The IPEN ageing and modernization program for its research reactors

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Nuclear and Energetic Research Institute - IPEN;

Brazilian National Nuclear Energy Commission - CNEN;

Contents

Research Reactors in Brazil

Research Reactors in Brazil

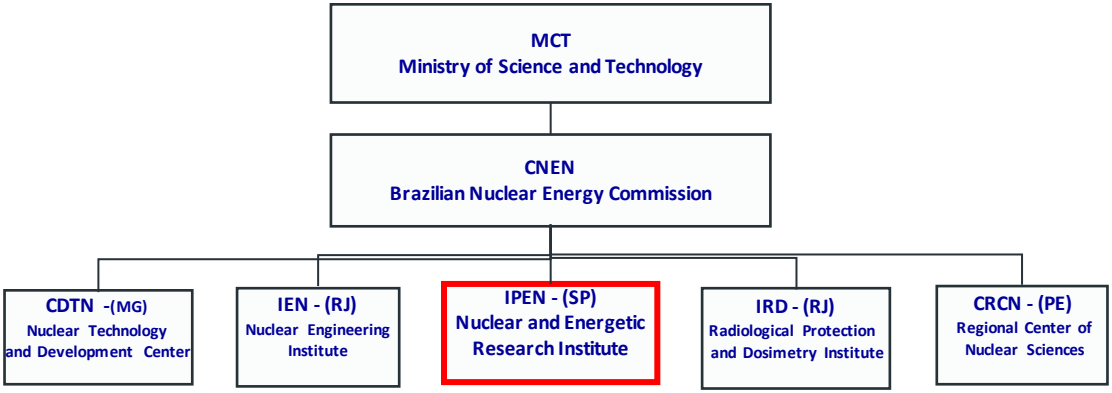
	IEA-R1	IPR-R1	Argonauta	IPEN/MB-01	RMB (under project)
Criticality	1957	1960	1965	1988	2026
Operator	IPEN-CNEN	CDTN-CNEN	IEN-CNEN	IPEN-CNEN	RMB-CNEN
Location	São Paulo-SP	Belo Horizonte-MG	Rio de Janeiro-RJ	São Paulo-SP	Iperó-SP
Type	Open Pool	Triga Mark-1	Argonaut	Critical Assembly	Open Pool
Power	5 MW	250 KW	500 W	100 W	30 MW
Fuel Enrichment	20%	20%	20%	20%	20%
Supplier	Babcock Wilcox	General Atomics	USDOE	IPEN	INVAP

CNEN is responsible for the operation of these reactors

IPEN is in charge of IEA-R1 and IPEN/MB01

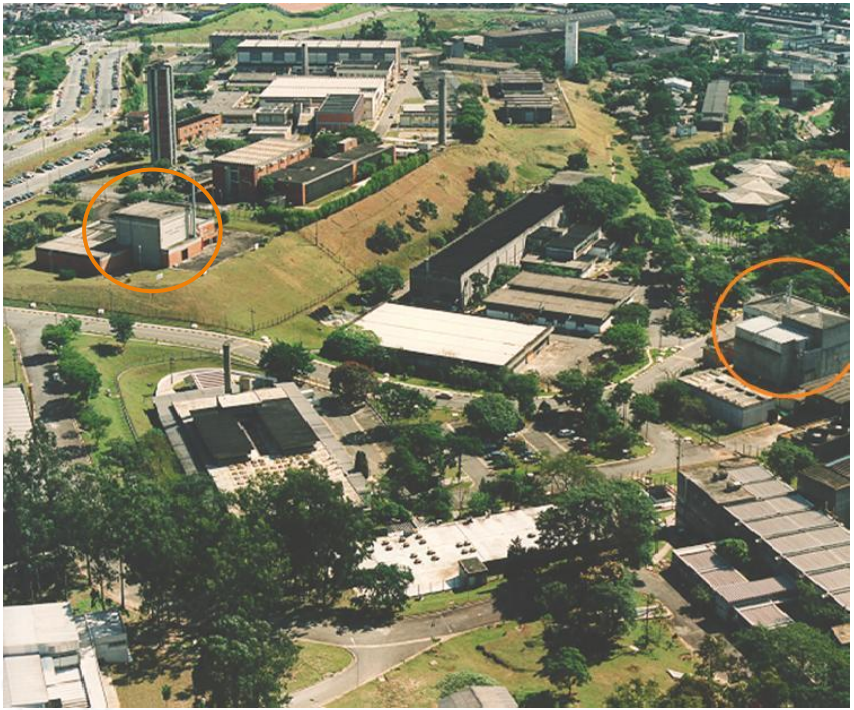
Brazilian National Nuclear Energy Commission - CNEN

- *Federal Government Autarchy under the Ministry of Science and Technology – MCTIC;*
- *Acts in Research and Development in the Nuclear Technology field, as well as rendering technological services and education;*
- ~~*Regulatory Board ;*~~



There are other (6) smaller units: Angra dos Reis District, Rio de Janeiro, RJ; Caetite District, Caetité, BA; Fortaleza District, Fortaleza, CE; CRCN-CO, Goiânia, GO; Planalto Central District, Brasília, DF; Laboratory Division of Poços Caldas, Poços de Caldas, MG.

Nuclear and Energetic Research Institute - IPEN



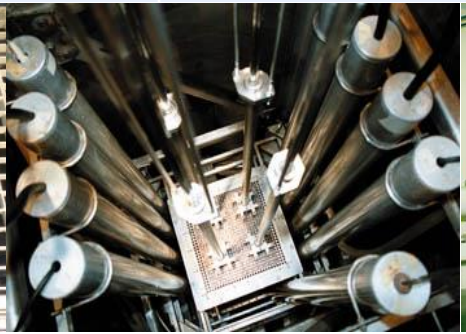
- ✓ *Located in the campus of University of São Paulo – USP*
- ✓ *Total area of about 500.000 m^2*
- ✓ *Total of 102.000 m^2 of building area;*
- ✓ *11 research Centers;*
- ✓ *About: 600 permanent staff;*
  200 Bachelor students
  400 PostGraduate students
  100 Post doc
  120 Volunteer

Total of 1420 workers

Nuclear and Energetic Research Institute - IPEN

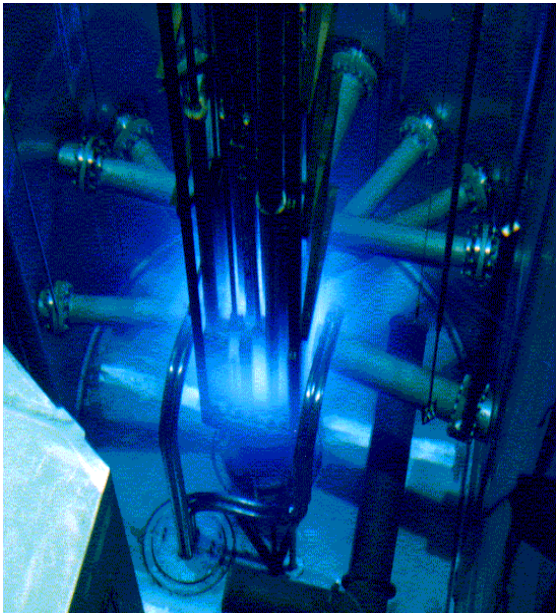
Main Facilities of IPEN

Nuclear	Radiactive
✓**IEA-R1 Research Reactor (1957 – 5MW)** ✓ **IPEN/MB-01 Reactor (1988 – 100W)** ✓ Fuel Factory	✓Cyclotron Accelerator (IBA Cyclone 30 - 1998) ✓ Cyclotron Accelerator (IBA 18/18 – under modification) ✓ Radiopharmacy unit (1959) ✓ Gamma Irradiation Co (2002); ✓ Table Top TeraWatt Laser (2005); ✓ *Unity of treatment and storage of radioactive waste.*



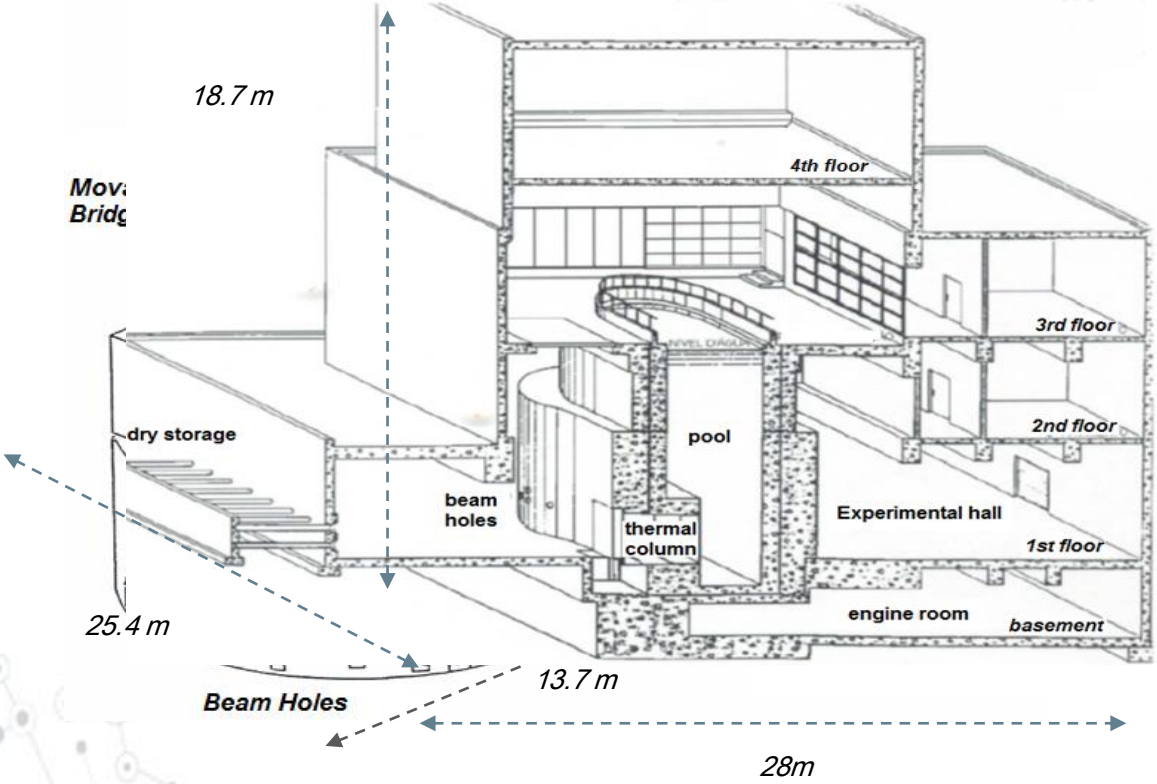
The IEA-R1 RR

The IEA-R1 RR- Main characteristics



- Constructor: Babcok-Wilcox;
- First criticality: September 16th, 1957;
- Type: open pool type reactor;
- Moderator and coolant: light water;
- Reflectors: graphite and beryllium;
- Operating power: 5MW;
- 8 radial and 1 tangential beam tubes;
- Thermal flux: 1×10^{14} n cm^{-2} s^{-1};
- Fuel elements: LEU made of U_3Si_2-Al, 3 $g.cm^{-3}$;
- control/safety rods of Ag-In-Cd alloy.

The NEAT-B1 building

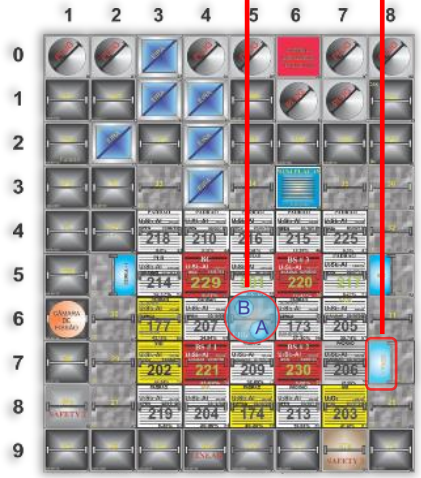


The IEA-R1 Core - irradiation devices

- **144 irradiation positions distributed in 9 irradiation devices**
  (5 water cooled irradiation element, 2 Water cooled beryllium irradiation elements, 1 Wire irradiation element and 1 Beryllium irradiation element)

Pos. 65 (Beryllium Irradiation Element)

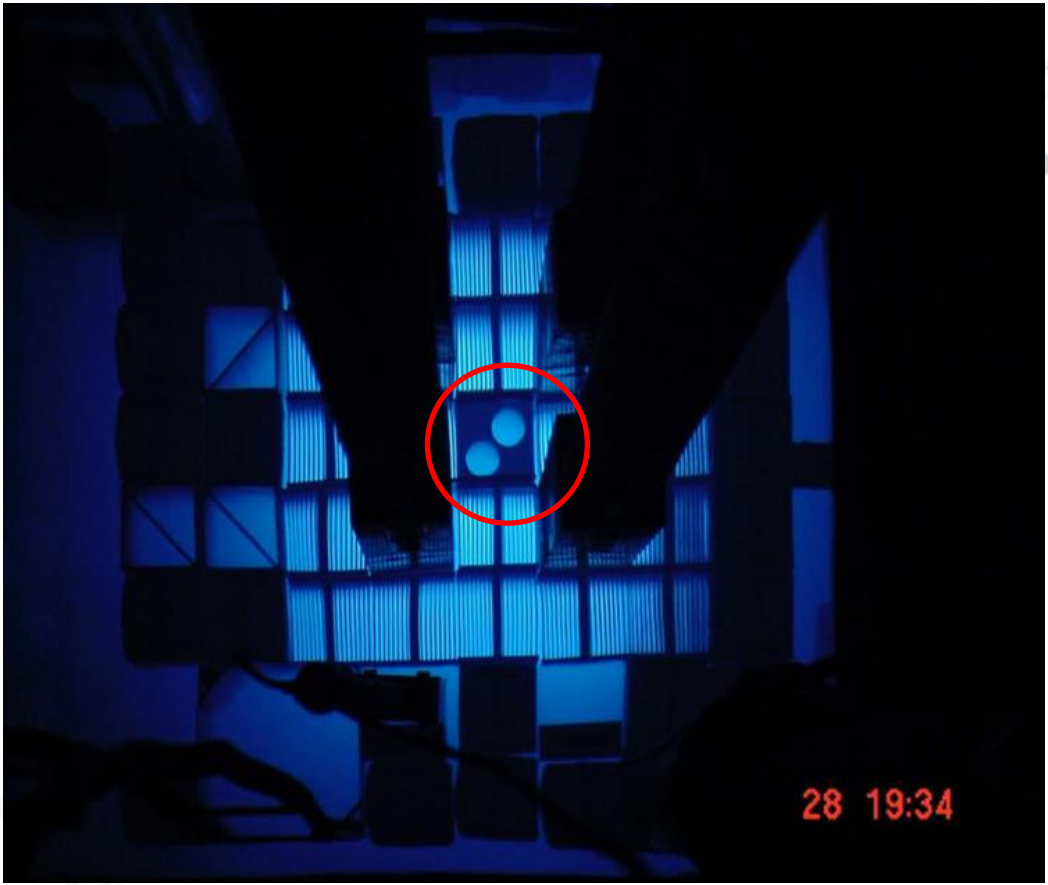
Side A	Side B
2,06E+13	1,05E+13
3,60E+13	2,31E+13
5,27E+13	3,60E+13
7,46E+13	5,79E+13
9,64E+13	7,97E+13
9,90E+13	9,39E+13
1,03E+14	1,09E+14
6,43E+13	8,49E+13



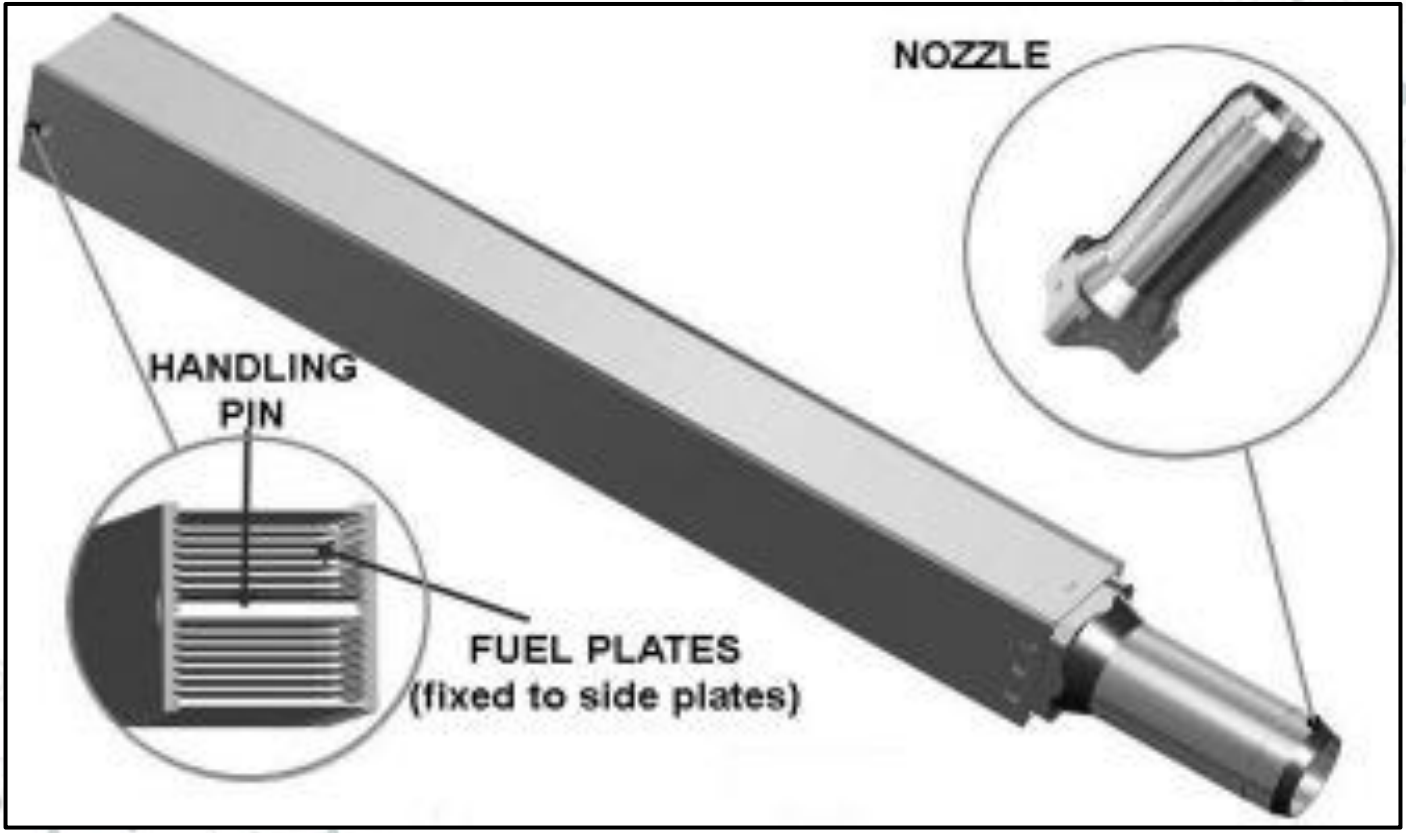
Pos. 58 (Water Cooled Beryllium Irradiation Elements)

Prat.
8,74E+12
2,31E+13
3,60E+13
4,89E+13
6,04E+13
6,56E+13
7,07E+13
5,91E+13

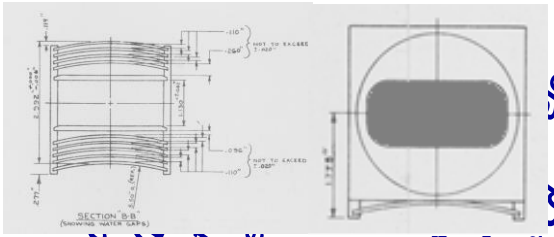
The IEA-R1 Core

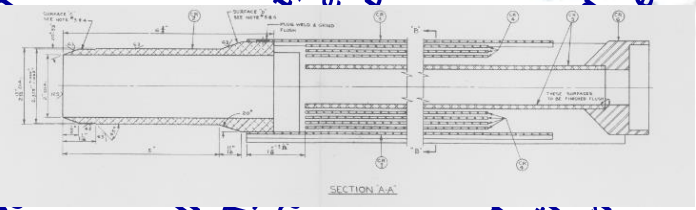


The IEA-R1 Core management timeline of fuel elements



The IEA-R1 Core management timeline of control bars





oval sh… carbide (… channels o… control fuel e…

Replaced… blades per… (4) of Ag-In-Cd, nic… plated by CER… element

Change al… (fork with A… plated,fabric…

4 (2) bars … covered wit… fabricated o… type …ed- …PEN) …-In-Cd …el,

1957

1968

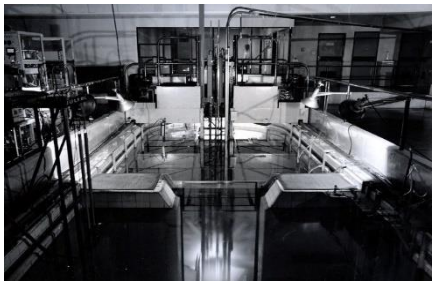
2003

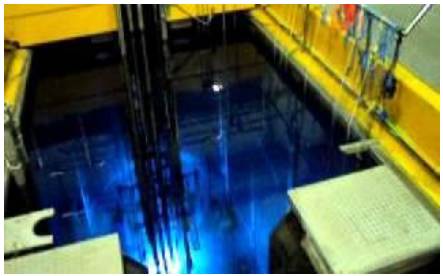
2022

The IEA-R1 maintenance and ageing program

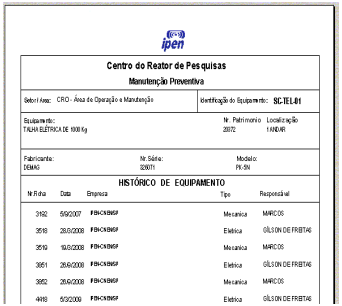
A large maintenance program with predictive, preventive and corrective maintenance, including calibration of documents, in order to meet national requirements. An in-house software help in the process-control.

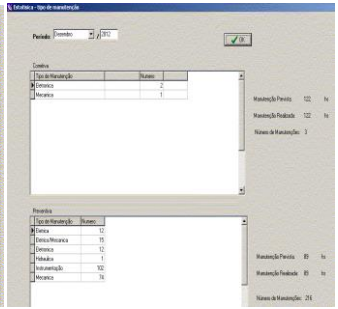
Throughout these 62 years a permanent modernization program is running which improved the reactor capability and refurbish all the componentes, always with the safety and reliable operation as a goal.

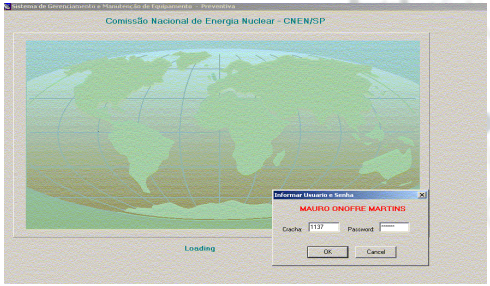




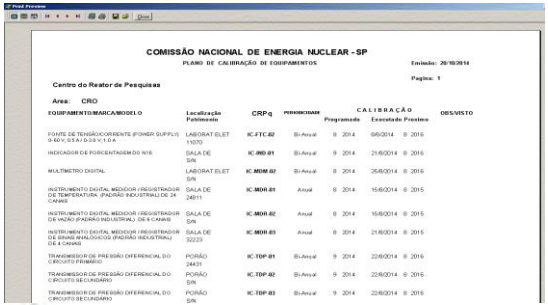
The Maintenance program software for control

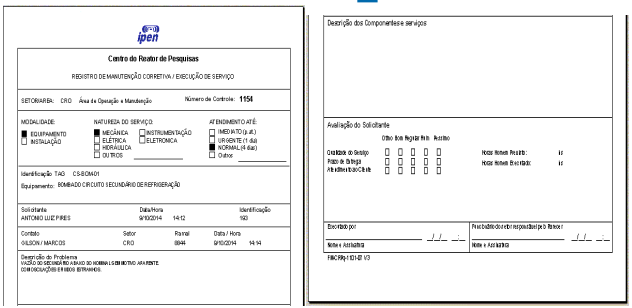






Preventive maintenance report





Calibration report

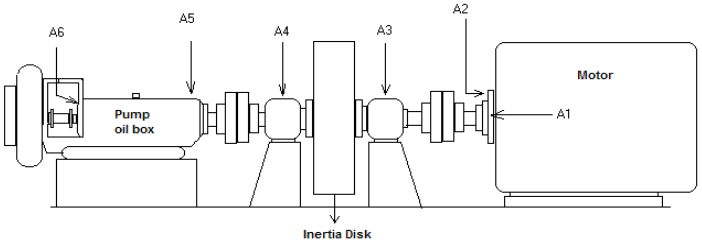
Corrective maintenance report

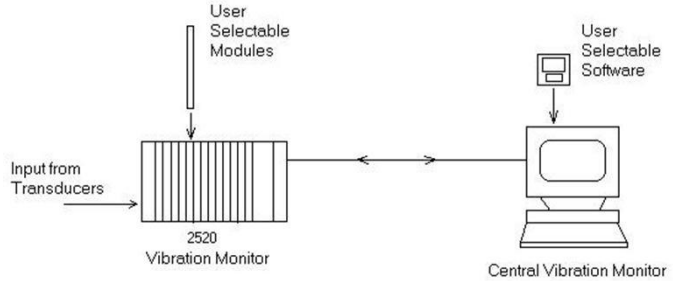
Maintenance Program
Operational Results

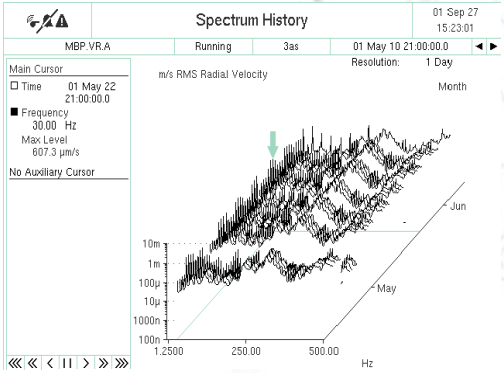
- *Preventive maintenance:*
  - *Total of equipment regitered: 1781.*
  - *Total preventive maintenance plans: 63 (54 equipment, 8 instalation and 1 ageing)*
- *Corrective Maintenance:*
  - *Total of CMR issued: 1174*
  - *Control console-118 and change of part of primary circuit-960 hours*
- *Calibration:*
  - *Total of instruments or meters on the caibration program: 200.*
  - *Shortest calibration interval: 1 year.*
  - *Longest calibration interval : 5 years.*

Maintenance Program
Predictive maintenance

- ***Primary circuit pumps monitoring***
- ***Secondary circuit pumps monitoring.***







Secondary Circuit Pumps Vibration Levels Verification

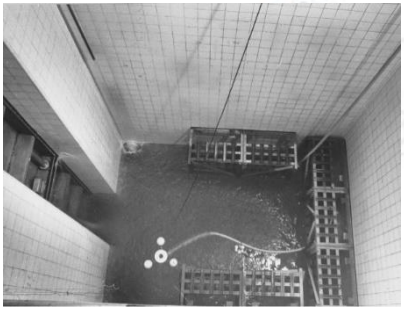
SISTEM: Vibration	**Evaluation Type:** Verification **Frequency:** Monthly	**IT/PO:** **Technical Specification:**
Goal: Ensure that the secondary circuit pumps are operating under satisfactory conditions.		
• **Necessary Conditions/ Special Care** Reactor in operation.		

Activity to be performed	Reference levels for RMSv (mm/s)		Results		
Measure vibration at the following points:			Pump:		
1.I (motor-radial housing): RMS and spectrum	Pump B102A	Pump B102B	B102A	B102B	
2.II (motor-axial housing): RMS and spectrum			MP (measured value):	S	US
3.III (engine bearing): RMS and spectrum					
4.IV (pump bearing): RMS and spectrum	1,20	1,20	I:		
Evaluation criteria:	0,90	0,90	II:		
If RMSv measured > 2 its reference level:	0,90	0,90	III:		
Perform more detailed analysis and keep the bearing under observation; it may be necessary corrective maintenance.	1,00	1,00	IV:		
If RMSv measured > 10 its reference level:					
NS condition, stop for corrective action.					
Abreviations:			Acellero meter:	TAG	
MP – Measurement Points			I		
VMS – Vibration Measurement System			II		
mm/s – millimeter per second			III		
US – Unsatisfactory			IV		
S – Satisfactory			VMS		
RMS – mean square or vibration effective value					
RMSv – RMS in speed, for a frequency band from 10Hz to 1000Hz					

Analyze:	
Conclusion:	
Evaluator(s):	**Signature and date:**
Disposition:	**Signature and date:**

The ageing program

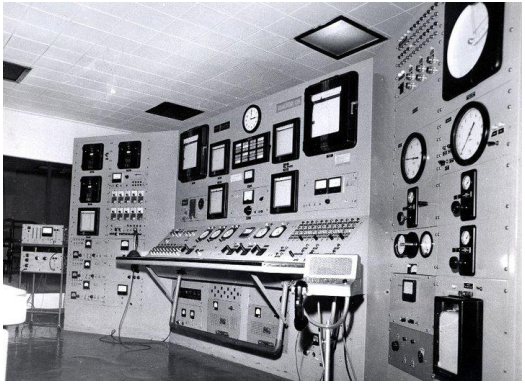
pool lining:1977-1978



The ageing program

control room

1957



1985

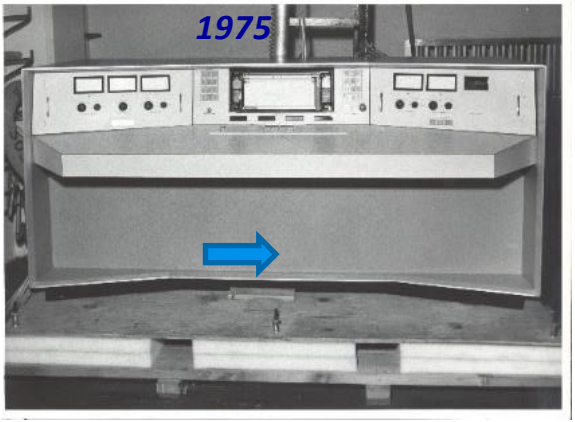
2011

The ageing program

control console - ongoing

1957

1975



2021 (?)

The ageing program

Cooling system

1974

2008

2014

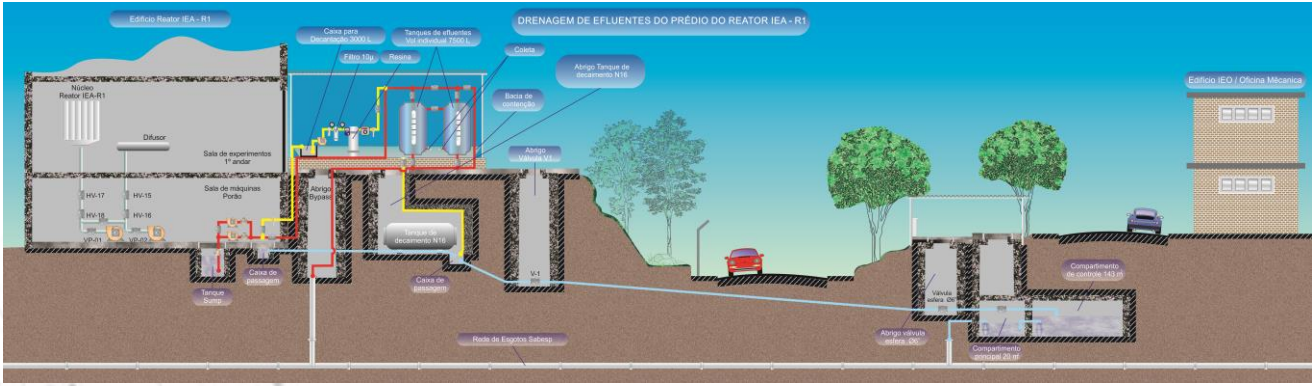
The ageing program

Cooling system

2014

2020

2020

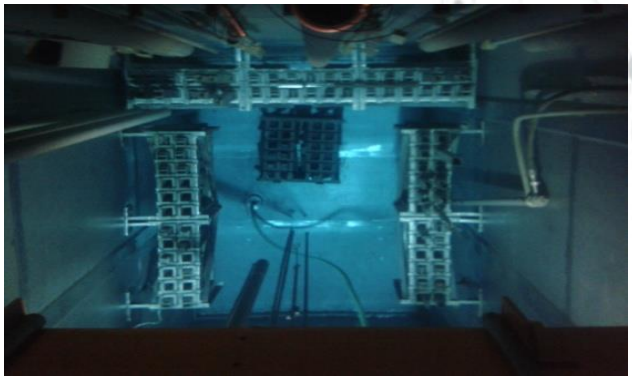


The ageing program

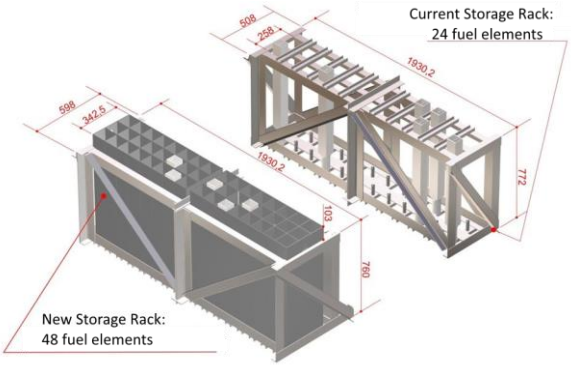
Spent Fuel Storage

1999 →127 s. f.e. returned to US

2007 →33 s. f.e. returned to US



2022 →ongoing new BORAL rack



Maintenance and Ageing program
QMS : Process based

Our activities were divided in 3 process;

I. Operation of the reactor;

II. Maintenance of the reactor;

III. Irradiation using neutrons.

Map of Process Sector: **CRPq/ CRO** Process: **MAINTENANCE OF THE IEA-R1 REATOR**

Goal: To maintain the reactor in operating conditions, complying with the relevant safety standards

WHO? (who take part in the process)	WITH WHAT? (Machines, Tools, Materials, Equipment, Hardware, Software, etc.)	WORK ENVIRONMENT
Maintenance Group Operation Team Companies hired to perform maintenance and calibration	Equipment, systems and components	Controlled environment from the point of view of dose and radioactive contamination

Supplierr (Input Process)	Input	PROCESS	Output	Client (Output Process)
Reactor Operation - Technical specifications	Preventive Maintenance Plan Calibration Plan Testing and Inspection Program Corrective Maintenance	The IEA-R1 reactor maintenance group supports the operation acting in: Control of equipment and systems (PG-CERPQ-1101) Preventive Maintenance Management (PG-CERPQ-1101 / Software PGE/ schedule) Calibration Program Management (Software PGE/ Schedule) Corrective Maintenance Management (Software PGE)	Equipment, systems and operating components, in order to allow the safe operation of the reactor Main records: Preventive and Corrective Maintenance Calibration Certificates Tests and Inspections	Reactor Opeation

how (INFORMATION)? (Procedures, Methods, Forms, Information, etc.)	Which METRIC is maintained to determine the effectiveness of the process? (Performance indicators)
PG-CRPq-1101 – Controle de Equipment conbtrol PO-CRO-1101 – Preventive maintenance Program of the IEA-R1 and WI PO-CRO-1003 – Tests and Inspections according to Technical Specifications and associated ITs IEA-R1 Reactor Safety Analysis Report	Number of operations at planned power / year Number of hours of operation / year Number of hours of operation performed / number of hours planned Dissipated energy / year

Process owner: **Assistant manager SEORE**

Rev	Data	Elaborate	Analyzed		Approved
00	10/10/2017	Alberto de Jesus Fernando	Mauro Onofre Martins	Rosemeire P. Paiva	Alberto de Jesus Fernando

The IPEN/MB-01 RR

Reactor History – First Core

- Construction Period : 1983 to 1988;
- Reactor totally designed by IPEN in partnership with the Brazilian Navy;
- First Criticallity : November 1988;
- First Core : 680 fuel rods (26x28 arrangement);
- Maximum Power Level: 100 watts;
- Enrichment : 4.3 %;
- Time operation: 30 Years (1988-2018);
- Total number of operation: 3663 (1988-2018) ;
- Operational Goals: 80% to reactor Physics Experiments , 15% to Educational Purposes and operators training and 5% to operational Purposes;

Reactor History – Second core

- *2015-1918 : Project of the new core ;*
- *Maximum Power Level: 100 watts*
- *Core Configuration : 4x5 Fuel Assembly;*
- *Number of fuel Assembly: 19 ;*
- *Enrichement: 19.75% (U_3Si_2-Al) ;*
- *Goal: Experiments comparison and validation (Benchmark) to methodology used to Project of the core of RMB reactor.*
- *First Criticality : March 2020*
- *Number of Operation : 17*

Reactor Preventive Maintenance

- *Some reactor systems are checked every two weeks, others every three months, every six months and others annually;*
- *Each 15 days the reactor shutdown to visual inspections and operational checks of its various systems and components;*
- *There are more than 50 maintenance activities checked by licensed reactor operators.*
- *When there is a need for predictive and corrective maintenance, companies with expertise in the area are hired to the job ;*
- *Air ventilation and conditioning system: Periodic exchange of air filters, gas of compressors, fan belts, valves limiting water flow. Monthly operational testing of chiller, cooling machines with the exchange of switches, gas recharging, carter oil, exchange of electrical resistances of the carter, etc.*
- *All maintenance records are kept for all life of the reactor for audits of the National Nuclear Regulator.*

Main Preventive Maintenances

- *Preamplifiers of the nuclear starting channels : Cleaning of contacts, bench test and eventual changes of electronic components;*
- *Control console : Cleaning of contacts, retightening connections, checking and changing indicators and lamps;*
- *Check the fall time of the control bars;*
- *Electronic radiological protection modules: Electronic modules are periodically calibrated and their operability is checked. In case of corrective maintenance its repair is carried out internally by reactor technicians;*
- *Nuclear Instrumentation Comparator Modules: Periodically, your operational set points are checked and calibrated within the annual reactor maintenance program;*

Modernization

The main upgrades that occurred to the new core with plate-type fuel elements:

Design, installation and commissioning of a new operational interlock system to allow the movement of control rods and filling of the moderator tank;

Design of a new step motor drive unit with interface to the reactor protection system and other components. Planned its installation in 2022.

New core - 4x5 with 19 fuel elements (IPEN) with Cd wires as burning poison. Adaptation to the dimensions of the moderator tank.;

Installation of heavy water reflectors confined in aluminum boxes positioned around the moderator tank with their respective feeding circuits.

Manufacture and installation of 4 hafnium plates to act as reactor control rods;

Design and manufacture of new preamplifiers for the reactor start-up channels;

Replacement of neutron detectors of starting channels for B-10 detectors, uncompensated ionization chamber-CINC by compensated ionization-CIC;

Water systems: Refurbishment of the reactor cooling towers used. Exchange of pumps of the condensing system of the towers; Exchange of pipes and valves. Maintenance of the solenoids of the quick-opening valves of the moderator tank.

Final remarks

- *IPEN has a large experience in Maintenance and Modernization of reactors;*
- *In 62 years of the IEA-R1 operation several things have changed (reactor power, its uses, the management, …);*
- *All the IPEN RR changes are guided by safety aspects;*
- *They are high quality facilities with components continuously renewed;*
- *The permanent staff have been gradually exchanged by an outsourced workforce;*

THANKS FOR YOUR ATTENTION!