The nuclear research centre at Bariloche, Argentina

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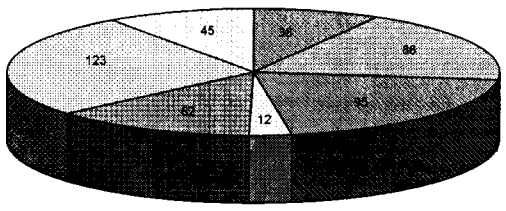
Abstract. The nuclear research centre at Bariloche (CAB) is one of the four centres under the Atomic Energy Commission of Argentina (CNEA). The research programme of CAB addresses various issues like nuclear reactor development, nuclear fuel and fuel cycle, applications of radioisotopes and radiation, and waste management. There is also a basic nuclear science component. The human resource development in the areas of physics and nuclear engineering is done in an associated Balseiro Institute which has undergraduate and graduate programmes as well as doctoral and postdoctoral research. The Centre interacts well with the society and provides services in the nuclear area. It has a close interaction with the nuclear sector of Argentina as also with many international organisations. Regulatory control over the Centre is carried out by the Nuclear Regulatory Authority of Argentina.

Introduction

The Atomic Energy Commission of Argentina (CNEA) is constituted by four centres dedicated to nuclear studies. These centres are located in Bariloche (Province of Rio Negro), Constituyentes (Buenos Aires), Ezeiza (Buenos Aires), and Pilcaniyeu (Rio Negro). The four centres are similar in their structure and have complementary roles in order to fulfill the global objectives of CNEA. In what follows I will refer only to the nuclear centre located in Bariloche, namely the Bariloche atomic centre (CAB).

Early developments in Bariloche took place in 1955, mainly in the area of the formation of human resources. At present the CAB is a high complexity nuclear and non nuclear research centre, with excellent scientific and technological backing, capable of dealing with the most diverse problems faced by the CNEA. At the moment the CAB has more than 120 researchers, 60 high qualified technicians, and 80 undergraduate students. The total staff distribution of the CAB is shown in Fig. 1, which also includes administrative and service employees.

The infrastructure available at the moment at the CAB is quite diverse, and its main components and laboratories are described below.



123 Researchers
62 Assisting Technicians
38 Administratives
45 Services
86 Undergraduates
95 Graduates
12 Postdoctoral

FIG. 1. Human resources at the CAB-IB.

- The RA-6 Nuclear Research Reactor, which has been designed and built in Argentina. The purpose of this reactor is to carry out teaching, training, research and development tasks in the field of nuclear engineering. It is an extremely versatile reactor, useful for very different requirements.
- The RA-6 is a 500 kW power reactor of the pool type, easy and secure to handle. The reactor itself possesses a wide array of equipment, both nuclear and conventional, a control room for training of personnel, and a nucleus of variable configuration
- A Freon Loop, which consists of a thermohydraulic circuit working at adequate pressures and temperatures in order to simulate operating conditions similar to that of nuclear reactors.
- A Linear Electron Accelerator of 25 MeV, used as a pulsed source of neutrons for study of materials, analysis by activation and irradiation studies.
- A Neutron Activation Analysis laboratory, supplemented by gamma spectrometry and appropriate outlying facilities.
- A vibration analysis laboratory totally equipped for anticipated diagnosis of failures and maintenance of rotating machinery.
- A nuclear materials laboratory, which has extensive experimental facilities for the characterisation of thermal properties of materials of nuclear interest up to very high temperatures.
- The laboratory for nuclear materials also includes facilities for thermogravimetric analysis, differential thermal analysis and dilatometry. It also has excellent facilities for the characterisation of powder materials, where particle size and specific area can be determined. Other facilities allow for the microstructural analysis of metallic alloys, ceramics and glasses, including the determination of materials phases and microhardness. It is also possible to carry out programmed thermal treatments at very high temperatures, in vacuum or in oxidant or reducing atmospheres.
- Equipment is also available for chemical analysis by means of atomic absorption, spectrophotometry and chromatography.
- A full equipped transmission and scanning electron microscopy laboratory.
- A laboratory for the study of the physical and chemical properties of materials. This laboratory is very complete and offers a variety of installations for the production of metallic and ceramic materials, as well as equipment for experiments in mechanochemistry (nanoparticles). Systems are also available for the production of controlled gaseous atmospheres, thermogravimetric analysis, automatic equipment for gaseous and cathodic hydruration as well as measurements of hydrogen absorption and desorption, dynamical spectroscopy of hydrogen desorption, and gas chromatography.
- A metallurgical laboratory, fully fitted with a complete array of basic equipment for routine metallurgical study of materials. This includes equipment for the absolute determination of hydrogen content. It has the necessary infrastructure for the production of refractory metallic alloys at a laboratory scale, and their detailed metallurgical characterization.
- A computer and software laboratory, for modeling of engineering systems and computational mechanics, which has very modern equipment, useful for carrying out complex scientific and technological computations.
- An extremely well equipped laboratory of atomic collisions and atomic physics, including electrostatic accelerators, collimated ions, and low energy accelerators. It also has an atomic force microscope, AES, XPS and LEED equipment, and sophisticated high vacuum infrastructure.
- A low temperatures laboratory, with complete equipment for research in superconducting materials, Helium 3 and Helium 4 cryostats, and calorimetric, magnetic and resistivity facilities. It also has high and low field SQUID magnetometers, cathodic erosion

machinery for the production of multinetwork thin films, and a laboratory for the production of superconducting materials.

- A laboratory for the study of the Properties of Metals, which includes a complete experimental set up for the production and characterisation of metallic samples, including thermodynamic, structural, physical and mechanical properties.
- A laboratory for magnetic resonances, fully equipped, covering wide ranges of frequencies, temperatures and magnetic fields.
- A laboratory for the study of optical properties of materials, equipped with Raman spectrometry, an optical cryostat and different types of laser systems.
- Extensive and modern calculation facilities appropriate for the areas of statistical physics, elementary particles and fields, theory of solids, and fusion and plasma physics problems are available.
- The library of CAB contains 17 200 books and 650 journals in the area of physics, chemistry, materials, and nuclear engineering. This library is considered one of the best in the country and amply satisfies the needs of CAB and CNEA.

General technical programs

One of the functions of CNEA is the development of advanced technologies in the nuclear field for peaceful applications. At the moment several high-priority, specific programs, are being developed at CNEA. These programs are listed below:

- Reactors and nuclear power plants, which include developments in the area of innovative and advanced reactors, and research reactors.
- Nuclear fuels and cycles, including the development of processes, new types of fuels and high density fuels for research reactors.
- Radioisotopes and radiations, which include the development of new products of medical use, industrial and agricultural applications, and the study of the therapy of brain tumors by boron neutron capture.
- Waste management and decommissioning, including low, medium and high activity wastes, burning of actinides, decommissioning of nuclear power plants, and soil remediation.
- Basic nuclear sciences.

Within the programs outlined above, the CAB deals with a wide range of specific problems. Among them we can mention the following research and development programs, most of which are carried out in collaboration with the other three centres of nuclear studies of CNEA.

Research and development programs at the Bariloche atomic centre

- Reactors. Design and detailed engineering of innovative and research reactors, experiments with research reactors, neutronic design criteria of reactors, development of codes for neutron transport, simulation and analysis of accidents, reliability of processes and safety in reactors, design of safety systems, analysis of critical design items, revision and validation of reactor modeling, analysis of power plant dynamics and operation supervision, analysis and design of nuclear reactor thermohydraulic systems, economic and control management
- Fuels design of high density fuels based on silicides, design of new fuels for research and power reactors, development of neutron probes, optimization of methods for obtaining uranium mixed oxides, vibrational analysis and remote monitoring of fuels, zircaloy

hydruration, kinetics of hydruration, hydrogen influence on the mechanical properties of zirconium based alloys.

- Radioisotopes and radiations. Brain: tumor therapy by boron neutron capture, implementation and starting up of the gamma detection system in the RA-6 reactor, beam and dosimetry optimization, experiments with phantoms, operation and procedure protocols, modeling and codes for patient treatment planning. Activation analysis for elements traces. Design and modeling of radioactive material containers. Radiation sensors by means of paramagnetic resonance spectrometry.
- Wastes. storage and immobilization of radioactive wastes in glasses, irradiation effects on glasses, isotopic composition and waste criticality, burning of actinides.
- Basic nuclear sciences. Basic research in physics, in the areas of solid state, low temperatures, magnetic resonance, atomic collisions, surfaces, metals and alloys, elementary particles and fields, and nuclear data.
- Basic research in physical chemistry, in the areas of thermochemistry, interaction of gases with metals, hydruration of metals, properties of metallic oxides, and properties of interfaces.
- Research and computational modeling in fluid dynamics, computational mechanics, mathematical aspects of computational modeling and simulation, computational modeling of thermochemical properties.

The matrix relation between the CAB infrastructure and its research and development programmmes is schematized in Figure 2

Other technical activities at the Bariloche atomic centre

Based its specific activities within CNEA, the CAB actively interacts with society in general. Among the types of activities developed in this sense, we can mention the following:

- Technology transfer and technological innovation tasks in nuclear and non nuclear fields, as required by third parties.
- The human resources and infrastructure of the CAB help to resolve the most diverse technological problems faced by other public entities or private companies.
- Some of the tasks performed correspond to the solution of a number of problems in the area of materials science, development of pilot power plants, technical assistance to nuclear power stations, computer science services, forensic technology, consultancy and technological planning, specific technical training, metrology, services to the oil industry, services in the area of medical supplies and instruments, and contributions to the study and improvement of legal norms for technological transfer activities within the country .
- Contribution to the formation of human resources in other regions of the country in the areas of physics and engineering, mainly by teaching advanced courses.
- Training at the CAB of human resources that do not belong to CNEA, in areas of nuclear interest.
- Courses given at the CAB for improvement of the teaching of mathematics, physics and engineering, aimed at high school teachers across the country, which include training in the experimental area.
- Periodic seminars on education in physics and engineering for the general public.
- Organization and management of scientific and technological meetings of all type in the Bariloche area.
- Assistance to the community of Bariloche in questions of safety and environment, mainly in what refers to the handling of toxic wastes, forest fires and other public emergencies .

		R&D Programmes at CAB-IB			
		REACTORS	FUELS	R & R	WASTES
I	RA-6	X		X	
N	FREON LOOP	X	X		
F R	LINAC	X	X		
A	NAAL			X	X
	AEROSOL. CHARACT.			X	X
S T	VIBRATION	X			
R U	NUCLEAR MATLS.		X		X
C T	ELECTRON MICRO-SCOPY		X		X
U R	PHYSICAL CHEMISTRY OF MATLS.		X		X
E	METALLU-RGICAL LAB.	X	X		
	COMPUTA-IONAL MECHAN-ICS	X	X		X

BASIC NUCLEAR SCIENCES: ATOMIC COLLISIONS, LOW TEMPERATURE, METALS, MAGNETIC RESONANCE, OPTICAL PROPERTIES LAB., THEORETICAL PHYSICS.

Fig. 2. Matrix relation between CAB infrastructure and R&D programmes.

In summary, the interaction of the CAB and CNEA with society in general is very intense and covers very diverse aspects.

The scientific and technological know-how of the Bariloche atomic centre and CNEA, and their readiness to collaborate, are widely acknowledged by society in general, and has fostered strong links with the community. Moreover, the nature of the activities at CAB has had over the years a positive influence on the public opinion, encouraging young people to look for new and promising possibilities in their professional development.

Challenges for the future

The CAB is faced with important and immediate challenges. Among them we have:

- To continuously establish new goals and orientations in their lines of work to satisfy the requirements of CNEA, bearing in mind that change is the only constant.
- To maintain and increase the potential for response to the demands of the CNEA in its traditional areas, especially in what refers to its high-priority programs.
- To find means for the preservation of the know-how and the scientific and technological infrastructure developed over the years.
- To be appropriately qualified to satisfy non nuclear technological demands.
- To generate the necessary connections with other nuclear centres, national and foreign institutions, and with other government organizations and private companies, in order to work co-ordinately on the type of scientific and technological problems which, because of their nature and magnitude, require such co-operation.
- To maintain an appropriate balance and connection between scientific and technological research, and between technological and economical development, aimed at the efficient and cost-effective resolution of interdisciplinary problems in nuclear and non nuclear fields.
- To identify future lines of work with the highest probability of being future high-priority needs of the CNEA.
- To promote the incorporation of young professionals to maintain the optimal average age among the personnel, and therefore the associated push and creativity towards the specific objectives of CNEA and CAB.
- To contribute to improve state policies in the area of nuclear technology to satisfy the needs of society.
- To optimize the use of the available public funds, generating the necessary actions that will guarantee the adequate completion of the tasks assumed. To consider their eventual re-structuring in order to keep adapted without loss of efficiency to possible adjustments in the resources assigned by the country.
- To improve co-operation with other foreign organizations with similar objectives.
- To maintain the recognition and international and regional leadership gained in the fields of science and technology, in particular in nuclear matters, in order to advise, participate and contribute to meet the international and regional challenges presented to CNEA.
- To promote in the media and other spheres of public influence the knowledge of the CAB and CNEA and their role as parts of society. This includes explaining their mission of contributing to guarantee in the near future the supply, as well as the completely secure handling, of nucleoelectric power and related technologies.
- The importance of the above goal has strongly to do with the protection of the environment at world level, in which CNEA and CAB are strongly involved. This is a problem that goes beyond the limits of our country and accounts for the need of urgent international co-operation.

National and international co-operation

At the international level, the CAB collaborates and participates in a variety of projects and events, both in nuclear and non nuclear fields. The character of this international co-operation is, on the one hand, to offer and contribute to the formation of human resources, and, on the other hand, to collaborate on equal footing with developed countries in R&D. This international co-operation is carried out in many cases with the participation of IAEA. For example, through this IAEA, five international scholarship holders were trained in Chemistry, Materials Science, Research Reactors and Neutron Physics during 1995–1999.

During 1997–1999, thanks to scholarships offered by CNEA, five postgraduate Latin American students specialized in Nuclear Energy and its Technological Applications, while during 1998–1999 six undergraduate students of the same origin were received at the CAB. Concerning international projects, there has recently been participation in the International Working Group on Fuel Cycle Options, as well as in co-ordinated research programs related with Fusion and Heavy Water Reactors.

Excellent bilateral cooperative relations exist with Germany, the USA (DOE.), Norway and Romania, focused mainly on nuclear-related areas.

The CAB regularly carries out and participates in the organization of international events in science and technology related with nuclear and non nuclear problems, which have always been of great success.

At the national level, there is an important nuclear sector external to CNEA consisting of state and/or private companies involved in the nuclear industry. The CAB interacts strongly with these companies, providing technological backing under the form of technical consultancies and services. Briefly, the following companies belong to the Argentinean Nuclear Sector:

- NASA, which manages the two Argentinean nuclear power stations in operation and a third power station under construction,
- CONUAR SA, a nuclear fuels manufacturer,
- INVAP SE, a company of applied research and advanced technology in the nuclear and
- ENSI SE, a heavy water production
- FAE SA, a company for the production of special alloys, mainly zircaloy,
- DIOXITEK, which runs a production plant for uranium dioxide of nuclear quality,
- FUESMEN, specialized in nuclear medicine,
- NM SE, specialized in engineering services in connection with ionizing radiations and exploitation projects of uranium minerals.

Finally, the Nuclear Regulatory Authority (ARN) should be mentioned. This is an independent national organization with which the CNEA and CAB strongly interact concerning the control, regulation and inspection of its entire nuclear installations and activities. In this way the CAB makes sure, and also gives assurance to the community, of the detailed compliance to all the conditions of safety, care and protection of persons and the environment demanded by society and national law .

Appendix

RECENT PUBLICATIONS BY THE BARILOCHE ATOMIC CENTRE

For the benefit of the reader, and as a specific description of some of the activities performed at the Bariloche atomic centre, below is given a set of recent publications. These publications should provide an overall picture of the current fields of interest at the Centre. For each cited publication, the author signaled in bold may be addressed for additional information. All the signaled authors have the following address: *Centro Atómico Bariloche, 8400 Bariloche, Rio Negro, Argentina; Phone (54) 2944 445100.* Alternatively, the following common e-mail address could be used: webmaster@cab.cnea.gov.ar

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