4,8,9,10,12
036- Magnet	Y-Y*	B	4,8,9,10,12
037- Control rod mechanism	Y-Y*	B	4,8,9,10,12
<b>Emergency Core Coolant System (ECCS)</b>			
038- Support structure	Y-Y*	B	5,9,12
039- Spray nozzle	Y-Y*	B	1,5,9,12
040- Piping	Y-Y*	C	5,9,12
041- Feed Water Storage System	Y-Y*	C	5,8,9,12
042- Valves	Y-Y*	C	4,8,9,12
043- Flow meter	Y-Y*	C	4,8,9,12
044- Level sensors	Y-Y*	C	4,8,9,12
045- Control instruments system	Y-Y*	C	8,9,12
<b>Secondary Water Coolant System</b>			
046- Secondary Circuit Pump- B 102A	N-N	C	4,5,6,7,8,9,12
047- Secondary Circuit Pump- B 102B	N-N	C	4,5,6,7,8,9,12
048- Cooling Tower A	N-N	C	4,5,6,7,8,9,12
049- Cooling Tower B	N-N	C	4,5,6,7,8,9,12
050- Piping	N-N	C	5,6,7,8,9,12
051- Valves	N-N	C	4,5,6,7,8,9,12
052- Flow Meter	N-N	C	4,5,6,7,8,9,12
053- Check valve	N-N	C	4,5,6,7,8,9,12
<b>Irradiation Monitoring Systems</b>			
054- Irradiation Detectors	Y-Y*	C	4,5,7,8,9,12
055- Irradiation alarms systems	Y-Y*	C	4,5,7,8,9,12

SYSTEMS / COMPONENTS	SAFETY RELATED	REPLACEMENT EASE	MECHANISMS
<b>Control System</b>			
056- Control panel	Y-Y*(1)	B	4,5,8,9,12
057- Power panel CP 02	Y-Y*(1)	B	4,5,8,9,12
058- Nuclear measure channels	Y-Y*(1)	B	4,5,8,9,12
059- Operation channels - CINC	Y-Y*(1)	B	4,5,8,9,12
060- Logarithm channel - CF	Y-Y*(1)	B	4,5,8,9,12
061- Power multiband linear channel - CIC	Y-Y*(1)	B	4,5,8,9,12
062- Safety channels	Y-Y*(1)	B	4,5,8,9,12
063- Safety rods	Y-Y*(1)	B	4,5,8,9,12
064- Control rods	Y-Y*(1)	B	4,5,8,9,12
065- Regulating rod mechanisms	Y-Y*(1)	B	4,5,8,9,12
066- SCRAM Circuit	Y-Y*(1)	B	4,5,8,9,12
067- Fission Chamber	Y-Y*(1)	B	4,5,8,9,12
068- Compensated Ionisation Chamber	Y-Y*(1)	B	4,5,8,9,12
069- Non-Compensated Ionisation Chamber	Y-Y*(1)	B	4,5,8,9,12
070- Recorder	Y-Y*(1)	B	4,5,8,9,12
071- Preamplifier	Y-Y*(1)	B	4,5,8,9,12
<b>Reactor Electric System</b>			
072- Internal electric line power	Y-Y*(2)	C	4,5,8,9,12
073- Thermal switch	Y-Y*(1)	C	4,5,8,9,12
074- Transformers	Y-Y*(1)	C	4,5,8,9,12
075- Command panels	Y-Y*(1)	C	4,5,8,9,12
076- Conventional electricity generators(220/440)	Y-Y*(1)	C	4,5,8,9,12
077- No-break generator (G220/440)	Y-Y*(1)	C	4,5,8,9,12
078- Uninterruptible Power Module (MPI)	Y-Y*(1)	C	4,5,8,9,12
079- Lightning protection	Y-M	C	4,5,8,9,12
080- Grounding circuit	Y-M	C	4,5,8,9,12
081- Inertial Flywheel of Diesel Generator	Y-M	C	4,5,7,8,9,12
<b>Instruments System</b>			
082- Thermocouple and pressure gauges	Y-Y*(1)	C	4,5,8,9,12
083- Temperature pressure registers	Y-Y*(1)	C	4,5,8,9,12
084- N16 gauges systems	M-M	C	1,4,5,8,9,12
085- Differential pressure signals	Y-Y*	C	4,5,7,8,9,12
086- Water pool level sensors and signals	Y-Y*(1,2)	C	4,5,7,8,9,12
087- Bean Holes shielding door state sensor	Y-Y*(1)	C	4,5,7,8,9,10,12
088- SAD (Data Acquisition System)	M-M	C	4,5,7,8,9,12

<b>SYSTEMS / COMPONENTS</b>	<b>SAFETY RELATED</b>	<b>REPLACEMENT EASE</b>	<b>MECHANISMS</b>
<b>Water Treatment System</b>			
089- Water softer unit	N-N	C	4,5,6,7,8,9,10,12
090- Brine tank	N-N	C	4,5,6,7,8,9,10,12
091- Cartridge filter	N-N	D	4,5,6,7,8,9,12
092- Charcoal filter	N-N	D	4,5,6,7,8,9,12
093- Resin bed A	N-N	D	4,5,6,7,8,9,12
094- Resin bed B	N-N	D	4,5,6,7,8,9,12
095- Conductivity cell	N-N	C	4,5,6,7,8,9,12
096- Flow meter	N-N	C	4,5,6,7,8,9,10,12
097- Piping	N-N	C	4,5,6,7,8,9,10,12
<b>Re-treatment system</b>			
098- Pool surface cleaning system	N-N	C	4,5,6,7,8,9,10,12
099- Cartridge filter	N-N	D	4,5,6,7,8,9,10,12
100- Charcoal filter	N-N	D	4,5,6,7,8,9,10,12
101- Resin bed A	N-N	D	4,5,6,7,8,9,10,12
102- Resin bed B	N-N	D	4,5,6,7,8,9,10,12
103- Conductivity cell	N-N	C	4,5,6,7,8,9,10,12
104- Flow meter	N-N	C	4,5,6,7,8,9,10,12
105- Piping	N-N	B	4,5,6,7,8,9,10,12
106- Tanks	N-N	B	4,5,6,7,8,9,10,12
<b>Reactor Drain System</b>			
107- Reactor building water collector (SUMP)	N-N	B	4,5,6,7,8,9,10,12
108- Water collector drain pump	N-N	C	4,5,6,7,8,9,10,12
109- Collect box	N-N	B	4,5,6,7,8,9,10,12
110- Passing valve (sphere)	N-N	C	4,5,6,7,8,9,12
111- Drain line	N-N	B	4,5,6,7,8,9,12
112- Protection valve(ball)	N-N	C	4,5,6,7,8,9,12
113- Retention tank	N-N	B	4,5,6,7,8,9,10,12
114- Retention tank Drain pump	N-N	C	4,5,6,7,8,9,10,12
115- Radioactive retention tank building (N16)	N-N	B	4,5,6,7,8,9,10,12
<b>Pneumatic Irradiation System</b>			
116- Terminal Station	N-N	B	4,5,8,9,10,12
117- Irradiation pneumatic tubes in pool	Y-Y*(3)	B	1,5,8,9,10,12
118- Pneumatics tubes	Y-M	C	5,8,9,10,12
119- Valves	Y-Y*(3)	C	4,5,8,9,10,12
120- Control System	N-N	B	4,5,8,9,10,12
121- Blower	N-N	B	4,5,8,9,10,12



<b>SYSTEMS / COMPONENTS</b>	<b>SAFETY RELATED</b>	<b>REPLACEMENT EASE</b>	<b>MECHANISMS</b>
<b>Beam Holes System</b>			
122- Beam Holes	Y-Y*(3)	B	1,4,5,8,9,10,12
123- Drainage System	Y-N	B	4,5,8,9,12
124- Seals	Y-Y*(3)	C	4,5,8,9,10,12
125- Flanged covers	Y-Y*(3)	C	4,5,8,9,10,12
126- Sliding doors	Y-N	C	4,5,8,9,12
<b>Storage and Handling Fuel System</b>			
127- Pool gate	Y-Y*(3)	B	1,4,5,8,9,10,12
128- Storage rack	Y-Y*(3)	C	1,4,5,8,9,12
129- Dry material storage building	Y-Y*(3)	B	1,4,5,8,9,10,12
130- Storage tubes for irradiation materials	Y-Y*(3)	B	1,4,5,8,9,12
131- Crane	Y-Y*(3)	B	4,5,8,9,10,12
<b>Compressing air Systems</b>			
132- Piping	N-N	C	4,5,8,9,12
133- Valves	N-N	C	4,5,8,9,12
134- Compressors	N-N	C	4,5,8,9,12
135- Regulators	N-N	C	4,5,8,9,12
<b>Fire Prevent Systems</b>			
136- Control panel in control room	Y-N	C	5,8,9,12
137- Control panel in emergency room	Y-N	C	5,8,9,12
138- Heat gauges (smoke)	Y-N	C	5,8,9,12
139- Temperature gauges	Y-N	C	5,8,9,12
140- Portable fire extinguisher	Y-N	C	5,8,9,12
141- Hydrants	Y-N	C	5,8,9,12
142- Fire door	Y-N	C	4,5,8,9,12
<b>Communication Systems</b>			
143- Telephones	Y-N	D	4,5,8,9,12
144- Internal telephones	Y-N	D	4,5,8,9,12
145- Low frequency internal communicators	Y-N	D	4,5,8,9,12
146- Annunciators System	Y-N	D	4,5,8,9,12

SYSTEMS / COMPONENTS	SAFETY RELATED	REPLACEMENT EASE	MECHANISMS
<b>Air-conditioning and ventilation systems</b>			
147- Fresh air admittance damper	Y-N	C	4,5,8,9,12
148- Air blend chamber	Y-N	C	4,5,8,9,12
149- Pre-filters	Y-N	C	4,5,8,9,12
150- Absolute filters	Y-N	C	4,5,8,9,12
151- Re-circulation ventilator	Y-N	C	4,5,8,9,12
152- Air distribution piping	Y-N	C	4,5,8,9,12
153- Exhauster piping	Y-N	C	4,5,8,9,12
154- Normal exhauster fan	Y-N	C	4,5,8,9,12
155- Pressure control damper	Y-N	C	4,5,8,9,12
156- Absolute and Charcoal filters	Y-N	C	4,5,8,9,12
157- Command panel	Y-N	C	4,5,8,9,12
158- Emergency ventilation system	Y-N	C	4,5,8,9,12
159- Chimney	Y-N	C	5,8,9,12
<b>Building and Containment</b>			
160- Structure	Y-Y*(3)	A	5,8,9,10,12
161- Penetration (doors, etc.)	Y-N	B	4,5,8,9,12
162- Biological Shield	Y-N	A	5,8,9,10,12
<b>Others</b>			
163- Organisation	Y-M	B	11
164- Training	Y-M	C	11
- Documentation			
165 Design	Y-Y*	B	- 12
166 Licensing	Y-Y*	C	- 9
167 SAR	Y-Y*	C	- 12
168 Technical specifications	Y-Y*	C	- 10
169 Procedures	Y-Y*	C	- 8,9,11
170 Maintenance program	Y-Y*	B	- 10,11,12
171 Control and inspection routines	Y-Y*	B	- 10,12
172 Reviews and assessment	Y-Y*	B	- 10,12
173- Physical protection/ Conventional safety	M-Y*	C	8,9,10
174- Safeguards	M-Y*	C	8,9



### 5.3(b) Table of Abbreviations

#### ABBREVIATIONS USED:

Safety related: Y - Yes  
Y\* or Y\*( ) Yes, according with SAR-IEA-R1 criteria  
N - No  
M - Maybe

Replacement Ease: A - No  
B - Difficult (technology or costly)  
C - Normal  
D - Readily

Mechanisms: 1 - Radiation 7 - Erosion  
2 - Temperature 8 - Technology Changes  
3 - Pressure 9 - Safety Requirements  
4 - Cycling 10 - Documentation  
5 - Corrosion 11 - Human Factors  
6 - Chemical 12 - Design/operation/maintenance

\* We adopt two abbreviations, the first "Y" is related with the criteria adopted according with the IAEA guides (ageing related) separated by "-" from the second "Y\*", that is general related to IEA-R1-SAR criteria (licensing). Others Y\* follow by parentheses is according with its specific safety systems relationship listed in IEA-R1 SAR. The Y\*(1) is related to guarantee safety criteria to the Reactor Protection System (SCRAM), Y\*(2) is related to criteria to ECSS and Y\*(3) is related to Reactor Pool Structure.



## 2. Questionnaire

### QUESTIONNAIRE ON RELATED DATA COLLECTION IEAR-1 IPEN REACTOR

1. Operation days per month	- 12 days
2. Operation hours per day	- 24 hours
3. Total Kwh per month	- 960 MWh
4. Average power during month	- 2 Kw
5. Reactor core condition:	
A. Number of fuel elements	- 25 fuel elements
B. Number of dummy elements	- 0 dummy
C. Number of control rods	- 1 rods
D. Number of safety rods	- 3 rods
E. Core Reactivity excess	- 7,6 % $\Delta$ k/k
6. Pool internal condition: During the last 5 years have you observed any defect(D), discolouring (C) or corrosion (R); or carried out any modification (F) or major maintenance (T) in the followings items?	
A. Fuel	- D,C,R,F
B. Core Structure	- D,T
C. Pool liner	- -
D. Reflector	- D,R
E. Control rods/mechanisms	- D,R,F,T
F. Beam tubes	- R,R,F,T
G. Fuel assemblies/storage	- D,R,F
8. Cooling Systems: Have you renewed (N); carried out major maintenance (T) on, or detected any corrosion (R), malfunction (M), or leakage (L) in the followings systems?	
A. Primary	- T,L
B. Pool	-
C. Emergency	- N,T
D. Make-up	-
E. Purification	- T,R,M,L
F. Secondary	- N,T,R,M

<p>9. Confinement or containment system:          Have you renewed (N); carried out any replacement / modifications (F), or major maintenance (T) on, or detected any defect/crack (D), or malfunction (M) in the followings items?</p> <p>A. Structures          B. Ventilation System          C. Isolation System</p>	<p>- <i>F,D</i>          - <i>N,F,D</i>          - <i>N,F,D</i></p>
<p>10. Auxiliary systems:          Have you renewed (N); carried out any major maintenance (T) on, or detected any malfunction (M) in, or do you not have (H), the followings items?</p> <p>A. Power systems          B. Emergency power systems          C. Fire Protection          D. Lightning protection          E. Communication          F. Crane/bridge          G. Handling/storage          H. Transfer/fuel casks          I. Rod waste/storage/disposal          L. Hot cell          M. Compressed air          N. Laboratories</p>	<p>- <i>T,M</i>          - <i>T,M</i>          - <i>N,T</i>          - <i>N</i>          - <i>T,M</i>          - <i>T,M</i>          - <i>M</i>          -          -          - <i>H</i>          - <i>T,M</i>          - <i>N</i></p>
<p>11. Experimental facilities:          Have you renewed (N); carried out any modification (F) on, or detected any defect/crack (D), or corrosion (R) in the followings items?</p> <p>A. Cold/hot source          B. Shielding          C. Rigs/loops          D. Beam tubes          E. Isotopes production/irradiation          F. Rabbit system          G. Thermal column          H. Dry room</p>	<p><i>N,F,D</i>  <i>F,D</i>  <i>F</i>  <i>D</i>  <i>F</i></p>

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