

**Ansto INVAP**

REPLACEMENT RESEARCH REACTOR

## Project Milestones

## Date

Request for Tender issued	August	1999
Reactor Contract awarded	July	2000
Application for Construction License presented to ARPANSA	May	2001
Reactor construction to start	February	2002
Start of commissioning	February	2005
Reactor at full power	August	2005

# The Company

**INVAP** is a technology development company with headquarters in Patagonia-Argentina. Its work in the nuclear field is supported by its close interactions with the Atomic Energy Commission of Argentina.

INVAP's activities cover a wide range of subjects. Many of the company landmarks are related to the design and construction of nuclear research reactors in Argentina and abroad.

One feature of all of INVAP's foreign proposals is the participation of the client's personnel in all stages of the project.

On 13 July 2000 contracts for the construction of Australia's Replacement Research Reactor, the most recent achievement of INVAP, were signed between the Australian Nuclear Science and Technology Organisation (ANSTO) and INVAP and its Australian alliance partners, John Holland Construction and Engineering Pty Ltd and Evans Deakin Industries Limited.

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**Ansto** is Australia's national nuclear science research organisation and the centre of Australian nuclear expertise. The core of this expertise depends on a functional and capable nuclear reactor. ANSTO's multidisciplinary expertise and research facilities are used to assist Australian industry, provide benefits to health care, develop environmental solutions, provide opportunities for advanced training and to provide technical advice to government on nuclear issues.

# The RRR Multipurpose Reactor

The Replacement Research Reactor is a 20 MW open pool reactor using low enriched uranium fuel, cooled by water and reflected by heavy water.

The Replacement Research Reactor (RRR) will be built by INVAP at the Lucas Heights Science and Technology Centre of the Australian Nuclear Science and Technology Organisation, located 35km South-West of the Sydney Central Business District, Australia.

The RRR is a multipurpose facility for radioisotope production, irradiation services and neutron beam research.

The reactor thermal power is 20MW and its compact core is designed to achieve high performance in the production of neutrons.

The facility comprises several buildings - Reactor Building, Neutron Guide Building, Offices and Visitor Centre Building, Auxiliary Building, Reactor Facility Substation and Cooling Towers - among which the reactor building stands out.

The reactor building contains all the nuclear systems and the reactor and service pools. It protects the reactor from all external events and also provides the structural basis for the reactor containment. The building is built of reinforced concrete, it is seismically qualified, and it has a metallic grillage for protection from light aircraft crash.

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*The design of the reactor has been optimised to comply with the radioisotope production requirements and to supply the neutron beams with the high neutron flux required for carrying out neutron research.*

### **The core**

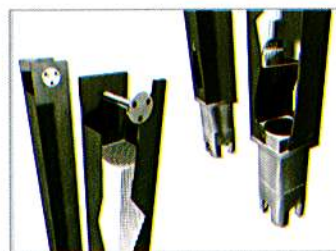
The compact core surrounded by a zircaloy chimney is located inside the reactor pool at 10m below the water level.

The core consists of an arrangement of 16 fuel assemblies formed by fuel plates containing low-enriched uranium. The fuel plates are separated from each other by coolant channels, which allow the circulation of cooling water to remove fission heat.

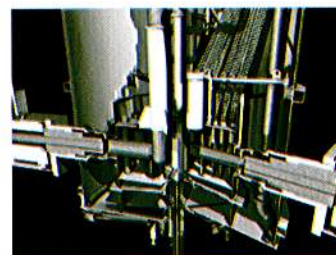
The core is cooled by demineralised water in a forced upwards flow. After shutdown the decay power is removed by natural circulation of reactor pool water. The reactivity control is performed by means of absorbing plates with vertical displacement.

The core is surrounded by a reflector vessel containing heavy water, which provides adequate neutron reflection and large volumes with high neutron fluxes. The neutron beam facilities and irradiation facilities are located in the reflector vessel.

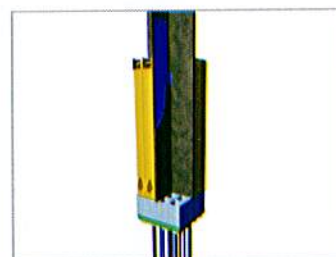
The reactor pool also contains, next to the core and reflector vessel, the piping for cooling systems, nuclear and non-nuclear instrumentation, and rigs for irradiation facilities.



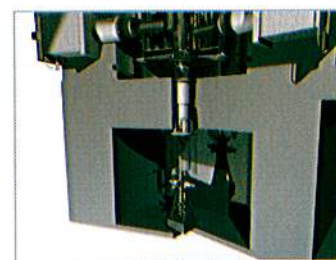
*Fuel assembly.*



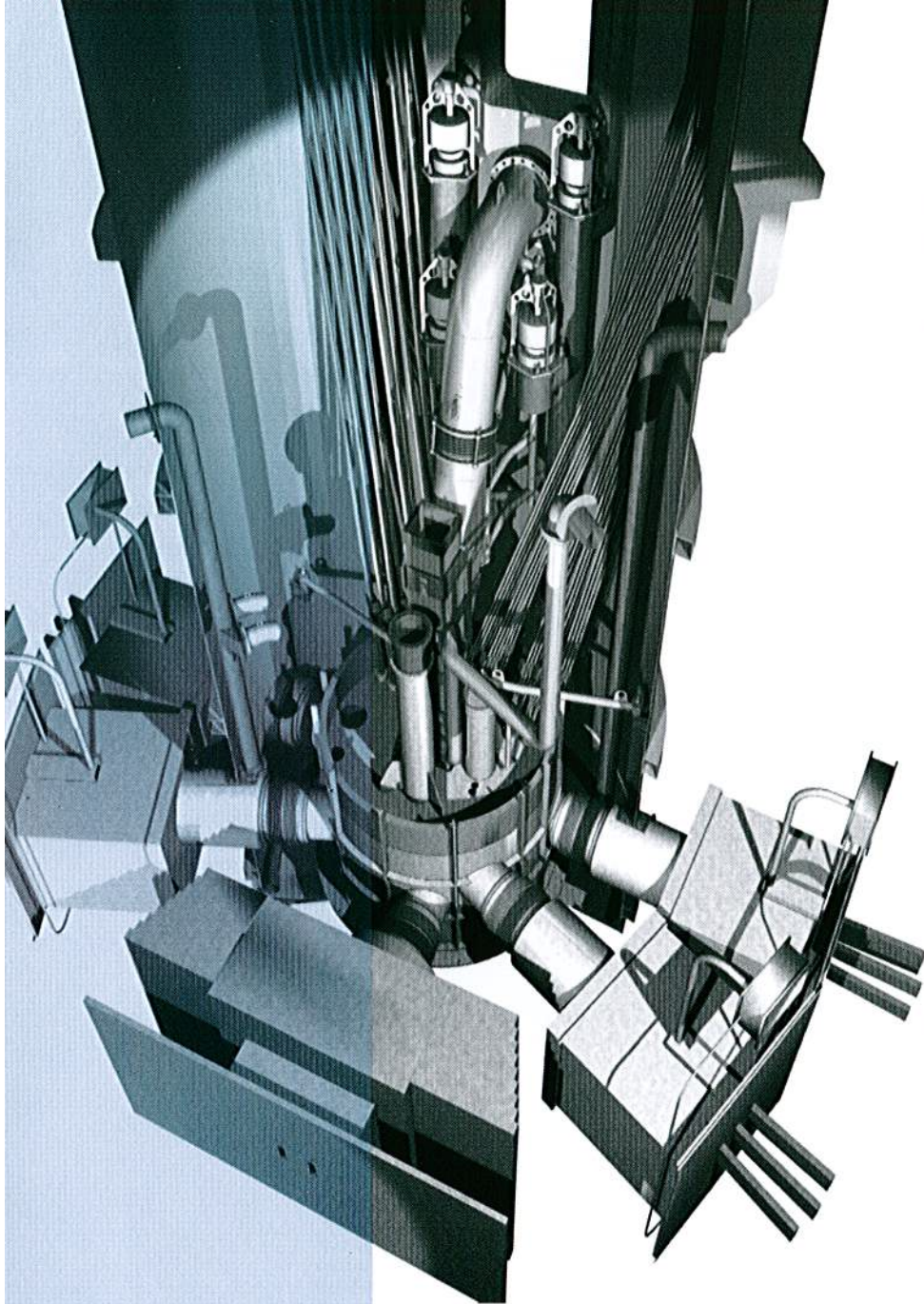
*View of core area.*



*View of arrangement of fuel assemblies.*



*Core and control rod drives.*



*Internal reactor tank*

### **The cooling systems**

The Primary Cooling System removes fission heat from the core by forced upward circulation of light water.

The design ensures a steady core coolant inlet temperature over the range of operating temperatures and regardless of variations in meteorological conditions prevailing at the site. Outside the pool, the primary cooling piping splits into three loops. Each loop consists of one pump and one heat exchanger with a capacity of 50% of the reactor power. One of the loops is kept on Stand by.

The Reactor and Service Pools Cooling System has the following functions:

- it removes irradiation rig heat by a downward forced circulation of light water during normal operation
- it removes core decay heat and provides continued cooling of irradiation rigs during Reactor shutdown
- it maintains the reactor pool water prescribed temperature limits in all anticipated operating conditions
- it removes spent-fuel decay heat

The Reflector Cooling and Purification System ensures the circulation, cooling and purification of The heavy water used as reflector.

The Secondary Cooling System cools the heat exchangers of the Primary Cooling System, the Reactor and Service Pools Cooling System, the Reflector Intermediate Cooling System and other reactor facilities. The heat is dissipated to the environment through cooling towers.

*All cooling systems have been designed to provide cooling of the core under normal or abnormal operating conditions with appropriate safety margins.*

A water purification and distribution system with mixed resin beds ensures that the coolant is kept within specifications. To reduce the radiation doses at the reactor pool surface a hot water layer is established by a special water purification and circulation system.

Heavy water quality is kept within the required values for safe operation using a mixed resin bed. Deuterium and oxygen concentrations are maintained by recombination.

All piping connections to the reactor tank are located above the core level and devices are provided to prevent the pool from draining by siphon effect.

Redundant flap valves are placed on the primary and pool circuits to permit natural circulation.

#### **Waste management**

The reactor is provided with facilities for the monitoring, control, segregation and classification of radioactive and non-radioactive waste.

The radioactive liquid waste management system classifies, collects, and temporarily stores liquid waste originated during operation of the reactor systems, facilities and labs.

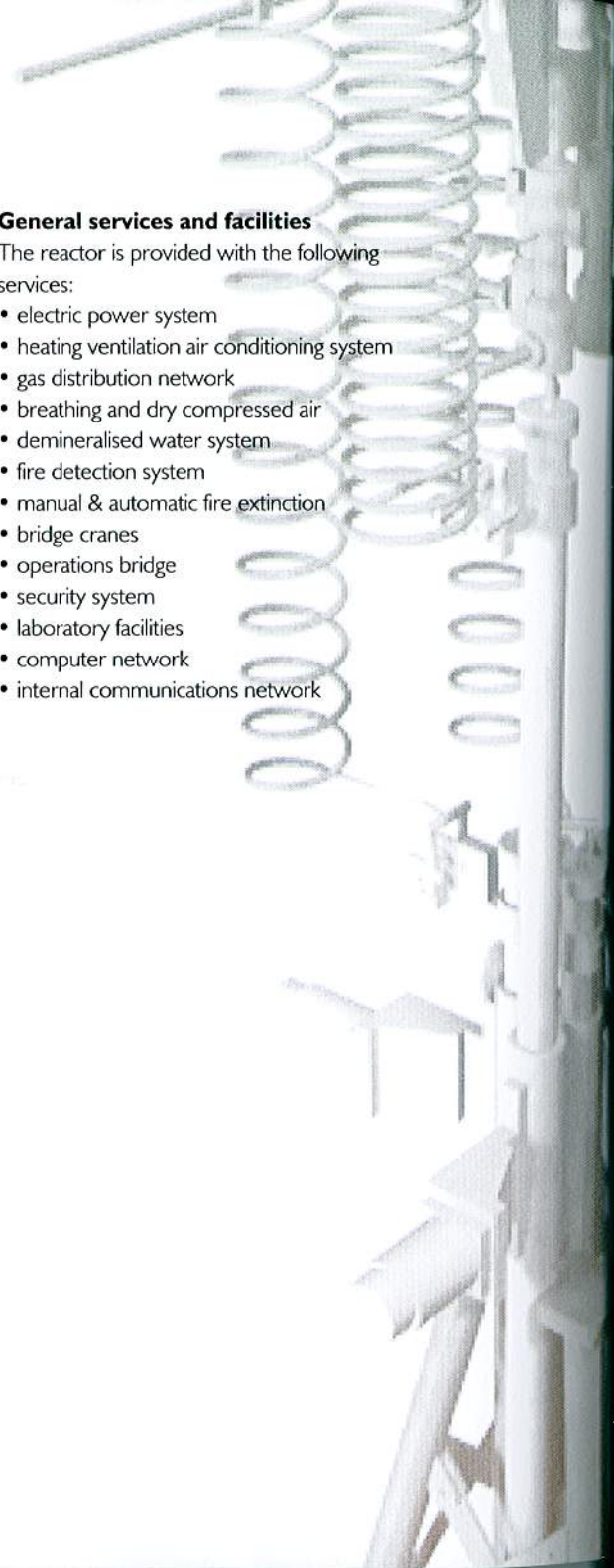
The system includes a refilling pool with enough capacity to store the maximum expected reactor water drainage.

Irradiated fuel assemblies are stored in baskets at the service pool storage rack. The basket design and coolant conditions ensure that the integrity of the fuel cladding is preserved. The service pool is provided with volume reduction facilities for metallic solid wastes.

#### **General services and facilities**

The reactor is provided with the following services:

- electric power system
- heating ventilation air conditioning system
- gas distribution network
- breathing and dry compressed air
- demineralised water system
- fire detection system
- manual & automatic fire extinction
- bridge cranes
- operations bridge
- security system
- laboratory facilities
- computer network
- internal communications network



# Safety

The RRR design and construction features ensure an effective protection for individuals, the general public and the environment against radiological hazards.

The plant construction is robust, with ample safety margins.

The plant has been designed in accordance to the requirements of the Australian Radiation, Protection and Nuclear Safety Agency (ARPANSA) and the International Atomic Energy Agency Safety Standards and Guides on research reactors safety.

The defence in depth and As Low As Reasonably Achievable (ALARA) principles have been applied in the design, with several levels of protection and multiple physical barriers to prevent radioactive releases.

Safety variables are monitored by the Reactor Protection Systems, which trigger safety systems automatically if predefined limits are reached.

At any time, the fission chain can be promptly terminated by the action of two diverse, redundant and independent shutdown systems.

*The reactor inherent safety is based on the open pool concept and the negative reactivity feedback coefficients of the core.*

*The reactor incorporates passive safety characteristics, that rely on natural laws for their effectiveness.*

The Safety Systems and the Reactor Protection Systems have "fail-safe" features that will take the reactor to a safe shutdown condition, when operation is abnormal.

#### **Reactor Shutdown**

The First Shutdown System quickly inserts five neutron absorbing plates into the core.

The Second Shutdown System dumps the heavy water of the Reflector Vessel into a storage tank, with drainage driven by gravity.

#### **Core Cooling**

Primary cooling pumps have flywheels to provide cooling during coast down.

No flow inversion is required to remove the decay heat by natural

convection. A large heat sink is provided by the water in the reactor tank.

A gravity driven water injection system together with the core chimney will keep the core cooled in case of a reactor pool Loss of Coolant Accident (LOCA).

#### **Containment System**

During normal operation the

circulation and exhaust of air is monitored and controlled. When required the reactor building can be isolated from the environment. A containment energy removal system maintains the pressure, temperature and humidity conditions inside the containment.

# Reactor facilities

The replacement research reactor will provide a reliable source of neutrons.

These neutrons will be used for two main purposes:

- radioisotope production
- scientific research

Neutrons will also be used for industrial purposes, such as production of silicon ingots for semiconductor manufacturing and material analysis through neutron activation techniques.

## Research facilities

The reactor is designed for supporting research with neutrons. The reactor will have three neutron sources, supplying neutrons of different energies:

- Cold Neutron Source, for producing very low energy neutrons
- Thermal Neutron Source, for producing medium energy neutrons
- The option for a Hot Neutron Source, for producing higher energies neutrons (future 2<sup>nd</sup> phase)

Five neutron beam assemblies are arranged tangentially around the reactor core, to extract neutrons from the neutron sources and direct them to the neutron guides.

The neutron guides transport the neutrons from the sources to the experimental instruments (which may be located up to 40 meters away from the core) ensuring that the transport losses are minimum.

Two large beam halls provide ample space and

facilities for placing the research instruments.

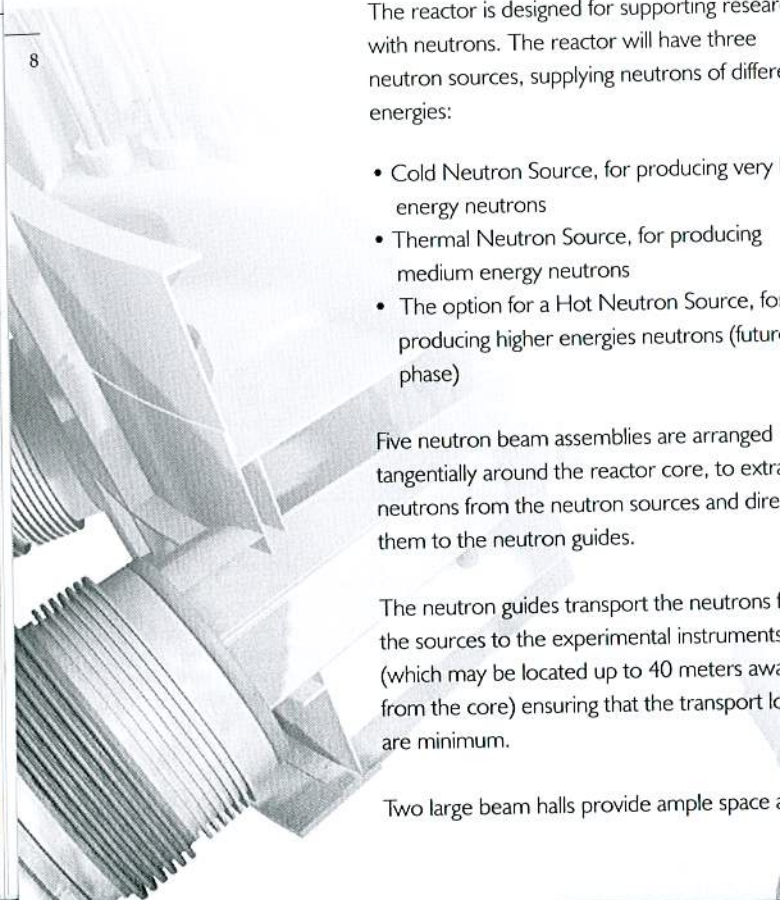
## Irradiation facilities

Radioisotopes are produced by introducing targets into dedicated irradiation positions in the reflector vessel.

The following irradiation facilities are provided:

- general purpose irradiation facilities
- bulk production irradiation facilities
- large volume irradiation facilities
- neutron activation analysis laboratory
- neutron transmutation doped silicon laboratory
- shielded hot cells for target loading, unloading and transfer to the radioisotope production plant

The reactor will produce radioisotopes and facilities for neutron activation analysis, and support material irradiation and neutron radiography to service the needs of the Australian industry, and resource and minerals processing.



# Instrumentation & Control System

The reactor is monitored, controlled and managed by the Instrumentation and Control System.

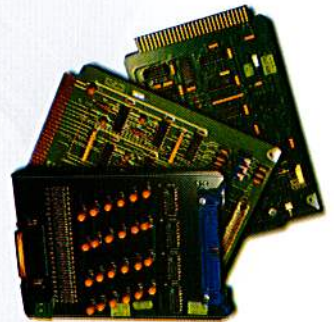
Three completely independent systems are provided in order to achieve the highest levels of reactor safety and availability:

- First Reactor Protection System
- Second Reactor Protection System
- Reactor Control and Monitoring System

The First Reactor Protection System is based on a state of the art fault tolerant controller, which monitors safety variables to detect potentially unsafe conditions. Its main functions are to trip the First Shutdown System and to trip the isolation of the containment.

The Second Reactor Protection System is based on hardwired technology that, monitoring a diverse set of safety variables, trips the Second Shutdown System.

Both systems have three independent and redundant channels for each safety parameter and a 2 out of 3 voting logic to trigger the safety actuation systems.



The Reactor Control and Monitoring System is a distributed, real time, state of the art computer-based and high availability system which monitors all plant and reactor parameters and presents them to the operator at the main control room, emergency control centre and local supervision centres. It enables reactor control, process commands and control loops.

The system has the following functions:

- reactor power control
- limitation actions (safety related functions)
- plant control
- supervision of the reactor and plant status
- interlock generation
- alarm generation
- event and signal recording



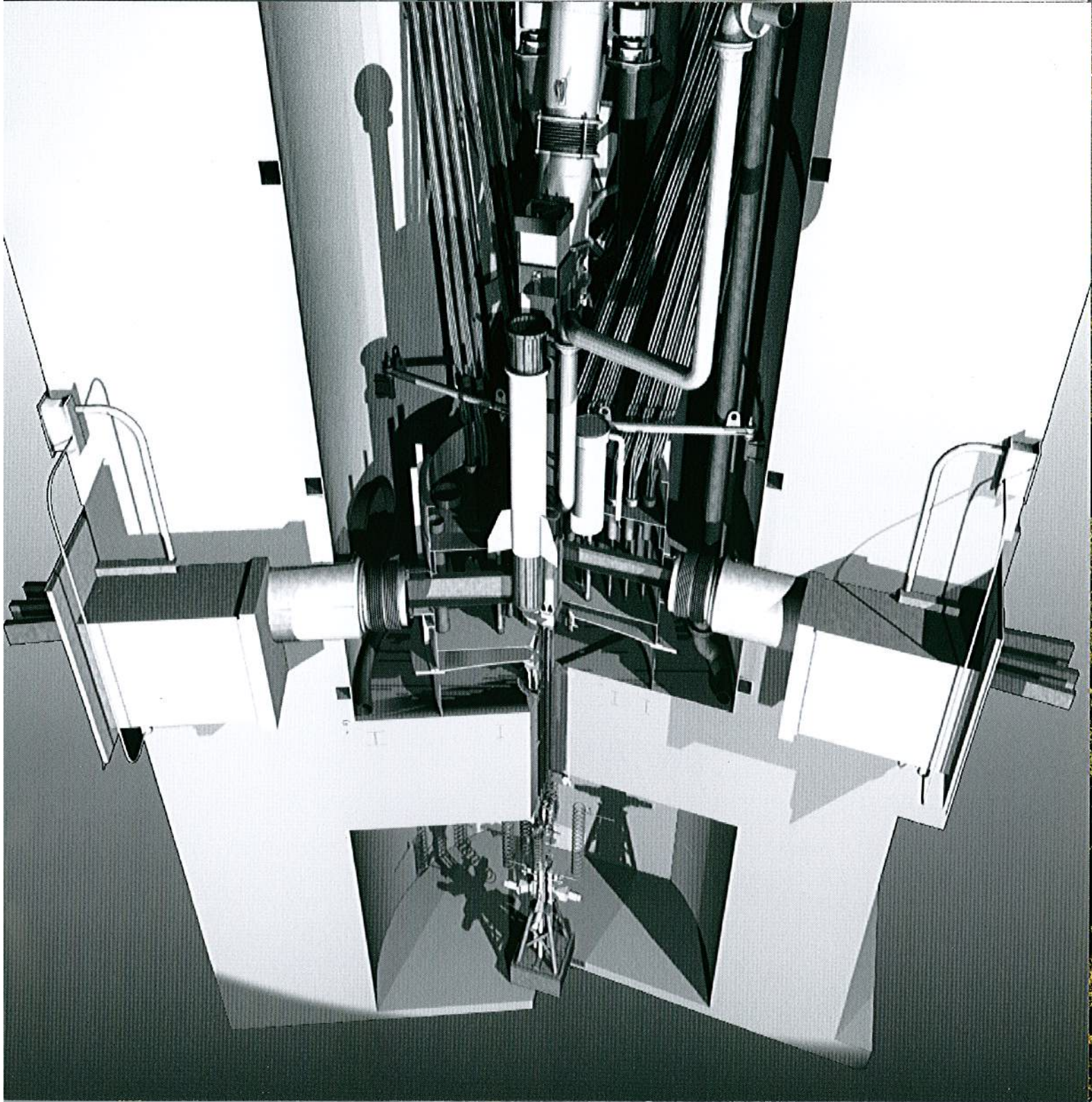
### Nuclear Instrumentation

A very complete set of nucleonic measurement channels monitors the neutron flux over the whole range of the reactor operation from source level to full power level.

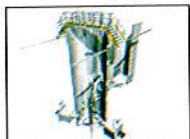
The system comprises the following channels:

- start up channel with three fission counters
- wide range log channel with three fission chambers
- power channel with three compensated ionisation chambers
- wide auto range channel with one fission chamber
- nitrogen-16 channel with one ionisation chamber

*Section view of core area*



# Data sheet



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## REACTOR

Type: Open pool  
Core thermal power: 20MW

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## CORE

Fuel type: 19.7% enriched  
Fuel element type: plate  
Coolant: light water  
Moderator: light water  
Reflector: heavy water  
Control: 5 absorbing plates  
Shutdown systems: 2 separate, diverse and independent systems

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## COOLING SYSTEMS

Core cooling  
3 centrifugal pumps (50% each)  
3 plate-type heat exchangers (50% each)  
Reactor and service pools cooling  
2 centrifugal pumps (100% each)  
1 plate-type heat exchanger

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## REACTOR TANK

Internal diameter: 4.5m  
Internal height: 14.1m  
Material: stainless steel

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## IRRADIATION FACILITIES

55 pneumatic position general purpose  
2 NAA pneumatic transport  
17 rig (5 targets each) for bulk production irradiation facilities  
7 Si doping facilities

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## RESEARCH FACILITIES

1 Cold Neutron Source (LD<sub>2</sub>)  
1 Thermal Neutron Source (D<sub>2</sub>O)  
1 - (Graphite) Hot Neutron Source (future 2<sup>nd</sup> phase)  
Cold Neutron Guide Lines: 3 installed  
System upgradeable up to 6 (future 2<sup>nd</sup> phase)  
Thermal Neutron Guides Lines: 3 installed  
System upgradeable up to 6 (future 2<sup>nd</sup> phase)  
Hot Neutron Lines: 2, independent

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## PROTECTION SYSTEMS

Two independent and diverse instrumentation systems that trigger the shutdown systems

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## CONTROL SYSTEM

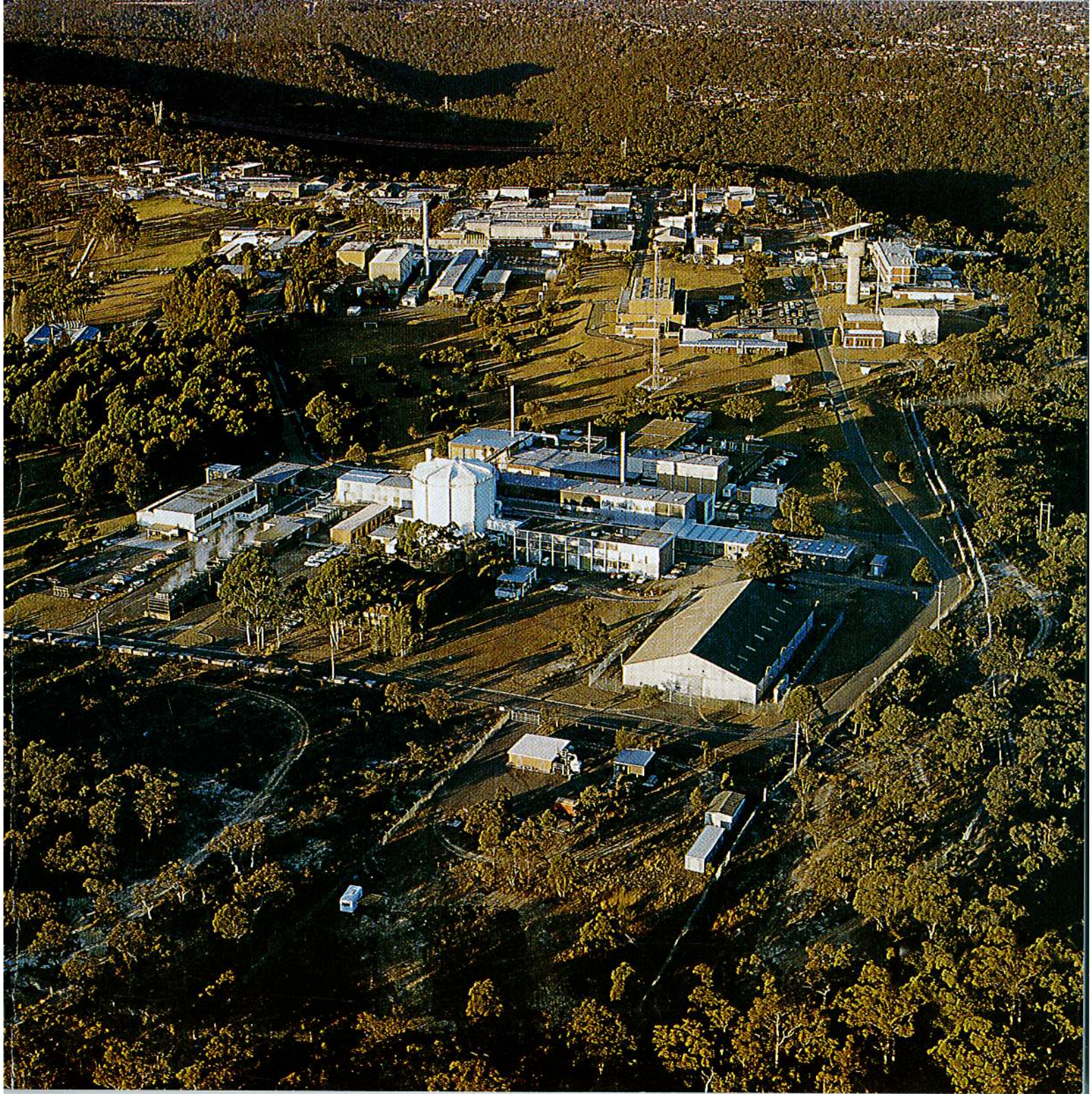
Computerised distributed control system  
Ergonomic control room design

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## NUCLEAR INSTRUMENTATION

Start-up channel: 3 fission counters  
Wide range log channel: 3 fission chambers  
Power channel: 3 compensated ionisation chambers  
Automatic power control:  
Wide auto range channel: 1 fission chamber  
Nitrogen- 16 channel: 1 ionisation chamber  
Radiological protection instrumentation

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