Research Reactors in Latin America and the Caribbean

IAEA
International Atomic Energy Agency

Contents

Introduction

Research reactors offer a diverse range of products and services. These include academic research, education and training, nuclear engineering and design as well as numerous applications, such as those used in medicine, agriculture, environment and industry. In many instances research reactor operating organizations serve also as Technical Support Organizations for nuclear utilities and national safety authorities.

This brochure provides a synopsis of the main research reactor activities in the Latin America and the Caribbean region. Contact information for each facility is also included.

Nine countries of the region have so far operated a research reactor. The first such facilities were introduced in the mid-1950s when Argentina and Brazil decided to launch nuclear power programmes.

Argentina chose to design and construct the reactors with its own technology, and this approach enabled the country later on to export its indigenous reactor designs to the region and beyond. The other eight countries opted to import research reactors from foreign suppliers, in the framework of bilateral agreements for the peaceful uses of atomic energy. In three Member States (Argentina, Brazil, and Mexico), the research reactors supported the deployment of nuclear power programmes.

As of July 2017, 16 research reactors are in operation in seven countries of the region (see Table 1[1]).

Table 1: RESEARCH REACTORS IN OPERATION
IN THE LATIN AMERICA AND THE CARIBBEAN REGION

Country	Name	Type	Power (kW)	Maximum neutron flux (s^{-1} cm^{-2})
Argentina	RA-0	Tank	0.001	1.0×10^{7}
Argentina	RA-1	Tank	40	1.0×10^{12}
Argentina	RA-3	Pool	10000	2.2×10^{14}
Argentina	RA-4	Homogeneous	0.001	6.0×10^{7}
Argentina	RA-6	Pool	1000	1.5×10^{13}
Brazil	Argonauta	Argonaut	0.5	1.0×10^{10}
Brazil	IEA-R1	Pool	5000	1.0×10^{14}
Brazil	IPEN/MB-01	Pool	0.1	1.0×10^{9}
Brazil	IPR-R1	TRIGA Mark I	100	4.3×10^{12}
Chile	RECH-1	Pool	5000	6.0×10^{13}
Colombia	IAN-R1	Converted TRIGA	30	7.8×10^{11}
Jamaica	UWI CNS SLOWPOKE	SLOWPOKE	20	1.2×10^{12}
Mexico	Nuclear-Chicago Mod 9000	Subcritical assembly	0.0	3.2×10^{4}
Mexico	TRIGA Mark III	TRIGA Mark III	1000	3.3×10^{13}
Peru	RP-0	Critical assembly	0.001	1.0×10^{7}
Peru	RP-10	Pool	10000	1.5×10^{14}

[1] IAEA Research Reactor Data Base (RRDB), https://nucleus.iaea.org/RRDB/.

In addition:

- Venezuela operated a research reactor, which is now in permanent shut down status. The basement of the reactor building was converted into an industrial gamma irradiator.
- Uruguay operated a research reactor, which has already been decommissioned.
- Argentina, presently with 5 research reactors in operation, has decommissioned one facility and has another under permanent shutdown.
- Mexico, presently with 2 research reactors in operation, has decommissioned one low power facility and has one subcritical facility under extended shutdown.
- Chile, presently with one research reactor in operation, has another facility in permanent shutdown.

Research reactors have made important contributions to the region in academia as several are located in university campuses. Experiments at research reactors support nuclear engineering, physics and chemistry curricula, while in some cases the low power training research reactors serve as the foundation for training nuclear power plant operators and regulators.

An important recent regional initiative is the IAEA's Internet Reactor Laboratory (IRL) project. With the RA-6 research reactor in Argentina, as a host institution, experience in research reactor operation and experiments can be transmitted live to any location (guest institution) via the internet. This grants interactive online access around the world to a powerful educational tool. The project primarily targets countries that have no research reactors but are interested in including reactor physics in their education and training curricula.

IRL demonstration at RA-6 research reactor in Argentina (CNEA)

Neutron activation analysis (NAA) and neutron beam based techniques such as neutron radiography and neutron scattering significantly contribute to materials characterization and non-destructive testing in cultural heritage, health and environmental monitoring as well as various industrial sectors, leading to safer and more efficient products. Many research reactors in the region have concluded successful partnerships with other research organizations, academia as well as diverse industries for these purposes.

Fission track dating laboratory at the Mining and Energy Planning Unit (UPME) in Colombia

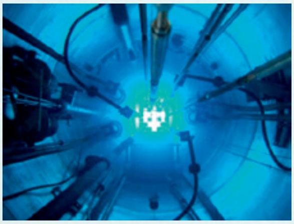
Radioisotope production, both for medicine and industrial sectors, is another prominent service ensured by research reactors in the region. Several research reactor facilities have spearheaded campaigns to try making the Latin America and the Caribbean region self-sufficient in the production of various radioisotopes such as $^{99}Mo/^{99m}Tc$, ^{131}I and ^{192}Ir. With a diversity of designs and power ratings, the region's research reactors are uniquely poised for this endeavour.

Another strong feature among the research reactors of Latin America and the Caribbean region is their firm commitment regarding nonproliferation. As well as being parties to the Treaty on the Non-Proliferation of Nuclear Weapons, all countries operating research reactors are part of a nuclear-weapon-free zone under the Treaty of Tlatelolco, which prohibits the use, production, storage and transport of nuclear weapons in the region. Additionally, all the facilities in the region operate with low enriched uranium (LEU) fuel. Within the last decade, Argentina, Brazil, Chile, Colombia, Jamaica and Mexico returned their stockpiles of highly enriched uranium (HEU) to the country of origin, affirming a regional commitment to fuelling research reactors with LEU.

There is high potential for increased use of existing research reactors in the region, as well as for new facilities to be built. Argentina and Brazil have developed a joint plan for new, indigenous, high power multipurpose research reactors: the RA-10 in Argentina is under construction and the RMB in Brazil is in an advanced design phase. Bolivia is initiating a project to have its first research reactor (low power) on the basis of a turnkey purchase from a non-regional supplier.

Hot cells (top) to prepare radiopharmaceuticals (bottom) after irradiation of various target materials at the Peruvian research reactor (IPEN)

RA-6



RA-6 reactor building (left) and reactor core during operation (right)

Located at the Bariloche Atomic Centre in the southwest of the country, the RA-6 reactor is owned and operated by Argentina's National Atomic Energy Commission (CNEA). It was designed and built by CNEA and commissioned in October 1982. Originally designed as an education and training reactor to support nuclear engineering and research at the Balseiro Institute, the RA-6 served for other uses and applications in its lifetime. Under the Global Threat Reduction Initiative its core was converted from HEU to LEU, providing an opportunity to optimize its applications and increase the neutron flux in the core and at the irradiation facilities. In addition, under a modernization and power upgrade project from 2007 to 2009, some structures, systems and components were modified or replaced in order to improve safety and reliability and increase maximum thermal power.

Technical features

- Pool type reactor with a maximum thermal power of 1 MW
- 19.7% enriched uranium silicide MTR fuel
- A maximum thermal flux of 1.5×10^{13} $cm^{-2}s^{-1}$
- Cooled and moderated by demineralized light water
- Graphite reflector
- 4 Ag-In-Cd coarse regulation control rods and 1 fine regulation control rod
- 5 radial and 2 in-core irradiation sites
- A pneumatic transport system
- 1 hot cell

Products and Services

The RA-6 reactor is used for a number of purposes, including research and development in reactor physics and nuclear engineering, education and training, Boron Neutron Capture Therapy (BNCT), NAA, neutron radiography, instrumentation and control testing and materials irradiation.

Argentina

Education and training

- Reactor design related research
- Hands-on-training courses and experiments
- RA-6 online, a part of the IAEA Internet Reactor Laboratory project, provides a data acquisition system and web platform for demonstrating reactor operation and experiments for distance learning

Neutron experiments

- NAA for biological, geological and environmental studies with a fast transfer pneumatic system
- NAA analyses of short and long-lived radionuclides
- Neutron radiography and tomography of hydrogen storage materials, glue-bonded metals, paints and zirconium alloys
- Neutron radiography and tomography for archaeological and paleontological studies of cultural heritage

Boron Neutron Capture Therapy

- RA-6 utilizes a neutron beam with thermal–hyperthermal composition
- Treatment of shallow tumours as in melanoma in the extremities of human patients and head and neck tumours in dogs and cats
- In vivo and in vitro experiments with hamsters and mice

Future Plans

In order to expand the range of uses for the RA-6 reactor, two projects are currently under development:

- A prompt gamma neutron activation analysis (PGNAA) facility for samples of less than 1 g of geological, atmospheric, biological and archaeological materials
- A neutron diffraction facility to study residual strain of materials used in academic and industrial applications.

Contact Information

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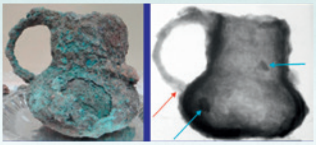
RA-6 control room



Study of a pottery artifact by neutron radiography

BNCT application facility

RA-6 reactor

RA-4

RA-4 reactor (left) and its control room (right)

The RA-4 reactor was installed at the National University of Rosario in November 1972. It is a homogeneous reactor with a maximum power of 1 W. Its core is a circular plate arrangement reflected by graphite. The plates are composed of a homogeneous mixture of U_3O_8 (<20% enriched) and polyethylene. The reactor was specifically designed for use in education and training.

Technical Features

- Homogeneous tank type reactor with a maximum thermal power of 1 W
- Homogeneous mixture of U_3O_8 (<20% enriched) and polyethylene plate type fuel-moderator
- A maximum thermal flux of 6.0×10^7 $cm^{-2}s^{-1}$
- Air cooled
- Graphite reflector
- 2 Cd plate control rods
- 6 irradiation sites
- Operates 4 hours per day

Products and Services

RA-4 is used exclusively for education and training in nuclear technology. It provides these services for operators, maintenance and support personnel, students and researchers.

Future Plans

Replacement of the nuclear and conventional instrumentation is expected.

Contact Information

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RA-3


RA-3 reactor building (left) and reactor core during operation (right)

The RA-3 reactor is owned and operated by the CNEA and is located at the Ezeiza Atomic Centre near Buenos Aires. It was designed and built by CNEA and commissioned in December 1967. Although other uses have been developed in its lifetime, the reactor mainly was ensuring radioisotope production and NAA. RA-3 originally operated as a 3 MW reactor with an HEU core, but conversion to LEU was achieved in 1989. This also included modification and replacement of systems in order to support an upgrade to 5 MW power. Without significant interference in radioisotope production, the reactor power was continuously upgraded from 1985 to 2004, resulting in present operation at 10 MW. The central irradiation facility in the reactor's thermal column yields a gamma dose rate of 5 Gy/h and a thermal flux of 10^{10} $cm^{-2}s^{-1}$, while the other channels are used for fission tracks and nuclear instrumentation testing.

Technical Features

- Pool type reactor with a maximum thermal power of 10 MW
- 19.75% enriched U_3O_8 fuel
- A maximum thermal flux of 2.2×10^{14} $cm^{-2}s^{-1}$
- Cooled and moderated by demineralized light water
- Graphite reflector
- 4 Ag-In-Cd coarse regulation control rods
- 6 in-core vertical irradiation sites and a thermal column
- A pneumatic transfer system
- 1 hot cell

Products and Services

Radioisotope production

- Fission-produced ^{99}Mo and ^{131}I
- Production of ^{51}Cr, ^{32}P, ^{153}Sm, ^{192}Ir and ^{177}Lu

Irradiation services

- NAA
- In vitro, in vivo and auto-radiography studies for BNCT
- Testing, qualification and calibration of nuclear instrumentation
- Nuclear fuel and material testing
- Irradiation of geological samples for thermos-chronology studies

Education and training

- Demonstrations and experiments for nuclear engineering students at the Nuclear Technology Institute Dan Beninson

RA-3 control room

Hall with crane apparatus

Future Plans

In order to expand the range of uses for the RA-3 reactor, three projects are currently under development:

- A prompt gamma neutron activation analysis (PGNAA) facility will be used for the detection of various elements. The thermal neutron flux at the sample position is currently 3.2×10^7 $cm^{-2}s^{-1}$
- A new irradiation loop device will allow for the testing of nuclear fuel rods at nuclear power plant conditions (e.g. power density, pressure, temperature and water chemistry)
- Upgrades to the neutron radiography facility will allow for the creation of online digital images.

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Argentina

RA-1

In 1957, Argentina's government decided to build its first nuclear research reactor. After a nine month construction, the RA-1 reached its first criticality in January 1958, with fuel obtained from the US. This was the first indigenous reactor in the region and marked a fundamental milestone in the region's history of nuclear energy.

The facility is located at the CNEA's Constituyentes Atomic Centre (CAC) in Buenos Aires province. It is an open tank type reactor with an authorized 40 kW thermal power rating and a 19.71% enriched uranium core. The RA-1 reactor produced the first radioisotopes for medical and industrial applications in the country. Additionally, it pioneered the training of human resources for the projects to construct three nuclear power plants in Argentina.

Technical Features

- Open tank type reactor with a maximum thermal power of 40 kW
- 19.71% enriched uranium oxide fuel
- A maximum thermal flux of 1.0×10^{12} cm^{-2}s^{-1}
- Cooled and moderated by demineralized light water
- Graphite reflector
- 4 Cd plate control rods
- 6 irradiation sites
- Operates, according to demand, an average of 160 days per year.

Products and Services

RA-1 offers a wide range of applications, such as neutron beam research for material studies and non-destructive analysis, NAA, neutron irradiation for materials testing for nuclear power plants and other groups, testing of nuclear detectors and instrumentation and mineralogy research. Another important area is its contribution to education and training in nuclear technology of operators, maintenance and operational staff of nuclear facilities, radiation protection personnel, students and researchers.

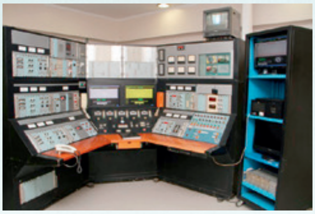
Education and training

- Training practices for the qualification and retraining of nuclear professionals and technicians
- Experiments for university and high school students

RA-1 reactor

Irradiation services

- Mineralogy studies
- Dosimetry research for BNCT
- Irradiation of in vitro cells and boron-treated tumours in animals for BNCT
- Irradiation of biological tissue to detect contaminants and other trace-elements
- Determination of material damage by irradiation of various materials and objects
- NAA for heavy metal, liquid, air and organic samples
- Radionuclide production for applications in the oil industry



Control room

Research and development

- Nuclear detector testing
- Testing and calibration of instrumentation and control systems and mixed field dosimeters
- Calibration of radioprotection equipment

Instrumentation over the RA-1 core

Future Plans

A change of fuel elements and increasing reactor power to 160 kW is projected. This increase in power will expand the reactor's range of services.

Contact Information

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RA-0

RA-0 core (left) and its control room (right)

The RA-0 research reactor was installed in the National University of Córdoba in 1965. The facility normally operates at very low power of 1 Watt. Consequently, it does not really need a cooling system to remove the very low heat produced. The main uses are related to research and training.

Technical Features

- Typical thermal power of 1 W and up to 10 W for short periods of time
- 19.71% enriched UO_2 fuel
- Maximum thermal flux of 10^7 $cm^{-2}s^{-1}$
- Cooled and moderated by demineralized light water
- Graphite reflector
- 4 Cd plate control rods
- 6 irradiation sites
- Operates 4 hours per day

Products and Services

The reactor provides education and training services in nuclear technology for operators, maintenance personnel, students and researchers.

Future Plans

The nuclear and conventional instrumentation will be replaced, and the design of a new MTR type core is underway.

Contact Information

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ARGONAUTA

Argonauta reactor building (left) and the reactor (right)

The Argonauta reactor (IEN-R1) achieved first criticality in February 1965 at the Nuclear Engineering Institute (IEN) on the campus of the Federal University of Rio de Janeiro. It is owned and operated by the National Nuclear Energy Commission (CNEN). The reactor operates an average of 350 hours per year.

Technical Features

- Tank type reactor with a maximum thermal power of 500 W (typically 340 W)
- Eight 19.91% enriched MTR plate type fuel elements
- A maximum thermal flux of 10^{10} $cm^{-2}s^{-1}$
- Cooled and moderated by light water
- Graphite and water reflectors
- 6 Cd plates (3 safety and 3 control)
- 15 radial and 1 tangential beam tubes
- 18 in-core irradiation positions
- A pneumatic transfer system for short term irradiations
- Operates at maximum 8 hours per day, 5 days per week

Products and Services

Education and training

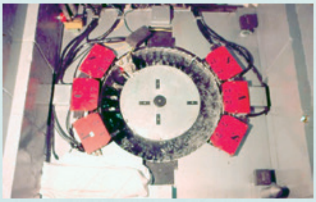
The Argonauta reactor serves a network of researchers from several universities and research institutions, mainly in Rio de Janeiro. The reactor is utilized for graduate and postgraduate courses in nuclear engineering and medical physics, contributing to many dissertations and theses. Training courses are offered for nuclear reactor operators, applications for technological development and industry, especially in the gas/oil and aerospace industries. The reactor facility is also hosting guided visits for high school, graduate and undergraduate students.

Irradiation services

- Production of ^{40}Ar, ^{79}Kr, ^{82}Br and ^{203}Hg for industrial applications
- Neutron radiography for aerospace applications
- Neutron activation analysis of various materials and samples

Research and development

- Radiotracer production for industrial applications
- Neutron diffractometry
- Neutron imaging by radiography and geochronology
- Nuclear data measurements and instrumentation development
- Radiation protection simulations



Core of the Argonauta reactor

Argonauta reactor control room

Future Plans

In 2017 a project was launched for adapting and modernizing the reactor and associated laboratories for the purpose of life extension and introducing new research areas, which include, among others:

- New applications of neutron radiography for industry and medical science
- Research in the production of radioisotopes for medicine
- New laboratories and associated equipment

Contact Information

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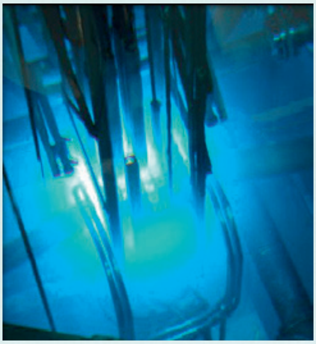
IEA-R1



IEA-R1 core

IEA-R1 facility

The IEA-R1 reactor is located at the Nuclear and Energy Research Institute on the University of São Paulo campus (IPEN USP). It was designed and built by the USA under the Atoms for Peace programme according to specifications from the National Nuclear Energy Commission (CNEN). The reactor achieved its first criticality in September 1957 and was converted to run on LEU fuel in 1997. Until today, IEA-R1 is the most powerful (5MW) research reactor in Brazil. As the main multipurpose facility at the Research Reactor Centre (CRPq), it is used for basic and applied research in nuclear and neutron beam science, as well as the production of radioisotopes for industry and nuclear medicine, reactor operator training and public visits.

Technical Features

- Pool type reactor with a maximum thermal power of 5 MW
- Twenty four 19.7% enriched MTR plate type fuel elements
- A maximum thermal flux of 10^{14} $cm^{-2}s^{-1}$
- Cooled and moderated by light water
- Graphite and beryllium reflectors
- 4 Ag-In-Cd fork type control rods
- 8 radial and 2 tangential beam tubes
- 144 in-core irradiation positions
- 2 short term pneumatic irradiation positions
- 1 large sample irradiation position
- Pneumatic transfer system to the radiopharmacy centre
- Operates 8 hours per day, 4 days per week

Brazil

Products and Services

Research and development

- Thermal and epithermal NAA
- High resolution neutron diffractometry
- Neutron imaging by radiography
- Geochronology
- Nuclear data measurements and instrumentation development
- Boron Neutron Capture Therapy (BNCT) studies

Irradiation services

- Production of ^{131}I, ^{153}Sm and ^{192}Ir for medical applications
- Production of ^{40}Ar, ^{79}Kr, ^{82}Br and ^{203}Hg for industrial applications
- Neutron transmutation doping for semiconductor manufacturing
- Production of calibrated standard sources and reference materials

Education and training

- Reactor operator training
- University level education and training
- Guided visit programme for graduate and undergraduate students

Future Plans

The IEA-R1 reactor maintains a continuous modernization programme that provides periodic upgrades to equipment and broadens the utilization of the reactor, including:

- Installation of a digital control console and beryllium neutron flux trap irradiation device
- Exchange of fuel plates and support trellis
- Research and development on ^{99m}Tc production by neutron capture and on an irradiation system for gaseous radioisotope production (e.g., ^{41}Ar, ^{79}Kr).

Contact Information

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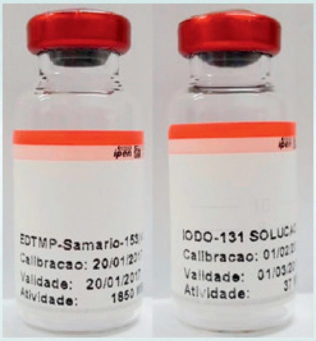
High resolution neutron diffractometer

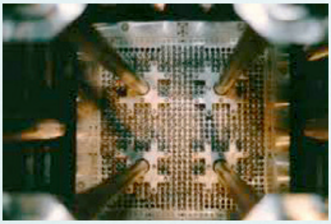


^{153}Sm and ^{131}I capsules

Applied physics demonstration

IEA-R1 control room

IPEN/MB-01

IPEN/MB-01 reactor building (left) and reactor core (right)

IPEN/MB-01 is a zero power reactor that first achieved criticality in November 1988. Its maximum power rating is 100 W. The reactor is operated by the IPEN USP and used for the acquisition of experimental data for the validation of nuclear reactor core design calculation methodology as well as education and training of licensed nuclear reactor operators . The current staff includes 18 licensed operators.

Technical Features

- Critical assembly with a maximum thermal power of 100 W
- 680 LEU fuel rods
- A maximum thermal flux of 10^9 $cm^{-2}s^{-1}$
- Cooled and moderated by light water
- 2 Ag-In-Cd control rods and 2 B_4C safety rods
- Operates an average of 130 days per year

Products and Services

Research and development

- Validation of reactor physics calculations
- Development of experimental techniques for reactor physics benchmarks
- Measurements of neutron flux distribution
- Measurements of neutron spectra and spectral indices
- Measurements of sample reactivity

Education and training

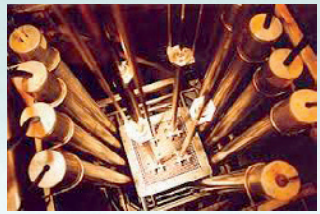
- Experiments for graduate and postgraduate courses
- Training and certification of nuclear power plant operators
- Training and certification for the National Nuclear Energy Commission (CNEN) and the Brazilian Navy

Future Plans

After 28 years of operation, a new core installation is expected in 2018–2019. IPEN/MB-01 will remain a zero power reactor with a 100 W maximum power, and its actual services will be unaffected. The new core will have the following features:

- 19 plate type fuel elements in a 5×4 arrangement, manufactured by IPEN USP
- U_3Si_2 fuel enriched to 19.75% ^{235}U

Control panel



Irradiation channels

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IPR-R1

IPR-R1 building (left) and reactor core (right)

The IPR-R1 is a TRIGA research reactor in operation since November 1960. It was originally part of the Radiation Research Institute of the Federal University of Minas Gerais School of Engineering. It is now operated by the Nuclear Technology Research Centre (CDTN), one of the major research institutes under the National Nuclear Energy Commission (CNEN). For a few years, it was also operated by the state owned company Nuclebrás. During its long history the reactor has been mainly a teaching and research facility, but it has also been used for occasional isotope production such as iodine for health applications, radioactive tracers for environmental research and cobalt sources for industrial applications. In the 1970s, it was heavily used for mineral sample characterization. This was also the facility where the operators of Brazil's first nuclear power plant received their initial training. Currently its main activities are NAA and delayed neutron analysis, isotope production for research, graduate student teaching and operator training. In addition to members of the scientific community, visitors are also regularly received for public information purposes.

Technical Features

- TRIGA type reactor with a licensed thermal power of 100 kW
- <20% enriched TRIGA UZrH fuel elements
- Cooled and moderated by demineralized light water
- 3 B_4C control rods
- Rotary specimen rack and central thimble irradiation facilities
- 2 pneumatic transfer systems
- Experimental neutron beam extractor

Products and Services

Research and development

- Prompt gamma neutron activation analysis
- Material irradiation and use of hot cells for testing
- Experimental radioisotope production for potential radiopharmaceutical and medical imaging applications

Irradiation services

- NAA and delayed neutron counting
- Production of low activity Co sources for industrial applications
- Radioisotope production on demand, e.g. radiotracers

Education and training

- Research reactor operator course
- Experiments for reactor physics University courses
- Guided tours

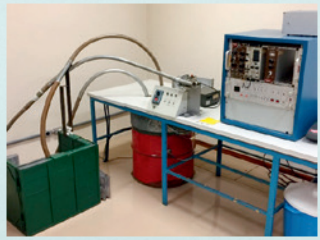
Future Plans

The IPR-R1 and its associated laboratories undergo regular maintenance and are upgraded periodically depending on the availability of funding. The following are current priorities:

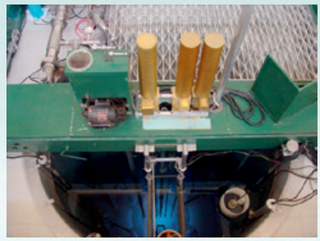
- Upgrades to the operating console, including digital data acquisition system
- Addition of another pneumatic transfer system

New services under consideration include:

- Research with neutron beams
- Prompt gamma neutron activation analysis
- Overhaul of courses for operator training and for graduate students



Pneumatic transfer system



IPR-R1 pool

Guided tour

IPR-R1 Control console

Contact Information

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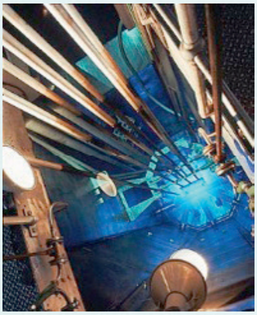
RECH-1



CEN La Reina RECH-1 facility (left) and reactor core (right)

Construction of the La Reina Nuclear Studies Centre (CEN La Reina) began in September 1968 on a site 12 km east of Santiago. Following negotiations with the United Kingdom to acquire a nuclear reactor, Fairey Engineering Ltd. initiated construction of the first Chilean research reactor, RECH-1, which received HEU fuel from the United States. RECH-1 is an MTR pool type reactor that achieved first criticality in October 1974. The reactor is housed in a reinforced concrete building maintained at an air pressure slightly lower than atmospheric, and its core lies in a pool of demineralized water at a depth of 10 m. Conversion to LEU fuel was completed in May 2006. Radioisotope production for radiopharmaceuticals began in 1974 and together with NAA is now the principal service, but the reactor facility also offers neutron depth profiling, radiography, diffractometry, prompt gamma activation analysis and diffuse scattering spectrometry facilities. The staff consists of 4 nuclear engineers, 6 reactor operators and 2 technicians.

Because of its location in a seismically active region, design and construction calculations allowed tolerance for ground acceleration of a 9.0 magnitude (Richter scale) earthquake. The reactor withstood without any damage two earthquakes in the region of magnitude 8.5 and 10.

Technical Features

- Pool type reactor with a maximum thermal power of 5 MW
- 19.75% enriched uranium silicide MTR fuel
- A maximum thermal flux of 6×10^{13} $cm^{-2}s^{-1}$
- Cooled and moderated by demineralized light water
- Beryllium reflector
- 6 Cd control rods
- 6 in-core irradiation sites and 5 beam tubes
- Operates approximately 22 hours per week

Chile

Products and Services

Education and training

- 5 beam tubes are devoted to research and education
- Experiments to support engineering, physics and chemistry theses
- Lectures and experiments within university curricula

Research and development

- NAA of multi-foils and unfolding algorithms, a methodology based on Bayes' theorem to obtain neutron flux measurements at the reactor core has been developed, expanding the use of data available in neutron databases
- NAA analyses of diverse samples such as:
  - geological samples, archeological artifacts and mining tailings
  - hair and clothing samples for studies of indigenous peoples' migration and diet
  - forensic samples in collaboration with national criminal police laboratories
  - rat tissue samples to determine the presence of Au for Alzheimer's research

Irradiation services

- Primary production of ^{99m}Tc and ^{131}I and secondary production of ^{24}Na, ^{86}Rb and ^{51}Cr for radiopharmaceuticals and the mining industry
- Fission track dating of geological samples
- Neutron activation analysis of material samples

Neutron depth profiling facility

Neutron diffractometry facility

RECH-1 control panel

RECH-1 new and former cooling systems

Future Plans

The facilities and instrumentation are currently undergoing modernization to expand the use of the techniques mentioned above. However, the present facilities are rarely used because of a lack of human resources. Neutron flux measurements according to Bayes' theorem will be extended to the experimental areas of the reactor using a customized neutron spectrometer and unfolding algorithms.

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IAN-R1

IAN-R1 reactor building (left) and reactor core (right)

The Colombian Geological Survey operates the country's only nuclear reactor IAN-R1, a small facility used mainly for NAA of soil and mineral samples, in Bogotá. IAN-R1 was donated by the United States under the Atoms for Peace programme and achieved first criticality in 1965. It is a pool type reactor, which has undergone HEU to LEU conversion using TRIGA-type fuel. The facility provides for several applications, including fission track dating, reactor operation training and education, and nuclear simulation. Radioisotope production, additionally, is under investigation by the Nuclear Affairs Division. The reactor operates Monday through Thursday for a maximum of 8 hours. The Reactor Manager, Reactor Operator, Radiation Protection Officer and Maintenance Engineer comprise the staff.

Technical Features

- Pool type reactor with a maximum thermal power of 30 kW
- TRIGA-type LEU fuel
- A maximum thermal flux of 7.8×10^{11} $cm^{-2}s^{-1}$
- Cooled and moderated by demineralized light water
- Graphite reflector
- 3 B_4C control rods
- 1 radial, 3 in-core and beam tube irradiation sites

Products and Services

As a part of the Colombian Geological Survey, the operation of IAN-R1 focuses on analysis of geological samples by NAA and fission track dating. However, the services of the reactor will expand to include target irradiation for radioisotope production and neutron radiography using two beam tubes.

Irradiation services

- NAA in various material samples and artifacts
- Fission track dating of uranium-bearing minerals and glasses

Education and training

- Introductory nuclear and reactor physics studies such as cross-sections, diffusion theory and reactor criticality
- Radiation protection studies such as interactions of radiation with matter, radioactive decay, and radiation shielding
- Reactor operator training courses, including experimental setup, operation, control rod calibration and power calibration
- Education and training of University and secondary school students
- Public visits

Future Plans

- Target irradiation for production of radioisotopes such as ^{131}I, ^{198}Au, ^{32}P, ^{82}Br and ^{140}La is under research and development stage
- Feasibility study on power upgrade from 30 kW to 100kW will be conducted.

NAA laboratory

NAA training

IAN-R1 reactor

Control room

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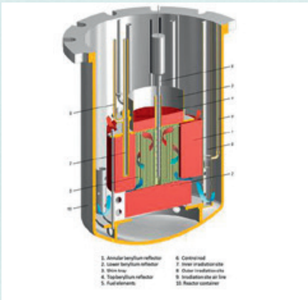
JM-1



Vertical cross-section of the JM-1 research reactor

ICENS building

The JM-1 research reactor is a SLOWPOKE-2 pool type reactor designed by Atomic Energy of Canada, Ltd. (AECL). It was commissioned in March 1984 at the International Centre for Environmental and Nuclear Sciences (ICENS) at the University of the West Indies, Mona Campus. Owned and operated by the University, it is primarily used for NAA of trace elements in studies related to health, the environment and agriculture as well as education and training. The reactor staff consists of seven reactor operators. After operating with HEU fuel for over three decades, the reactor was converted to LEU fuel in 2015, making the region HEU-fuel free.

Technical Features

- SLOWPOKE-2 type reactor with a maximum thermal power rating of 20 kW.
- 19.86% enriched UO_2 fuel in zircaloy cladding
- A maximum thermal flux of 10^{12} $cm^{-2}s^{-1}$
- Cooled and moderated by light water
- Beryllium reflector
- 1 central cadmium control rod
- 4 inner and 1 outer irradiation sites

Products and Services

Research at the JM-1 facility is primarily related to studies of the environment, agriculture and health. The main analytical techniques are NAA, X ray fluorescence spectrometry, atomic absorption spectrometry, inductively coupled plasma optical emissions spectrometry and anodic stripping voltammetry. Because of its location on a university campus, the reactor is also utilized in education and training course and workshops. As a by-product of the reactor associated facilities, a personnel exposure monitoring service is offered to the many users of ionizing radiation in Jamaica and other countries in the Caribbean region.

Irradiation services

- NAA in the areas of environmental protection, mineral exploration, agriculture and food security, nutrition and health, climate change, forensics

Radiation monitoring and survey

- Thermoluminescent detector monitoring of over 1300 local individuals and of over 300 individuals in the Caribbean region
- Radiological site surveys

Education and training

- Nuclear engineering as part of University courses
- MSc and PhD project research
- Professional courses and workshops in radiological protection

Future Plans

- An upgrade to a digital control system and Reactor Information Management System is planned for implementation in 2017–2018
- A new dedicated teaching laboratory will be used for courses, workshops and orphan radiation sources search and recovery for the Latin America and Caribbean region
- Production of short-lived radioisotopes for climate change research
- Research in radiation induced modification of polymers

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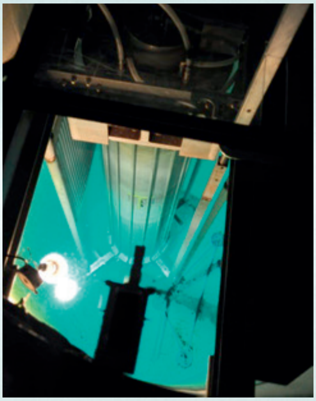
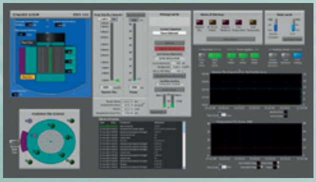
Part of the pneumatic irradiation facility of NAA



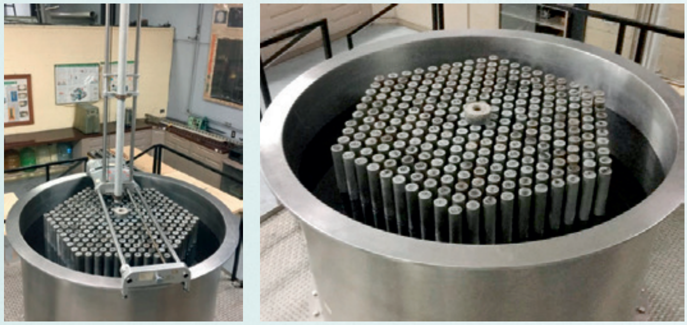
JM-1 reactor pool

Reactor core during operation at 20 kW



Digital control console screen

Nuclear-Chicago Modelo 9000



Nuclear detector handling system over the Nuclear-Chicago Modelo 9000 subcritical assembly

The Nuclear-Chicago Modelo 9000 subcritical assembly was manufactured and built as a student training reactor. It was acquired by the National Polytechnic Institute of Mexico (IPN) in 1969. The facility is located at the Superior School of Physics and Mathematics in Mexico City. The core of the assembly is made up of 1400 natural uranium fuel elements. Each cylindrical element has a central channel and an aluminum jacket, with a weight of about 1.80 kg. The fuel elements are arranged in 280 pipes, each containing 5 elements, in a hexagonal array within a cylindrical vessel.

Technical Features

- Pool type sub-critical assembly with zero power
- Natural uranium fuel
- A maximum thermal flux of 3×10^4 cm^{-2}s^{-1}
- Cooled and moderated by light water
- Light water reflector
- 5 Ci Pu–Be neutron source

Products and Services

The primary use of the reactor is for experiments by nuclear engineering Master's Degree students to determine reactor physics parameters. Some services are provided in collaboration with the National Institute for Nuclear Research (ININ) TRIGA Mark III reactor.

Neutron howitzer

HPGe gamma spectrometer

Education and training

- Reactor physics and nuclear instrumentation experiments
- Nuclear safety and radiation protection experiments
- Alpha, beta, gamma and neutron spectrometry experiments
- Thermoluminescent dosimetry

Irradiation services

- In, Au and Ag foil activation by the reactor or neutron source
- NAA using gamma and beta spectrometry

Contact Information

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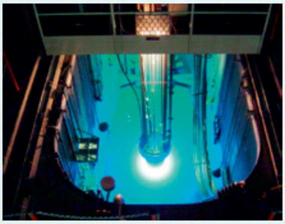
TRIGA Mark III



Reactor building at the Dr. Nabor Carrillo Flores Nuclear Centre (left) and reactor core during operation (right)

Owned and operated by the National Institute for Nuclear Research (ININ), the TRIGA Mark III reactor is located in the Dr. Nabor Carrillo Flores Nuclear Centre. The Centre also houses a linear accelerator, a gamma irradiation plant and a radiopharmaceutical production plant to support and supplement the research reactor. The TRIGA reactor achieved first criticality in November 1968 to initiate nuclear research in Mexico and support the national nuclear power programme. After operating with HEU fuel for 20 years, the reactor was converted to a mixed core in November 1988 and reconverted to exclusively LEU fuel in March 2012.

Technical Features

- TRIGA type reactor with a maximum thermal power of 1 MW
- TRIGA LEU fuel
- Movable core within the pool
- A maximum thermal flux of 3×10^{13} $cm^{-2}s^{-1}$
- Cooled by light water in natural convection
- Moderated by graphite elements
- Light water reflector
- 4 B_4C control rods
- 6 in-core irradiation positions
- Rotating specimen rack, dry exposure room, beam ports and horizontal and vertical thermal columns out-of-core irradiation positions

Products and Services

Radioisotope production

- Reactor operates 20–24 hours per week to produce ^{153}Sm; samarium lexidronam doses are prepared in the radiopharmaceutical production plant

Neutron activation analysis

- Analysis of biological, mineral and environmental samples, with the present capacity of approximately 300 samples per year

Education and training

- Touch screen guide to facility activities and tours for high school students
- Approximately 2000 students tour the Research Centre annually
- Reactor operation and radiation measurement experiments for engineering graduate students at 4 Mexican universities

Future Plans

- Currently seeking ISO accreditation for testing and calibration regarding NAA
- New NAA laboratory, featuring an automatic sample changer, is under construction

Contact Information

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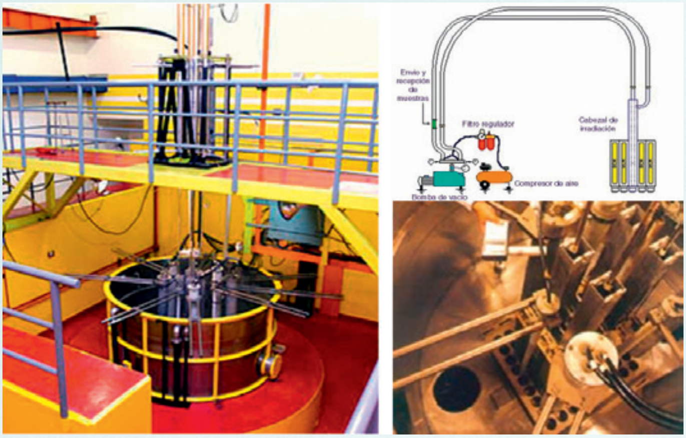
Graduate students from the Autonomous University of Zacatecas conducting an experiment

TRIGA Mark III reactor

Staff in the control room

RP-0 and RP-10



RP-0 top showing bridge mechanisms (left), pneumatic delivery system, control rods and neutron detectors (right).

Two research reactors are in operation in Lima, the RP-0 of 1 W maximum thermal power and RP-10 of 10 MW. Both are owned and operated by the Peruvian Institute of Nuclear Energy (IPEN).

Constructed by Argentina, the RP-0 is dedicated exclusively to education, training and simulation of reactor physics parameters. The reactor has MTR type fuel elements containing uranium oxide enriched to <20% for a maximum neutron flux of 10^7 $cm^{-2}s^{-1}$. First criticality took place in July 1978.

Reactor RP-10 achieved first criticality in November 1988. It was also built by Argentina, and is a pool type facility used for several applications. Among the most important uses of the reactor are the production of radioisotopes for the regional and national market and NAA. The reactor is also occasionally used for neutron radiography and education. RP-10 currently operates at full power no more than 15 hours per week, and has a trained staff of 30 engineers, physicists and technicians.

Technical Features

- Pool type reactor with a maximum thermal power of 10 MW
- <20% enriched MTR fuel with uranium silicide pellets
- A maximum thermal flux of 1.5×10^{14} $cm^{-2}s^{-1}$
- Cooled and moderated by light water
- Beryllium and graphite reflectors
- Cadmium control rods
- 1 central, 1 pneumatic and 3 additional irradiation sites
- Operates Monday–Wednesday for research and NAA and Friday–Saturday for radioisotope production

Peru

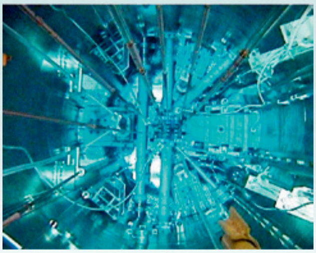
Products and Services

Targets are irradiated in the RP-10 reactor to produce a number of radioisotopes. NAA is another important irradiation service, with the neutron beam utilized to some extent. Experiments are arranged upon request for education and training courses for operators and universities, and the facility is frequently open to public visits. Neutron diffraction and prompt gamma facilities were formerly operated.

RP-10 facility at IPEN

Irradiation services

- Production of radioisotopes such as ^{99}Mo/ ^{99m}Tc , ^{131}I, ^{153}Sm, ^{192}Ir, ^{32}P, and ^{35}S
- NAA of biological, geological, silica, ceramic and uraniferous materials



Core in operation

Education and training

- University courses in reactor physics (neutron fluxes distribution, reactivity coefficients measurements, control rods and reactor power calibrations) and nuclear physics (half-life, nuclear reactions, detector characteristics, multi-element analysis)
- Training courses for operators and maintenance staff in reactor physics, thermo-hydraulics and reactor systems
- Guided tours for university and secondary school students as well as general public

Radioisotope production cells

Future Plans

The RP-10 reactor has completed fuel conversion from uranium oxide to uranium silicide. As a result, neutron flux at the irradiation positions has increased by as much as 20%, enabling the reactor to diversify its products and services, including:

- Production of radioisotopes ^{64}Cu, ^{74}As, ^{177}Lu, ^{90}Y, ^{111}In, peptides, AcMos
- Production of technetium generators
- Neutron diffraction and prompt gamma neutron activation facilities.

Modernization of reactor instrumentation and control system as well as implementation of remote access for education and training purposes are also planned in the future.

Sample station for the pneumatic transfer system

A course for school teachers

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