OTHER PRODUCTS DEVELOPED IN THE NUCLEAR DIVISION

- **Radioisotope Production Facilities:**
INVAP has designed, built, and commissioned several facilities to produce a wide range of radioisotopes including radiopharmaceuticals such as Tc99
- **Site evaluations:**
Site selection and characterization services for nuclear related facilities are provided by INVAP worldwide
- **Instrumentation and Control:**
INVAP is a world-class designer and supplier of neutronic and radiation protection instruments specially tailored to the customer needs.
Total refurbishments of the whole I&C system in aged nuclear reactors are also provided
- **Support to Nuclear Power Plants:**
Tailor made components and engineering services are routinely supplied by INVAP to Nuclear Power Plants in Argentina and abroad. This includes from refuelling calculations up to spent fuel dry storage complexes

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NUCLEAR REACTORS

INVAP
Custom Designed Technology

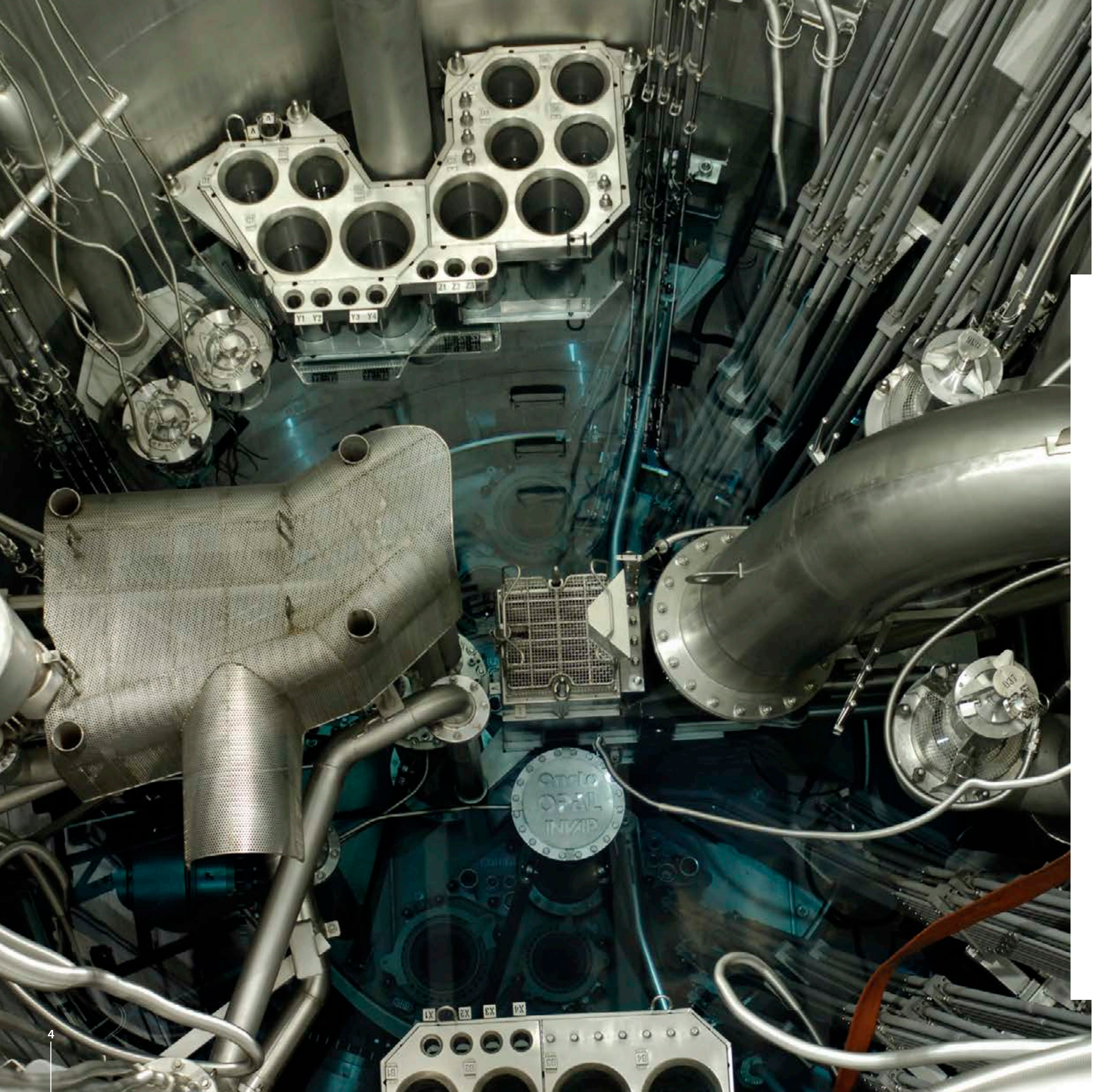
CONTENTS

INTRODUCTION

INVAP is aware of the current challenges in the demanding nuclear global market and has the skills and know-how to respond to them with innovative and effective ideas from the design stage up to the after sale support.

The company has a long traceable record in applying state of the art engineering and managerial techniques to deliver complex facilities and critical components worldwide within schedule and budget.

INVAP is recognized as a leader in blending new technologies onto proven reactor designs, thanks to a resourceful staff of professionals continuously exploring the possible applications of recent developments coming from nuclear and other high-tech areas.



CLIENT-FOCUSED SKILLS AND SERVICES

Throughout its extended permanence in the nuclear arena, INVAP has had a successful experience in exploring and addressing the client needs and preferences early in the design process in order to develop products that often exceed, in quality and performance, the client's original requirements.

INVAP's international portfolio ranges from deploying facilities in developing countries, which required establishing an infrastructure to support the operations, up to the design and construction of brand new reactors to be integrated into a working nuclear center with particular rules and practices.

In both opposite scenarios, INVAP is experienced in delivering first class sustainable facilities, fully operative as per the original schedule and within the budget agreed on with the client.

ENGINEERED SUCCESS

INVAP is proud of its pursuit of new, cost-effective and timely solutions for nuclear clients. These have included reactor cores tailor made for maximum performance, neutron beams optimized for maximum neutron fluxes and innovative irradiation systems technology.

In all its projects, INVAP implements a solid engineering and management approach based on a well rooted Safety Culture. Its facilities are designed through the implementation of a thorough defense in depth scheme, which ensures that all foreseeable abnormal scenarios are adequately managed to prevent their escalation into unwanted events.

NUCLEAR EXPERTISE

INVAP has been involved in nuclear projects for more than 30 years. During that time, its teams have worked on more than 15 nuclear reactors and other related facilities across the world.

SUSTAINABLE RESEARCH REACTORS

Millions of medical scans and treatments are done globally each year that require radioactive isotopes. Research reactors play a vital role in producing radionuclides, base material for the radiopharmaceutical industry and nuclear medicine centers worldwide. INVAP designs and provides the research reactors to produce these isotopes.

INVAP also designs and provides the radiochemical facilities needed to handle and process the radionuclides, which turn them into patient care products. In doing so, it has to fulfill stringent requirements from both the radiological and biological viewpoints.

The reactor and the radiochemical processing facilities delivered by INVAP to ANSTO in Australia received the USA FDA approval, which certifies compliance with one of the most stringent set of requirements in the field.

In modern multipurpose reactors, the production phase is generally combined with research applications, thus producing a synergetic mix very profitable for the organizations running the facilities.

INVAP is recognized as a skilled designer of flexible and high performance reactor cores able to accommodate both activities in a safe and efficient manner.

FROM PLANNING TO JOURNEY'S END

INVAP's nuclear projects range from the complex definition of the reactor specifications, to the development of utilization plans, environmental consultancy or siting studies.

In other cases, INVAP provides specific services such as the modification of a reactor core, the refurbishment of nuclear instrumentation or the modernization and upgrading a reactor. The successful refurbishment of the Romanian reactor (a high power TRIGA design) is a proof of the expertise developed within INVAP.

To carry out its projects, INVAP leads multidisciplinary project teams encompassing companies from all over the world, ensuring a seamless and efficient integration of efforts from design to commissioning.

Throughout these activities, INVAP engineering and project management teams have demonstrated an outstanding expertise and capability, receiving the client's recognition.

NUCLEAR REACTORS

INVAP designs and builds turn-key nuclear reactors for the following applications:
- Neutron beam research (including cold neutron beams)
- Radioisotope production for medical, agricultural and industrial applications
- Silicon doping by neutron transmutation
- Beams and facilities for Boron Neutron Capture Therapy (BNCT)
- Neutron radiography (underwater and beam based)
- Training on nuclear science and reactor operation
- Material testing
- Benchmarking of neutronic calculation codes

For each project involving a nuclear facility, INVAP performs different activities such as:
- Project management
- Definition of the consolidated list of requirements based on client needs and expectations, future users requirements, local and national regulations, best international practices and applicable state of the art technologies
- Safety evaluations supporting the Safety Analysis Report
- Screening and integration of specialized companies, to deliver specific one-of-a-kind components
- Development of a suitable framework to validate special customized solutions
- Training of the client staff (academic and on-the-job)
- Know-how transfer by including client representatives in the design team

Other services provided include:
- Redesigning the core of existing reactors with two aims:
  - Migration from HEU to LEU
  - Incorporation of new irradiation facilities and applications
- Neutronic, thermo-hydraulic, shielding and safety calculations
- Update and upgrade of Reactor Control, Monitoring and Protection systems
- Development of Cold Neutron Sources for existing reactors
- Design, manufacture, installation, start-up and staff training for radioisotope (including radiopharmaceutical) production facilities

INVAP

Milestone Projects in Research Reactors

RA6 1982

Designed, built and commissioned by INVAP for the Argentine Atomic Energy Commission (CNEA). The RA6 is 100% Argentine technology.

- Power: 1MW
- Use: research and training
- Location: Argentina

NUR 1989

Designed, built and commissioned by INVAP for HCR-COMENA (Algerian Atomic Energy authority).

- Power: 1MW
- Use: research, radioisotope production and training
- Location: Algeria

RA8 1997

Designed, built and commissioned by INVAP as a Critical Facility, to carry out tests supporting the CAREM nuclear power plant design.

- Power: 100W
- Use: measurement of nucleonic parameters and validation of the calculation line for the CAREM NPP
- Location: Argentina

ETRR2 1998

Designed, built and commissioned by INVAP for AEA (Egyptian Atomic Energy Authority).

- Power: 22MW
- Use: radioisotope production, research, beams utilization, BNCT neutrography, silicon transmutation and training
- Location: Egypt

OPAL 2006

Designed, built and commissioned by INVAP for ANSTO (Australian Nuclear Science and Technology Organization).

- Power: 20MW
- Use: radioisotope production, research, beams utilization (including cold neutrons) and silicon transmutation
- Location: Australia

Where we are now

PALLAS

- INVAP: contractor for design, engineering, procurement and construction management, for PALLAS Foundation
- Power: 25 MW
- Use: radioisotope production for medicine, industry and research, and testing of nuclear fuels and materials
- Location: The Netherlands

RMB

- INVAP: contractor for design, engineering, manufacturing, nuclear installation testing and commissioning for IPEN
- Power: 30MW
- Use: radioisotope production, research, beams utilization (including cold neutrons) and silicon transmutation
- Location: Brazil

RA10

- INVAP: contractor for design, engineering, manufacturing, nuclear installation testing and commissioning for CNEA
- Power: 30MW
- Use: radioisotope production, research, beams utilization (including cold neutrons) and silicon transmutation
- Location: Argentina

LPRR

- INVAP: contractor for design, engineering, manufacturing, nuclear installation testing and commissioning for KACST
- Power: 100W
- Use: training in nuclear science, radiochemistry and reactor fundamentals
- Location: Saudi Arabia

NUR+

- INVAP: contractor for design, engineering, manufacturing, nuclear installation testing and commissioning for COMENA
- Power: 3.5MW
- Use: extended range of research, radioisotope production and training
- Location: Algeria

INVAP NUCLEAR REACTORS IN THE WORLD

ARGENTINA
RA6

The RA6's basic design was developed by CNEA, who later handed over to INVAP the responsibility to build the reactor.
Honoring this appointment, INVAP lead the group of specialists that built the reactor in accordance with the original schedule.
The facility is a Pool Type Reactor fueled with LEU MTR assemblies in a variable core configuration, featuring forced downward cooling flow. Reactivity is controlled by five plate type Control Rods; four of them have SCRAM capabilities and the fifth acts as Shim Control rod to provide fine adjustments.
The reactor civil works consist of three separate concrete structures, each designed and constructed in compliance with seismic regulations. The inner structure holds the Reactor Pool while the others compose the Reactor and the Auxiliary Buildings respectively.
The Reactor Building, housing among other systems the Reactor Pool, Spent Fuel Pool and the Primary Cooling System, constitutes a barrier against a very unlikely release of radionuclides owing to a ventilation system including HEPA and charcoal filters and keeping the internal pressure below the atmospheric value.
The Auxiliary Building hosts the ancillary systems, lecture rooms, labs and three control rooms, namely:

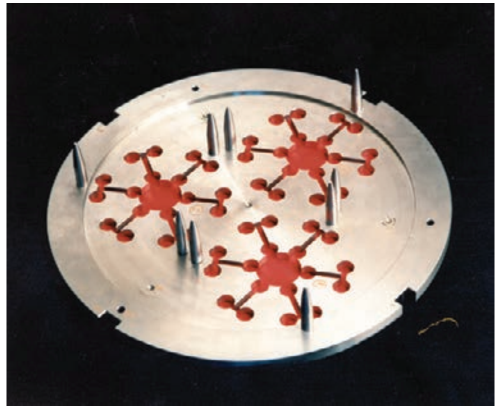
- Main Control Room: to operate the facility.
- Emergency Control Room: to ensure the reactor is scrammed and to track the evolution of relevant parameters in case the Main Control Room renders inoperable.
- Training Control Room: to provide limited and controlled operation of the Shim Control Rod driver for training purposes.

Recently, the RA6 has been upgraded to 1MW from the original power of 0.5 MW. A further increase up to 3 MW is under consideration. The facility is operated on a routine basis and provides support to the Instituto Balseiro's Nuclear Engineering career and Research Programs, ranging from NAA applications in Environmental Science up to BNCT treatments and Molten Fuels loop tests.

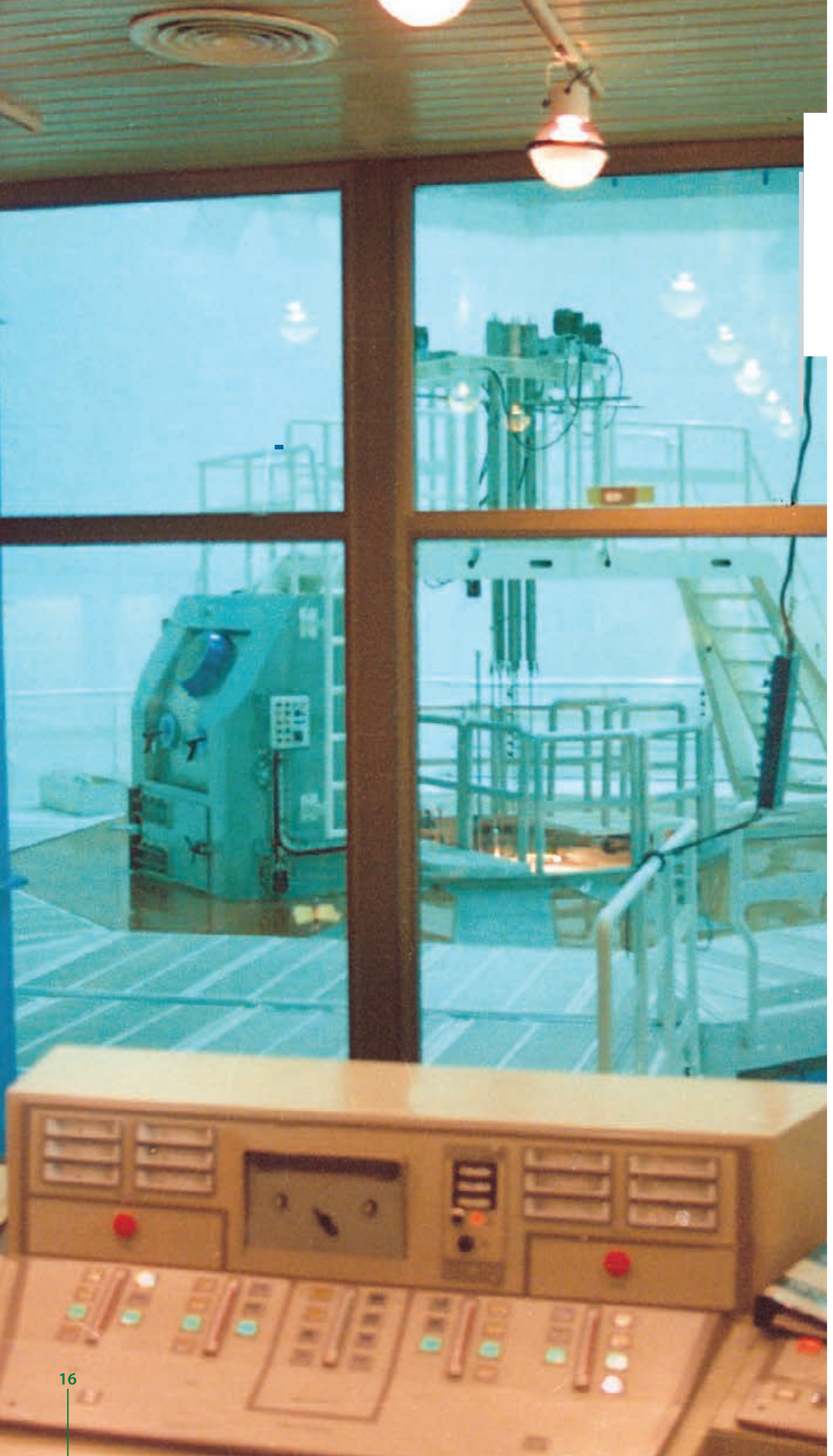
Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Bariloche, Argentina
Performance	
Thermal Power	1 MW upgradeable
Max. Thermal Neutron Flux	$2\ 10^{13}$ n/cm^{2}s
Technical Specs	
Fuel Type	LEU MTR type
Fuel Material	U_3Si_2 (4.8 g U/cm^3)
Cladding Material	Aluminum
Cycle Length	As per experimental requirements
Coolant	Water
Moderator	Water
Reflector	Graphite
Core Cooling	Forced, downwards
Reactivity control	Five control plates (Ag-In-Cd)
Control and Monitoring System	Hardwired
Protection System	Hardwired – based in rod insertion
Experimental Facilities	
Five Beam Tubes	Used for neutron-radiography, prompt gamma analysis, and other applications
Pneumatic Rabbit System	For Neutron Activation Analysis
BNCT Bunker	Featuring epi and thermal beams

ARGENTINA
RA8

The RA8 is a Zero Power Reactor or Critical Assembly running normally at 10 W with short transient peaks up to 100 W. The core is located inside a steel pool (Reactor Pool) surrounded by a concrete biological shield.
The facility is fueled by Zircalloy rods containing U pellets with 1.8 % enrichment. The fuel rods are arranged in a hexagonal geometry defined by two grids that also guide 13 control plates. Although the reactor concept is simple and no cooling circuits are required, safety systems are elaborate to prevent criticality accidents. The facility has two diverse SCRAM systems, each able to shutdown the reactor when requested by the protection system.
The RA8 is currently in long-shutdown status after having successfully completed the original R&D program and additional related experiments.



Reactor Information	
Facility Type	Critical Assembly
Location	Pilcaniyeu, Argentina
Performance	
Thermal Power	10 W nominal/ 100 W peak
Max. Thermal Neutron Flux	$2\ 10^8/2\ 10^9$ n/cm^{2}s
Technical Specs	
Fuel Type	Fuel pins
Fuel Material	UO^2
Cladding Material	Zry
Cycle Length	Not applicable
Coolant	Water
Moderator	Water
Reflector	Water
Core Cooling	Natural circulation
Reactivity control	Up to 13 (Ag-in-Cd) control plates/ Moderator height
Control and Monitoring System	Hardwired
Protection System	Hardwired Two scram systems
Experimental Facilities	
Off line Gamma Scanning	For core flux profile measurements
Moderator Heating/ Cooling System	For reactivity coefficient measurements
Boric Acid Dilution System	For reactivity coefficient measurements



ALGERIA

NUR

The NUR reactor (NUR stands for luminosity in Arabic) is an evolution of the RA6 reactor, of similar conception in many of its systems, tailored to suit the Algerian site characteristics and infrastructure.

The facility is a 1 MW Pool Type reactor using LEU MTR fuel assemblies in a variable core array with downward cooling water flow.

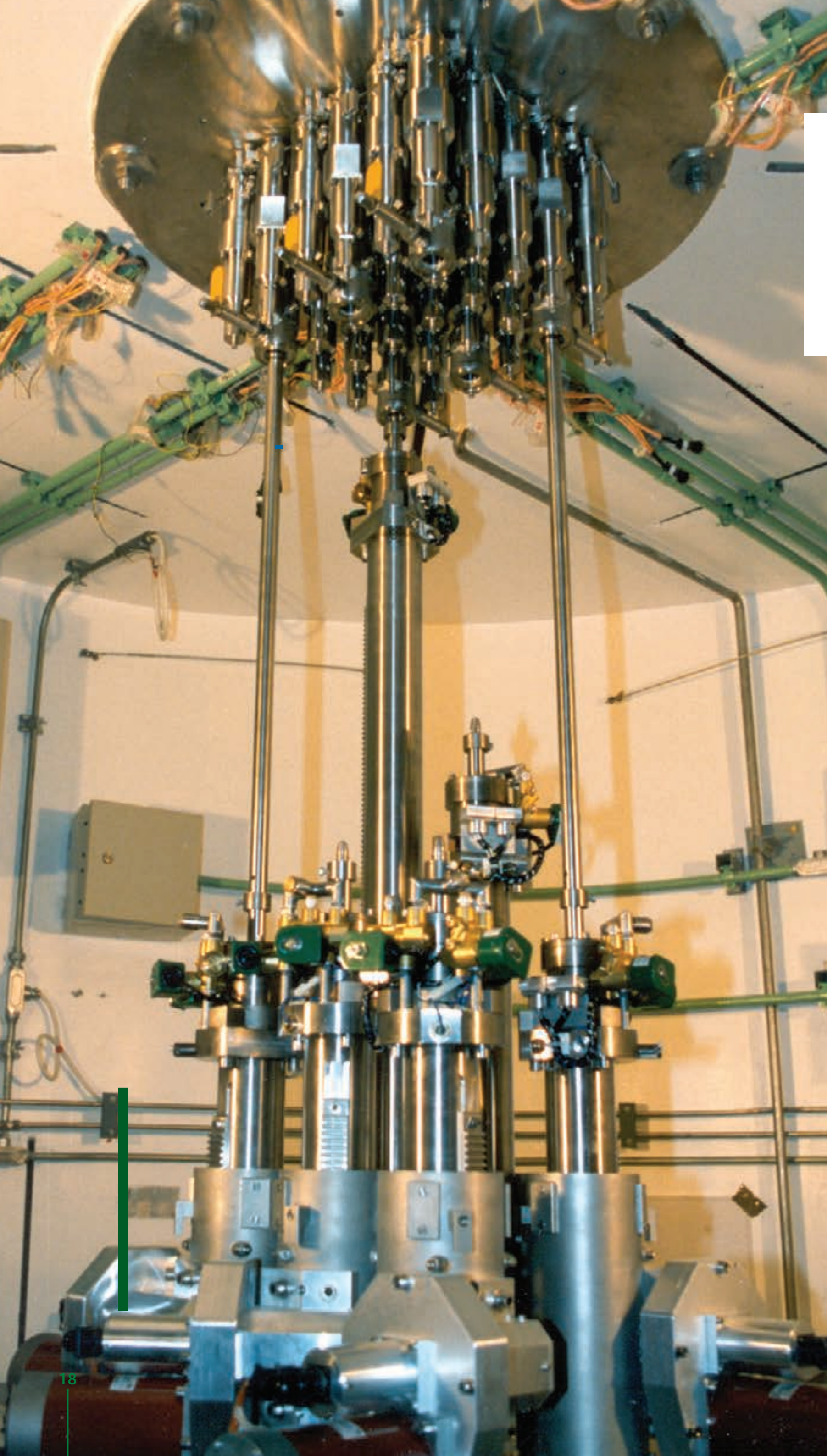
The major improvements compared with RA6 were the development of a digital supervision and control system and the integration of a hot cell at the top of the Reactor Pool to facilitate handling of radionuclides.

The reactor has a Training Control Room as in RA6, thus enabling the preparation of both technical and scientific human resources for Algeria and neighboring countries.

Beams tubes were integrated into the Reactor Pool Concrete Shield to provide neutrons for experiments, which includes a Neutron Radiography facility.

The involvement of local resources and an efficient project management allowed INVAP to complete the construction of the facility in 18 months in spite of facing complex logistics framework.

Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Alger, Algeria
Performance	
Thermal Power	1 MW
Max. Thermal Neutron Flux	$2\ 10^{13}$ n/cm^{2}s
Technical Specs	
Fuel Type	LEU MTR type
Fuel Material	U_3O_8 (3.0 g U/cm^3)
Cladding Material	Aluminum
Cycle Length	As per experimental requirements
Coolant	Water
Moderator	Water
Reflector	Graphite
Core Cooling	Forced, downwards
Reactivity control	Five control plates (Ag-in-Cd)
Control and Monitoring System	Software based
Protection System	Hardwired – based in rod insertion
Experimental Facilities	
Five Beam Tubes	Neutron Radiography, Sans, Reflectometry
Pneumatic Rabbit System	Analysis, Sample Irradiation



EGYPT

ETRR2

The ETRR2 was designed and built by INVAP for the AEA (Egyptian Atomic Energy Authority) at Inshas, in the outskirts of Cairo. INVAP supported AEA in developing specifications to match the Egyptian needs and to ensure that the ETRR2 would be a world class reactor featuring the latest technologies available and in accordance with the best international practices in the field.
The reactor was timely delivered within the agreed budget and reached its maximum power early on 1998. The know-how transfer program that accompanied the project and the intensive training, both theoretical an on-the-job, performed by INVAP allowed AEA to develop the required human resources to operate the facility immediately after the commissioning.
The ETRR2 is a pool type multipurpose reactor with a maximum power of 22 MW, also able to operate at 11 MW in steady conditions, using 50 % of the cooling capacity thus cutting operational costs if the demand allows it.
The cooling flow is upwards, through a core grid with 30 positions to accommodate LEU MTR fuel assemblies or irradiation boxes.

The core is reflected by beryllium boxes located in another grid also prepared to host irradiation facilities. There are two diverse SCRAM systems; one based on six control rods located in the core and the other based on the injection of a gadolinium solution in narrow boxes located between the core and the beryllium reflector.
Beams, underwater facilities (such as a graphite thermal column) and shielded bunkers allow undertaking activities ranging from Neutron Radiography up to Silicon Ingot transmutation.
The ETRR2 is currently being upgraded to irradiate uranium targets in the core, aiming at producing Mo99. The irradiated uranium plates and other radionuclides produced in the ETRR2 are processed in a Radioisotope Production Facility developed and constructed by INVAP in the same ETRR2 site.

Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Cairo, Egypt
Performance	
Thermal Power	22 MW
Max. Thermal Neutron Flux	$2\ 10^{14}$ n/cm^{2}s
Technical Specs	
Fuel Type	LEU MTR type
Fuel Material	U_3O_8 (3.0 g U/cm^3)
Cladding Material	Aluminum
Cycle Length	As per experimental requirements
Coolant	Water
Moderator	Water
Reflector	Beryllium
Core Cooling	Forced, upwards flow
Reactivity control	Six control plates (Ag-In-Cd)
Control and Monitoring System	Software based
Protection System	Hardwired/ Two scram systems
Experimental Facilities	
Five Beam Tubes	Neutron Research & Radiography
Pneumatic Rabbit System	Neutron activation analysis, sample irradiation
Vertical Channels	NTD, Radioisotope Production Facilities

AUSTRALIA

OPAL

The OPAL reactor was designed and built by INVAP for ANSTO (Australian Nuclear Science and Technology Organization) in Lucas Heights, few kilometers away from Sydney. The OPAL requirements were extremely demanding, requiring INVAP's design team to push the available technologies to the limit. The requirements were exceeded, as demonstrated during the Performance Demonstration Tests following the Commissioning Stage, while complying with the most stringent safety regulations stated by ARPANSA (Australian Radiation Protection and Nuclear Safety Agency) and periodically audited by IAEA.

OPAL was delivered in accordance with project schedule within the agreed budget and, thanks to the know-how and training material transfer timely made by INVAP, it was operated by ANSTO staff since the very moment in which the nuclear fuel arrived to the site.

OPAL is a pool type multipurpose reactor with a maximum power of 20 MW and a very compact core (only 16 LEU MTR fuel assemblies) in order to provide the required neutron fluxes. The core is surrounded by a large heavy water tank, which acts as reflector, which provides space for the irradiation facilities and holds in its interior five beam ports with several neutron guides. Coolant flow is upwards, produced by a system with passive devices such as flywheels and flap valves to ensure adequate cooling in case of power loss.

Two diverse SCRAM systems are available; one is based on five control rods and the other on the partial dumping of the heavy water reflector.

A state of the art Cold Neutron Source feeds two beam-ports connected to super-mirror guides to deliver neutrons to scientific instruments located at the Reactor Block face or in a dedicated Neutron Guide Building. Thermal neutron beams are also provided and the design has previsions to install and operate a Hot Neutron Source.

OPAL has multiple radioisotope production facilities including Mo99 produced by fission in uranium targets. These facilities are complemented by a set of hot cells and lifting and transport devices, including a 57-position pneumatic transport system.

The radioisotopes produced in OPAL satisfy the domestic demand thus shielding Australia from the fluctuations of the international market.

Moreover, ANSTO currently exports Mo99 to counties including USA, China, Japan and South Korea, and has the capacity to double its exports.

Nuclear transmutation of silicon ingots is also a routine activity in OPAL, performed in six positions available in the heavy water tank, which cover the range of diameters used by manufacturers currently and in the foreseeable future.

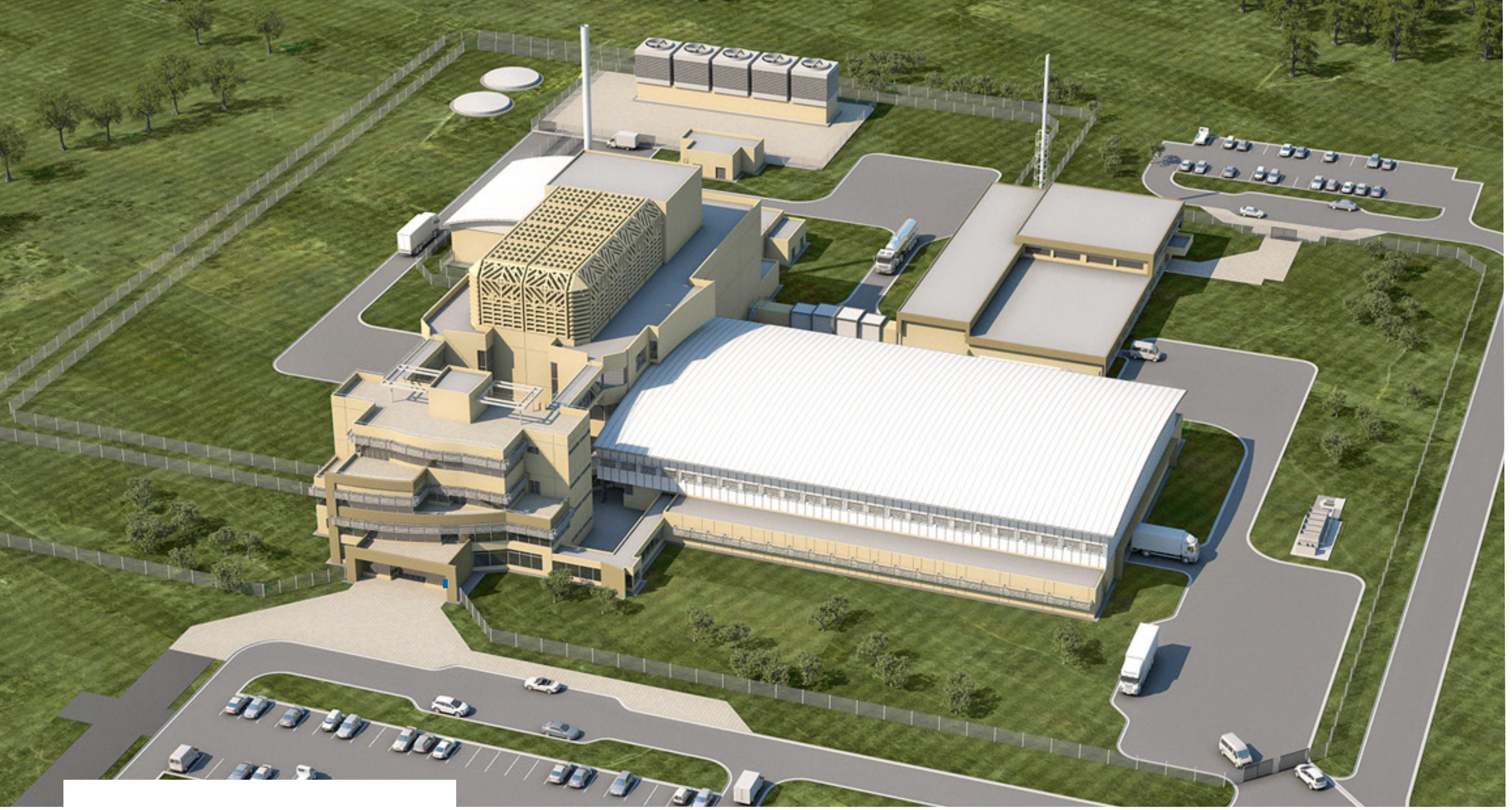
Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Sydney, Australia
Performance	
Thermal Power	20 MW
Max. Thermal Neutron Flux	3.5 10^{14} n/cm^{2}s
Technical Specs	
Fuel Type	LEU MTR type
Fuel Material	U_3Si_2 (4.8 g U/cm^3)
Cladding Material	Aluminum
Cycle Length	26 or 33 days
Coolant	Light water
Moderator	Water
Reflector	Heavy water
Core Cooling	Forced, upwards flow
Reactivity control	Five control plates (Hafnium)
Control and Monitoring System	Software based
Protection System	Two protection systems and two scram systems
Experimental Facilities	
Five Beam Tubes	Experiments with cold and thermal neutrons
Pneumatic Rabbit System	57 facilities for sample irradiation and neutron activation analysis
Vertical Channels	17 facilities for Radioisotope production
Cold Neutron Source & Thermal Neutron Source	Powder Diffraction (2), Single-Cristal Diffraction, Sans, Reflectrometry, Strain Scanning, 3-Axis Spectroscopy

SAUDI ARABIA
LPRR

Low Power Research Reactor (LPRR) is designed by INVAP for education and training capabilities in nuclear physics and nuclear engineering; but LPRR´s distinguished features, particularly regarding design, safety, operation and user´s capabilities, present the opportunity to shorten the time for developing indigenous resources towards creating national infrastructure for KACST (King Abdulaziz City for Science and Technology) on a plot located in the northwest of Riyadh.
The LPRR is a multipurpose low power research reactor for training and development of human resources and also to become itself a tool for R&D.
The reactor is of an open-pool design, which means that the core is located inside a pool of de-mineralized water that provides both cooling and shielding for radiation from the core. The reactor power is rated at 30 kW, and it can also operate at 100 kW for periods of at least 5 hours a day.
The low power is the key safety feature: when the power of the core is compared with the a size of the core and the inventory of coolant, the margins towards the fuel design limits are big enough to accommodate the transients following all the Design Basis scenarios and all the foreseeable scenarios with multiple failures (Beyond Design Basis).

The core consists of cylindrical shape fuel rods made of UO2 uranium pellets enclosed in a Zircalloy-4 cladding. The reactivity is controlled by six control rods belonging to the Reactor Shutdown System. The fuel is low enriched uranium, with a U235 content of 2.1 %. Fission heat is removed by demineralized water circulating through the space among the fuel rods by natural convection. The Primary Water System removes the heat from the pool water and transfers it to the Secondary Water System.
Engineered Safety Features are capable of maintaining the reactor in a safe condition under all design basis scenarios. The unique LPRR design allows coping with all design basis scenarios without surpassing the fuel design limits even with failure of the ESFs.

Reactor Information	
Facility Type	Pool Type reactor, Fuel Rod
Location	Riyadh, Saudi Arabia
Thermal Power	100 kW
Performance	
Max. Thermal Neutron Flux	2 10^{12} n/cm^{2}s^1
Technical Specs	
Fuel Type	PWR-like Cladded Rods
Fuel Material	UO2 sinterized pellet, 2.1 % enrichment
Cladding Material	Zircalloy
Cycle Length	Lifetime
Coolant	Water
Moderator	Water
Reflector	Graphite
Core Cooling	Natural Convection
Reactivity control	Six control rods (Hafnium)
Control and Monitoring System	Software based
Protection System	One protection systems and one scram systems
Experimental Facilities	
One Beam Tube	For neutron radiography, neutron scattering and Time of Flight measurements
Pneumatic Rabbit System	For neutron activation analysis
Vertical Channels	3 facilities for radioisotope production, one in-core and two located at the graphite reflector Training Twin-console, mirroring the control room Full-scope autonomous simulator

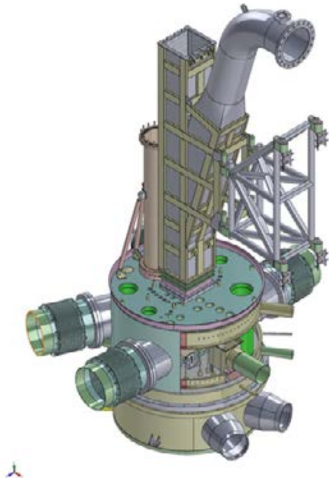


ARGENTINA
RA10

The RA10 Research reactor is a multi- purpose open-pool type reactor, designed jointly between INVAP and the Atomic Energy Commission of Argentina (CNEA), currently under construction, at the Ezeiza Atomic Center in the Province of Buenos Aires.

It has a nominal fission power of 30 MW, with a neutronic flux capable of insuring its simultaneous use for a wide spectrum of applications. The core, with 19 LEU MTR fuel assemblies and 6 positions available for materials irradiation tests, is surrounded by a large heavy water tank which acts as a neutron reflector, provides space for irradiation facilities and holds beam ports for neutron guides. The coolant fluid and moderator is light water, with upwards flow produced by a system with passive devices such as flywheels and flap valves to ensure adequate cooling in case of power loss.

Reactor shut down can be achieved by two different means, which are the insertion of six Control Rods into the core, or the partial drainage of the heavy water from the Reflector Vessel. Also, two types of neutron sources are foreseen: a cold neutron source with two tangential beams, and thermal neutron source with two beams; both with several neutron guides.



RA10 has multiple radioisotope production facilities, including Mo99, among others. These facilities are complemented by a set of hot cells and lifting and transport devices. Other activities to be performed at RA10 are: Silicon neutron transmutation doping, neutron activation analysis, materials testing and production of sealed radioactive sources.

With this project, Argentina will expand the current capabilities of radioisotope production (the RA-3 reactor, located at the Ezeiza Atomic Center), adding technological development in the field of fuels and nuclear materials, through adequate irradiation facilities that allow increase the experience that the country has in the area and expanding the supply of services to the world market.

Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Ezeiza, Argentina
Performance	
Thermal Power	30 MW
Max. Thermal Neutron Flux	2.9 10^{14} n/cm^{-2} s^{-1}
Technical Specs	
Fuel Type	LEU MTR
Fuel Material	U_3Si_2-Al (4.8 g U cm^{-3})
Cladding Material	Aluminum
Cycle Length	29.5 days
Coolant	Light water
Reflector	Heavy water
Core Cooling	Forced, upwards
Reactivity control	Six control plates (Hafnium)
Control and Monitoring System	Software based
Protection System	One protection systems and two SCRAM systems
Experimental Facilities	
Five Beam Tubes	Experiments with cold and thermal neutrons
Pneumatic Rabbit System	14 facilities for sample irradiation and neutron activation analysis
Vertical Channels	18 facilities for Radioisotope production
Irradiation in-core	6 positions
Silicium Irradiation	5 positions
Cold Neutron Source & Thermal Neutron Source	Powder Diffraction (2), Single- Cristal Diffraction, SANS, Reflectometry, Strain Scanning, 3-Axis Spectroscopy

BRAZIL
RMB

The Brazilian Multipurpose Reactor (RMB) is a 30 MW multi-purpose open-pool research reactor designed by INVAP S.E. (Argentina) and the Brazilian Commission of Nuclear Energy (CNEN). The RMB is called to become a high performance multifunctional international facility.

In 2010, following recommendations of COBEN (Bi-national Commission on Nuclear Energy), a committee responsible for a bi-national cooperative agreement between Brazil and Argentina, a decision was taken to adopt, for the new Research Reactors of Brazil (RMB) and Argentina (RA10), a conceptual model based on INVAP designed OPAL research reactor, as a reference for radioisotope production and neutron beams utilization.

For the Brazilian reactor, is cooled and moderated by light water and reflected by heavy water and Beryllium. The heavy water reflector makes possible to create large irradiation volumes where many irradiation positions are located. The Beryllium reflector adds irradiation volume with size and geometry flexibility, since the Beryllium blocks can be easily changed to accommodate the reactor to future irradiation requirements.

It's utilization covers a wide range of applications: material testing, fuel testing, radioisotope production and neutron beam utilizations. The material testing irradiations can be performed at the in-core irradiations positions where there are large irradiation volumes with high fast flux levels. The fuel testing irradiations are located at the Beryllium grid where the reflector flexibility can accommodate facilities for testing in steady state conditions and facilities to perform ramping tests.

The radioisotope production requirements are covered with many irradiation positions located at the heavy water reflector. Considering the irradiation requirements for the different radioisotopes, the irradiation positions are classified by the thermal flux level into high flux, medium flux and low flux.

Five irradiations positions are assigned to perform NTD for different sizes of Silicon ingots. Several pneumatic irradiation facilities enhance the irradiation capabilities of the RMB for other radioisotope production, as well as NAA, DNAA and CNAA.

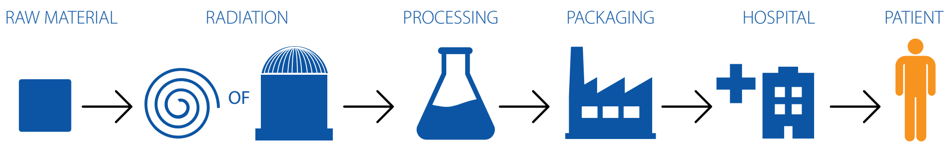
To provide services on neutron beam utilization, the reactor has a neutron beam for neutron imaging, two neutron beams with thermal spectrum and two neutron beams with cold neutrons. The cold neutrons are provided by a high-performance liquid deuterium Cold Neutron Source. At a certain distance from the core, the neutrons are transported by super-mirror guides to the experiment location.

Reactor Information	
Facility Type	Pool Type MTR reactor
Location	Iperó, São Paulo, Brazil
Performance	
Thermal Power	30 MW
Max. Thermal Neutron Flux	2.9 10^{14} n/cm^2 s^1
Technical Specs	
Fuel Type	LEU MTR
Fuel Material	U_3Si_2-Al (4.8 g U cm^{-3})
Cladding Material	Aluminum
Cycle Length	33 Full Power Days
Coolant	Water
Reflector	Heavy water
Core Cooling	Forced, upwards
Reactivity control	Six control plates (Hafnium)
Control and Monitoring System	Software based
Protection System	2 independent shutdown systems; hafnium plates and D20 reflector tank emptying
Experimental Facilities	
Five Beam Tubes	Experiments with cold and thermal neutrons
Pneumatic Rabbit System	14 facilities for sample irradiation and neutron activation analysis
Vertical Channels	18 facilities for Radioisotope production
Irradiation in-core	6 positions
Silicium Irradiation	5 positions
Cold Neutron Source & Thermal Neutron Source	Powder Diffraction (2), Single- Cristal Diffraction, SANS, Reflectometry, Strain Scanning, 3-Axis Spectroscopy

THE NETHERLANDS
PALLAS

The arrival of the new PALLAS-reactor is essential for the health of millions of people across the globe; not only for diagnostic purposes but also for therapy. The possibilities for therapy through radio-pharmaceuticals, which can only be made in a reactor, are rapidly increasing, allowing people to live longer thanks to successful treatment.

PALLAS has been designed for production of (medical) isotopes, and for conducting nuclear technological research. This new reactor, will replace the High Flux Reactor (HFR) in Petten, which is almost 60 years old and situated fifty kilometers to the north of Amsterdam.



INVAP is in charge of the design of the reactor; of the integration of the engineering of the whole plant; of nuclear safety; and of the efforts to assist Pallas in obtaining the licenses that authorize the construction and operation of the reactor, based on local regulations and those of the International Atomic Energy Agency (IAEA) of the United Nations.

For this design, it was taken into account the world wide knowledge available on reactors with high neutron fluxes and the concepts successfully demonstrated in our OPAL reactor in Australia, while incorporating several improvements to take in account the requirements specified by PALLAS.

Its innovative design will provide PALLAS with a wide flexibility and operational availability. The core of the reactor will be configured for the production of different types of radioisotopes, which will allow it to respond more effectively to changes that may occur in the market, either by increasing the demand for radiopharmaceuticals or by developing new products.

The PALLAS reactor will use only LEU fuels (short for low-enriched uranium).

The main uses foreseen for the PALLAS are undertaking the production of radioisotopes and research and development activities in the field of material and nuclear fuel.

ISOTOPE PRODUCTION