(Pasta 8472 a 9732)

relatório OU

separata

ARCAL LXVIII "SEGURIDAD DE REACTORES DE INVESTIGACION"

WORKSHOP:

"GESTION DE ENVEJECIMIENTO DE REACTORES DE INVESTIGACION"

"SAFETY OF RESEARCH REACTORS: IEA-R1 AGEING MANAGEMENT"

Altair A. Faloppa
Daniel K. S. Ting

IPEN-CNEN/SP - BRASIL

IPEN, LIMA, PERU
25 - 29, NOVIEMBRE, 2002

ACUERDO REGIONAL DE COOPERACION PARA LA PROMOCION DE LA CIÊNCIA Y LA TECNOLOGIA NUCLEARES EN AMERICA LATINA Y EL CARIBE

CONTENTS

1. INTRODUCTION

This report is the outcome of the activities developed during the project ARCAL XLIV and ARCAL LXVIII related to Ageing Management of Research Reactors.

The purpose of these projects were to carry on studies and consolidate a knowledge base and technical capability to manage research reactors ageing and to increase the use more safety standard in the back fitting and upgrading of operating reactors.

An ageing management self assessment of IEA-R1 - IPEN Research Reactor and overall ageing studies were conducted following the IAEA recommendations contained in the Technical Report 338: "Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety", IAEA - Services Series - "Guidelines for the Review of Research Reactor Safety" and in the TECDOC 792: "Management of Research Reactor Ageing". [1], [2], [3]

During the years 1999 and 2000 the project ARCAL XLIV began the establishment of the knowledge base and technical capability to manage research reactors ageing and to use more recent safety standards in the direction of creating a common mmon mety to treat the ageing effects in all participating countries. Perform studies and assessment about the entire IEA-R1 reactor; the ageing management self-assessment studies were the first step in the direction of introducing an Ageing Management Program in the IEA-R1, according to IAEA guides and recommendations.

The preliminary result of this work was condensed in the "Ageing Management Self-Assessment Report", which was presented in the First Workshop of Ageing Management in Santiago, Chile. The self-assessment resulted in the identification of critical components for the ageing management program and also, recommendations for improvement of the Inspection and Testing Plan and Organization of Documents and Records procedures were included. In addition, the two Heat Exchangers, the two primary pumps, and the reactor data acquisition system were selected to be monitored during the development of the project. In the two Heat Exchangers was performed study applying the complete methodology of ageing studies.

In the period from 2001 to 2002 the project ARCAL LXVIII has been focused in an effort to create the knowledge base and to deepen the study about ageing mechanisms and common problems in all countries participating in this project. The focus has been on ageing studies about the components chosen to be monitored and an improvement of a common methodology to manage the ageing problem agreed before.

In addition, although the TRIGA IPR-R1 CDTN Research Reactor situated at Belo Horizonte (Brazil) is not formally enrolled in this ARCAL project of Ageing Management, it is import to report that there an Ageing Management Program is being implemented using the same methodology of described in this report. Nowadays, they have some selected items under ageing surveillance.

In addition, others ageing studies has been conducted by IEA-R1 reactor staff to improve knowledge base and manage the ageing of the reactor.

On balance, the purpose of this report is to summarise the activities developed during this project, showing the evolution of the ageing management of the reactor and the related activities.

2. IEA-R1 RESEARCH REACTOR STATUS

Since this project ARCAL started it has contributed to indicate directions to better manage the ageing program and the safety operating of the reactor. Most of the recommendations indicated in the self-assessment realized were adopted or considered. For instance the maintenance program and testing and the inspection program were totally revised to introduce the concept of ageing management. The status of these activities are described bellow.

2.1. Reactor description and modifications

The IEA-R1 reactor is pool 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 16th, 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. [6]

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 2002 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^{16} decay tank to reduce operational dose;
1976: - Replacement of the original instrumentation and control operation console;
- Replacement of the original control drive mechanism;
- Changes in the pneumatic system in order.
1978: - Replacement of the original ceramic liner of the pool walls by steel liner;
- Installation of an 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
2001: - Main maintenance of the Cooling Towers
2002: - Main maintenance of Primary Pumps
- Installation of Beryllium Reflectors

2.2. Modernisation plan

Regarding the continuous modernization program of the reactor, a Planning for the triennium 2002 – 2004 was prepared focusing on the improvement of the operating and maintenance of the equipment.

In the year 2002 the most significant actions were the installation of the Beryllium reflectors, reform of the secondary pumps, installation of the isolation valve in the pneumatic system, reform of the secondary cooling towers and installation of the fuel storage racks inside the pool.

Beryllium reflectors are subject of investigation about ageing effects in many countries which use it in their pool reactors. Beryllium is commonly associated with production of Helium gas and Lithium isotopes, the consequence is the early ageing (swelling). On this way, a special surveillance was prepared to monitor the ageing of this reflector.

To the biennium 2003-2004 the planned activities are listed below:

- Installation of the Molybdenum Irradiator
- Replacement of the water treatment and re-treatment system
- Replacement of the graphite reflectors.
- Optimisation of the Reactor Core (Reflectors, Control Rods and Cooling system)
- Installation of a new Heat Exchanger
- Increase the burned fuel storage capacity.
- Conclude the reforms of the electric system panel
- Replacement of the Control Panel and the Nuclear Instrumentation Channels

2.3. Maintenance

The Maintenance Program was totally revised and a comprehensive review was performed in accordance the standard ISO 9000. A Maintenance Software Program was created based on DELPHI Language and using the software received from the RECH-1-CHILE Maintenance Software as reference. This program is used for corrective and preventive maintenance and instruments calibration plan. The procedure is in use and it generates reports about executed services and keeps all the maintenance records.

The maintenance group is part of the team conducting the implementation of the ISO 9000 series, aiming the certificate in operating and maintenance. The Calibration Program and was totally revised the procedures were adequate to ISO 9000.

For a better visualisation a resumed table containing all IEA-R1 reactor systems and maintenance program schedule is presented below:

Reactors systems:
Primary Circuit
Secondary Circuit
Nuclear Instruments – Control Console, Security Channel and General instruments
Pneumatic System
Handling and Storage fuel System
Ventilation System
Air Conditioning System
Rabbit Pneumatic System
Emergency Power Supply
Emergency Core Coolant System
No-Break System

Maintenance Program Schedule:

Preventive Maintenance	
Mechanic	Verified Items: Oil level, cooling liquid level, lubrication system condition. General Checks: Valves, Pumps, electrical motors, fans, heat exchangers, re-screw nuts and bolts, strap tension, Filters clean, etc. Tri-monthly all rotating equipment are verified by thirdly part company. Bi – monthly the Air Conditioning System is verified by thirdly part company. Weekly the Pneumatic System is verify by maintenance staff. Bi-weekly the emergency electric generators are verified by thirdly part company.
Electric	Verified Items: Nuclear Instruments, Water Treatment, Electrical motors, etc. General Checks: frequency, electric current, voltage, isolation, electric contacts, heating, etc Bi-weekly the emergency electric generators are verified by thirdly part company. Tri-monthly all rotating equipment are verified by thirdly part company. Weekly maintenance staff verifies the Pneumatic System. Bi – monthly the Air conditioning System is verified by thirdly part company.
Instruments	The preventive maintenance are executed in the items below: Nuclear instruments are checked; Start –up channel cables are replaced and calibrated; Security and linear channel cables and connectors are replaced; SCRAM chain are totally verified; Temperature and flow sensors are calibrated; Conductive meters are calibrated and the water treatment and re-treatment are verified.
Chemistry	Special operator staff treats the water of the primary system. The secondary water chemistry treatment is treated by thirdly part company supervised by maintenance staff. A monthly report is presented with result of the all analyses and treatment executed.
Predictive Maintenance	
	Vibrating monitoring of the rotating equipments. On-line vibration monitoring system. Tri-monthly all rotating equipment are verify by thirdly part company.

2.4. Quality Assurance

As mentioned before, the new organizational structure to manage and operate the IEA-R1 reactor was created and it is named CRPq - Centro do Reator de Pesquisa (Research Reactor Center). Not only the organizational structure was changed but also the management staff was replaced.

A special committee nominated by the IPEN Superintendent has the task to implement a Quality Assurance Program for the IEA-R1 reactor in order to fulfil ISO 9000 standard and, in this way, an institutional plan has been implemented to reach the certificate ISO 9001.

The structural and operational procedures for the Safety Revision Committee are being revised in order to improve its performance as well as to assure the committee independence from the operational area.

A team inside the CRPq is carrying out the improvement of the Quality Assurance Program. They are attending the institutional committee revising the reactor, operating, systems and products to obtain the ISO 9001 certificate.

The ISO 9001 requires an organization and directive that is in charge of the Steering Committee composed by specialized members from IPEN staff, realizes frequent meetings to discuss the standards implementation.

All procedures has been revised and implemented, the Safety Analysis Report is under revision by specific group according to their acquaintances and all operator staff is in retraining to be adequate to the new procedures. At present, the CRPq is under external auditory, step conducted by C. Vanzolini Foundation, a Brazilian Certified Institution for ISO 9000. The CRPq expected to be certificate until December 2003.

At the same time, the IPEN is working with a third party who supply companies to obtain the certificate in their products and services.

A special care has been taken with the mass of old documents and engineering documents that were not according to the new standard, including design drawings, specifications, data books, report, records date, etc.

2.5 Testing and Inspection Program

Regarding the Testing and Inspection Program, some management tools were developed to deal with ageing of some critical components of the IEA-R1 reactor.

The first results showing the most critical items are already included and their testing, inspection or maintenance as foreseen in the PIT. As described before, the maintenance program was totally revised and some new components are under surveillance, once they are included in the new maintenance scope with ageing management requirements.

According to the recommendations in the Ageing Management Self-Assessment, a cross checking was performed between the table of critical items selected for ageing management based on the importance of a given item regarding safety and replacement case with the Testing and Inspection Plan and the old Maintenance Program. Some items were removed and others were included in the new procedure. The main components and structures included in this approach are: core, including core fuel and fuel elements storage, safety rod, control rods, control rod mechanisms, reflectors, nuclear instruments channels, pool and its elements, emergency core cooling system, primary system, heat exchangers, and rotating equipment.

The Testing and Inspection Program has been gradually implemented. A first series of inspection activities was done in some components, such as core structure, pool liner, beam holes, and pictures were taken and recorded in VHS videos to record the inspections as the present situation to compare in the future to observe the evolution of the ageing.

In table 1 the revised schedule of the Testing and Inspection performed by reactor operator and maintenance staff is presented.

TABLE 1 - TESTING AND INSPECTION PLAN SUMMARY

TASK	COMPONENTS	TEST / INSPECTION	FREQUENCY / STARTED
1	ESNR (Structure)	Visual	February/ 00
2	Emergency coolant system	Visual	Bimonthly /July-98
3	Pool liner	Visual/Camera	Annually / February-00
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 Half-yearly / 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 Half-yearly / September-97 Annual / September-97
9	Control and Safety rods	Visual Fall Test	Half-yearly / September-97 Quarterly / September-97
10	Control rods leader	Visual	Half-yearly / September-97
11	Reflectors	Visual	3 years / September. -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	Rotating 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	Half-yearly /July/97
24	Power command panels	Full Check	Annual /July/97

ipen

3. AGEING MANAGEMENT STUDIES

3.1. Common Methodology Proposal - Methodology Based on IAEA Documents

A better understanding of the ageing effects and management of the reactor remaining life can be obtained adopting a methodology to study all components of the reactors. From our experience in this project we can present a proposal to manage the ageing problem, proposing a methodology that is a compendium of 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 Import to Safety."

The summary below shows a general task sequence of the preliminary Common Ageing Reference Schedule proposed to be discussed and adopted, that is a mixing between the usual guide for Methodology for the Management of Ageing of Power Reactor and the usual guide for Management of Research Reactor Ageing.

1) COMMON GROUND - GENERAL DEFINITION

The first action is to create a common ground, definitions and steps to investigate the ageing phenomena introducing and scattering the concepts below:

- Definitions and management of ageing
- General safety requirements
- Service condition and ageing
- Physical conditions and Ageing mechanisms
- Current trends and future activities in research on ageing
- Non-physical conditions and effects
- Selection and categorisation of systems/components/equipment
- Critical Items
- Ageing surveillance activities in: Testing and Inspection Program, Maintenance Program and Monitoring and Diagnosis
- Data collection and records keeping
- Systems to be Monitored and Diagnoses
- Quality Assurance

2) AGEING STUDIES

I- THE SELF-ASSESSMENT OF THE REACTOR

A self-assessment is required to evaluate management and operating system of the reactor in:

- Operational Procedures
- Maintenance Program
- Testing and Inspection
- Documents and Data

In the sequence, according to the methodology proposed by IAEA TECDOC 792, the task is to prepare a detailed listing of IEA-R1 systems and components with their classifications.

- List of all plant systems and structures:

1. Evaluation of all plant systems and structures
   - List of system and structures selected for component level evaluation.

2. Evaluation of all components within the selected system and structures
   - List of components selected for ageing management studies.

II- INTERIM AGEING STUDIES:

1. Review of existing information relating to the understanding of components ageing:
   - Components design and specifications;
   - Materials and materials properties;
   - Service conditions;
   - Performance requirements;
   - Operation, surveillance, maintenance (histories);
   - Generic data on research, operating experience.
2. Documentation of current understanding of component ageing and associated data needs.
3. Review of current methods for monitoring and mitigation of ageing.
   - Testing, Inspection and On-line monitoring;
   - Maintenance, replacement and operating conditions.
4. Report of interim ageing assessment and recommendation for follow-up work:
   -Understanding ageing;
   -Monitoring and mitigating ageing;

III- COMPREHENSIVE AGEING STUDIES

1. Studies on understanding ageing;
   -Research on ageing mechanisms;
   -Root cause analysis;
   -Post-service examinations and tests.

2. Studies on monitoring ageing:
   -Identification of component condition indicator;
   -Development of diagnoses method;
   -Enhancements in data trending and evaluation;
   -Development of models to predict remaining service life.

3. Studies on mitigation of ageing:
   -Methods and practices for maintenance;
   -Operating conditions and practices;
   -Improvement of design and materials.

4. Report: Assessment of ageing and recommended application of results:
   -Understanding ageing;
   -Monitoring ageing;
   -Mitigate ageing.

3.2. Methodology Review Applied to the IEA-R1 Reactor

Following the scheme proposed above, the first activity was to define a common ageing terminology and concepts based on IAEA guideline indications by operational staff of the reactor and other engineers involved in this project. Meetings and internal seminars to discuss and define the concepts and the ageing management strategy were conducted.

At the same time, as mentioned in [6] a detailed listing of IEA-R1 systems and components with their classifications was prepared. 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(Safety Analysis Report). 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 fill the columns with information about whether the components are safety related, replacement easy and ageing mechanism involved, based on criteria defined in table presented in aforementioned document and using the abbreviations detailed below.

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, satisfies 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 adopting a particular solution, the associated column was filled taking both criteria into consideration.

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 indication " replacement easy" was defined using strictly the criteria stated in the guide mentioned before, not using intermediary grading between them to classify the components. We understand the criteria as 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. Below are presented the abbreviations used to classify the indications to all components analysed.

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.

From the classified list we selected some critical items to be studied and kept under surveillance, including in the Test and Inspection Program.

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 sorted by number of ageing mechanisms involved. 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)	033 - 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 multi-band 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

As mentioned in the self-assessment report [6], 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 mechanism and the dry material storage, were not usually considered as important items to be monitored, but they showed up as an important ageing related items in this listing.

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. From the conclusions of this study was performed the revision of the maintenance program as indicated in the item 2.3.

In order to self asses 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. Nowadays the implementation of the ISO 9000 series solves the problems pointed out in this study (see item 2.4).

A survey on existing Testing and Inspection plan in execution 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 searched through available procedures, reports and registers (see item 2.5).

From the list of critical items some were selected to start the Interim Ageing Studies based on the importance of a given item regarding safety relationship, replacement ease and problems related with maintenance or performance.

The Heat Exchangers were selected as a case study to apply the entire method of ageing studies. In addition, the Primary Pumps and SAD have been studied and reported in this project making it more comprehensive and complete.

A comprehensive survey about the Heat Exchangers since their fabrication to nowadays was performed. Documents, technical information, corrective and preventive maintenance historical details, inspections and modifications were reviewed and analysed in view of understanding the effects of the ageing in their components.

In the same way studies in the primary and secondary systems were performed to identify problems and consequences for the Heat Exchangers.

4.AGEING STUDIES RESULTS

4.1 Ageing Studies

4.1.1 Description

The first results of the Heat Exchangers ageing studies were presented in the report in the last ARCAL meeting realized in 22 – 26 October/2001 in São Paulo, Brazil -"Safety of Research Reactors: Ageing Studies – Phase II" [7]. This report updates the information and describes other conclusions.

As described in document [6], the IEA-R1 Reactor Coolant System is composed by the primary and the secondary loops. The primary coolant flows through the tubes or the shell of one of two tube-and-shell Heat Exchangers, pass through a flow orifice, and then back through the bottom of the pool and into a diffuser pipe on the bottom of the pool in order to ensure 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. Secondary coolant is pumped from the shell side or tube side depending on 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.

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^3 nitrogen-16 decay tank. 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.

In annex 5.1 and 5.2 the flow sketch of the system are presented to better visualize the primary and secondary functioning.

The Coolant System is composed of two Heat Exchangers. The older Heat Exchanger (A) was originally designed and built by Babcock &Wilcox in 1957 and the newer Heat Exchanger (B) was designed and built by CBC, a Brazilian company, that was installed with the second coolant loop in 1974. Both were designed to dissipate 5 MWth each, but until the last upgraded were used to dissipate 2 MWth."

A summary of the data for both Heat Exchangers is presented below, including maintenance history, inspections and main problems, and afterwards, the conclusions of this study are presented detailing the ageing mechanisms and future actions to manage the remaining life.

ipen

HEAT EXCHANGER "A" - B&W

B&W Data Resume

Type	Shell-and-tube - One pass shell
Material	Shell side: Carbon Steel Tube side: S. Steel
Shell Internal Diameter	1073 mm (42,25")
Tube Numbers	847
Tube Nominal Diameter	15,88 (5/8") BWG 18
Tube Thickness	0,55 mm
Tube Length	6,75 M
Tube Arrangement/Pass	Square/22,23
Primary Flow	Tube side
Secondary Flow	Shell side
Shell side temperature	inlet: 27,5°C outlet: 37,5°C
Tube side temperature	inlet: 44,0°C outlet: 38,0°C
Heat exchanged	$4,29x10^6$ Kcal/h

- Summary of the inspections carried out up to this time:

There is no detailed report about inspections performed in this Heat Exchanger. However, we could find records about some modifications and inspections.

1956	Fabricated
1957	Installed and started operating
1974	New arrangement and secondary redundancy installed.
1978	Tube leaking and shell side fouling cleaned.
1980	Repair and maintenance. Testing and Cleaning performed.
2000 - December	Maintenance and Inspection Performed: - Changed the layout.
2001 - February	- Visual Inspection
2002 - January	- Visual Inspection

- Summary of problems reported:

It was installed to dissipate 5 MW, however, since it was installed it was almost never used to dissipate this power. Firstly, there is no need because the Reactor has been operating up to 2MW. Secondly, when it was required to dissipate 5MW it did not reached this result. Since a redundant heat exchanger (TC-B) was installed that dissipate 5 MW, the Heat Exchanger B&W was only used to dissipate up to 2MW.

It presented some mud and fouling in the shell side and corrosion pitches are noticed since the first maintenance.

ipen

HEAT EXCHANGER "B" - CBC

CBC Data Resume

Type	Shell-and-tube - Two pass shell
Material	Shell cover: Carbon Steel Shell : S. Steel Tube side: S. Steel
Shell External Diameter	940 mm
Tube Numbers	1900
Tube Nominal Diameter	12,7 mm
Tube thickness	0,55 mm
Tube length	6,25 M
Tube Arrangement/Pass	Triangul ngularp-1 5
Primary Flow	Shell side
Secondary Flow	Tube side
Shell side design temperature	inlet: 44,5°C outlet: 37,7°C
Tube side design temperature	inlet: 29,0°C outlet: 37,7°C
Heat exchanged	$4,40x10^6$ Kcal/h

- Summary of the Inspections carried out up this time:

1971	Fabricated.
1974	Installed and started operating.
1981	Maintenance and Inspection Performed: - Repair and maintenance; - Testing and Cleaning performed.
1989 - January	Inspection Performed: - Hydrostatic Test; Cleaning performed; - 02 tubes leaking/plugged.
1996 - November	Inspection Performed: - Hydrostatic Test; Cleaning performed; - 01 tube leaking/plugged.
1997 - February	Inspection Performed: - Hydrostatic Test; Eddy Current; Cleaning performed; - 03 tubes leaking/plugged.
2000 - July	Inspection Performed - Hydrostatic Test; Cleaning performed; - 02 tubes leaking/plugged
2001 - March	Inspection performed - Visual Inspection; Hydrostatic Test;
2002 - March	Inspection performed - Visual Inspection; Vibration Analysis.

- Summary of problems reported:

It was installed to satisfy attending redundancy criteria required by safety analysis. Since the Heat Exchanger "A" presented some problems in early eighties, the Heat Exchanger "B" was used more intensively In this way it require more maintenance. Vibration, fouling and tube leaking are the main problems found in the maintenance historical data.

4.1.2 Ageing Mechanisms Effects

As described before, the first step was to conduct a survey about the documentation and construction materials specification to evaluate the original design conditions considering the Heat Exchanger as a non nuclear equipment.

Owing to the secondary system start presenting a flow reduction, an engineering study was performed in the direction of identify the root causes. The Thermo-Hydraulic division of the Nuclear Engineering Center conducted experiments on hydraulic balance, *inter allia*, analysing pressure drop, flow rates inlet and outlet, temperatures. Mass and energy calculations were done and the experimental results compared to the original design conditions. [7], [8], [9]

During this procedures, inspections were performed improving the data base available to this analysis. From the results it was concluded that there was a mistake during the assembly of the Heat Exchanger (A) or during a major modification. The Heat Exchanger was inverted, the inlet piping was installed at the outlet flange, although it is symmetric, there is an impingement protection on the inlet side to block the jet force directly on the tube beam. The change of layout was already performed, however the results indicated that this was not the main reason to cause the flow reduction. [7], [8], [9]

Making a deeper analysis of the reports, history of the Heat Exchangers, the ageing mechanisms involved and considering their past operational time resulted in the following conclusions.

Analysing the coolant system, specially the Heat Exchangers, in the light of the ageing mechanisms definition and considerations, the temperature and pressure were confirmed as mechanisms without influence in ageing because the temperature and pressure operating are lower than the limit to damage the components material.

The corrosion and erosion were confirmed as important to be considered regarding the ageing problem because problems found in the secondary circuit generate consequences in both Heat Exchangers. An effect of corrosion is deposition of particles (corrosion products) in vulnerable places to impair the malfunction of a component.

The secondary circuit, including the Heat Exchangers, shows generalised corrosion in some degree. Considering the heat exchanger "A"(B&W) the shell side presents lesser level of corrosion (photo 2), although, the tube present high level of inner tubes fouling and deposition of particles. On the other hand, in the tube outer side presents good conditions (photo 1). In the heat exchanger "B"(CBC) the tube side and shell cover, corrosion is present (photo 4, 5). Considering corrosion degradation, the shell side of this heat exchanger presents good condition (photo 3). In (photo 6, 7) is presented the corrosion in Tower Coolant Structure, and in the (photo 8) corrosion in the secondary tube.

In the Heat Exchanger "A", an internal inspection inside the tube beam was planned to be executed with micro-camera, but it was not possible yet because there is not appropriate probe available (diameter < 3 mm) to make the inspection between tubes.

Although, as foreseen in the modernization plan, the Heat Exchanger "A" will replaced to a new. The replacement became necessary because the condition of the Heat Exchanger A (B&W) has steadily deteriorated and service reliability has suffered as a result.. In view of proposed ageing studies, a post service analysis will be performed on the removed Heat Exchanger and the comprehensive study will supply important new information to the ageing common data base and design the new heat exchange.

The chemistry effects were not considered in the first analyses as an ageing mechanism, but in the present study we are interested in understanding its effects. To do this, to understand the effect and in order to detect abnormal conditions a survey of the existing water chemistry parameter records of the cooling water was performed. The conclusion indicated some mistakes in the water treatment, the pH parameter was not set correctly in the secondary water conditions inducing corrosion on the mechanical components and piping

Presently, the water chemistry parameters were reformulated and the secondary coolant system treatment is being operated by third-part furnisher, the water is weekly analysed verifying the pH and conductivity. The primary coolant is daily analysed verifying the conductivity, pH, radiochemistry and chlorides.

The cycling was not considered in the preliminary analysis, however it is present in both Heat Exchangers, associated with vibration, that was reported several times. Vibrations develop loading stresses which may cause cracking of material and eventually a fatigue fracture. Change of original position or of a set point is another phenomenon connected to vibration.

Considering the heat exchanger "A" vibration and tube leaking was reported in late seventies (1978). It was disassembled, repaired and cleaned. There is no comprehensive report about the maintenance executed, the tubes that presented leaking were changed and the secondary side presented fouling. After this main maintenance, there was not vibration phenomena reported again, however it was not used intensively or above 2 MWth.

According to informal reports these problems were associated with over flow and/or construction or defects. However there is no final conclusion about this problem. Actually, due the secondary water flow in the tube side this one-pass- shell Heat Exchanger presents condition to accumulate fouling and corrosion (Photo 7), mainly because the water was no properly treated and filtered.

In the Heat Exchanger "B" vibration was reported since it was installed. Because the reactor operated until 2 MW this phenomena rarely occurred, and when this phenomena occurred the IEA-R1 operators performed a flow reduction and compensate with other operational manners in the coolant towers. This way it almost never work a long time with this supposed vibration related.

Owing to the up-grade the reactor power from 2 to 5 MW a study was performed to analyze the flow increase conditions and its consequences in the primary and secondary system. In the Heat Exchanger "B" the most important item determined to be analyzed was the vibration induced by the increasing the flow because it was reported in other occasions.

A study [11] was realized to evaluate the conditions increasing the flow from 1200 gpm to 1600 gpm and analyze this vibration phenomena. This way, was create a first vibration baseline, and the conclusion indicates that the sounds-vibration comes from hydraulic phenomena (gases and vortex) and there is not tube resonance to create crack and fatigue.

The effects under tube beam of the Heat exchanger was not analyzed yet, this way there is no data to conclude the entire effects of the flow increasing and if induce vibrations.

It expect realize another vibration analyses to monitor the evolution of the vibration in case of the flow increasing.

Considering the other mechanisms, such as Technology Changes, Safety Requirements, Documentation, Human Factors and Design/operation/maintenance, associated to ageing in the preliminary assessment of the Heat Exchanger they will be progressively solved in the reviewing of the SAR and implementation of the ISO 9000 series.

4.1.3 Conclusions and Recommendations

The ageing studies carried out have provided useful information on the present status of the components of the system, for instance, ageing studies has identifying the major repairs and refurbishing requirements for primary coolant systems.

As a measure to face ageing related problems, the plant requires a greater amount of surveillance and preventive maintenance and to minimize this degradation performing studies and actions to manage the equipments remaining life. These repairs and refurbishing actions should be considered if IEA-R1 is to continue to operate satisfactorily in the future.

It had been recognised for many years that a gradual degradation is occurring in the Heat Exchangers and some action was necessary to stop the corrosion process. The secondary water treatment was inadequate due to a incomplete water qualify specification as well as inappropriate water treatment procedure, this problem can be confirmed by comparing the two Heat Exchangers secondary side tubes. The first action was to give more importance and focus to the secondary water, and changing the secondary water treatment parameters to minimise the fouling problem. In addition, the Coolant Tower "B" was totally renewed and a new filter was installed.

Considering the Heat exchanger "A", it will probably be replaced and no preventive actions will be conducted to manage or prolong its remaining life time. In this way, as mentioned before, only post service analysis will be performed.

Considering the Heat Exchanger "B", the analysis shows a progressive tube leaking in the last decade, and some tubes are degraded as describe in testing reports. The Eddy Current analysis realised is not conclusive about the situation of the tubes condition, and a new analysis must be considered. Up to now this equipment presents 9 tubes leaking, the corrosion is the possible cause of the Heat Exchanger "B" tube leaking.

Some actions were performed or are expected to be performed in view of managing its ageing or were indicated in case to increase the secondary outflow, prevention of induced vibration and corrosion, and extend its remaining life time such as:

- To install Bourdon pressure indicators on Heat Exchanger secondary side outlet tube visualising and better monitoring the Heat Exchanger performance
- To Install a baffle in the inlet pipe side
- To install the Vent Valve (to prevent gases and vortex)
- Eddy Current test and analysis (new test)
- Hydrostatic Test (PIT)
- Visual Inspection and Cleaning.

4.2 ON–LINE PUMPS VIBRATION MONITORING AND DIAGNOSIS

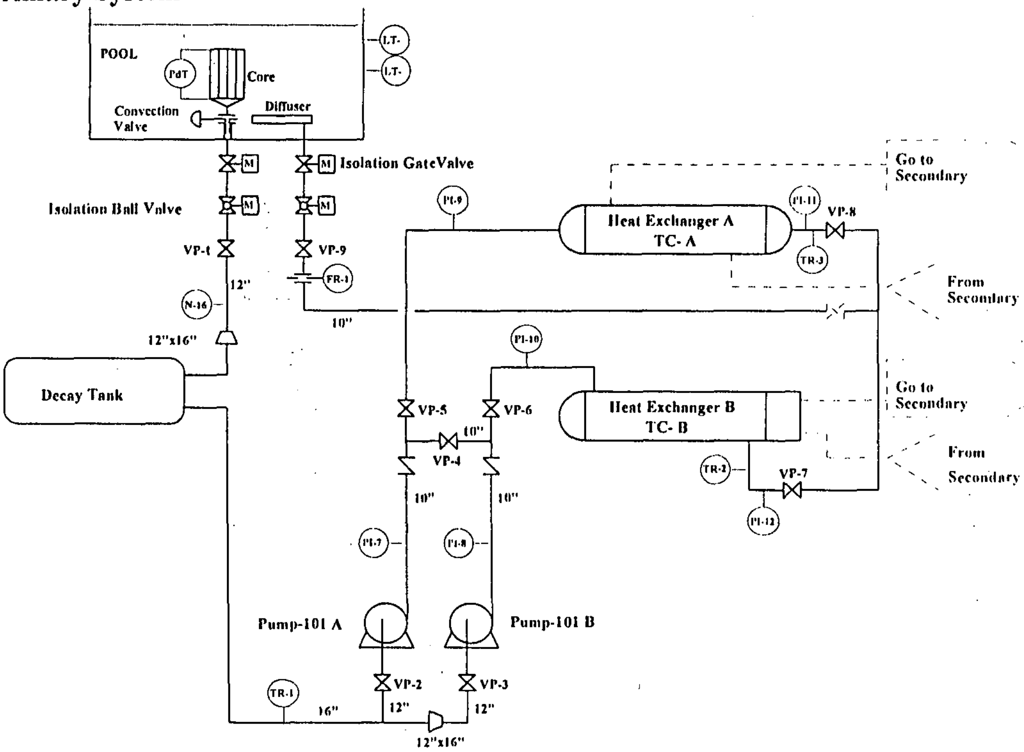
As part of the ageing studies report, the status of the Monitoring Diagnostics of the IEA-R1 Pumps Vibration Analysis is described in a separate report by Mr. Erion Elbeneve.

4.3 THE DATA ACQUISITION SYSTEM (SAD) AND PLANT CONDITION MONITORING

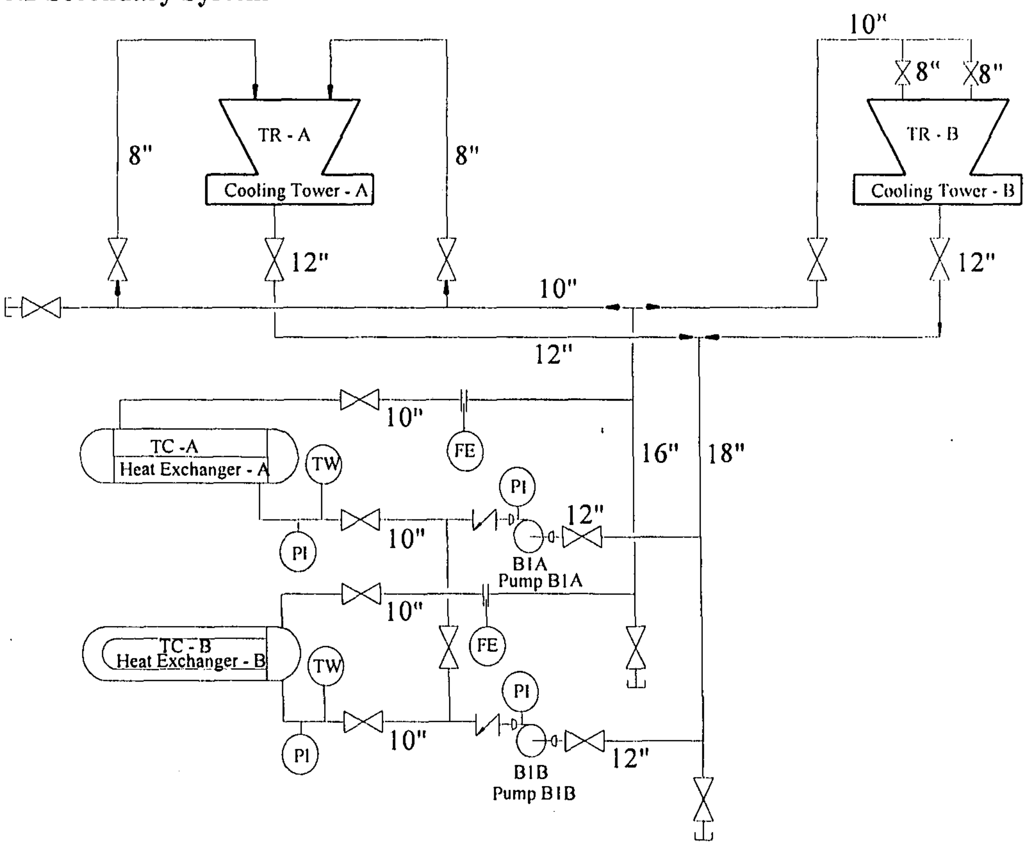
As part of the ageing studies report, the status of the Data Acquisition System - Fault Monitoring and Detection in IEA-R1 Process Sensors is described in a separate report by MSc Iraci M. Gonçalves.

5. ANNEX

5.1 Primary System

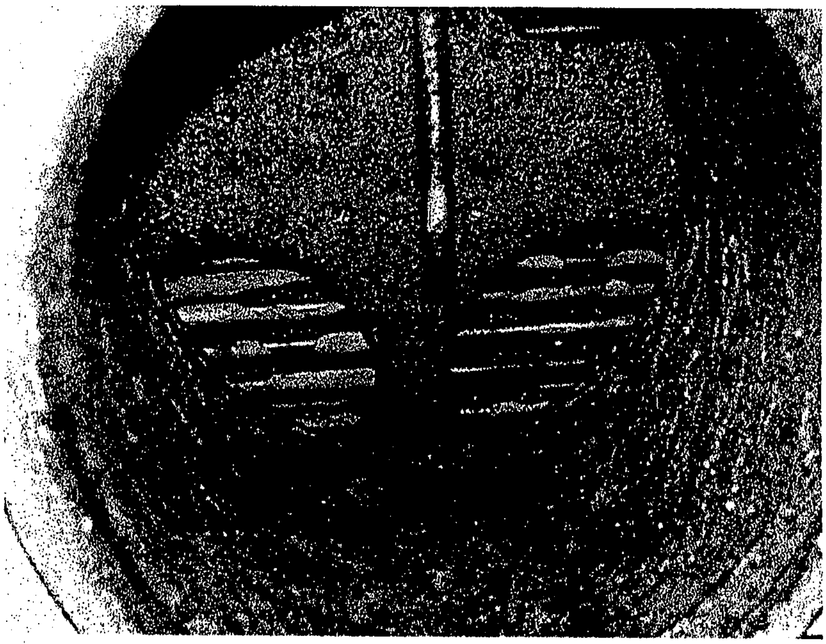


5.2 Secondary System

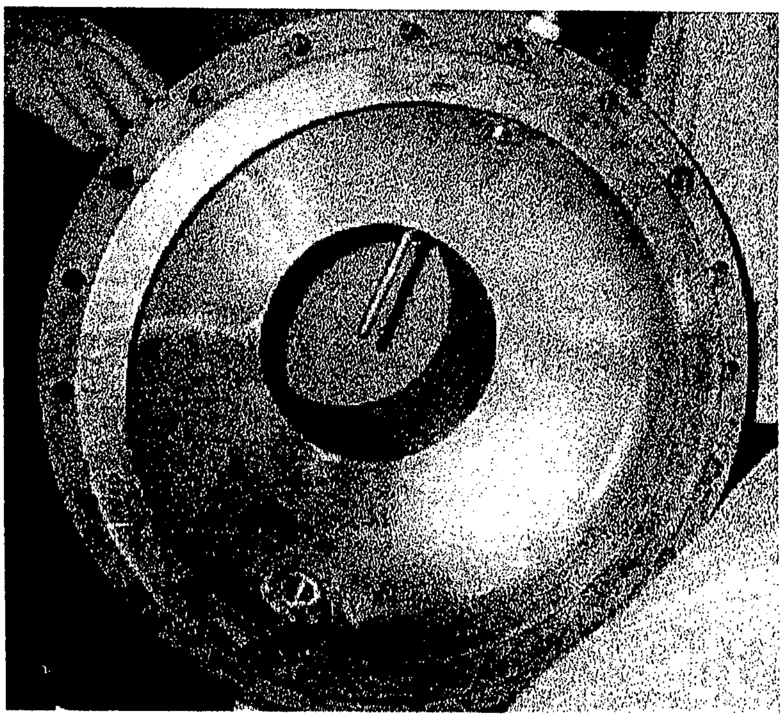


5.3 Photos

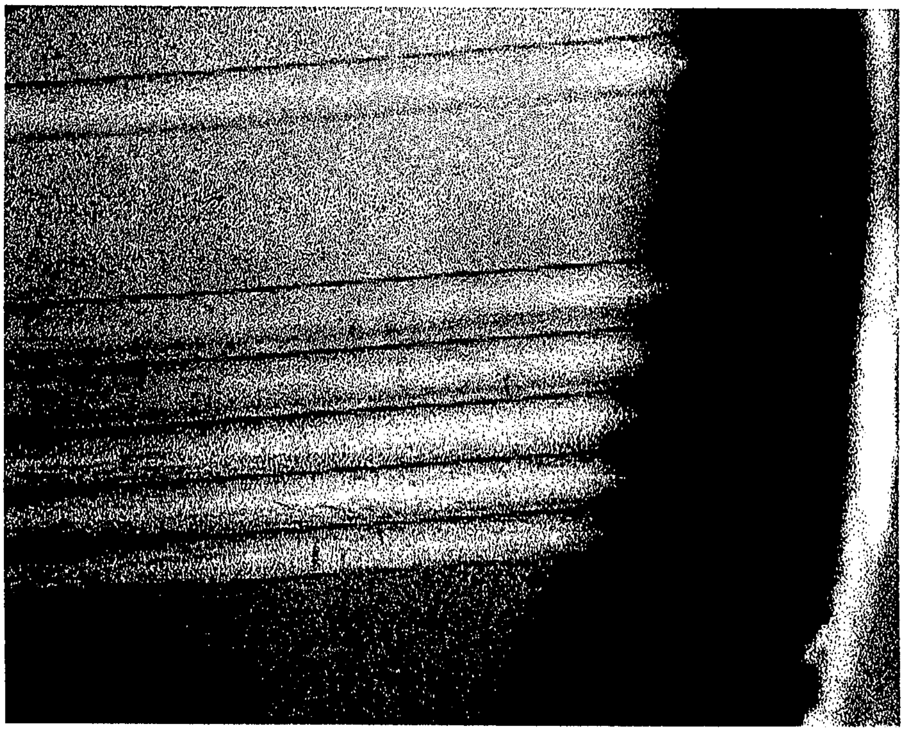
1 – Heat Exchanger "A" - B&W - Tube Beam/Secondary Water



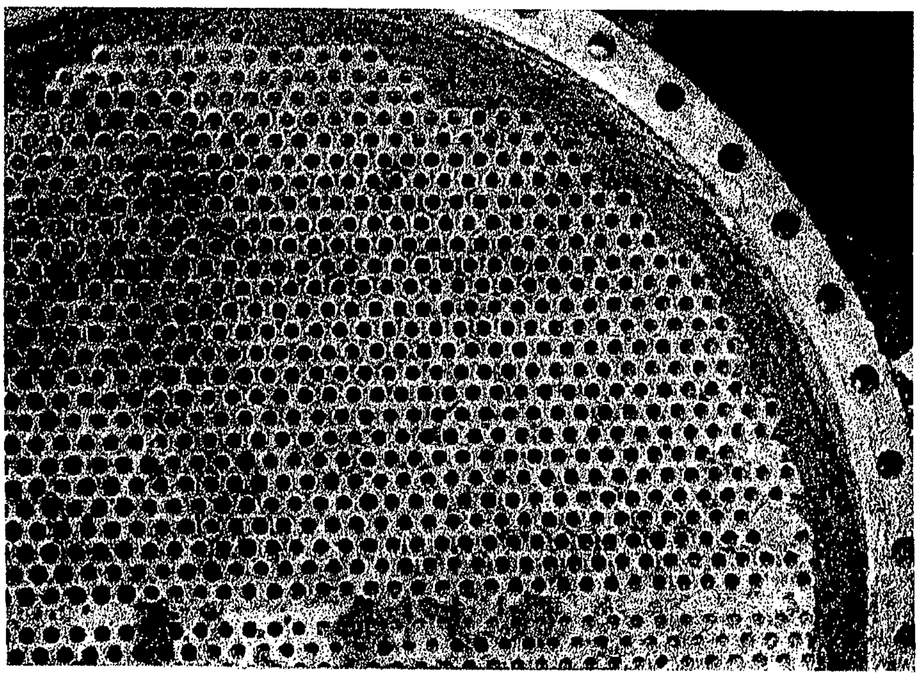
2- Heat Exchanger "A" - Cover Side/Primary Water



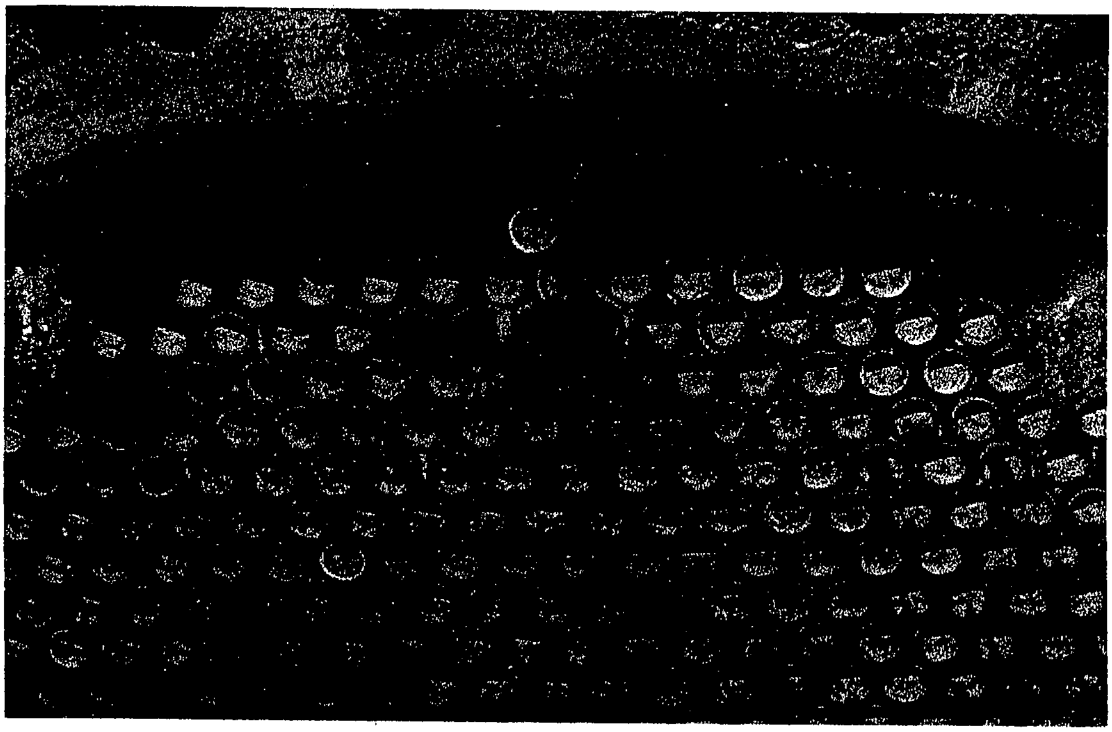
3 - Heat Exchanger "B" - CBC – Tube Beam/Primary Water



4 – Heat Exchanger - CBC – Flange Side/Secondary Water

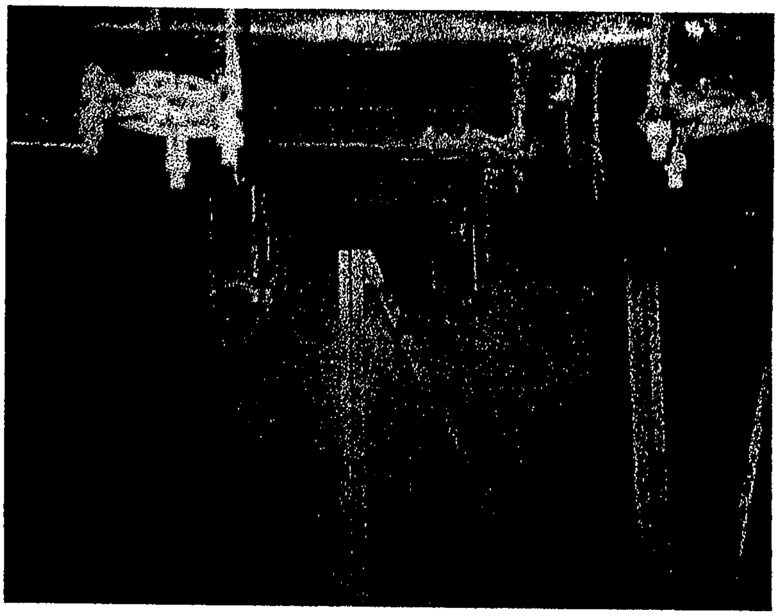


5 – Heat Exchanger CBC – Flange Side / Secondary Water

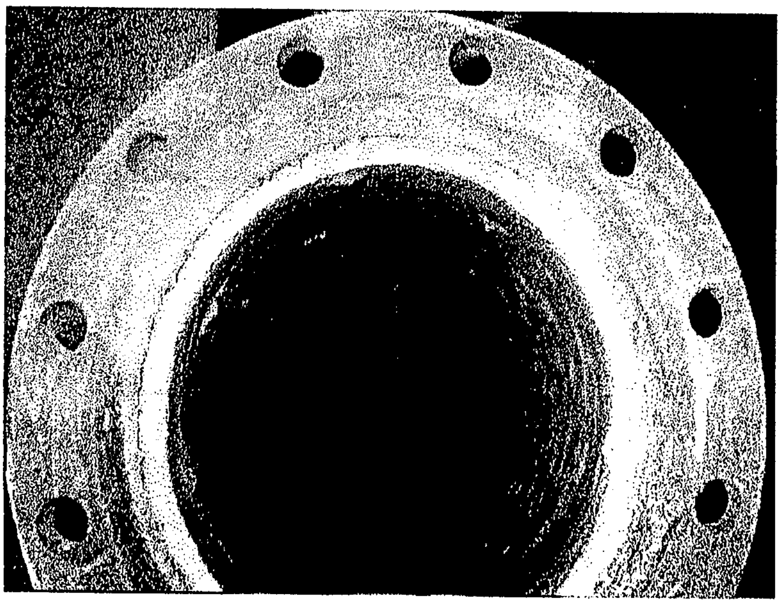


6 – Cooling Tower Structure- Secondary Water

7– Cooling Tower Sprinkles – Secondary Water



8– Secondary Piping



ipen

6. REFERENCES

[1] **IAEA-TECDOC 792** - "Management of Ageing in Nuclear Research Reactor", March, 1995.

[2] **IAEA- Services Series** - "Guidelines for the Review of Research Reactor Safety", December 1997.

[3] **IAEA- TECHNICAL REPORT 338** - "Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety", 1992.

[4] **IAEA ARCAL PROGRAM - 1999/2000** - PROJECT PROFILE - BRA007

[5] **Instituto de Energia Atômica** - RAS - Relatório de Análise de Segurança do IEA-R1, São Paulo, Maio de 1974.

[6] **Faloppa, A. A. & Ting, D.K.S.** – "Ageing Management Self Assessment Report of the IPEN IEA-R1 Reactor", presented at The Workshop on Ageing Management of Research Reactors, 2-6 of August, 1999, Santiago, Chile.

[7] **Faloppa, A. A. & Ting, D.K.S.** – "Safety of Research Reactors: Interim Ageing Studies", November 2000, Bariloche, Argentina.

[8] **Faloppa, A. A.** – "Safety of Research Reactors: Ageing Studies – Phase II", presented at The Workshop on Ageing Management of Research Reactors, 22 - 26 of October, 2001, São Paulo, Brasil.

[9] **Torres, Walmir M. & Baptista Filho, Benedito D.** – "Avaliação da redução de vazão nos trocadores de calor do circuito primário do reator IEA-R1." Relatório Técnico, 1999.

[10] **Soares, Adalberto J-** "Ageing Effects on specific structures Systems and Components of Research reactors" - ", presented at The Workshop on Ageing Management of Research Reactors, 22 - 26 of October, 2001, São Paulo, Brasil

[11] **Alvin de Castro, A.** – "Medidas de vibração do Trocador de Calor B do IEA-R1" Relatório Técnico, PSE.CEND.IEAR1.030.01 –RELT.001.00, 2002.

[12] **TEMA - Standards of The Tubular Exchanger Manufactures Association,** – Seventh Edition 1988.

OJ

Relatório

PTC 2002

IPEN/CNEN-SP
BIBLIOTECA
"TEREZINE ARANTES FERRAZ"

Formulário de envio de trabalhos produzidos pelos pesquisadores do IPEN para inclusão na Produção Técnico Científica

AUTOR(ES) DO TRABALHO:
Altair Antonio Faloppa
Daniel Kao Sun Ting

LOTAÇÃO: REC RAMAL:9198

TIPO DE REGISTRO:

art. / periód.:	X	Publ. IPEN		. resumo	
cap. de livro		Art. conf		outros (folheto, relatório, etc...)	

TITULO DO TRABALHO:
"SAFETY OF RESEARCH REACTORS: IEA-R1 AGEING MANAGEMENT"

APRESENTADO EM: (informar os dados completos - no caso de artigos de conf., informar o título da conferência, local, data, organizador, etc..)
Arcal LXVIII "Segurid de Ractores de Investigaciona - Gestion de Envejecimiento"
IPEN, LIMA, PERU - 25 - 29, Novembro, 2002 - AIEA

PALAVRAS CHAVES PARA IDENTIFICAR O TRABALHO:

Ageing Management, IEA-R1, Envelhecimento, Reatores de Pesquisa

ASSINATURA: [signature]

DATA: 23/12/2002

CENTRO DE ENGENHARIA NUCLEAR

MONITORAÇÃO E DIAGNÓSTICO

"SAFETY OF RESEARCH REACTORS: IEA-R1 AGEING MANAGEMENT"

Informe do "Taller Final sobre Envelhecimento de Reatores de Pesquisa" do Projeto ARCAL LXVIII

Artigo Científico
P&D.CEND.IAEA.002.00
ARTC.001.00

AUTOR	Rubrica	Data	VERIFICADOR	Rubrica	Data
Altair Antonio Faloppa	[signature]	23/12/02			
Daniel Kao Sun Ting	D. Ting	24/1/03			

APROVAÇÕES		Rubrica	Data
Chefe de Área	Daniel Kao Sun Ting	D. Ting	24/1/03
Lider	Daniel Kao Sun Ting	D. Ting	24/1/03
Gerente do Centro	Antonio Teixeira e Silva	[signature]	29/1/03

ARQUIVO	Vanda P. Costa	[signature]	13/1/03

FM-CEN-0502.001-001 V0