NATIONAL REPORT OF BRAZIL 2008

FOR THE 3rd REVIEW MEETING OF THE JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT

OCTOBER 2008

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October 2008

FOREWORD

On 29 September 1997, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was open for signature at the headquarters of the International Atomic Energy Agency in Vienna. Brazil signed the Convention on October 11th, 1997 and ratified it by the Legislative Decree n. 1.019 of November 14th, 2005. Brazil deposited the instrument of ratification with the Depositary on 17 February 2006.

The Convention objectives are to achieve and maintain a high level of nuclear safety worldwide in spent fuel and radioactive waste management. One of the obligations of the Parties to the Convention is the preparation of a periodical National Report describing the measures taken to implement each of the obligations of the Convention, including a description of the policies and practices related to spent fuel and radioactive waste management and an inventory of related material and facilities.

Brazil has not participated in the First Review Meeting and prepared a National Report for the Second Review Meeting and made a presentation under the condition of "late ratifier". However, the Report was not reviewed by the Parties according to the normal review process.

The National Report of Brazil 2008 is, therefore, presented to the Parties of the Convention for review for the first time. This National Report 2008 was prepared by a group composed of representatives of the various Brazilian organizations with responsibilities related to safety of spent fuel and radioactive waste. The National Report 2008 contains a description of the Brazilian policy and program related to the safety of nuclear energy, and an article-by-article description of the measures Brazil is taking to implement the Convention obligations, according to the format of document INFIRC/604.

SUMÁRIO

Em 29 de setembro de 1997 a Convenção Conjunta sobre Segurança no Gerenciamento de Combustível Nuclear Usado e sobre Segurança no Gerenciamento de Rejeitos Radioativos foi aberta para assinaturas na sede da Agência Internacional de Energia Atômica em Viena. O Brasil assinou a convenção em 11 de outubro de 1997 e ratificou-a através do decreto legislativo n. 1.019 de 14 de novembro de 2005, depositando o instrumento de ratificação no Depositário em 17 de fevereiro de 2006.

O objetivo da Convenção é alcançar e manter um alto nível de segurança no gerenciamento de combustível nuclear usado e de rejeitos radioativos em todo o mundo. Uma das obrigações das Partes da Convenção é a preparação a cada 3 anos de um Relatório Nacional descrevendo as medidas tomadas a fim de cumprir os objetivos da Convenção.

O Brasil não participou na Primeira Reunião de Revisão. E um primeiro Relatório Nacional do Brasil foi elaborado e apresentado na Segunda Reunião de Revisão na condição de "ratificador atrasado". Por isso aquele Relatório Nacional não foi revisto pelas Partes da Convenção de acordo com o processo de revisão formal. Portanto este Relatório Nacional 2008 atualizando as informações contidas no Relatório Nacional anterior é submetido às Partes da Convenção para revisão a avaliação pela primeira vez.

Este Relatório Nacional 2008 foi preparado por um grupo composto por representantes das várias organizações brasileiras com responsabilidades relacionadas com a segurança de combustíveis usados e rejeitos radioativos, e é apresentado às Partes da Convenção. O Relatório contém uma apresentação da política nuclear brasileira, o programa relacionado com a segurança nuclear e uma descrição das medidas tomadas pelo Brasil para implementar as obrigações de cada artigo da Convenção. O conteúdo do Relatório segue as Diretrizes estabelecidas pelas partes durante a reunião preparatória da Convenção contidas no documento INFIRC/604 de 1 de julho de 2002.

As considerações finais apresentadas na seção K levam à conclusão de que o Brasil alcançou e vem mantendo um alto nível de segurança na gerência de combustíveis usados e de rejeitos radioativos em todas as suas atividades. Ações efetivas contra o potencial risco radiológico foram implementadas e mantidas a fim de proteger os indivíduos, a sociedade e o meio ambiente de possíveis efeitos da radiação ionizante, evitando acidentes nucleares com conseqüências radiológicas e mantendo-se preparado para agir efetivamente em uma situação de emergência.

Consequentemente, o Brasil alcançou os objetivos da Convenção Conjunta sobre Segurança no Gerenciamento de Combustível Nuclear Usado e sobre Segurança no Gerenciamento de Rejeitos Radioativos.

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Section A - INTRODUCTION

A.1. THE BRAZILIAN NUCLEAR POLICY

The Constitution of 1988 of the Federal Republic of Brazil states in its articles 21 and 177 that the Union has the exclusive competence for managing and handling all nuclear energy activities, including the operation of nuclear power plants. The Union holds also the monopoly of the survey, mining, milling, exploitation and exploration of nuclear minerals, as well as of the activities related to industrialization and commerce of nuclear minerals and materials. The Union is also responsible for the final disposal of radioactive waste. All of these activities shall be solely carried out for peaceful uses and under the approval of the National Congress.

The national policy for the nuclear sector is implemented according to the Plan for Science and Technology 2005/2010 (Plano Plurianual de Ciência e Tecnologia – PPA), which establishes quantitative targets that define the Government strategy. One of the items of the PPA is the National Nuclear Power Policy, aiming at guiding research, development, production and safe use of all forms of nuclear energy.

An important target of the current PPA is to increase the participation of nuclear energy in the national electric power production. This involves the continuous development of technology for the design, construction and operation of nuclear power plants and industrial facilities related to the nuclear fuel cycle. The development of human resources for the establishment and continuity of these activities is also addressed in this plan.

The plan for Science and Technology also envisages the growth of nuclear technology use in other areas such as medicine, industry and food irradiation. To accomplish this, research and development institutions operate research reactors and isotope production facilities, as well as develop the related technology and train the required manpower.

The National Nuclear Energy Commission (Comissão Nacional de Energia Nuclear - CNEN) was created in 1956 (Decree 40110 of 10/10/1956) to be in charge of all nuclear activities in Brazil. Later, CNEN was re-organized and its responsibilities were established by Law 4118/62 with alterations established by Laws 6189/74 and 7781/89. Thereafter, CNEN assumed Regulatory Body roles, including regulating, licensing and controlling nuclear energy utilization. At the same time, nuclear power generation was transferred to the government sector associated to energy issues. CNEN is also in charge of research and development and production of radioisotopes. According to Brazilian Legislation, CNEN is also the governmental body responsible for receiving and disposing of radioactive waste from the whole country.

A.2.THE BRAZILIAN NUCLEAR PROGRAMME

A.2.1. Nuclear Power Plants

Currently, Brazil has two operating nuclear power plants (Angra 1, 657 MWe gross/627 MWe net, 2-loop PWR and Angra 2, 1350 MWe gross /1275MWe net, 4-loop PWR). A third plant (Angra 3, 1345 MWe gross/1275 MWe net, PWR, similar to Angra 2) has had the construction temporarily interrupted, but recently a Governmental decision was made to restart the implementation of the Angra 3 project. Angra 1, 2 and 3 are located in a common site, near the city of Angra dos Reis, about 130 km south of Rio de Janeiro.

The construction of nuclear power plants in Brazil has required considerable effort in qualifying domestic engineering, manufacturing and construction companies, in order to comply with the strict nuclear technology transfer. The result of this effort, based on active technology transfer, has led to an increase in the participation of domestic technology in the nuclear power sector.

Brazil has established a nuclear power utility and engineering company, Eletrobras Termonuclear S. A. (ELETRONUCLEAR), a heavy components manufacturing company, Nuclebras Heavy Equipment (Nuclebras Equipamentos Pesados - NUCLEP), a nuclear fuel manufacturing plant (Fábrica de Combustível Nuclear - FCN) and a yellow-cake production plant belonging to the Nuclear Industries of Brazil (Indústrias Nucleares do Brasil - INB). Brazil also has the technology for uranium conversion and enrichment, as well as private engineering companies and research and development institutes devoted to nuclear power development. Over 15,000 individuals are involved in nuclear fuel cycle activities. Brazil ranks sixth in the world in terms of uranium ore reserves, which amounts to approximate 310,000 t U_3O_8 *in situ*, recoverable at low cost.

According to the 10-year Expansion Plan of Eletrobras (the Brazilian electric power company), Angra 3 is due to enter commercial operation in the middle of next decade. The plant is also included in the pluriannual planning of the Brazilian Federal Government.

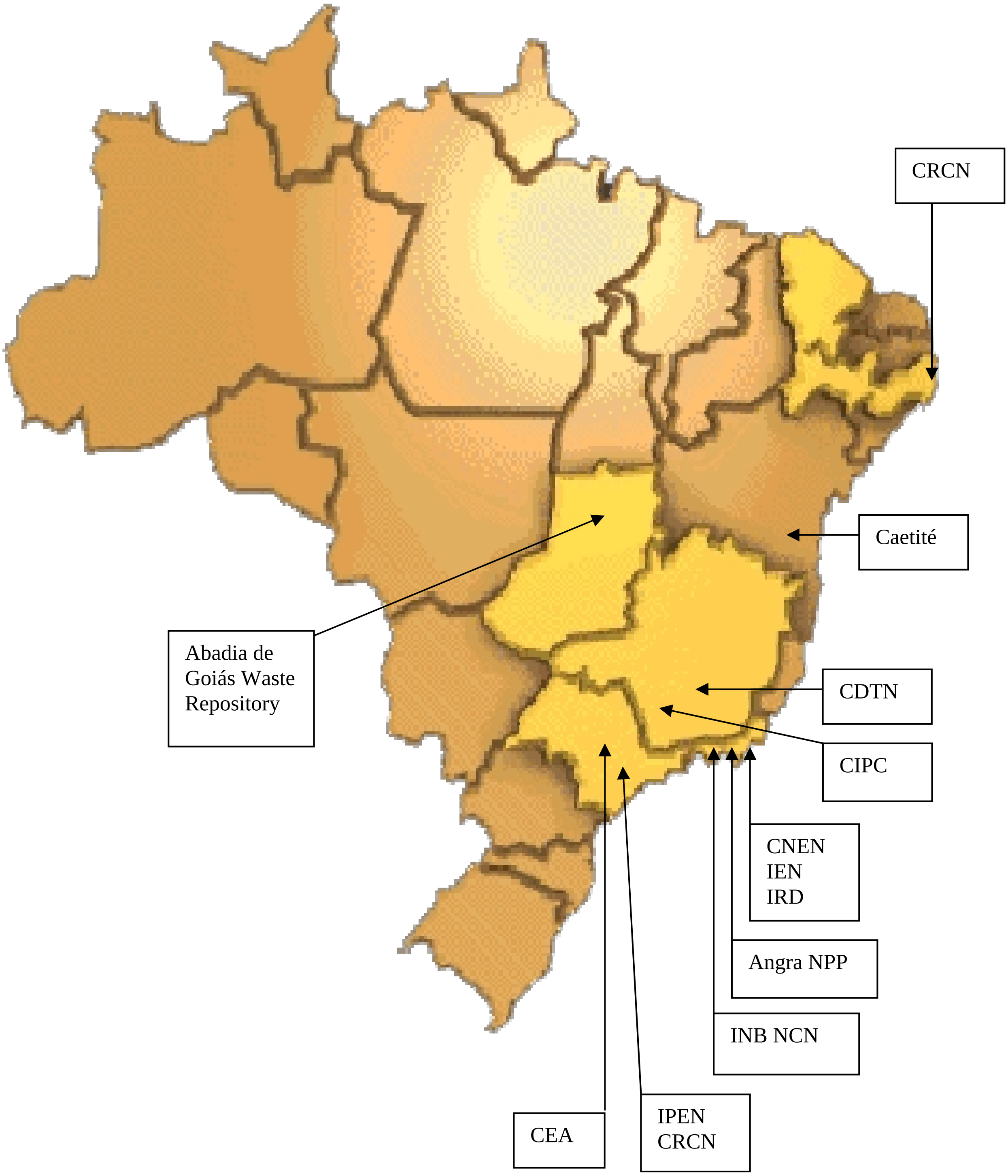

Figure A.1. Main Brazilian Nuclear Installations and Organizations

A.2.2. Research Reactors (RR)

Brazil has 4 research reactors operating at CNEN institutes.

A.2.2.1. IEA- R1

IEA-R1 is the largest research reactor in Brazil, with a maximum power rating of 5 MWth. IEA-R1 is a pool reactor, with light water as the coolant and moderator, and graphite and beryllium as reflectors. The reactor was commissioned on September 16, 1957, when it achieved its first criticality. Although designed to operate at 5 MW, the reactor operated only at 2 MW between the early 1960's and mid 1980's, on an operational cycle of 8 hours a day, 5 days a week. IEA-R1 is currently operating at 3.5 MWth with a 64-hour cycle per week. The reactor originally used 93% enriched U-Al fuel elements. Currently, it uses 20% enriched uranium (U_3O_8-Al and U_3Si_2-Al) fuel that is produced and fabricated at IPEN. The reactor is operated and maintained by the Research Reactor Center (CRPq) at IPEN, Sao Paulo, which is also responsible for irradiation and other services.

The IEA-R1 reactor is located in a multidisciplinary facility which has been consistently used for research in nuclear and neutron related sciences and engineering. The reactor has also been used for training, radioisotope production for industrial and nuclear medicine applications, and for general irradiation services. Several departments of IPEN routinely use the reactor for their research and development work. Scientists and students from universities and other research institutions also use it for academic and technological research. The largest user of the reactor is the Research Reactor Center from IPEN, which is interested in basic and applied research in the areas of nuclear and neutron physics, nuclear metrology, and nuclear analytical techniques.

In the early 1960's, IPEN produced ^{131}I, ^{32}P, ^{198}Au, ^{24}Na, ^{35}S, ^{51}Cr and labeled compounds for medical use. After 1980, it started producing ^{99m}Tc generator kits from the fission of ^{99}Mo imported from Canada. This production is continuously increasing, with the current rate of about 17000 Ci of $^{99m}T_C$ per year. The ^{99m}Tc generator kits, with activities varying from 250 mCi to 2,000 mCi, are distributed to more than 300 hospitals and clinics in Brazil. Several radiopharmaceutical products based on ^{131}I, ^{32}P, ^{51}Cr and ^{153}Sm are also produced at IPEN.

During the past few years, a concerted effort has been made in order to upgrade the reactor power to 5 MWth. One of the reasons for this decision was to produce ^{99}Mo at IPEN, thus minimizing the cost and reliance on only one or two international suppliers. The reactor cycle will be gradually increased to 120 operating hours per week.

A.2.2.2. IPR – R1

The IPR-R1 TRIGA (Training, Research, Isotopes, General Atomics), located at the Nuclear Technology Development Center – CDTN, at the campus of Federal University of Minas Gerais in Belo Horizonte, has been operating for 48 years. It was the second Brazilian RR. The IPR-R1 is a pool type nuclear research reactor, with an open water surface and the core has a cylindrical configuration (Fig. A.2). The first criticality was achieved on November 1960. At present, the reactor operates at 100kW and the certification process to operate at 250kW is at the final stage. The operation regime of the reactor is 12 hours per week, 40 weeks per year. The integrated burn-up of the reactor since its first criticality until present is about 83 MW-day. Due to the low nominal power, spent fuel is far from being a problem, except for aging concerns. The first fuel assembly replacement of the reactor is not expected to occur before 2015.

The IPR-R1 is mainly used for thermohydraulical and neutronics research, neutron activation analysis and applied research, as well as for the production of some radioisotopes, like ^{60}Co that is used in the stainless steel industry, and tracers that are used in the environmental research activities. Additionally it is also employed to train the Brazilian NPP operators.

Figure A.2. IPR-R1 – Reactor Core and Control Room

A.2.2.3. Argonauta – IEN

The third Brazilian RR is named Argonauta, and is located at the Institute of Nuclear Engineering (Instituto de Engenharia Nuclear – IEN) on the campus of the Federal University of Rio de Janeiro, in Rio de Janeiro city. The first criticality of the reactor was reached on February of 1965. The reactor can operate at a maximum power of 1kW during an hour or 500 W continuously. It is usually operated in the range of 170 to 340 W. The accumulated burn-up of the reactor since its first criticality is less than 1%, and as in the case of IPR-R1, due to the low nominal power, storage of spent fuel is not a problem. It is used mainly for training purposes, research and sample irradiation.

A.2.2.4. IPEN MB-01

The most recent Brazilian RR is IPEN/MB-01, also located at IPEN. This research reactor is the result of a national joint program developed by CNEN and the Brazilian Navy.

The first criticality of the IPEN/MB-01 reactor was reached on 9 November 1988. From that date to May 2008, more than 2150 operation were made to measure Reactor Physics parameters to validate neutronic codes, train reactor operators and teach graduate and post-graduate courses. Some critical experiments are international benchmarks of the Nuclear Energy Agency (NEA-OECD). The IPEN/MB-01 reactor is a zero power reactor because the maximum power level is 100 watts with an average thermal neutron flux of about 5.0×10^8 $n/cm^2.s$. This neutron flux is not high enough to raise the temperature during its operation and fuel burn up. The reactor, a water tank type critical facility, has a core that consists of up 680 stainless steel fuel pins with UO_2 pellets inside. The diameter of the pins is 9.8 mm, and their length is 1194 mm. The pins have an active length of 546 mm, filled with 4.3% enriched UO_2 pellets. The remainder of the pins is filled with Al_2O_3 pellets.

The pins are manually inserted into a perforated matrix plane, making it possible any desired experimental arrangements within a 28 x 26 matrix. The control and safety rods are composed of a total of 48 pins that contain absorbing neutron material. Each safety and control rods has 12 pins . Ten nuclear channels around the structure that sustains the matrix plate complement the critical arrangement, which is maintained within a stainless steel tank. Deionized water is used as a moderator and for the natural cooling system.

A.2.3. Nuclear Installations

A.2.3.1. Mining and Milling

Two facilities have been in operation in Brazil. The first one, in Poços de Caldas, operated between 1982 and 1995. All the economically recoverable uranium was extracted and currently no mining activity is underway. The site is being prepared for decommissioning.

A new mining facility has been in operation since 2000 in Caetité, with reserves of 100,000 t of U_3O_8, and a capacity of 400 t/year of yellow cake (U_3O_8) production, which can be expanded to 800 t/year.

The deposit of Santa Quitéria, located in the interior of the State of Ceará, is the largest discovered uranium reserve in Brazil. An estimated 142.2 thousand tonnes of uranium is inter-mixed with phosphates. The economic viability of the mine depends on the exploration of the associated phosphate, which will be used in the production of fertilizers. INB hopes the mine will be operational by 2012. It is planned to produce 1,600 tonnes of U_3O_8 per year as a by-product of 240,000 tonnes of P_2O_5.

A.2.3.2. Monazite Sand Extraction

Brazil has large natural deposits of monazite sand in its Central–East Coast. These have been in exploration since the 1950's. The only treatment facility in operation is located at Buena, in Rio de Janeiro state. The facilities in São Paulo state are no longer in operation.

A.2.3.3. Uranium Enrichment and Fuel Manufacture

An industrial complex in Resende contains two units operated by INB related to the manufacture of nuclear fuel for the Brazilian nuclear power plants.

In the first unit, uranium hexafluoride is converted into UO_2 powder and fuel pellets are manufactured. The current nominal capacity is of 165 t/year of UO_2 powder, and 120 t/year of UO_2 pellets, although only part of this is actually produced.

In the second unit, PWR fuel assemblies are manufactured using fuel pellets from the first unit and additional components imported or produced locally. The nominal capacity is 240 t/y of uranium. From 1982 to 2007, this unit produced 978 fuel assemblies for Angra 1 and Angra 2.

At the same site, installation of a plant for uranium enrichment based on ultracentrifuge technology developed by the Brazilian Navy is underway, with initial operation scheduled for 2008. The nominal capacity of this initial phase will be 2.4 ton of SWU.

A.2.4. The Navy Program

The Brazilian Navy started in 1979 a research and development program with the objectives of designing, constructing and operating a nuclear submarine. To coordinate these activities, the Navy Technological Center at São Paulo (CTMSP) was created, comprising facilities in the cities of São Paulo and Iperó (Centro Experimental Aramar – CEA). The most important facilities include offices, laboratory workshops, a pilot scale fuel manufacturing unit (LABMAT); uranium Enrichment Laboratories (LEI and USIDE) and a Radio-ecological Laboratory (LARE). Still under construction is the UF_6 conversion facility (USEXA), and a land based prototype reactor (LABGENE) for a nuclear propelled submarine.

A.2.5. Radioactive Installations

In Brazil, the radioactive installations, including the use of radioactive sources, are classified in 5 areas: medical, industrial, research and education, distribution and services.

In 2008, the national registry included 3750 radioactive installations. Table A.1 shows the distribution by areas of application in recent years. It is expected that this growing trend will continue in the following years.

Table A.1. Distribution of Radioactive Installation Licenses by Area (2008).

Area	2008
Medicine	1326
Industry	1355
Research	744
Distribution	75
Services	250
Total	**3750**

A.2.5.1. Medical Installations

Radiotherapy Services

A total of 251 facilities are in operation. Brazil follows the world trend to substitute the cobalt sources (129 facilities) by linear accelerators. There is also a national plan to re-equip hospitals with 30 oncology centres.

Nuclear Medicine Services

The use of radioisotopes in medicine is growing steadily, with the substitution of external irradiation by internal therapy using new radiopharmaceuticals, requiring an increased attention to the adaptation of the physical installations, especially with respect to the treatment and storage of waste and the release of effluents.

A.2.5.2. Industrial Installations

A total of 5607 sources are being used in industrial installations as described below.

Industrial Radiography Services

The development of the Brazilian gas pipeline network and of the offshore oil industry has significantly increased the demand for industrial radiography services. This has required a large effort to prepare the necessary personnel and develop the required procedures, especially for contractors.

Utilization of Nuclear Measuring Instruments

The chemical, metallurgic, petrochemical, plastic, paper and other industry are increasingly using measuring instruments (gauges) based on radioactive sources. Portable instruments used for density measurement are becoming more widespread. Sources such as ^{137}Cs, ^{241}Am, ^{90}Sr and ^{85}Kr are the most used.

Oil Exploration Well Profiling

In 2008, 9 organizations operated 22 bases for exploring oil in the North, Northeast and the Central coastal region using radioactive sources. Sources such as ^{241}Am, ^{60}Co, ^{226}Ra, ^{137}Cs and ^{241}Am/Be neutron sources are being used.

A.2.5.3. Industrial Irradiators

There are four ^{60}Co large-size industrial irradiators operating in São Paulo state. They are used for sterilization of medical equipment and food irradiation. A new facility has recently started its licensing process. One additional irradiator is installed in the city of Manaus, but its activities are currently halted, due to pending licensing issues.

Regarding smaller irradiators, three units are operating in the country: two at the CNEN's research centers (IPEN, in São Paulo and CDTN, in Belo Horizonte), and another one in Piracicaba, at the University of São Paulo's Center of Nuclear Energy for Agriculture, CENA.

A.2.5.4. Research Facilities

The use of radioisotopes in research occurs at CNEN research institutes (IPEN, IEN, and CDTN), other research centers and universities. The type of research is diverse, including nuclear physics, biology, agriculture, health, hydrology and environment. Generally, small sources of ^{3}H, ^{14}C, ^{22}Na, ^{55}Fe, ^{63}Ni, ^{125}I, ^{226}Ra, ^{35}S e ^{32}P are used for research applications.

Since 1986, IEN also has a cyclotron (CV-28), which is used in the production of radiopharmaceuticals for use in diagnostic examinations. The Institute has adopted the KIPROS system (Karlsruhe Iodine Production System). This ^{123}I production routine provides conditions for labeling special molecules. The first one was MIBG, which has its main application in cardiology. Presently, IEN delivers only to the largest cities in the country. Another important radioisotope produced for medical purposes is ^{18}F, considered the newest and most innovative technology in nuclear medicine.

Radioisotopes for medical uses are produced at IPEN in the Cyclotron Accelerators Center and in the Research Reactor Center. These radioisotopes, together with imported ones, are processed at the Radiopharmacy Center, following the requirements of the ISO 9002 standards and distributed just-in-time to hospitals all over the country, serving over 2.3 million patients per annum. A total of about 6.4×10^2 TBq of ^{18}F$^-$, ^{67}Ga, ^{123}I, ^{131}I, ^{99}Mo, ^{153}Sm, ^{35}S, ^{32}P and ^{51}Cr compounds are processed annually at IPEN.

A.2.6. Waste Repository at Abadia de Goiás

Following the 1987 accident with a disused ^{137}Cs source that resulted in the contamination of a significant part of the city of Goiânia, two near surface repositories containing 3.500 m^3 of radioactive waste were constructed in Abadia de Goiás in 1995.

A long-term safety assessment of both repositories was done at that time confirming the safety of the two repositories. According to the requirements of the final safety assessment report, the long-term safety assessment must be repeated as part of the institutional control reporting requirements. After seven years of disposal, a second safety assessment was performed by CNEN to verify again the safety of both systems. This will be described in detail in items D.6 and H.7.

A.3. STRUCTURE OF THE NATIONAL REPORT

This First National Report was prepared to fulfill Brazilian commitments with the Convention [1]. Section B to K present an analysis of the Brazilian structures, actions and activities related to the Convention's obligations, and follow the revised Guidelines for the preparation of National Report [2]. In Section B, some details are given on the existing policies and practices. Section C defines the scope of application of the Convention in Brazil. Section D presents the inventory of installations and facilities. Section E provides details on the legislation and regulations, including the regulatory framework and the regulatory body. Section F covers general safety provisions as described in articles 21 to 26 of the Convention. Section G addresses the safety of spent fuel management, including during siting, design, construction and operation. Section H addresses the safe management of radioactive waste. Section I presents a case of transboundary movement of spent fuel. Section J details the situation of disused radioactive sources.

In general, the report presents separately the different types of facility, whenever possible. Nuclear power plants, due to their complexity, are always treated separately.

Section K describes planned activities to further enhance nuclear safety and presents final remarks related to the degree of compliance with the Convention obligations.

The report also contains two annexes where more detailed information is provided with respect to spent fuel storage and radioactive waste facilities, and the Brazilian nuclear legislation and regulations. A third annex presents a list of used abbreviations.

Section B – POLICIES AND PRACTICES

B.1. INTRODUCTION

Brazilian practices related to spent fuel and radioactive waste management are similar to most international practices.

The policy adopted with regards to spent fuel from nuclear power plants is to keep the fuel in safe storage until an international consensus is reached about reprocessing and recycling the fuel, or disposing it of as such. Therefore, spent fuel is not considered radioactive waste in the sense of this Convention.

Regarding radioactive waste, the policy is to keep safely isolated from the environment for time being, while a permanent solution is expected on a national level.

The basic legislation governing this policy is the Brazilian Constitution, which establishes in its article 21 that “all the nuclear energy activities shall be solely carried out for peaceful uses and always under the approval of the National Congress”; the Law 6.189 of 16 December 1989, which attributed to CNEN the responsibility for the final disposal of radioactive wastes; and the recent Law n. 10.308 of 20th November 2001 which established rules for the siting, licensing operation and regulation of radioactive waste facilities in Brazil (see also E.2).

B.2. RADIOACTIVE WASTE

B.2.1. Types and Classification

The waste classification system adopted in Brazil is the same one adopted by the IAEA. Radioactive wastes are classified into three categories, as shown on Table B.1 below.

On the Table, short lived are those radionuclides with half-lives lesser than 30 years such as: ^{60}Co, ^{90}Sr, ^{137}Cs etc.

The types of waste are those normally generated by the sources presented in section A of this document and are described in more detail in the inventory presented in section D.

Table B.1. Waste Classification

Category	Characteristics	Disposal Option
1. Exempt waste	Activity levels equal or bellow the exemption limits that was based in a maximum impact dose of 0,01 mSv/yr for public	No radiological restriction
2. Low and Intermediate level waste	Activity levels above exemption limit and heat generation equal or below 2 kW/m^3.	
2.1. Short lived	Long lived alpha emitter contents equal or below 4000 Bq/g and the average specific activity of all radionuclides in the package (immobilized) below 400 Bq/g.	Near surface repository or geological.
2.2. Long lived	Alpha emitter radionuclides concentration above limits cited before for short live	Geological repository
3. High level waste	Heat generation above 2kW/m^3 and alpha emitter concentration above the limits allowed for low and intermediate level wastes – short lived (2.1)	Geological repository

Section C – SCOPE OF APPLICATION

C.1. DEFINITION OF SCOPE

According to the definition of the Convention and the Brazilian policies and practices described in section B, the activities and facilities covered by this report include all spent fuel and radioactive waste related to the Brazilian nuclear programme described in section A.2.

As mentioned in B.1, spent fuel from NPPs is not considered radioactive waste, pending an international consensus and a national decision about the possibility of reprocessing this fuel, or disposing it of as such.

Waste containing only natural occurring radioactive material will be included in the scope only to the extent that they are produced in the processing of uranium and thorium containing ores, such as Monazite sand processing, as described in sections H.2.2.2, H.2.2.3, and H.2.2.4.

So far, there is no spent fuel within the military or defense program in Brazil. The management of waste generated in the nuclear submarine program of the Brazilian Navy, although of minor importance and small quantity, is described in section D.4.

Section D - INVENTORY AND LISTS

This section describes the facilities and activities that produce spent nuclear fuel and radioactive waste, and present a description of the inventories. More detailed information is presented in Section H and on a table format in Annex 1.

D.1. NUCLEAR POWER PLANTS

As mentioned in item A 2.1, Brazil has two nuclear power plants in operation (Angra1, 657 MWe gross / 627 MW net, 2-loop PWR and Angra 2, 1350 MWe gross/1275 MWe net, 4-loop PWR) and one under planning (Angra 3, PWR, similar to Angra 2, with construction temporarily interrupted). Angra 1, 2 and 3 are located at a common site, near the city of Angra dos Reis, about 130 km from Rio de Janeiro.

D.1.1. Angra 1

Site preparation for Angra 1, the first Brazilian nuclear unit, started in 1970 under the responsibility of FURNAS Centrais Eletricas SA. The initial work for construction of the plant began only in 1972, shortly after the contract with the main supplier of equipment, Westinghouse Electric Co. (USA), was signed. The Westinghouse contract included supply and erection of the equipment, as well as engineering and design of the plant on a turnkey basis. Westinghouse sub-contracted Gibbs and Hill (USA) in association with the Brazilian engineering company PROMON Engenharia S.A. for engineering and design.

CNEN granted the construction license for the plant in 1974. The operating license was issued in September 1981, at which time the first fuel core was also loaded. First criticality was reached in March 1982, and the plant was connected to the grid in April 1982. After a long commissioning period due to a steam generator generic design problem, which required equipment modifications, the plant finally entered into commercial operation on 1st January 1985.

In 1998, plant ownership has been transferred to the newly created company ELETRONUCLEAR, which has absorbed all the operating personnel of FURNAS and part of its engineering staff, and the personnel of the design company Nuclebras Engenharia (NUCLEN).

D.1.1.1. Angra 1 Spent Fuel Management

With respect to spent fuel of Angra 1, the spent fuel pool capacity has been expanded by the installation of compact racks to accommodate the spent fuel generated for the expected operational life of the unit.

The current status at Angra1 fuel pools is presented on Table D.1.

Table D.1. Spent Fuel Assemblies Stored at Angra 1 (March 2008)

Storage place	Angra 1	
	Capacity	Occupied
New Fuel Storage Room	45	0
Region 1 Spent Fuel Pool	252	142
Region 2 Spent Fuel Pool	1000	508
Reactor Core	121	121
Note: By definition of INFCIRC/546 “SPENT FUEL” means nuclear fuel that has been irradiated in and permanently removed from a reactor core. Included in this inventory there are fuel assemblies that are not yet considered “spent fuel”, since they may be reused in future cycles.		

D.1.1.2. Angra 1 Radioactive Waste Management

Angra 1 nuclear power plant is equipped with systems for treatment and conditioning of liquid, gaseous and solid wastes. Concentrates from liquid waste treatment are solidified in cement and conditioned in 200 litter drums (up to 1998) and 1 m^3 steel containers (after 1998). Solid waste may be conditioned in drums or in special boxes. Gaseous waste is stored in holdup tanks and may be released from time to time. These tanks have the capacity for long-term storage, which eliminates the need for scheduled discharge. For the time being, medium and low level waste is being stored on site in a separate storage facility. (See D.1.4).

Generated volume of solid radioactive waste material is kept to a minimum by preventing materials from becoming radioactive, by decontaminating and reusing radioactive materials, by monitoring for radioactivity and separating non-radioactive material prior to conditioning and storage, and by other volume reduction techniques. Procedures, personnel training and quality control checks are used to ensure that radioactive materials are properly packed, abelled and transported to the storage facility.

In 2006, the Eletronuclear supercompacted about two thousand drums of radioactive waste by using a mobile supercompactor. The crashed drums were placed inside metallic boxes type B-25. Consequently, 128 metallic boxes were loaded with the pressed drums. These boxes were stored in the on site Storage Facility 1.

D.1.2. Angra 2

In June 1975, a Cooperation Agreement for the peaceful uses of nuclear energy was signed between Brazil and the Federal Republic of Germany. Under that agreement Brazil accomplished the procurement of two nuclear power plants, Angra 2 and 3, from the German company, KWU – Kraftwerk Union A.G., later SIEMENS/KWU nuclear power plant supplier branch.

Considering that one of the objectives of the Agreement was a high degree of domestic participation, Brazilian engineering company Nuclebras Engenharia S.A. – Nuclen (now ELETRONUCLEAR, after merging with the nuclear part of FURNAS, in 1997) was founded in 1975 to act as architect engineer for the Angra 2 and 3 project, with KWU as the overall plant designer, and, on the process, to acquire the required technology to design and build further nuclear power plants.

Angra 2 civil engineering contractor was Construtora Norberto Odebrecht and the civil works started in 1976. However, from 1983 on, the project suffered a gradual slowdown due to financial resources reduction. In 1991, Angra 2 works were resumed and in 1994, the financial resources necessary for its completion were defined. In 1995, a bid was called for the electromechanical erection and the winner companies formed the consortium UNAMON, which started its activities at the site in January 1996.

Hot trial operation was started in September 1999. In 24th March 2000, after receiving from CNEN the Authorization for Initial Operation (AOI) initial core load started, followed by initial criticality on 17th July 2000, and first connection to the grid on 21th July 2000. The power tests phase was completed in November 2000. The commissioning phase was a very successful one. No major equipment problems occurred in spite of the very long storage time (~20 years), indicating the high quality of the component conservation program. The Angra 2 NPP has been operating at full power since mid November 2000 and went into commercial operation on 21th January 2001. The Authorization for Initial Operation (AOI) has been extended periodically, basically due to problems with the environmental licence.

D.1.2.1. Angra 2 Spent Fuel Management

In the case of Angra 2, the spent fuel pool, which is located inside the steel containment, has two types of racks:

a) Region 1: normal racks with capacity for 264 fuel assemblies, equivalent to one full core plus one reload of fuel of any burnup and with enrichment up to 4.3%;

b) Region 2: high-density storage racks with storage capacity for 820 spent fuel assemblies. The fuel assemblies to be stored in region 2 must have a given minimum burnup, which is a function of the initial enrichment. This spent fuel storage capacity is sufficient for about 15 years (14 cycles) of operation, which means that additional spent fuel storage space, either of the wet or dry type, will have to be provided in the medium term.

The current status at Angra 2 fuel pools is presented on Table D.2.

Table D.2. Spent Fuel Assemblies Stored at Angra 2 (March 2008)

Storage place	Angra 2	
	Capacity	Occupied
New Fuel Storage Room	75	0
Region 1 Spent Fuel Pool	264	39
Region 2 Spent Fuel Pool	820	233
Reactor Core	193	193

Note: By definition of INFCIRC/546 "SPENT FUEL" means nuclear fuel that has been irradiated and permanently removed from a reactor core. Included in this inventory there are fuel assemblies that are not yet considered "spent fuel", since they may be reused in future cycles.

D.1.2.2. Angra 2 Radioactive Waste Management

Angra 2 nuclear power plant is equipped with systems for treatment, conditioning, disposal and storage of liquid, gaseous and solid radioactive wastes. All Angra 2 waste treatment systems are highly automated to minimize human intervention and reduce operating personnel doses. Liquid waste is collected in storage tanks for further monitoring and adequate treatment or discharge to the environment. The concentrate resulting from the liquid waste treatment is further processed in order to reduce water content before being immobilized in bitumen and conditioned in 200-liter drums. Spent resins and filter elements are also immobilized in bitumen and conditioned in 200-liter drums. Compactable and non-compactable solid waste is conditioned in 200-liter drums. Gaseous waste is treated in the gaseous waste treatment system, where the radioactive gases are retained in delay beds containing active charcoal to let them decay well below allowable levels, before release into the environment throughout the 150m high plant vent stack. No residues are produced in the gaseous waste treatment system, as all the system's consumables, mainly filter and delay bed fillings, are designed to last for the whole plant lifetime. The drums with waste are initially stored within the plant prior to being transported to the on site storage facility, still at the plant site.

Generated volume of solid radioactive waste material is kept to a minimum by preventing materials from becoming radioactive, by decontaminating and reusing radioactive materials, by monitoring for radioactivity and separating non-radioactive material prior to conditioning and storage, and by other volume reduction techniques. Procedures, personnel training and quality control checks are used to ensure that radioactive materials are properly packed, labeled and transported to the storage facility.

D.1.3. Angra 3

Recently (March 2008), the Federal Government through its National Council for Energy Planning approved the restart of construction of Angra 3 after a 23-year interruption.

But, even before construction authorization for Angra 3 was given, some progress has been made. In 2005, following authorization for site preparation work, the rock excavation for the plant foundation was cleaned up and stabilized. Engineering work was continued with adaptation for Angra 3 of Angra 2 material and equipment specifications, upgrading the design with basis on the Angra 2 and international operational experience as well as continuation of contacts with the potential equipment suppliers. An important formal step on the Government side was inclusion, in March 2006, of Angra 3 in the Electric Energy Expansion Decennial Planning, covering the period 2006 – 2015, following a detailed evaluation of the Brazilian viable energy generation alternatives.

Concerning Angra 3 economics, the calculated cost of its MWh competes with the cost of energy from new hydro plants and is lower than gas or coal generation, as it has been shown in the last auction of future energy market.

Most of its components of imported scope are already in Brazil and the site is ready for concrete pouring. All the required engineering is essentially available since for economy and standardisation reasons Angra 3 is to be as similar as possible to Angra 2. This concept has been submitted to and accepted by CNEN, proposing “Angra 2 as-built” as the reference plant for Angra 3. In this context, the only major technical modification planned for Angra 3 is the replacement of the conventional instrumentation and control by a modern digital system. Another difference between the two units refers to the site: Angra 2 was constructed on pile foundation, while Angra 3 should be built on sound rock.

Concerning supplies, more than 65% in value of the imported equipment is already stored in the warehouses, including not only the primary circuit heavy components and the turbine-generator set but also special pumps, valves and piping material. Excellence of the preservation plan for long-term storage has been demonstrated during Angra 2 completion, whereby no relevant equipment malfunction due to long-term storage had adverse impact on plant commissioning or initial operation. The preservation measures, including the 24 months inspection program, continue to be applied for the Angra 3 components stored at the site.

For the restart of construction, two licenses are required: the Construction License from the Nuclear Regulatory Body – CNEN, based on the acceptance of a Preliminary Safety Analysis Report (PSAR) and the Installation License from the Environmental Regulatory Body – IBAMA, based on the acceptance of an Environmental Impact Assessment (EIA).

The Preliminary Safety Analysis Report (PSAR) for the Nuclear Licensing process is under review by ELETRONUCLEAR to be delivered to CNEN. CNEN has already conducted a preliminary evaluation and identified to ELETRONUCLEAR the necessary modifications for further review.

The environmental licensing has proceeded with preparation and submission of the Angra 3 Environmental Impact Assessment (EIA) to IBAMA. Still in the frame of the environmental licensing process, public hearings to inform the population of the contents of the EIA were held in all municipalities bordering the emergency planning zones of the Plant. ELETRONUCLEAR received the pre-installation license from IBAMA in 2008.

Plant construction is planned to last 66 months, from starting of reactor annulus slab concrete work up to the end of power tests and start of commercial operation.

D.1.3.1. Angra 3 Spent Fuel Management

The spent fuel will be stored similarly to Angra 2.

D.1.3.2. Angra 3 Radioactive Waste Management

The radioactive waste will be treated and stored similarly to Angra 2.

D.1.4. On Site Initial Storage Facility

The waste of Angra 1 and Angra 2 is being stored in an initial storage facility located at the Angra site. The storage facility consists of two buildings, which are submitted to CNEN inspections.

Attending to a Brazilian Government request, an IAEA mission was received in 2000 to review the conditions of the initial storage. The mission praised the storage condition and the effort carried out in the past to repack some of the initial waste and reduce its volume. The mission also presented some recommendations on the waste storage facility status. Taking into consideration the IAEA mission and CNEN recommendations, the storage facility is being expanded. The implementation of the third storage building is in the final stage of construction and commissioning.

For additional information on this storage facility, see section H.2.

D.1.5. Old Steam Generator Storage Facility

With the plans for replacement of Angra 1 steam generators, a new facility is under construction on site. The Old Steam Generator Storage Building is a reinforced concrete structure designed to provide shielding and storage for the two Angra 1 replaced steam generators and all associated contaminated material. In the future, it also will store the reactor pressure vessel head, one radioactive waste evaporator and one residual heat exchanger.

It is located inside the ELETRONUCLEAR property area, close to the site dock and within the site boundary. The old steam generators will be arranged side by side in separate compartments. The building is designed to be seismic qualified according to Angra 1 class I structure design criteria and the concrete wall thickness provides radiological shielding according CNEN-NE-3.01 standard and annual limit of operational dose.

D.1.6. Waste repository for low and intermediate level waste

The plans for final disposal of waste generated from the Angra nuclear power complex (units 1,2 and future 3), are still under development, as described in items H.3.2 and H.5.2.2.

D.2. RESEARCH REACTORS

D.2.1. Spent Fuel Management

Research reactors (RR) have been in operation in Brazil since the late 1950’s and, as a result, some amount of spent fuel assemblies (SFA) has accumulated. Table D.3 shows the RR operating in Brazil.

Table D.3. Research Reactors in Brazil

	IEA-R1	IPR-R1	ARGONAUT	IPEN/MB-01
Criticality	September 1957	November 1960	February 1965	November 1988
Operator	IPEN-CNEN/SP	CDTN-CNEN/MG	IEN-CNEN/RJ	IPEN-CNEN/SP
Location	São Paulo	Minas Gerais	Rio de Janeiro	São Paulo
Type	Pool	Triga Mark I	Argonaut	Critical assembly
Power Level	2-5 MW	250 kW	200 W	100 W
Enrichment	20%	20%	20%	4.3%
Supplier	Babcock & Wilcox	General Atomics	USDOE	Brazil

Of the research reactors shown on Table D.3, the only RR that is subject to concerns related to spent fuel storage is IEA-R1. Part of its spent fuel was returned to U.S.A., when in 1999 Brazil shipped 127 LEU and HEU fuel elements. Later, on November 2007, 33 spent fuel elements stored in the pool of the IEA-R1 reactor and containing uranium of US origin were also shipped back to Savannah River Site Laboratory, South Carolina, USA.

These storage concerns were the driving force for Brazil to also join an IAEA Regional Project. The objectives of the Project are to provide the basic conditions to define a regional strategy for managing spent fuel and to provide solutions taking into consideration the economic and technological realities of the countries involved. In particular, to determine the basic conditions for managing RR spent fuel during operational and interim storage as well as final disposal, and to establish forms of regional cooperation for spent fuel characterization, safety, regulation and public communication.

The Brazilian part of the Latin American Spent Fuel Database is presented on Table D.4, showing the main characteristics of the fuel elements used in the Brazilian research reactors.

Table D.4. Fuel Element Characteristics

Facility	Fuel Type	Fuel Material	Enrichment	Cladding Material
IEA-R1	MTR	U_3O_8-Al U_3Si_2-Al	LEU 19.9%	Aluminum
IPR-R1	TRIGA	U-Zr-H	LEU 20%	Aluminum/SS*
ARGONAUTA	MTR	U_3O_8-Al	LEU-19.0-19.9%	Aluminum
IPEN-MB-01	Pin PWR	UO_2 Pellets	LEU 4.35 %	SS

The present RR spent fuel inventory is shown on Table D.5. The only reactors subject to concerns related to medium and long-term storage are IEA-R1 and IPR-R1. The other ones are low- and zero- power reactors with very low burn up. Taking these facts into consideration and the storage capacities presently available, some projections for the next 10-15 years have been made.

Table D.5. SFA Inventory at Brazilians Research Reactors

Facility	# of FA in Present Core	Average # used per year	SFA Storage		SFA % Average Burnup
			At RR	Outside RR	
IEA-R1	24 LEU, Silicide-9; Oxide-15	~18, expected for 120 h/week, 5 MW	16 wet	0	~30
IPEN-MB-01	680 pins	NA	0	0	NA
IPR-R1	59 rods (LEU)	NA	0	0	~4
IEN-R1	8 LEU	NA	0	0	NA

NA = not applicable

Presently, storage facilities at IEA-R1 consist of racks located in the reactor pool with a capacity of 156 assemblies. Figure D.1 illustrates the storage area in the IEA-R1 reactor. According to the newly proposed operation schedule (5 MW, 120 hrs per week), 18 to 20 assemblies will be spent annually. Currently, 21 storage positions are occupied, suggesting that within 7 to 10 years the wet storage facility at the reactor will be full. Although there are 50 dry storage horizontal tubes (within each of which three standard spent fuels can be stored) located in the reactor building, significant modifications will be required before any decision to store spent fuels in these tubes can be made. As a result, a project to assess and design an “at-reactor” dry-storage, with a total capacity for approximately 200 SFA, has been initiated. The options assessed envision that the present dry storage could be refurbished or a new dry storage could be built in a building close to the reactor building.

IPR-R1 has no short- and medium-term storage problems, due to its low nominal power. The first fuel assembly replacement is not expected to occur before 2015.

Finally, Brazil has not adopted a technical solution for spent fuel or high-level waste disposal. Nonetheless, given that the Brazilian legal framework regarding waste disposal has been established, the solution to be adopted will have to be discussed at the national level.

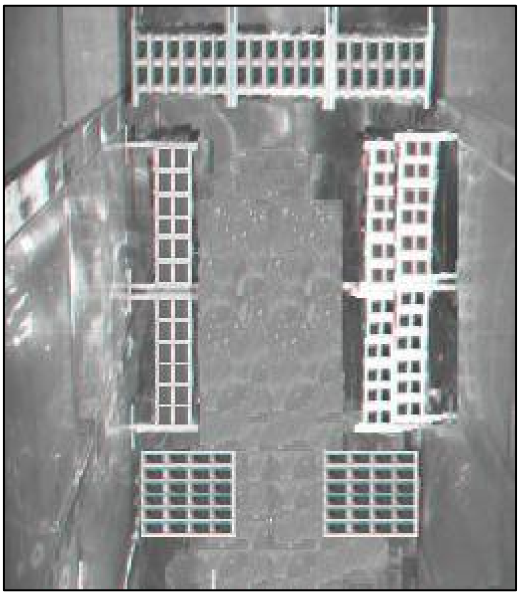

Figure D.1: IEA-R1 wet storage

D.2.2. Radioactive Waste Management

The radioactive waste of the research reactors is managed together with the radioactive waste of the institutes to which they belong, as described in section D.5.

D.3. OTHER NUCLEAR INSTALLATIONS

D.3.1. Indústrias Nucleares do Brasil (INB)

D.3.1.1. Waste from Fuel Cycle and Monazite Processing Facilities

The uranium mining and milling industrial complex (Complexo Industrial de Poços de Caldas - CIPC), located at the Poços de Caldas *plateau*, in the state of Minas Gerais, produced, from 1982 to 1995, 1170 tons of ammonium diuranate (yellow cake). The waste generated in this process is kept in a 29.2 hectare dam system, with an actual volume capacity of 1 million cubic meters. It is estimated that 4.8 TBq (130 Ci) of ^{238}U, 15 TBq (405 Ci) of ^{226}Ra and 4.2 TBq (112 Ci) of ^{228}Ra were disposed of in this site to the present date (See also H.2.2.4).

The operation of the rare-earth production line of Usina de Santo Amaro (Santo Amaro Mill - USAM) in São Paulo has generated Mesothorium (a material containing ^{228}Ra) and Cake II (called *Torta II* – composed basically of thorium hydroxide concentrate). These materials, although not formally classified as waste, are presently stored in Poços de Caldas (CIPC) and São Paulo (USIN and Botuxim). In Poços de Caldas (CIPC) there are about 1200 m^3 of Mesothorium and 7250 m^3 of Cake II presently stored.

In the Interlagos facility (USIN), there are about 39 m^3 of Mesothorium and 325 m^3 of Cake II presently stored and in the Botuxin storage facility (São Paulo) there are about 2190 m^3 of Cake II presently stored (See H.2.2.2.).

D.3.1.2. Fuel Element Manufacturing Facilities

The waste volume generated by the fuel element assembly unit and by all other pilot scale fuel cycle facilities is negligible when compared to the above-mentioned figures. All the material is currently stored inside the production facility. An initial storage facility has been built and, as soon as its license is issued by CNEN, all the material stored in the production plant will be transferred to this storage area

D 3.1.3. Radioactive Waste - URA

The Uranium Concentrate Unit (URA) project adopted as a basic design premise the minimization of effluent generation. Treatment and containment systems and were introduced in order to reduce the residue, waste and effluent generation, thus minimizing the environmental impact of the facility.

The waste management systems were developed with the requirements of preserving the local environment by recycling industrial waters. Mine tailings are piled up on the sides of the hills in a dry condition. The depleted ore is placed together with the mine tailings, using procedures that eliminate or reduce the production or promote the retention of dust. Liquid production is reduced by promoting effluent recycling, thus reducing treatment needs. The mud resulting from liquid residue treatment is kept in closed tailing ponds equipped with bottom and side drainage, so as to retain solid phase and allow liquid recycling. Radium isotopes from industrial liquid residues are precipitated and retained whenever concentrations are above the permissible values for discharge to the environment.

The total mining tailings production is estimated in 12,210,000 tons, with a mean uranium grade of 0.0007 % (U_3O_8). The total solid waste produced by the depleted ore from leaching piles is estimated in 2,140,000 tons, with mean uranium grade of 0.08 % (U_3O_8).

The mine tailing was sited considering that the area has good geological conditions and the component rocks have good mechanical stability. The top soil was removed and retained for further recovery of the site. The area does not have any water source or surface water body. The rain water that percolates the tailing is retained in ponds and is used in the industrial process. The inclination of the side of the hill is less than eighteen percent (18 %), which enhances the efficiency of rain water drainage.

The main liquid waste production is one hundred and eighty thousand cubic meters per year (180,000 m^3/y), with uranium concentration of about 0.003 g/l. The total volume of the tailing ponds is about four hundred thousand cubic meters (400.000 m^3), divided into four pond units.

D.4. NAVY INSTALLATIONS at São Paulo (CTMSP) and Iperó (CEA)

The waste volume generated by these activities is very small when compared to the figures mentioned above. All the material is currently kept on an initial storage on both sites.

At CTMSP the radioactive waste, mainly contaminated laboratory material, is transferred to nearby IPEN.

At CEA, an initial waste storage facility is available in form of a warehouse. One hundred nine drums containing about 8,413 kg of waste are currently stored there. These are mainly contaminated materials such as plastic, paper and tools (See also H.2.3).

D.5. CNEN INSTITUTES

D.5.1. IPEN

The Radioactive Waste Management Laboratory (LRR) was formally created in 2003 as a new research center of the Institute for Energy and Nuclear Research (IPEN), in order to perform research and development, teaching and waste treatment activities in the field of radioactive waste. The laboratory is in charge of treating and temporarily storing the radioactive waste generated at IPEN, as well as those generated at many other radioactive facilities all over the country. The main features of the laboratory include units for: waste reception and segregation; decontamination; liquid waste immobilization and conditioning; in-drum compaction of compressible solids; spent sealed sources and lightning rods disassembly; primary and final waste characterization; storage of untreated and treated waste. For further description, see item H.2.4.1.

D.5.2. CDTN

Besides the radioactive waste generated in its own laboratories, CDTN has received disused sealed sources from other users, like industries, hospitals and universities. These sources include, among others, radioactive lightning rods, smoke detectors, nuclear gauges and teletherapy units, which are stored at CDTN's interim storage facility (see H.2.4, Table J2 and Annex 1). In December 2007, the facility was storing 7,037 disused sources, with a total activity of 1.73×10^8 MBq, and ninety five 200-liter drums of treated wastes of very low activity, and the volume occupied was about 27% of the total. In addition, 3.1 m^3 (3.9×10^6 MBq) of untreated liquid wastes were in the initial storage room.

The strategy implemented for the management of radioactive waste at CDTN is based on the standard CNEN-NE-6.05 and takes into account the available infrastructure. The main features of the management program are:

- To register the waste and disused sealed source inventory using an electronic database.
- To minimize the waste generation by suitable segregation and characterization.
- To reduce the volume by chemical treatment of the aqueous liquid waste, and by compacting and cutting the solid waste;
- To solidify by cementation the sludge arising from the chemical treatment, and to immobilize the non-compactable solid waste in cement/bentonite.

D.5.3. IEN

IEN has originally had a small area (120 m^2) for storage of radioactive waste. In 2007 IEN built a new storage facility with 972 m^2. IEN stores waste that has similar characteristics to the waste received at the other CNEN institutes. Additionally, IEN also stores the radioactive waste generated in its own installations.

D.5.4. CRCN – CO

CRCN-CO has also a small interim storage facility for radioactive waste collected in the Midwest region (see Fig. D.2). This waste is periodically transferred to CDTN.

Figure D.2. Interim storage facility at CRCN-CO

D.6. WASTE REPOSITORY AT ABADIA DE GOIAS (Closed)

The waste generated in the decontamination process following the radiological accident with a ^{137}Cs medical source in Goiânia are currently stored in a final repository at Abadia de Goiás, a small town circa 23 km from Goiânia.

Approximately 3,500 m^3 of waste were generated, with an estimated overall activity lying between 47.0 TBq (1270 Ci) and 49.6TBq (1340 Ci). The waste was temporarily stored in open-air concrete platforms, occupying an area of about 8.5 x 10^6 m^2 at a site near the village of Abadia de Goiás. (Fig. D.3)

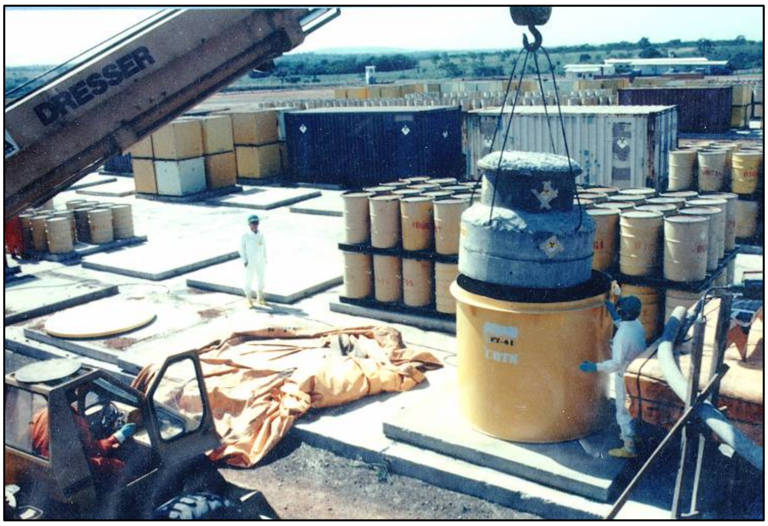

Figure D.3. Temporary storage

The drums and the metal boxes containing waste were classified into five groups, taking into account the decay period needed for the contents of the package to reach a Cs^{137} concentration level not greater than 87 Bq/g, as described on Table D.6.

Table D.6. Waste from Goiânia Accident

GROUP (Time - years)	Number Metallic Boxes	Volume (m^3)	Number of Drums	Volume (m^3)	Storage Activity * (TBq)	Total Volume (m^3)	Current Activity (TBq)
I (t=0)	404	686.8	2710	542	0,06	1228,80	0,03
II (0 < t < 90)	356	605.2	980	196	0,476	801,20	0,250
III (90 < t < 150)	287	487.9	314	62.8	1,44	550,70	0,76
IV (150< t <300)	275	467.5	217	43.4	13,67	510,90	7,19
V (t > 300)	25	42.5	2	0.4	30	42,90	15,80
Total	1347	2289.9	4223	844.6	45,71	3134,50	24,03

*NOTE: * Storage Activity: at the time of storage / ** Current Activity: as of March 2008.*

The following packages were also used in Goiânia:

- 1 metal package for the headstock, with the remaining source (4.4 Tbq and with 3.8 m^3, of Group V);
- 10 ship containers (374 m^3, with 0.4 TBq, from Group I); and
- 8 special concrete packages (1.4 m^3, with 0.7 Bq, from Group V)

According to the IAEA classification, all the radioactive waste collected in Goiânia fall into the category of “low level – short lived” waste and this allows its disposal at shallow depths, in engineered storage facilities. The Group I waste, having specific activities below 87 Bq/g, could actually be exempted from regulatory control – which means that it could effectively have been released into ordinary waste systems. Nevertheless, it was decided to build in Goiânia two repositories: a more simplified one, called *Great Capacity Container* (Figure D.4) for the disposal of Group I waste (about 40% of the total) and a repository with more elaborate engineered barriers for the disposal of Groups II to V waste, called *Goiânia Repository* (Figure D.5).

Figure D.4. Great Capacity Container

Figure D.5. Repository at Abadia de Goiás

In conclusion, the problem of providing final disposal for the waste generated in the Goiânia Accident is thoroughly addressed. All the waste has been disposed in two near surface repositories, which have already been closed and with environmental restoration performed. More information on the environmental monitoring program for the repository is provided in section H.7 of this document.

Section E - LEGISLATIVE AND REGULATORY SYSTEM

E.1. Article 18. IMPLEMENTING MEASURES

Brazil has taken legislative, regulatory and administrative measures to ensure the safety of its nuclear facilities, including spent fuel and radioactive waste facilities.

The Federal Constitution of 1988 establishes the distribution of responsibilities among the Union, the states, the federal district and the municipalities with respect to the protection of the public health and the environment, including the control of radioactive products and installations (Articles 21, 22, 23 and 24). The government is the sole responsible for nuclear activities related to electric power generation, and also for regulating, licensing and controlling nuclear safety (Articles 21 and 22). The Comissão Nacional de Energia Nuclear (Brazilian National Commission for Nuclear Energy - CNEN) is the national regulatory body, in accordance with the National Nuclear Energy Policy Act.

Furthermore, the constitutional principles regarding protection of the environment (Article 225) require that any installation which may cause significant environmental impact shall be subject to environmental impact studies that shall be made public. More specifically, for nuclear facilities, the Federal Constitution (Article 225, paragraph 6) provides that a specific law shall define the site of any new nuclear reactor facility. Therefore, nuclear installations are subject to both a nuclear license by CNEN and an environmental license by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute for the Environment and Renewable Natural Resources – IBAMA), with the participation of state and local environmental agencies as stated in the National Environmental Policy Act. These principles were established by the Federal Constitution of 1988, when Angra 1 was already in operation, and Angra 2 was in construction. Therefore, licensing of these power plants followed slightly different procedures, as described below.

CNEN is under the Ministry of Science and Technology (MCT). The relation amongst regulatory organizations and operators is shown in Figure E.1.

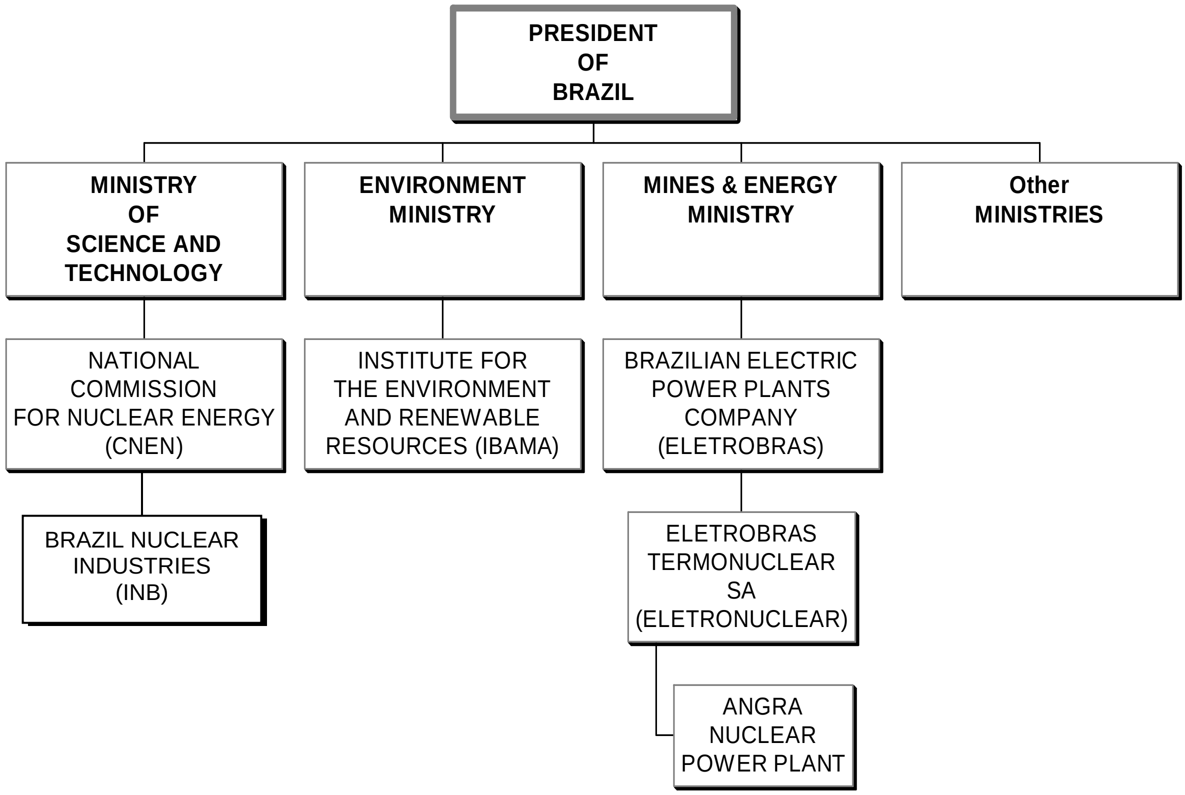

Figure E.1 – Brazilian Organizations Involved in Nuclear Safety

E.1.1. Nuclear licensing process

CNEN was created in 1956 (Decree 40.110 of 10/10/1956) to be responsible for all nuclear activities in Brazil. Later CNEN was re-organized and its responsibilities were established by Law 4118/62 with alterations determined by Laws 6189/74 and 7781/89. Thereafter, CNEN became the Regulatory Body in charge of regulating, licensing and controlling nuclear energy. Since 2000, CNEN has been under the Ministério da Ciência e Tecnologia (Ministry of Science and Technology - MCT).

CNEN responsibilities related to this Convention include:

- the preparation and issuance of regulations on nuclear safety, radiation protection, radioactive waste management, nuclear material control and physical protection;
- licensing and authorization of siting, construction, operation and decommissioning of nuclear facilities;
- regulatory inspection;
- acting as a national authority for the purpose of implementing international agreements and treaties related to nuclear safety, security and safeguards;
- participating in the national preparedness and response to nuclear emergencies.

Under this framework, CNEN has issued radiation protection regulations and regulations for the licensing process of radioactive and nuclear facilities, safety, security and nuclear material control during operation, management of radioactive waste, siting of waste repositories, quality assurance, reporting requirements, plant maintenance, and others (see Annex 2. Item 2.3 for a list related of CNEN regulations).

The licensing regulation CNEN-NE-1.04[3] establishes that no nuclear installation shall operate without a license. It also establishes the necessary review and assessment process, including the specification of the documentation to be presented to CNEN at each phase of the licensing process. It finally establishes a system of regulatory inspections and the corresponding enforcement mechanisms to ensure that the licensing conditions are being fulfilled. The enforcement mechanisms include the authority of CNEN to modify, suspend or revoke the license.

The licensing process is divided in several steps:

- Site Approval;
- Construction License;
- Authorization for Nuclear Material Utilization;
- Authorization for Initial Operation;
- Authorization for Permanent Operation;
- Authorization for Decommissioning

Federal Law 9756, approved in 1998, establishes taxes and fees for each individual licensing step, as well as for the routine work of supervision of the installation by CNEN.

For the first step, site selection criteria are established in Resolution CNEN 09/69 [4], taking into account design and site factors that may contribute to violation of established dose limits at the proposed exclusion area for a limiting postulated accident. Additionally, by adopting the principle of “proven technology”, CNEN regulation NE 1.04 requires for site approval the adoption of a “reference plant” for the nuclear power plant to be licensed.

For the construction license, CNEN performs a detailed review and assessment of the information received from the licensee in a Preliminary Safety Analysis Report (PSAR). The construction is followed closely by a system of regulatory inspections.

For the authorization for initial operation, CNEN reviews the construction status, the commissioning program including results of pre-operational tests, the final Physical Protection Plan, updates its review and assessment of facility design based on the information submitted in the Final Safety Analysis Report (FSAR), and authorizes the nuclear material utilization. Startup is closely followed by CNEN inspectors, and hold points at different stages are established.

Authorization for permanent operation is given after a complete review of commissioning test results and the solution of any deficiencies identified during construction and initial operation. The authorization establishes limits and conditions for operation and lists the programs which should be kept active during operation, such as the radiological protection program, the physical protection program, the quality assurance program for operation, the fire protection program, the environmental monitoring program, the qualification and training program, the preventive maintenance program, the retraining program, etc. Reporting requirements are also established through regulation CNEN-NE-1.14 [5] and CNEN-NN-2.02 [19]. These reports, together with a system of regulatory inspections performed by resident inspectors and headquarters personnel, are the basis for monitoring safety and nuclear material control during operation.

The main tasks during the licensing process are the safety evaluation of the applicant documentation and the regulatory inspections. During the period of 2006-2008, 70 Evaluation Reports were issued related to Angra Unit 1, out of which 3 related to the radioactive waste systems. For Angra 2, 60 Evaluation Reports were issued, 4 of them related to radioactive waste. Also 80 regulatory inspections were conducted in both units, 35 in Unit 1, 40 in Unit 2, and 5 for issues related to both units. Of these, 6 were related to the radioactive waste area.

Other governmental bodies are involved in the licensing process, through appropriate consultations. The most important ones are the Institute for Environmental and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA), which is in charge of environmental licensing, and the coordination of Nuclear, Technical and Scientific Program of the Ministry for Science and Technology (PTCN/MCT) with respect to emergency planning aspects.

E.1.2. Environmental licensing

IBAMA was created through Law n. 7735 of 22 February 1989 under the Ministério do Meio Ambiente (Ministry for Environment - MMA) with the responsibility to implement and enforce the National Environmental Policy (PNMA) established by Law N^{o}. 6938/81. The objective of the PNMA is to preserve, improve and recover the environmental quality, ensuring the conditions for social and economic development and for the protection of human dignity.

The PNMA established the National System for the Environment (SISNAMA), which is composed by the Conselho Nacional para o Meio Ambiente (National Council for the Environment - CONAMA) and executive organizations at the federal, state and municipal levels. The central executive body for SISNAMA is IBAMA, which is, therefore, responsible for the environmental licensing process of any installation with potentially significant environmental impact.

The environmental licensing process includes the following steps:

- Pre-installation Licence, given at the preliminary planning stage, approving the siting and general concept of the installation, evaluating its environmental feasibility and establishing the basic requirements and conditions for the next implementation phases.

- Installation Licence, authorizing the construction of the installation in accordance with the approved specifications, programs and projects including measures that are considered essential to protect the environment.
- Operating Licence, authorizing the operation of the installation after the verification of the effective fulfilment of the previous licence conditions, and the effective implementation of measures to protect the environment during operation.

One of the requirements for the issuance of a Pre-installation Licence is the development of an Environmental Impact Study (EIA) and the preparation of an Environmental Impact Report (RIMA). The RIMA is prepared to explain the project and evaluate other alternative sites and technologies and to describe the proposed activities, in order to allow for public participation and discussion with the local community in an effective way.

Public participation in the environmental licensing process is ensured by legislation through the conduct of public hearings (CONAMA Resolution 09/87). One of the requirements is transparency in the process, through the publication in the official newspapers and local press of any licence application and the decision to grant it or not by the relevant environmental agencies.

E.1.2.1 Environmental Licensing of Angra 1, 2 Radioactive Waste Storage Facilities

The construction of Angra 1 and Angra 2, including the radioactive waste stored on site, took place before the creation of IBAMA. The operation of Angra 1 started in 1981, before the current environmental regulation was established.

At that time, the Fundação Estadual de Engenharia do Meio Ambiente (State Foundation for Environment Engineering - FEEMA), the Rio de Janeiro state agency in charge of environmental matters, issued an Installation License.

Since 1989, with the definition of the legal competence of IBAMA for environmental licensing of nuclear installations, with the participation of CNEN and state and local environmental agencies, IBAMA has been involved in the licensing process of the radioactive waste storage facilities in Angra 1 and Angra 2.

Currently the low and intermediate radioactive waste from the nuclear power plants are stored in two storage facilities named Storage Facility 1 and Storage Facility 2, with modules 2A under operation and module 2B under licensing and commissioning.

Storage Facility 1 entered operation in 1981, with the operation of Angra 1 and is almost completely full (Figure E-2). Storage Facility 2A also contains waste from Angra 1. Both storage facilities are “initial” in nature, since the waste should be later removed to a final repository. For both storage facilities, ELETRONUCLEAR must submit basic documentation that will permit IBAMA to assess the environmental impact of their operation. This documentation will also serve as a basis to define plans and programs detailed in an Environmental Control Plan (PCA) for obtaining a formal Operating License, according to the current regulation.

Figure E.2. Angra 1, 2 Radioactive Waste Storage Facilities

The operator has requested the expansion of the storage capacity of the site through the construction of a third storage facility (Storage Facility 3) at the same location. The Environmental Impact Study (EIA) and the Environmental Impact Report (RIMA) were prepared and submitted to IBAMA.

The RIMA served also as a basis for the public hearings, which took place in the surroundings of the plant, within the environmental licensing process. Based on these evaluations and taken into consideration the discussion during the hearings, IBAMA issued the Installation License. ELETRONUCLEAR expects to obtain the IBAMA Operation License in 2008.

Since CNEN has the technical competence for the evaluation of radiological impact in the environment, IBAMA and CNEN have established a formal agreement to specify the respective scope of action and to optimize both licensing processes.

E.1.2.2. Environmental Licensing of the Repository at Abadia de Goiás

The repository at Abadia de Goiás, which belongs to CNEN, has received an Installation License from IBAMA in 1996. At present, IBAMA is following up the initial operation of the repository through reports and inspections. An Environmental Plan including air samples, sediments samples, surface water and underground water as well as external radiation doses around the two repositories has been executed every year since its construction. More detail of this environmental plan can be seen on item H of this report.

E.1.2.3. Other Pre-existing Storage Facilities

Other pre-existing radioactive waste storage facilities that are now also being licensed by IBAMA, are located at IPEN, CDTN and IEN (see D.5. and H.2.2).

In 2002, IBAMA licensed CDTN facilities, including the radioactive waste storage hall (IBAMA Operation License Nr. 225/2008, of 8 August 2002). On 28 November 2006 this license was renewed for additional six (6) years.

The other two storage facilities are in a process of compliance of the existing situation with the current legislation, to obtain an Operating License. This is done through a legal instrument called “Termo de Compromisso” (Term of Commitment), in which the organization commits itself to fulfill specific requirements established by IBAMA.

At IPEN, the existing storage for treated waste will be restructured and will receive 650 m^2 of extra area. In 2007, CNEN issued a preliminary authorization for building new storage area and IPEN applied for a license of construction. The next phase will be hiring the company to carry out construction work.

E.1.3. Emergency preparedness legislation

With respect to emergency preparedness, additional requirements have been established by the creation of the System for Protection of the Brazilian Nuclear Program (SIPRON) through Law 1809 of October 7, 1980. The subsequent Decree Nr.2210 of April 22, 1997 defined the Secretaria de Assuntos Estratégicos (Secretariat for Strategic Affairs - SAE), directly linked to the Presidency of the Republic, as the Central Organization of SIPRON responsible for the general supervision of the preparedness and response to nuclear emergencies in the Country.

More recently, the Governmental restructuring through Law Nr. 10.683 of May 28, 2003 has designated the Ministry of Science and Technology (MCT) as the state department with competence for nuclear energy policy. And SIPRON, which now stays under the Coordination of Technical and Scientific Nuclear Program of MCT (See Fig. E.3).

The Decree Nr. 2210 also established a Coordination Commission (COPRON) composed of representatives of the agencies involved. Besides ELETRONUCLEAR, as the operator, and CNEN, as the nuclear regulatory body, other agencies are involved as support organizations of SIPRON, such as the municipal civil defense, the state civil defense, the Angra Municipality, the IBAMA, the National Road Authority, the National Army, Navy and Air Force, and the Ministries of Health, Foreign Relations, Justice, Finance, Planning and Budget, Transportation and Communications.

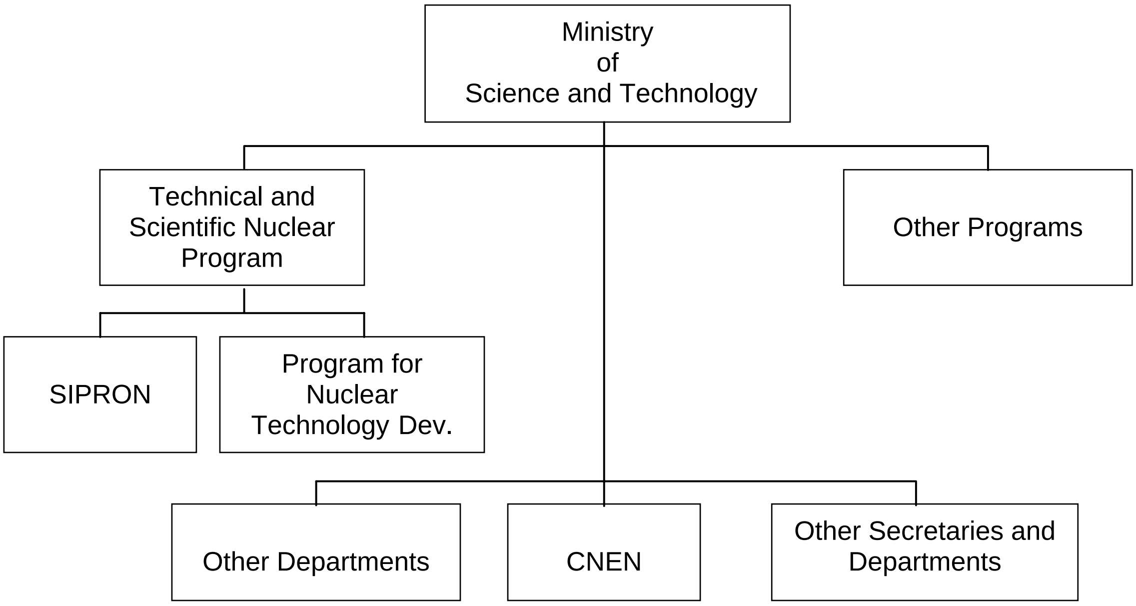

Figure E.3. SIPRON position within the MCT Structure

SIPRON guidelines, issued by COPRON (see Annex 2, item 2.5), require that support organizations of SIPRON prepare, keep up to date and exercise a plan for nuclear emergency situations. As a matter of fact, the guidelines require that CNEN and other organizations and agencies involved have their emergency plans, as well.

E.2. Article 19. LEGISLATIVE AND REGULATORY FRAMEWORK

Brazil has established and maintained the necessary legislative and regulatory framework to ensure the safety of its nuclear installations, including irradiated fuel and radioactive waste. A list of existing norms and regulations is presented in Annex 2.

As mentioned before, the Law n. 10308 of 20 November 2001 establishes the new legal framework for the solution of the radioactive waste issue in Brazil.

The Law confirms Government responsibility for the final destination of radioactive wastes, through the action of CNEN. However, it also opens the possibility for the delegation of the administration and operation of the radioactive waste storage facilities to third parties.

The Law defines four types of storage facilities: initial, operated by the waste generator; intermediate; final (also called repository); and temporary, which may be established in case of accidents with contamination.

The Law establishes the rules for site selection, construction and operation, and licensing and control of the storage facilities by CNEN. The Law also establishes the financial arrangements for the transfer of waste to CNEN and the compensation to the municipalities that accept in their territory the construction of radioactive waste storage facilities.

Additional regulations from CNEN related to waste disposal were already in place and are being revised to conform to the new Law 10308. These include regulations CNEN-NE-6.05 on Management of Radioactive Waste in Radioactive Installations [6], CNEN-NE-6.06 on Site Selection for Radioactive Waste Storage Facilities, and NN-6.09 on Acceptance Criteria for Final Disposal of Low and Intermediate Level Radioactive Waste [7].

E.3. Article 20. REGULATORY BODY

As mentioned in item E.1.1, the Brazilian National Commission for Nuclear Energy (CNEN) has been designated as the regulatory body entrusted with the implementation of the legislative framework related to safety of nuclear and radioactive installations. Other governmental bodies are also involved in the licensing process, such as the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA).

E.3.1. CNEN

CNEN authority is a direct consequence of Law 4118/62, which created CNEN, and its alterations determined by Laws 6189/74 and 7781/89. These laws established that CNEN has the authority “to issue regulations, licenses and authorizations related to nuclear installations”, “to inspect licensed installations” and “to enforce the laws and its own regulations”.

Effective separation between the functions of the regulatory body (CNEN) and the organization in charge of the promotion and utilization of nuclear energy for electric power generation (ELETRONUCLEAR) is provided by the structure of the Brazilian Government in this area. While CNEN is linked to the Ministry of Science and Technology (MCT)**,** ELETRONUCLEAR is fully owned by ELETROBRAS, a state holding company of the electric system, which is under the Ministry of Mines and Energy (MME) (see Figure E.1).

The structure of CNEN is presented in Figure E.4. The organizational unit involved with the licensing of nuclear installations is the Directorate for Radiation Protection and Nuclear Safety (DRS). Review and assessment is performed mainly by the General Coordination of Nuclear Reactors (CGRN), which is in charge of nuclear power plants and research reactors, by the General Coordination of Nuclear Installations (CGIN), which is in charge of other nuclear installations, and by the Safeguards and Physical Protection Coordination (COSAP). The General Coordination for Medical and Industrial Installations (CGMI) is in charge of radioactive installations and medical uses. The Radioactive Waste Coordination (COREJ) is in charge of radioactive waste management and disposal. In the areas of radiation protection and environmental monitoring, technical support is obtained from the Institute for Radiation Protection and Dosimetry (IRD). The regulations and standards are developed by working groups under the coordination of the Norms Division (DINOR).

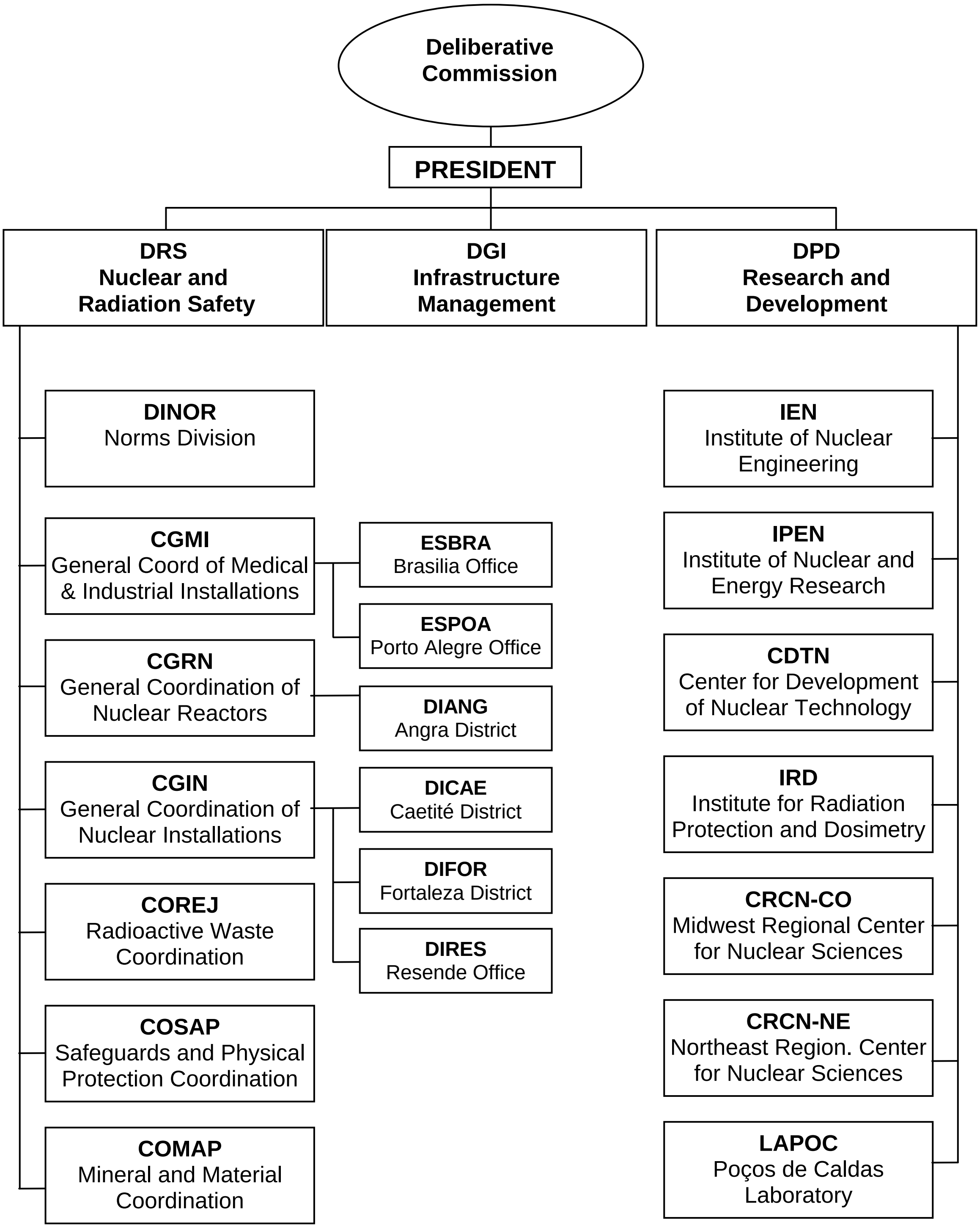

Figure E.4. Simplified CNEN Organization Chart

Adequate human resources are provided to CNEN. A total staff of 2756 people, out of which 85% are technical staff, is available at CNEN and its research institutes. Forty eight percent (48%) of the staff is comprised of university graduates, 17% having a master degree and 7% having a doctoral degree. CGRC itself comprises 183 people, 149 of which are technical.

The main activities are review and assessment of the submitted documentation, and inspection of licensee's activities. Inspection activities are conducted periodically for all installations and on a permanent basis for the nuclear power plants, enrichment facility and the uranium mine by resident inspectors at the respective sites. Complementary to field activities, operation follow up and nuclear material control are performed also based on licensee reports, as required by licensing conditions and regulations CNEN-NN.1.14 [5] and CNEN-NN-2.02 [19].

DRS technical staff receives nuclear general training and specific training according to the field of work, including both academic training and course attendance, technical visits, participation in congresses and national and international seminars.

Financial resources for CNEN are provided directly from the Government budget. Since 1998, taxes and fees are being charged to the licensees, but this income is deducted from the Government funds allocated to CNEN.

Salaries of CNEN staff are subject to the Federal Government policies and administration.

E.3.2 IBAMA

The licensing structure of IBAMA is presented in Figure E.5. The environmental licensing for nuclear installations is conducted by the Directorate for Licensing and Environmental Quality, more specifically by its General Coordination for Environmental Licensing. This Coordination has a multidisciplinary technical staff of 70 professionals (8 PhD, 17 MSc, 15 Specialists and 30 Graduates), 15 of which are dedicated to the licensing of nuclear power plants (2 PhD, 5 MSc, 8 Graduates). There is an effort to adequate these human resources to an increased demand of evaluation in the nuclear area.

For the licensing process of Angra 2, IBAMA worked in close cooperation with CNEN in relation with the radiological impact aspects. Both also cooperated with the Rio de Janeiro State Foundation for Environmental Engineering (FEEMA) and the Angra dos Reis Municipal Secretary for Environment and, in the case of the Final Repository at Abadia de Goias, with the Goias State Foundation for the Environment (FEMAGO).

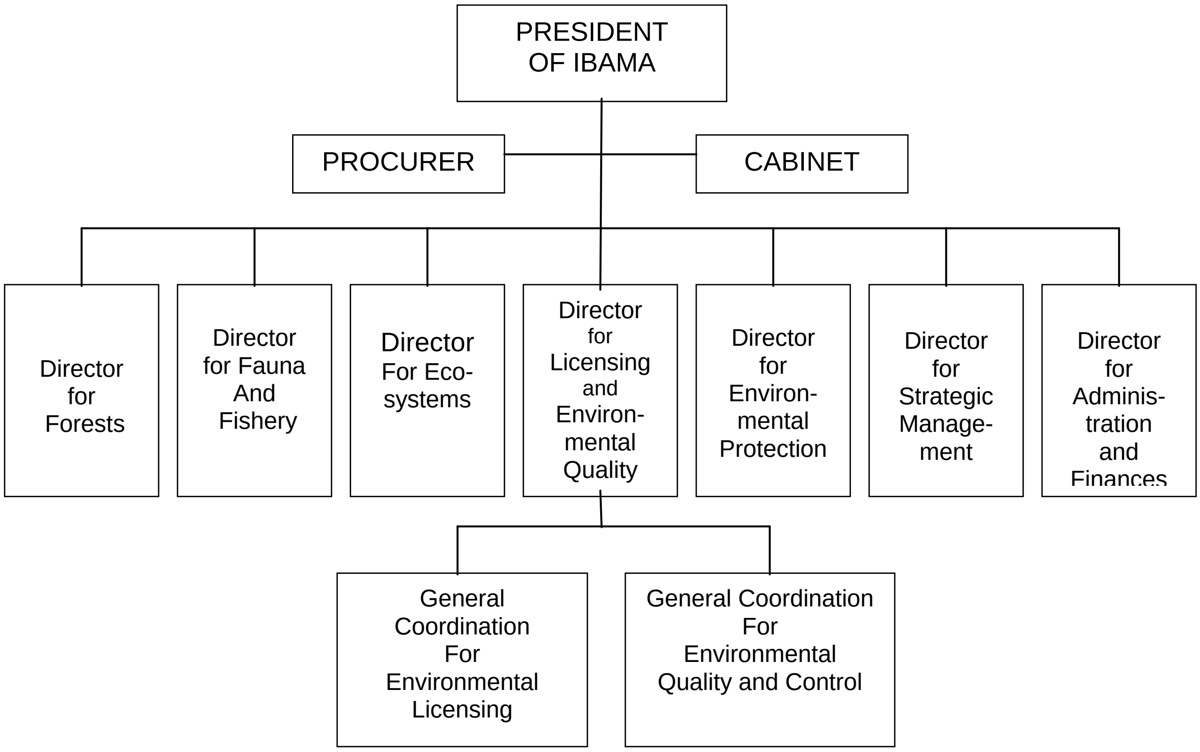

Figure E.5. IBAMA Structure

Section F - OTHER GENERAL SAFETY PROVISIONS

F.1. Article 21. RESPONSIBILITY OF LICENCE HOLDER

The Brazilian legislation defines the operating organization as the prime responsible for the safety of a nuclear or radioactive installation, including the management of spent fuel and radioactive waste.

Therefore, to obtain and maintain the corresponding licences, the operating organization must fulfill all the requirements established in the legislation and in the ensuing regulations presented in Annex 2.

F.1.1. Nuclear Power Plants

In the case of nuclear power plants, the regulation CNEN-NE-1.26 [8] defines the operating organization as the prime responsible for the safety of a nuclear installation by explicitly stating: "**The operating organization is responsible for the implementation of this regulation.**"

ELETRONUCLEAR, as the owner and operator of the Angra 1 and Angra 2 plants, has issued an Integrated Safety Management Policy stating its commitment to safe operation, as follows:

"Eletrobrás Termonuclear S.A. – ELETRONUCLEAR is committed to clean power generation and high safety standards."

Therefore, its staff commitment to perform all safety-related activities in an integrated manner is essential, laying emphasis upon Nuclear Safety, which includes Quality Assurance and Environmental as well as Occupational Safety, Occupational Health and Physical Protection,

The following principles must be heeded:

1. Nuclear Safety is a priority, precedes productivity and economic aspects and should never be impaired for any reason.

2. Legal requirements and other requirements related to the various integrated safety aspects should be complied with.

3. Personnel and service supplier qualification training should ensure knowledge on the various integrated safety aspects required for proper performance of safety-related work.

4. People health and safety hazards and also environmental impacts should be preventively minimized or eliminated.

5. Communication procedures inside and outside the Company should be transparent and appropriate so that any unsafe condition can be promptly reported.

6. The Company should seek to improve continuously its Integrated Safety Management practices. ”

For the proper implementation of this safety policy, ELETRONUCLEAR established a program that complies with the concept included in the Safety Series No. 75 of the International Nuclear Safety Group, INSAG, where safety objectives and established requirements, appropriate management structures, the necessary resources and adequate self-assessment are defined.

CNEN, through the licensing process, and especially through its regulatory inspection program, ensures that the regulatory requirements for safe operation are being fulfilled by the licensee. The licensee reports periodically to CNEN in accordance with regulation CNEN-NE-1.14 [5]. In addition, CNEN maintains a group of resident inspectors on the site, who can monitor licensee performance on a daily basis. Finally, a number of regulatory inspections by headquarter staff take place every year, focusing on specific topics or operational events.

F1.2. INB Facilities

As the organization responsible for the operation of its Industrial Units, INB prioritizes safety in all of its activities as a basic principle.

As the oversight body, CNEN maintains a program of constant inspections in addition to a resident inspector in INB facilities, whose job it is to track the operating routine of the units and report any occasional abnormality.

Internal audits in the areas of Quality Assurance, Environment and Workplace Safety are routinely performed in all facilities in order to detect any situation that may represent an unsafe operating condition. Additionally, with a view to enhancing safety culture in the company, INB accepted the invitation extended by the International Atomic Energy Agency (IAEA) to cooperate in project SEDO (Safety Evaluation During Operation), the results of which will serve as parameters for application to other manufacturing facilities of member countries of the IAEA.

In 1997, in pursuit of continual improvement, INB implemented and certified the quality assurance system of FCN Resende under Brazilian standard NBR ISO 9001/1994. In 2007, by adopting management standards NBR ISO 14001 and OHSAS 18001, the company expanded its certification to the areas of environment and occupational safety, respectively, through the Integrated Management System (SIG) by the BR TÜV certifying body. All these certifications are valid until 16 February 2009, when they will be reviewed.

F.2. Article 22. HUMAN AND FINANCIAL RESOURCES

F.2.1. Human resources

F.2.1.1. Nuclear Power Plants

Adequate human resources are available at ELETRONUCLEAR with its own personnel or from contractors. Currently ELETRONUCLEAR has a total of 2231 employees on its permanent staff, distributed as follows:

- 694 (31%) have a university degree;
- 1025 (46%) are technicians;
- 207 (9%) are managers, most of them with university degree;
- The remainder 305 (14%) are administrative personnel.

A Project called "Determination of the Technological Know-how of ELETRONUCLEAR" was initiated in 2001, which aimed the identification, in a formalized and systematic way, of the existing know-how within the company. In particular, loss of knowledge due to the personnel retirement was the most important aspect of this program. This was a pilot project with the main objective of introducing Knowledge Management as a systematic approach in the company, in order to preserve the essential knowledge necessary for the safe and efficient construction and operation of its nuclear installations.

The planned actions within this program have been accomplished. The major knowledge gaps have been identified and actions to fulfill these gaps are being implemented. The results are available for further routine use by the different technical organization units of the company.

Activities related to qualification, training and retraining of plant personnel are performed by the Training and Simulator Department of ELETRONUCLEAR. Three main areas exist at the training facilities, close to the site:

- General Training Center
- Angra 2 Simulator Training Center
- Maintenance Training Center.

The requirements for organization and qualification of Angra 1 and Angra 2 staff are established in the chapter 13 of the FSAR. Implementation and updating of these requirements are subject to CNEN audits.

Specialized training is also provided for the different groups of plant personnel, as listed below:

- Maintenance and Chemistry personnel follow an extensive qualification program established in the Plant Operations Manual, which is subject to CNEN audits.
- Radiological Protection technicians, the Fire Brigade and Security personnel follow an extensive qualification program based on CNEN regulations, which is also subject to CNEN audits.

Technical Exchange Visits and Reviews of the training program and training center by experts from International Atomic Energy Agency, the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO) have provided valuable contribution to the identification and implementation of good practices for enhancing the quality of the training activities.

A total of 36 qualified personnel are directly involved in waste and spent fuel management, as described in the table F.1 below.

Table F.1. Personnel involved in spent fuel and radioactive waste management at Angra 1 and Angra 2 NPPs

Qualification	**Quantity**	**Education**
Radiological Protection Supervisor	2	University degree
Senior Reactor Operator	2	University degree
Nuclear Physicist	2	University degree
Nuclear Engineer	4	University degree
Engineering Support	1	University degree
Operators	7	Technician
Radiological Protection Technician	8	Technician
Auxiliary Technician	10	Secondary

CNEN monitors the adequacy of the human resources of the licensee through the evaluation of its performance, especially through the analysis of the human factor influence on operational events. The training and retraining program is also evaluated by CNEN within the licensing procedure and through regulatory inspections.

Radiation Protection Supervisor certification is done in accordance with regulation CNEN – NN 3.03 “Certification of the Radiation Protection Supervisor Qualification” [9]. At the end of 2007, three Radiation Protection Supervisors were qualified for Angra 1 and Angra 2, two of these were also qualified for Waste Management. In 2008, two additional Radiation Protection Supervisors were qualified for both plants. In 2007, two Radiation Protection Supervisors were qualified for the Environmental Monitoring Laboratory.

F.2.1.2. INB Facilities

Over the past recent years INB sponsored a number of training events, including a Technology Training Program for twenty-nine engineers, in partnership with the Federal University of Rio de Janeiro. This training program was focused on maintaining the know-how and nuclear technology of the company, in light of the retirement of senior engineers with specific knowledge on the nuclear fuel cycle.

Activities related to training planning and management are a shared responsibility between the Personnel Assignment and Training sections. Three main employee qualification events are normally undertaken:

Compulsory Courses: Training programs essential to performing a specific task. The participation on such courses is mandatory, as a consequence of the requirements of control, oversight and licensing bodies.

Education Scholarships: Masters degree, undergraduate and graduate training programs, and foreign language courses. The application of the knowledge acquired in these courses is expected to contribute to improving employee’s job performance and the company’s results.

Nonregular courses: Other personnel training programs as deemed necessary to improve employee’s professional performance and the company’s results.

At present, INB has approximately 930 employees in total. Table F.2 shows INB regular workforce by location at each of the company units.

Table F.2. INB personnel – regular workforce by location

Location	University degree	Technical	Clerical	Management	Total
Resende, RJ	154	232	100	40	526
Rio de Janeiro, RJ	57	22	40	32	151
Caetité, BA	10	115	0	9	134
Buena, RJ	0	51	9	2	62
Caldas, MG	8	14	13	6	41
São Paulo, SP	0	3	2	1	6
Fortaleza, CE	0	0	1	1	2
Santa Quitéria, CE	0	0	3	0	3
Brasília, DF	1	1	2	0	4
Total	230	438	170	91	929
Percentage	25%	47%	18%	10%	100%

Table F.3 shows the qualification of INB personnel directly involved with radioactive waste management at Caetité, Buena and Caldas facilities.

Table F.3. INB personnel involved in radioactive waste management at Caetité (URA), Buena (UMP) and Caldas (CIPC)

Qualification	Quantity	Education
Radiological Protection Supervisor	2	University degree
Engineering Support	6	University degree
Radiological Protection Technicians	8	Technician
Auxiliary Technicians	12	Secondary

Table F.4 shows the qualification of INB personnel involved with radioactive waste management at Resende facilities, where nuclear fuel is manufactured.

Table F.4. INB Personnel involved in radioactive waste management at Resende

Qualification	Quantity	Education
Radiological Protection Supervisor	2	University degree
Engineering Support	3	University degree
Operators	2	Secondary
Radiological Protection Technicians	10	Secondary
Auxiliary Technicians	1	Primary

Certification of radiation protection supervisors is done in accordance with regulation CNEN – NN 3.03 "Certification of Radiation Protection Supervisor Qualification" [9].

F.2.1.3. Other Installations

All nuclear or radioactive installations licensed by CNEN must have a certified Radiation Protection Supervisor, authorized in accordance with regulation CNEN-NN-3.03 [9]. The regulation requires different qualification for each different type of installation.

Besides that, sufficient qualified staff should be available for handling radioactive waste. For instance, at IPEN, the staff of the radioactive waste unit is shown on Table F.5, together with the spent fuel management staff.

Table F.5. Personnel involved in spent fuel and radioactive waste management at IPEN

Qualification	Quantity	Education
Radiological Protection Supervisor	6	University degree
Senior Reactor Operator	7	University degree
Physicist	5	University degree
Chemist	3	University degree
Nuclear Engineer	4	University degree
Engineering Support	4	University degree
Operators	14	Technical
Radiological Protection Technicians	9	Technical
Auxiliary Technicians	7	Secondary

At CDTN a total of 21 qualified people are directly involved in waste and spent fuel management. Table F.6 shows the profile of the CDTN staff that is involved on the waste and spent fuel management activities. Among them, seven have doctoral degrees and five have master degrees. At CDTN, all the staff that work with radioactive waste management received training in Brazil and abroad in this subject. They are trained to work with administrative and technical activities. Specialized internal and external training is available for the whole staff, including radiation protection and safety courses. Technical visits, courses and meetings are included in this training, and the majority of the staff has had some training in other countries, through IAEA and CNPq (Brazilian Research and Development Council) programs.

Table F.6. Personnel involved in spent fuel and radioactive waste management at CDTN

Qualification	Quantity	Education
Radiological Protection Supervisor	1	University degree
Senior Reactor Operator	2	University degree
Senior Reactor Operator	2	Technical
Nuclear Engineering	9	University degree
Radioactive Waste Technicians	4	Technical
Radiological Protection Technicians	1	Technical
Operator	2	Secondary

At IEN, 19 people are involved in waste management and radiation protection. Out of these, 8 have university degrees.

F.2.2. Financial Resources

F.2.2.1. Nuclear Power Plants

As a governmental enterprise, ELETRONUCLEAR has its financial situation subjected to the holding company ELETROBRAS, which controls all federal electric utilities in Brazil.

The basic source of revenue of ELETRONUCLEAR comes from selling electric power from Angra 1 and Angra 2 (1902 MWe of net installed capacity), through a long-term energy supply contract ending in 2014, at a guaranteed minimum rate, which is 120.35R$/MWhr (~70US$/MWhr, in April 2008). The long-term contract is one of the mechanisms applied to protect the nuclear generation from unforeseeable situations that might occur with the ongoing liberalization of the Brazilian electric power market.

Adequate funds are made available through annual budgets, which include the waste management program. For illustration purposes, the 2008 ELETRONUCLEAR budget for the waste management program is estimated in about R$16 million (~US$ 9 million).

The provision of funds for decommissioning activities is obtained from ratepayers, and is included in the tariff structure, during the same period of depreciation of the plant (3.3%/year). For Angra 1, presently, a reference decommissioning cost of 307 million dollars is estimated, corresponding to about 10% of the construction cost. For Angra 2 the decommissioning costs are estimated in about 426 million dollars.

F.2.2.2 Nuclear Fuel Cycle Plants

Indústrias Nucleares do Brasil S.A. – INB is a mixed economy company (state- and privately-owned), under the share control of CNEN and linked to the Ministry of Science and Technology – MCT. INB is in charge of exercising the monopoly of the Union in the nuclear fuel cycle part that covers the stages from the uranium mining to the manufacturing of the fuel elements used in the Angra 1 and Angra 2 nuclear power plants.

The company headquarters are in the city of Rio de Janeiro, with regional offices in the cities of Brasilia, São Paulo and Fortaleza and industrial units located in the following places:

- In Caetité, Bahia, the Uranium Concentrate Unit - URA is located and in operation. At URA, the uranium ore is extracted and processed for the production of uranium concentrate (U_3O_8);
- In Resende, in the state of Rio de Janeiro, are located the facilities of the Nuclear Fuel Manufacturing Plant – FCN, which comprises: manufacturing of components and assembly of fuel elements and, uranium enrichment plant (first cascade), reconversion of UF_6 and chip manufacturing;

- In Buena, in the state of Rio de Janeiro, the Unit of Heavy Minerals is in operation – UMP. This activity not associated to the nuclear fuel cycle, but it is where the following minerals are extracted: zirconite, rutile, ilmenite and monazite;
- In Caldas, Minas Gerais, the first uranium mine of Brazil is located, together with the ore processing unit. The industrial activities there were paralyzed for lack of economic viability. Currently, decommissioning and environmental remediation are being developed.

Operational Revenue

- The company's main client is ELETRONUCLEAR, operator of the nuclear power plants Angra 1 and Angra 2.
- Gross revenue from the sale of goods and services comprises the revenue relative to the contracts of i) uranium concentrate, ii) conversion, enrichment and management and iii) fuel element manufacturing, signed with ELETRONUCLEAR for the reloads of Angra 1 and Angra 2, as well as the sale of products of the Heavy Minerals Unit - Buena.
- Budget resources of the National Treasury – resources of the tax budget of the Union, passed on by the National Treasury Secretariat, intended for payment of expenses with personnel (salaries, benefits and labor sentences).

F.2.2.3. Other Installations

At all CNEN's institutes the funds for the spent fuel and waste management come from the general budget that is provided by the Science and Technology Ministry. At CDTN, some additional funds come from the FAPEMIG (State Foundation for Research Support), IAEA, FINEP, CNPq and other governmental Institutions, through special projects. The annual budget for these activities at CDTN, including human resources, is around 1.48 million dollars.

F.3. Article 23. QUALITY ASSURANCE

The requirement for a quality assurance program in any nuclear installation project in Brazil is established in the licensing regulation [3]. Specific requirements for the programs are established in a specific regulation, Quality Assurance for Safety in Nuclear Power Plants and Other Installations, CNEN-NN-1.16 [10], which is based in the IAEA code of practice 50-C-QA Rev.1 - Quality Assurance for Nuclear Power Plants, but with the introduction of the concept of an Independent Technical Supervisory Organization (Organização de Supervisão Técnica Independente - OSTI) [11].

F.3.1. Nuclear Power Plants

ELETRONUCLEAR has established its quality assurance programs according to the requirements mentioned above. The corresponding procedures have been developed and are in use. The program provides the control of the activities influencing the quality of items and services important to safety. These activities include both spent fuel storage and radioactive waste management. The quality assurance programs are described in Chapter 17 of the FSAR.

The Quality Assurance Superintendence (SQ.G), reporting to the Planning, Management and Environment Directorate (DG), is responsible for the establishment and supervision of the ELETRONUCLEAR Quality Assurance System.

The ELETRONUCLEAR Quality Assurance Advisory (AGQ.T) group is responsible for the coordination and performance of internal and external audits in order to verify compliance with all aspects of the quality assurance program. All audits are performed in accordance to written procedures. In the case of internal audits, persons involved with the activities being audited have no involvement in the selection of the audit team. Audit reports are distributed to, and formally reviewed by organizations responsible for the area being audited and also by the Committee for Nuclear Operation Analysis (CAON). In the period 2006/2008, up to this date, 70 external audits and 116 internal audits were conducted.

Audits and inspections by CNEN verify that quality assurance requirements are being implemented and that the quality assurance has been effective as a management tool to ensure safety. During the period of 2006-2007, CNEN conducted 39 audits or regulatory inspections in Angra 1, 2 and 3. Of these audits, 4 were dedicated to radioactive waste storage.

The Quality Assurance Superintendence (SQ.G) also takes part of the Committee for Nuclear Operation Analysis (CAON), which is a collective body under the coordination of the Operations Coordination Superintendence (SC.O) whose purpose is to examine, follow-up and analyze issues concerning Angra 1 and 2 operational safety and to make recommendations to improve safety. In the same way, the Superintendence participates in the Plant Operation Review Committees (CROU´s), which are collective bodies under each respective unit manager with the responsibility to review and analyze, on a closer basis, questions related to operating the units.

F.3.2. CNEN Installations

CNEN has also established its own Nuclear Safety Policy [17] and Quality Assurance Policy [18]. Under these policies, all units have to establish their own quality assurance system.

Besides that, some units which are involved with industrial production have been independently certified by external organizations, such as the ISO 9000 certification obtained in 2002 by IPEN for its 4 centres: Cyclotron Accelerator

Centre, Nuclear Engineering Centre, Radiopharmacy Centre and Research Reactor Centre.

As another example, the Radioactive Waste Management Program of CDTN is also subject to Quality Assurance procedures. The institute has a general Quality Assurance Program which includes a particular section on Waste Management. Specific procedures exist to regulate the operational activities, such as waste segregation, collection, treatment and tests for waste product quality assessment. At the end of 2007, a new concise Quality Assurance (QA) System was implemented, which is divided in two parts that are complementary. The first part contains CDTN's QA Manual, where the policies are described together with nine general procedures. The second part comprises the specific QA Manuals for the laboratories and special services. They are in force within the scope of the Program, establishing the applicable standards and the responsibilities for the different sections of the institute involved.

IEN is now concluding the phase of preparation and approval of quality procedures that establish routines and responsibilities in the process of waste management. All the strategy for the management of radioactive waste at IEN is based on the standard CNEN-NE-6.05 and takes into account the available infrastructure.

F.3.3. Quality Assurance at Navy Installations

The necessary quality for the projects developed at the Navy Technological Center has been assured by the application of procedures and instructions established from a Quality Management System, since the beginning of the activities, in accordance with Standard CNEN-NE-1.16 – Quality Assurance for Safety of Nuclear Power Plants and Other Installations [10], applicable to constructions, services, material purchases and internal activities related to projects under development.

In the CTMSP structure, the Quality Superintendence, directly under the Director, is responsible for the Quality management System, being independent of all other organizational sectors from CTMSP.

F.3.4. Quality Assurance at INB facilities

According to the requirements of the standard CNEN-NN-1.16 [10], INB systematically submits to CNEN updates of the Quality Assurance Program Procedures (PGQs) for its facilities.

In 1996, the company implemented and certified, per NBR ISO 9001 Standard, the Quality Assurance System for the Nuclear Fuel Factory at Resende. Subsequently, in 2007, by adopting management standards NBR ISO 14001 and OHSAS 18001, INB expanded the scope of certifications in the areas of environment and occupational safety, respectively, through its Integrated Management System – SIG.

It is worth noting that the requirements of the referred standards, besides being in line with CNEN-NN-1.16 prioritises customer satisfaction, management responsibility, process control and the use of quality indicators with pre-established targets.

The greatest advantage from adopting such standards through an integrated management system at Resende consists in the fact that the company controls and continually improves its processes for activities pertaining to quality, environment, safety, health and physical protection.

Other units of INB operate with the Quality Assurance System on the basis of CNEN-NN-1.16 standard, and strictly focuses on nuclear safety.

INB has set as a goal the adoption of management standards NBR ISO 9001, NBR ISO 14001 and OHSAS 18001 for all of its decentralized units.

F.4. Article 24. OPERATIONAL RADIATION PROTECTION

Radiation protection requirements and dose limits are established in Brazil in the regulation for radiation protection [12]. This regulation requires that doses to the public and to the workers be kept below established limits and as low as reasonably achievable (ALARA).

Implementation of this regulation is performed by developing the basic plant design in accordance with the ALARA principle and by establishing a Health Physics Program at each installation. The plant design is assessed by the regulator at the time of the licensing review by evaluating the dose records during normal operation.

The Role of CNEN

Regulation CNEN-NN-3.01 - Basic Standards of Radiation Protection [12], of July 2005, is the primary regulatory standard with which all practices have to comply. The main aspects regarding radiation protection and discharge requirements are as follows:

- Controls are established in terms of effective dose equivalent for all nuclear facilities on an annual basis, considering 12 consecutive months;
- The primary annual dose limit to members of the public is 1 mSv effective dose equivalent applied to all practices during all their life stages, i.e., past, present and future;
- For each single justified practice, the discharges should not reach activity concentrations that exceed the maximum authorized annual limit of 0.3 mSv to the critical group, taking into account all exposures pathways and all radionuclides present in the effluents. The assessment shall consider conservative hypotheses. This limit is intended to be applied during the licensing stage and used as a ceiling in the optimization process;

- Exemption to demonstrate the optimization process must comply with;
- An effective dose equivalent to workers less than 1 mSv/y; and
  - An effective dose equivalent to public less than 10 μSv/y; and
  - A collective effective dose equivalent less than 1 man-Sv/y.

The dose constraint is used to establish upper operational levels of activity concentration for effluent discharges to the environment. There are two ways of establishing such levels:

- The operator proposes the upper levels, based on environmental modelling during the licensing. The whole process is verified and approved by the regulatory body.
- In cases where the procedure is not presented or is not accepted, the regulatory body establishes these levels.

In both cases, CNEN performs an independent assessment to establish or approve upper levels for effluent discharges to the environment. The procedure used is based on the critical group approach and follows the model proposed by IAEA as described in Safety Series 57, adapted to the local conditions and the uses of the environment. The definition of the critical group follows the recommendations of ICRP Publication 43.

To the possible extent, local data are used in the model. These data are assessed from licensing documentation provided by the operator, including from the Environment Impact Assessment Report (RIMA) provided to IBAMA.

Basic controls for effluent releases required by the regulation CNEN-NN 3.01 - Basic Standards of Radiation Protection [12] include:

- Nuclear installations that release radioactive effluents into the environment should make use of internal and external monitoring and control systems;
- All radioactive material discharged to the environment should be analyzed, accounted and registered;
- Periodic inspections are carried out by the regulatory authority, in order to verify compliance with the standards;

CNEN regulation NE1.04 - Licensing of Nuclear Installations [3] also requires the establishment of basic controls such as:

- The installation must provide systems to control and limit radioactive releases into air and water;
- Technical specifications related to the release limits and monitoring of radioactive effluents must be approved by CNEN;
- The operator must establish and carry out appropriate monitoring programs;
- Documented management systems are required to ensure compliance with authorization conditions;

- Effluents release accounting, dose calculation, environmental monitoring and the amount of disposed waste shall be registered and made available for further inspections;
- Operational reports that shall be provided by the operator according to regulation CNEN-NE 1.14 [5] include:
    - Monthly historical operation report;
    - Semi-annual Effluents Release Report;
    - Dose Assessments to the Critical Group;
    - Annual Environmental Monitoring Program Report – Impact Evaluation;
    - Unusual Events Report.

For nuclear installations, the Institute of Radiological Protection and Dosimetry of CNEN (IRD) performs independent assessment of the radiological protection aspects, including analysis of licensing documents, such as safety analysis reports, and operational documents such as radiation protection plan, monitoring programs and operational procedures.

During the operational period, IRD establishes a specific routine program for each nuclear installation to control the execution and the adequacy of the program performed by the operators. The program includes occupational monitoring control and environmental monitoring control:

- audits of data records of the radiation protection service, including assessment of workers' doses;
- audits of data records of the radiation protection service training program;
- inspection and execution independent area monitoring program;
- assessment of the results of the area monitoring program, and comparison with the results provided by the operator;
- assessment of the periodical worker monitoring reports provided by the operator;
- independent effluent monitoring, based on composed samples, to be compared with the values reported by the operator;
- dose assessment based on actual effluent release data;
- programmed inspection including a joint environmental sampling, together with the operator;
- assessment of results of the environmental monitoring program, and comparison with results provided by the operator;
- audits of records and laboratories related to the effluents and environmental controls of the installation performed by the operator;
- assessment of the periodical reports provided by the operator on effluents and environmental monitoring.

During the decommissioning period, the program usually implemented by IRD includes occupational monitoring control and environmental monitoring control:

- analysis and approval of decommissioning documents, such as safety analysis reports, and operational documents such as monitoring programs;
- audits of data records of the radiation protection service, including assessment of workers' doses;
- evaluation of special decontamination proceedings;
- regulatory inspections and execution of independent area monitoring program;
- assessment of the results of the area monitoring program, and comparison with results provided by the operator;
- assessment of the periodical worker monitoring reports provided by the operator.

The joint sampling program takes into account main relevant pathways, critical group location, the diversity of environmental media, and the maintenance of an independent historical record database.

Except for the Waste Repository at Abadia de Goiás and USIN, no specific program addresses exclusively the interim waste storage inside the installations. Rather, all procedures related to the verification of compliance to national regulations performed by IRD are applied to the installation as a whole.

For the nuclear medicine practices, IRD performs a biannual inspection at each licensed installation. The objective of the inspections is to verify compliance with CNEN regulatory standards defined on regulation CNEN-NE-6.05 [6], which establishes the exemption levels for solid and liquid waste. The inspections verify the records and inventories of sources and waste, and independent radiometric and surface contamination measurements are performed on the waste storage room and other laboratories.

In the period 2006-2007, IRD conducted 122 inspections distributed as follows:

- Nuclear power plants: 12 inspections;
- Research reactors: 9 inspections;
- Other nuclear installations: 18 inspections;
- Navy Installation at São Paulo (CTMSP) and Iperó(CEA): 5 inspections;
- Nuclear Medicine Services: 157 inspections;
- Radiotherapy Services: 131 inspections.

F.4.1. Nuclear Power Plants

The Health Physics Program of Angra 1 and Angra 2, included in Chapter 12 of the Final Safety Analysis Reports, sets forth the philosophy and basic policy for radiation protection during operation. The general policy is to maintain radiation exposure of the workers below the limits established by CNEN and to keep exposures as low as reasonably achievable (ALARA), taking into account technical and economical considerations.

The annual dose limits to workers are 20 mSv for effective dose in a single year, 15 mSv averaged over five years, and 500 mSv for dose equivalent for individual organs and tissues, except in the case of the eye lens, for which the limit is 150 mSv. For pregnant women, the limit is reduced to 1 mSv for the entire pregnancy period. Pregnant women shall not work inside controlled areas.

The actual personnel radiation doses for workers at Angra Nuclear Power Plants are much lower than the established limits. The dose distribution for workers at the Angra site demonstrates an adequate radiological protection program, with almost all averaged annual accumulated individual doses below 5 mSv and no one with radiation dose above the annual administrative dose limit (20 mSv). Dose distributions for the year 2007 are presented in Figs. F.1 and F.2. The collective doses over the past recent years are shown in Figs. F.3 and F.4.

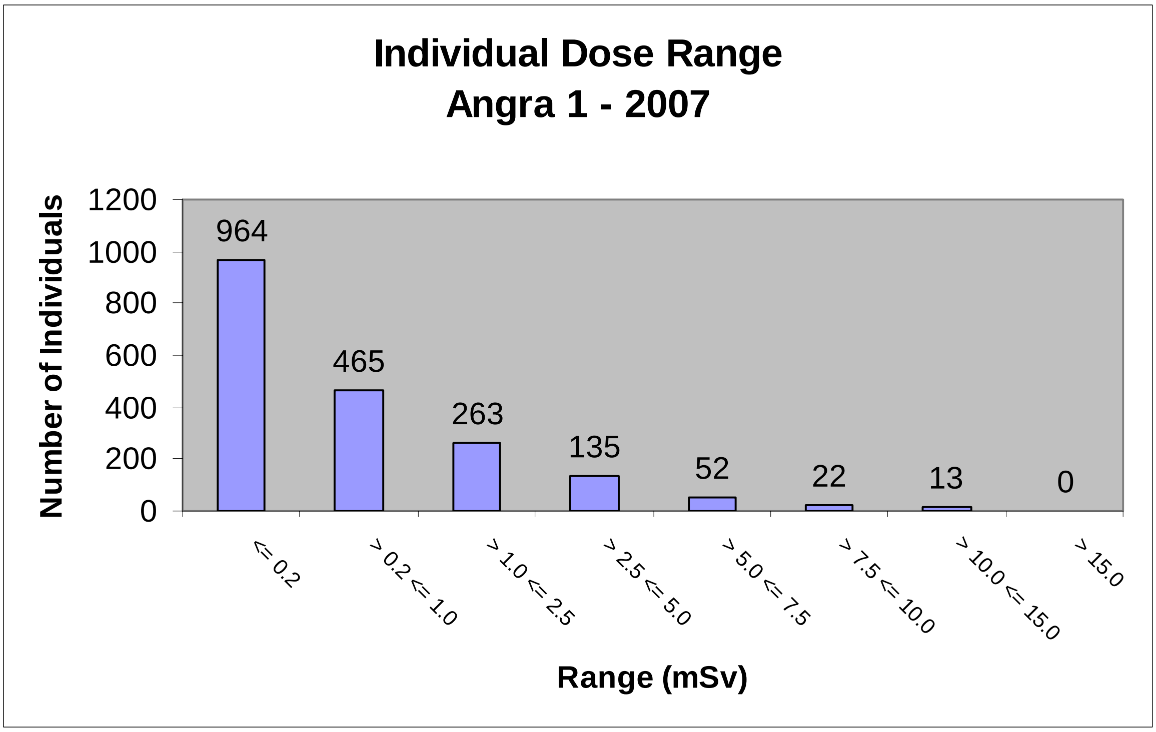

Figure F.1. Individual Dose in Angra 1

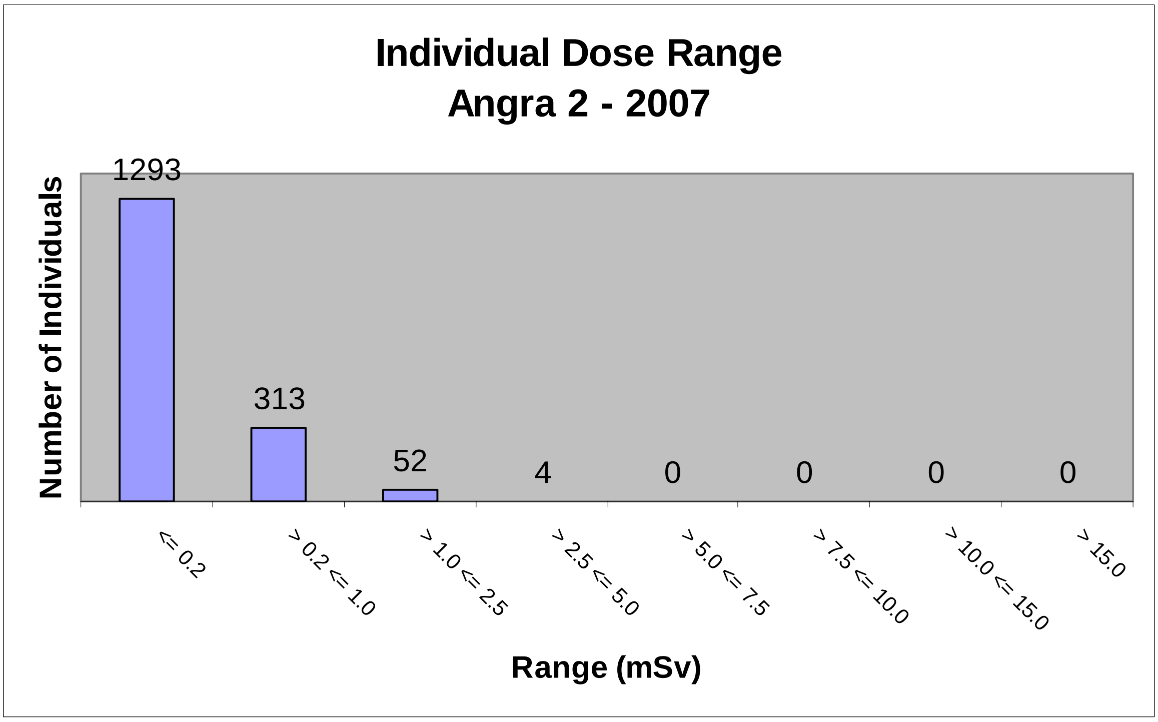

Figure F.2. Individual Dose in Angra 2

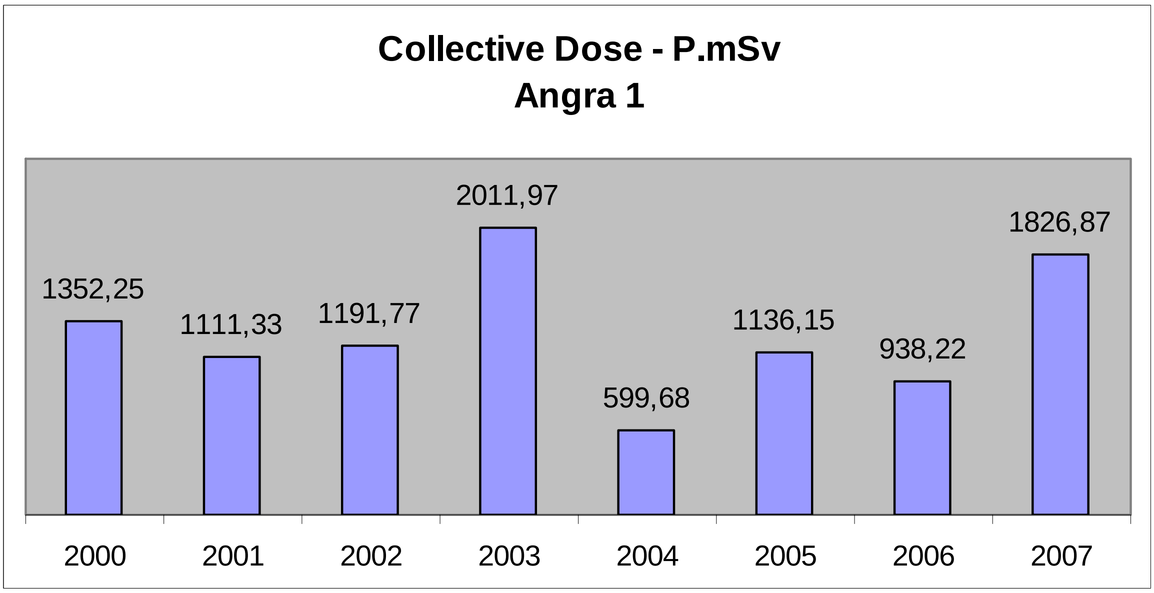

Figure F.3. Collective Dose in Angra 1

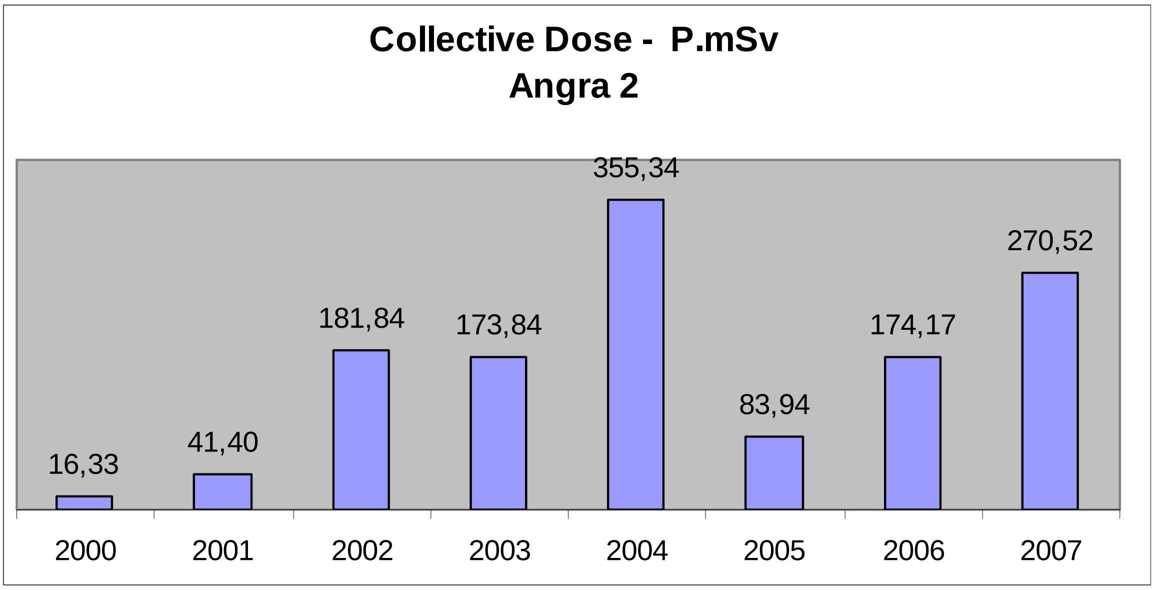

Figure F.4. Collective Dose in Angra 2

The release of radioactive material to the environment is controlled by administrative procedures and is kept below the limits established by CNEN. Additionally, the amount of radioactive waste and the radioactive effluents discharged to the environment also follow the ALARA principle.

The effluent limits are in accordance with the limits fixed in the Offsite Dose Calculation Manual (ODCM), approved by CNEN. In this manual, the dose for the hypothetical critical individual is calculated.

According to the CNEN regulation [5], a report of solid waste and effluents is issued every semester, documenting the liquid and gaseous effluents (reporting the present radionuclides and concentration) and solid waste quantity sent to the on-site storage facility. Also, the effective dose for the critical individual is presented. In 2007, this dose reached a value of 1,3 x 10^{-3} mSv for Angra-2 operation and a value of 3,3 x 10^{-3} mSv for Angra-1 operation, which are much lower than the 1,0 mSv/year value established in regulation CNEN-NN-3.01 [12].

An ALARA Commission for the plant, composed of different groups (Operation, Maintenance, Chemistry, System Engineering and Radiation Protection), is in charge of implementing and monitoring the ALARA Program that describes procedures, methodologies, processes, tools and steps to be used in planning the work. The ALARA Program is continuously being revised and represents the best effort to minimize occupational doses.

A Radiological Environmental Monitoring Program, based on CNEN requirements, is conducted by ELETRONUCLEAR to evaluate the possible impacts caused by plant operation. This program defines the frequency, places, types of samples and types of analyses for the survey of exposure rates. The evaluation of exposure rates is also made by direct measurement using thermoluminescent dosimeters distributed in special sectors around the Angra site, and at points located in the nearest villages and cities. The results of the monitoring programme are compared with the pre-operational measurements taken, in order to evaluate any possible environmental impact. Annual reports are presented to CNEN. To the present date, no impact has been detected.

IBAMA also monitors the impact of the plants on the environment through a system of inspections in which the State Foundation for Environmental Engineering (FEEMA) and the City Administration of Angra dos Reis also participate.

Typical results of the monitoring program are presented in Figure F.5.

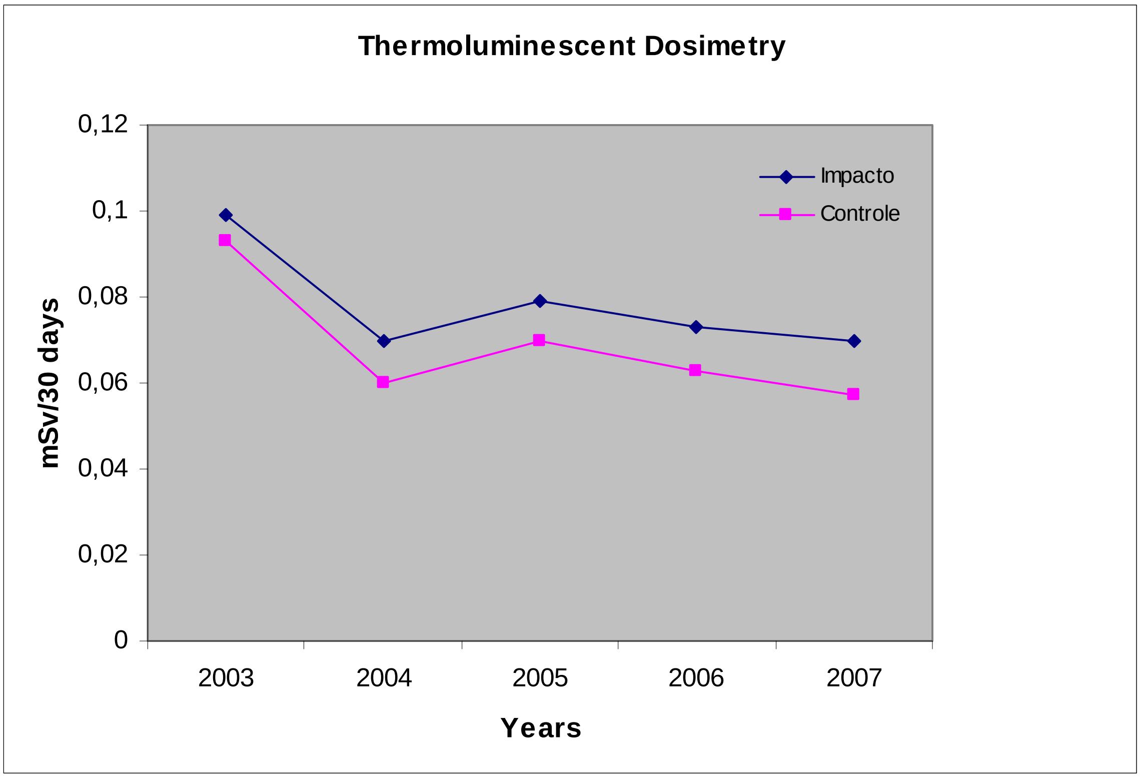

Figure F.5. Environmental Monitoring Program Results for 2003-2007

F.4.2. INB Facilities

The primary purpose of the Radiation Protection Program is to keep the radiation exposure of the workers as low as reasonably achievable (ALARA).

All occupationally exposed individuals in the supervised and controlled areas are monitored by means of individual dosimeters (TLD badges). The dosimeters are supplied by a laboratory duly certified by CNEN and are changed on a monthly basis.

Individuals not exposed occupationally are monitored with prompt reading dosimeters when they access the supervised and controlled areas.

All occupationally exposed individuals (OEI) attend radiation protection, emergency preparedness, first aid, and industrial safety training sessions on a yearly basis.

For occupational exposure, the legal primary dose limits for occupational exposures are an effective dose of 20 mSv per year averaged over five consecutive years and an effective dose of 50 mSv in any single year. For public exposures, the dose limit is an effective dose of 1 mSv in a year.

At FCN the dose constraint values are established at 40 mSv per year and 16 mSv per year averaged over five consecutive years.

In order to achieve effectiveness in the radiological control, all the radiometric data is classified according to pre-established reference levels which determine the actions to be performed according to their magnitude.

Thus, FCN presents values that show a suitable Radiological Protection Program, for which 100% of OEI have received for the last 5 years, the external doses classified as recording level.

Also for the last 5 years, the aerosol monitoring presents 100% of the obtained values as a recording level at FCN - Components and Assembling and 97% at the conversion and UO_2 pellets facilities.

From the accumulated operational experience since the beginning of FCN operation, there is an estimation that the average effective equivalent dose resulting from occupational activities performed in the plant is below 5.0 mSv/yr for OEI.

Figure F.6 shows the distribution of individual doses obtained in 2007, Figure F.7 shows collective dose values for the past 5 years.

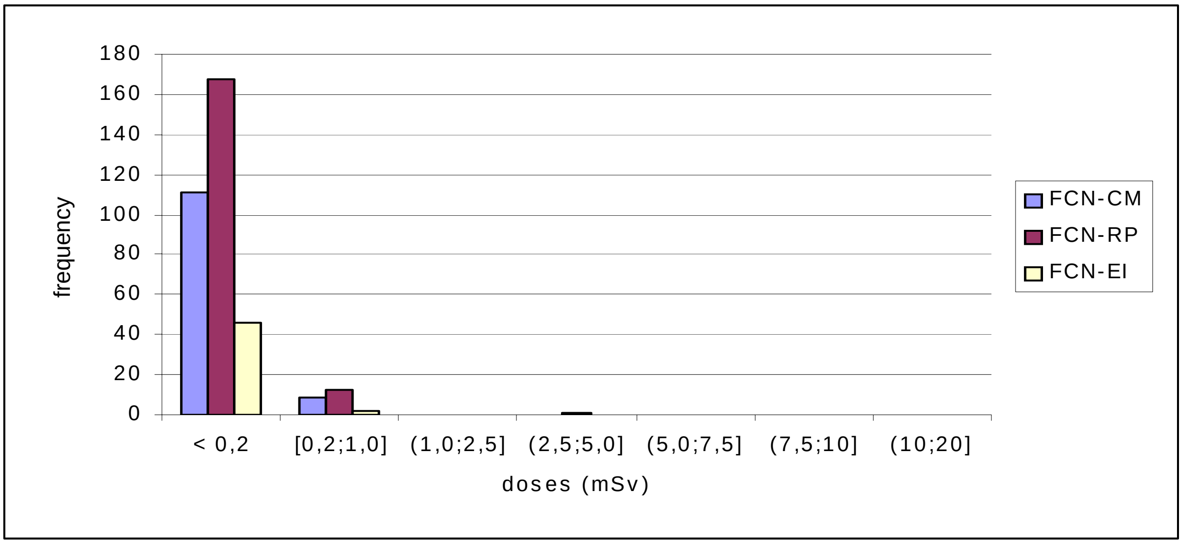

Figure F.6 - Individual Dose 2007

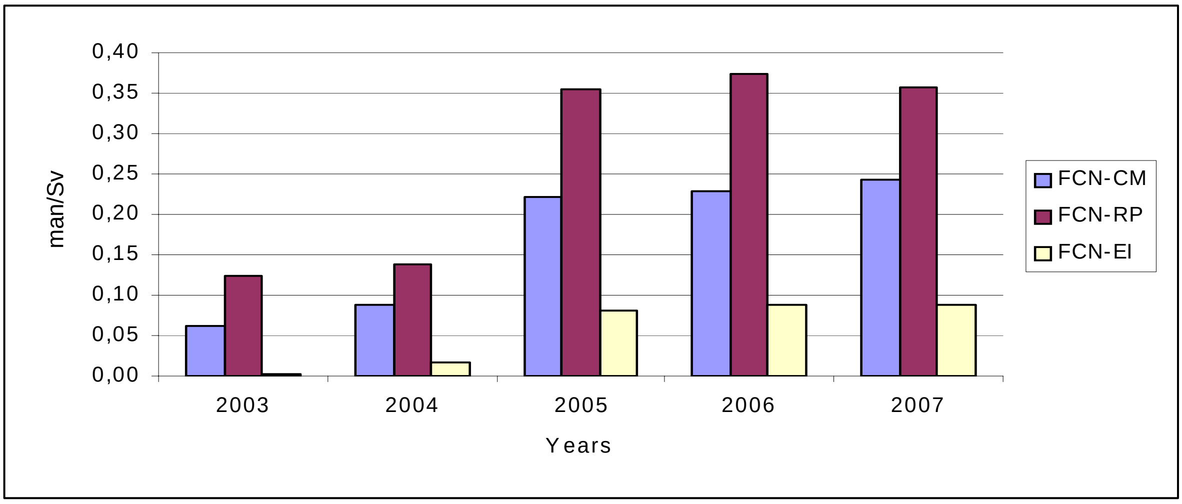

Figure F.7 - Collective dose

Regarding the URA facility, the mean effective annual doses resulting from occupational activities performed in the plant are shown in Figure F.8, for the past 5 years.

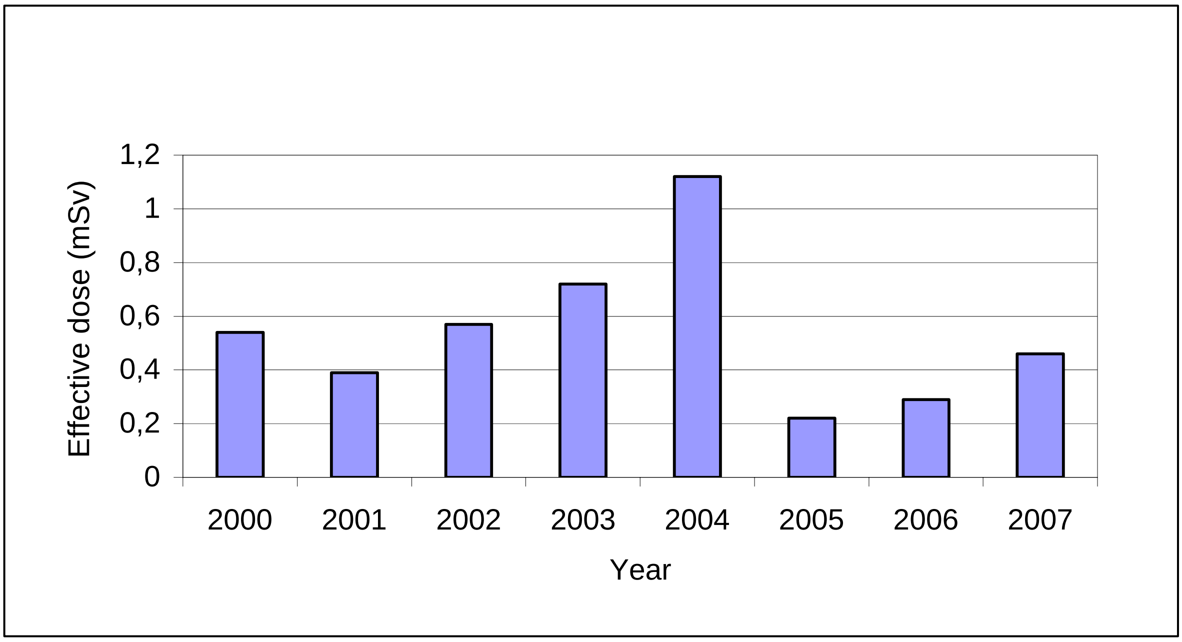

Figure F.8. Mean Annual Effective Dose from Occupational Exposures – URA.

F.5. Article 25. EMERGENCY PREPAREDNESS

As mentioned in E.1.3, Brazil has established an extensive structure for emergency preparedness under the so-called System for Protection of the Brazilian Nuclear Program (SIPRON). This includes organizations at the federal, state and municipal level involved with licensing and control activities as well as those involved with public safety and civil defense. Operators of nuclear installations and facilities and supporting organizations are also part of SIPRON.

SIPRON was established by Law 1.809 of 7 October 1980. Recently, a governmental restructuring (through Law 10.683 of 28 May 2003) has designated the Ministry of Science and Technology (MCT) as the state department with competence for nuclear energy policy. SIPRON now stays under the responsibility of a Special Advisor to the Minister as a part of the coordination of Technical and Scientific Nuclear Program of MCT.

The Decree 2.210 of 22 April 1997 also established a Coordination Commission (COPRON) composed of representatives of the agencies involved. Besides ELETRONUCLEAR, as the nuclear power plant operator, and CNEN, as the nuclear regulatory body, other agencies are involved as support organizations of SIPRON, such as the municipal civil defense, the state civil defense, the Angra Municipality, the IBAMA, the National Road Authority, the Army, the Navy, the Air Force, and the Ministries of Health, Foreign Relations, Justice, Finance, Planning and Budget, Transportation and Communications.

The approach to emergency preparedness is based in a “municipalization” of the response action to an emergency situation, using mainly the resources available at the municipality. The state and federal governments complement the local resources as necessary. In this way, SIPRON works at the operational level with the municipal government and the state government, and at the political level through the Federal Government, which provides the necessary material and financial resources.

A National Center for Management of Nuclear Emergency Situation (CNAGEN) has been created in Brasilia, in the MCT, in order to coordinate the actions. A State Center for Management of Nuclear Emergency Situations (CESTGEN) has been established in Rio de Janeiro. A Center for Coordination and Control of Nuclear Emergency Situation (CCCEN) and a Center for Information in Nuclear Emergency (CIEN) have been established in the city of Angra dos Reis.

Corresponding plans have been prepared for CNEN, for its support Institute for Radiation Protection and Dosimetry (IRD) and for other agencies involved, and detailed procedures have been developed and are periodically revised.

F.5.1. Nuclear Power Plants

Legislation

With respect to emergency preparedness, additional requirements have been established by the creation of the Brazilian Nuclear Program Protection System (SIPRON) by Law 1.809 of 7 October 1980. The subsequent Decree 2.210 of 22 April 1997 established the Secretaria de Assuntos Estratégicos (Secretariat for Strategic Affairs - SAE), directly linked to the Presidency of the Republic, as the Central Organization of SIPRON responsible for the general supervision of the preparedness and response to nuclear emergencies in the Country.

Since 2000, a Governmental restructuring has designated the Ministry of Science and Technology (MCT) as the Central Organization for SIPRON.

The Decree 2210 also establishes the Brazilian Nuclear Program Protection System Coordination Commission (COPRON) composed of representatives of the agencies involved.

SIPRON guidelines, issued by COPRON, require that ELETRONUCLEAR, the Municipal and State Civil Defenses prepare, update and practice a plan for nuclear emergency situations. The guidelines also require that all organizations and agencies involved have their complementary emergency plans.

Emergency Preparedness

The planning basis for on- and off-site emergency preparedness in case of an accident with radiological consequences in the Angra Nuclear Power Station is based on the Emergency Planning Zone (EPZ) concept.

The Emergency Planning Zones encompass the area within a circle with radius of 15 km centered at the nuclear power plants. This EPZ is further subdivided in 4 smaller zones with borders at approximately 3, 5, 10 and 15 km from the power plants.

On Site Emergency Preparedness

The On-site Emergency Plan covers the area of property of ELETRONUCLEAR, and comprises the first zone. For this area, the planning and all actions and protection countermeasures for control and mitigation of the consequences of a nuclear accident are responsibilities of ELETRONUCLEAR.

Specific Emergency Groups (Power Plants - Units 1 and 2, Support Services, Head Office and Medical) under the coordination of the Site Manager are responsible for the implementation of the actions of the On-site Emergency Plan. Emergency Centers for coordination of the Emergency Plan activities, equipped with redundant communication systems and emergency equipment and supplies are established in different locations inside this area.

A redundant meteorological data acquisition and processing system composed of 4 meteorological towers, provides continuous data on wind temperature, speed and direction, as well as air temperature gradient, to a computerized system in the Technical Support Center / Control Room of Units 1 and 2, through which is made the follow up and calculation of the spreading of the radioactive cloud.

The On-site Emergency Plan involves several levels of activation, from Facility Emergencies, Alert at Facility, Area Emergency, to General Emergency.

The initial notification for activation of the On-site Emergency Plan is done by the Shift Supervisor from the Control Room, which notifies the Plant Manager, as Emergency Group coordinator, which alerts the coordinators of the other Emergency Groups, the Site Manager and the Regulatory Body (resident inspector and Headquarter). The plant personnel are warned by means of the internal communication system, sirens and loudspeakers.

Twenty-four-hour / 7-day-a-week on-call personnel, under the responsibility of the Site Manager, ensures the prompt actuation of the Emergency Groups.

Training and exercises (5 per plant) are performed yearly.

Off Site Emergency Preparedness

Brazil has established an extensive structure for emergency preparedness under the System for Protection of the Brazilian Nuclear Program.

SIPRON issued a set of General Norms for Emergency Response Planning, consolidating all requirements of related national laws and regulations. These norms establishes the planning, the responsibilities of each of the involved organizations and the procedures for the emergency centers, communications, intelligence and information to the public.

COPRON has established a Committee (COPREN/AR) for planning and preparedness of the response to a nuclear emergency at Angra Nuclear Power Plant. This committee conducts an off-site emergency plan practice every year. In a given year, the practice is a partial exercise with only the communication system and the emergency centers activated. In the next year, a general exercise includes sirens actuation, evacuation and sheltering of part of population, external monitoring, road and air and sea navigation control.

At the off-site level, a National Center for Management of Nuclear Emergency Situation (CNAGEN) has been created in Brasilia (capital of Brazil). A Regional Center for Management of Nuclear Emergency Situations (CESTGEN) has been established in Rio de Janeiro city. A Center for Coordination and Control of Nuclear Emergency Situation (CCCEN) and a Public Information Center (CIEN) have been established in the city of Angra dos Reis. The activities of these centers during an emergency have been established in SIPRON General Norms and were approved by the state governor in the revised Rio de Janeiro State Plan for External Emergency.

Corresponding plans for CNEN, its support Institute for Radiation Protection and Dosimetry (IRD) and other involved agencies have been prepared, and detailed procedures have been developed.

F.5.2. Other Facilities (Research Reactors)

The safety analysis performed for other installations such as research reactors indicates that only “on-site emergency is required”. The on-site emergency plan covers the area within the operator’s property, and comprises the reactor building and surroundings. It involves several levels of activation, from single alert status, to reactor building evacuation and isolation.

Specific Emergency Groups, under the coordination of the COGEPE (General Coordinator for Emergency Plan), are responsible for the implementation of the actions of the on-site emergency plan. COGEPE is also responsible for plant personnel emergency training and exercises planning.

IPEN also maintains a Nuclear and Radiological Emergency Response Team. Training activities in nuclear and radiological emergency for fire brigade companies, professionals of medical area, safety officers and employees are carried out systematically, with the participation of qualified observers.

At CDTN, a radiological emergency service is also available around the clock, including weekends and holidays. The emergency team is made up of 18 trained people who are able to deal with situations arising from radioactive source losses, en route accidents with vehicles transporting radioactive sources, or source mishandling at the user’s premises. The most common tasks carried out by the CDTN response group so far have been the investigation of possible site contamination in airports, stealing of lightning rods, possible presence of orphan radiation sources in junkyards and industrial areas and the disappearance of medical sources from hospitals. The response group members also give lectures on emergency response, radiation protection and radiation source handling to specific groups, e.g. firefighters and Army special battalions.

F.5.3. INB

The Nuclear Fuel Manufacturing Facility located in the Resende municipality established a Local Emergency Plan mainly focused on the possible accident occurrences within its facilities. There is no possibility of these accidents reaching the surrounding areas.

The Local Emergency Plan can be activated by a wide variety of possible incidents, such as fire, radiological accidents, and intrusion scenarios into the facilities. There is an organizational emergency structure establishing the responsibilities, as well procedures for each emergency group formed by the plant technical personnel.

Although it is very unlikely that accidents in that facility reach the surrounding areas, an emergency general coordination was established with supporting groups such as the municipal civil defense, the fire brigade, the police, and CNEN emergency group. The Emergency Response Planning Committee in Resende - COPREN/RES, has been coordinating this task besides supporting SIPRON.

The effectiveness of the Local Emergency Plan is verified through simulated emergency exercises. The plan coordinator prepares a scheduled program on an annual basis with various scenarios of possible accidents. Emergency exercises are performed on monthly basis. After accomplishing this simulation, a meeting takes place in order to evaluate the performance of the group as a whole and a report with recommendations is prepared. Besides that, a meeting with all the participants of the program is held every three months, in order to discuss problems that may have some implications in the plant facility, such as the alarm system operation, specialized personnel hiring and communication system operation during an emergency situation.

F.6. Article 26. DECOMMISSIONING

Brazil is taking steps to establish a national regulation that sets the guidelines for the composition of funds for facility decommissioning, spent fuel management and radioactive waste management and disposal.

F.6.1. Nuclear Power Plants

A recent study made by ELETRONUCLEAR has established the alternatives for the future decommissioning of Angra 1 and Angra 2 Nuclear Power Plants, analyzing the financial resources, based on 17 American Nuclear Power Plants, 10 European Nuclear Power Plants and the specific study elaborated by Krsko Nuclear Power Plant, similar to Angra 1.

ELETRONUCLEAR considers as the best alternative the SAFSTOR (Safe Storage), which consists of the confinement of the Plant for a period of 10 up to 30 years, to reduce the amount of contaminated material, and radiation exposure.

The financial resources for decommissioning Angra 1 and Angra 2 would be subsidized through electrical energy taxes from those plants, with governmental authorization.

The national approach on waste from the above mentioned decommissioning is on a latent status, to be analyzed and defined later, after the definition and conclusion of the final disposal site for the LLW-Low Level Waste and ILW-Intermediate Level Waste from Angra Nuclear Power Plants.

F.6.2. Research Reactors

No decommissioning policy has been adopted. However, at CDTN a group has just begin to study and to prepare a preliminary decommissioning plan for IPR-R1.

F.6.3. Nuclear Installations

F.6.3.1. Decommissioning of Usina de Santo Amaro (USAM)

The Santo Amaro monazite sand treatment facility (USAM) is the only decommissioned nuclear facility in Brazil. USAM operated since the 1950's in a small town near São Paulo, separating rare earth materials from monazite sand coming from the Buena Beach in Espírito Santo state. The growth of urban areas around the site led to the decision to decommission the facility.

The facility went through a complete decommissioning process. After transporting all separated useful material and the waste to other site at USIN (see H.2.2.2), the buildings were demolished and the site decontaminated. A detailed radiation monitoring program was conducted and the site was declared free for unrestricted use. The formal decommissioning process was formalized through a resolution of the Deliberative Commission of CNEN in January 1999. A view of the area before decommissioning is show in Figure F.9.

Figure F.9. Area occupied by USAM in Santo Amaro, SP.

Before decommissioning, the monitoring program proposed by the operator and approved by CNEN fulfilled the need for following up the environmental behavior of the site soil contamination and for assessing the radiological impact on the environment that resulted from the pre-existing site contamination and due to the radiation emitted by the stored radioactive materials in Warehouse A. A program for occupational exposure assessment was also implemented by the operator.

The monitoring program performed by the operator analyzed the concentrations of soluble ^{226}Ra and ^{228}Ra in water from wells around the site, wells inside Warehouse A and a creek close to the site area. External doses were measured by a TLD net around the site and around Warehouse A.

The control performed by IRD included the assessment of reports provided by the operator and regulatory inspections, where the access control for restricted areas was verified, and measurements of dose rates inside and surrounding Warehouse A were performed.

In December 1997, INB submitted a comprehensive plan for demolishing USAM buildings and some soil samples were sent for laboratory analysis, especially for determining existing radionuclides and total alpha and beta/gamma activities.

CNEN also required that INB submitted: (i) a detailed decommissioning plan, including waste management and radiological procedures for demolishing the buildings (floors, walls, sanitary system, water distribution system etc); (ii) procedures that would be adopted for the radiological characterization of the site (depth of soil samples, sampling frequency etc.) and frequency of reports to be submitted to CNEN; (iii) the radiological criteria to be used for clearance; (iv) a radioactive waste management plan, including the adequate description of packages; (v) description of the scenarios that would be used for the determination of soil clearance values (cutoff limits) due to the goal of releasing the area for unconditional use; (vi) radiological procedures for the workers involved in the clean up; and (vii) procedures to control and guarantee that the doses on the neighbouring population would not exceed 1 mSv/y.

In 1997, an environmental monitoring control program was implemented by IRD for the USIN site, including the assessment of documents provided by the operator, auditing records related to the environmental monitoring program and a joint sampling procedure for well and surface water.

The duplicate sampling program has shown that the results obtained by INB were compatible with those obtained by the regulatory body and that the area was adequately controlled.

On March 1998, CNEN authorised the demolition of the area occupied by the monazite physical treatment unit, with the exception of some compartments in the area of thorium crystallisation, since the contamination levels detected were above the established clearance levels. Some soil contamination was also detected. On June 1998, CNEN authorised the complete demolition of these compartments. On July 1998, another room from the monazite chemical treatment unit was demolished, after the procedures proposed by the operator were approved by CNEN. On August 1998, the last room and the administrative building was demolished, also after specific authorization by CNEN.

The radioactive waste generated from these decommissioning steps were placed in metallic boxes and metallic containers, transported to another INB installation, USIN, and stored in a shed. All the conditioning and transport of the waste were inspected by CNEN.

The scenario calculations performed by the Institute of Radiological Protection and Dosimetry (IRD), based on unconditional use of the area (soil), led to a clearance value of 600 Bq/kg of ^{226}Ra for soil.

All the clean-up work of the soil was inspected and audited by CNEN during the months of January through December 1998.

On December of 1998, experts from IRD conducted a complete radiometric survey of the soil within the plant, concluding that the clean-up performed at the soil surface was sufficient to reduce the surface contamination of the area to the same levels of the natural background of the region. Figure F.10 shows the site after the end of the decommissioning activities of the USAM monazite processing plant.

Figure F.10. Clean area after USAM decommissioning work

A total of 13,000 m^2 of constructed area has been demolished and an area of 16,503 m^2 of soil has been removed (at an average of 50 cm of soil depth, resulting in a waste volume of the order of 8,250 m^3). The waste that was slightly contaminated and classified as radioactive, occupying a volume of 372 m^3, is stored in a shed of INB in São Paulo.

One hundred and thirty four workers from INB (operator) were involved in the decommissioning work and their recorded doses can be seen on Table F.7, which shows that all of them received radiation doses far below the Brazilian dose limit of 50 mSv/a, adopted at the time. These dose values are also below the new limit of 20 mSv/a adopted by Brazil.

Table F.7– Radiation doses to workers involved in decommissioning USAM

Dose	Number of workers
>10 mSv	0
> 5 mSv and ≤ 10 mSv	8
> 1 mSv and ≤ 5 mSv	46
> 0.1 mSv and ≤ 1 mSv	30
Undetectable	50

INB has successfully decommissioned a monazite processing plant in Brazil, over a period of approximately 5 years, under close surveillance of CNEN, as depicted in Figures F.9 and F.10.

After decommissioning USAM, INB sold the land to a construction company, which has designed and built six 26-floor residential buildings. The project includes apartments with private areas of 120, 170 and 220 m^2, the target public being upper middle-class. Figure F.11 shows the area of the former USAM, now occupied by new construction: six buildings, recreational area with swimming pools, sport courts and playground.

Figure F.11. New residential buildings built in USAM decommissioned area

F.6.3.2. Decommissioning of the Mineral Treatment Facility at Poços de Caldas (UTM)

Parts of the old Mineral Treatment Facility (UTM) at Poços de Caldas mining and milling complex are currently being decommissioned by INB. INB is in the process of hiring a specialized company for the preparation of the Remediation Plan, which is intended to cover all installations of UTM.

F.6.3.3. Decommissioning of USIN

In 2004, INB resumed studies aimed at chemically and radiologically characterizing the land owned by USIN. In 2006, INB submitted to CNEN the Land Decontamination Plan, presenting the radiological characterization of the soil over the entire area and the remediation plan for those points presenting anomalies caused by radioactive materials stored in that location.

The remediation procedure estimates that 680 m^3 of soil will be moved by the decontamination work, of which approximately 80 m^3 will be segregated as low-level radioactive waste and temporarily stored in USIN's Shed A.

INB is expecting the definition of the position of CNEN on the national repository for low- and intermediate-level radioactive wastes so that studies and plans can be developed for transfering the waste stored at USIN. From the establishment of that position, a new radiological assessment of Shed A and of the local soil will be done, along with the decontamination plan and the subsequent total decommissioning of the facility.

Section G - SAFETY OF SPENT FUEL MANAGEMENT

G.1. Article 4. GENERAL SAFETY REQUIREMENTS

Since the current situation is the storage of spent fuel in the plant pools, the general safety requirements for the management of spent fuel are contained in the safety requirement for siting, design and operation of the nuclear reactors. Regulation CNEN-NE-1.04 [3] applies to the fuel stored in the nuclear power plant. Additional requirements are established in Regulation CNEN-NE-1.26 [8], for the operational phase, and Regulation CNEN-NE-1.14 [5] establishes the necessary reporting requirements.

G.2. Article 5. EXISTING FACILITIES

G.2.1. Nuclear Power Plants

The design of the fuel pools and associated cooling systems and fuel handling systems assure adequate safety under authorized operation and under postulated accident conditions.

Both units are provided with facilities that enable safe handling, storage and use of nuclear fuel. The facilities are designed, arranged and shielded such as to rule out inadmissible radiation exposure to the staff and the environment, release of radioactive substances to the environment, and criticality accidents.

In Angra 1 the new fuel dry storage room and the spent fuel pool are located in the Fuel Handling Building, having connections with the reactor via the fuel transfer system and the refueling machine. The path of the nuclear fuel inside the plant up to the reactor is: the entrance gate, the cask opening area inside the fuel building, the new fuel storage area, the transfer canal (or temporarily in the spent fuel pool), the fuel transfer system, the refueling machine and the reactor core.

In Angra 2 the dry new fuel storage room and the spent fuel pool are located inside the Reactor Building. The path of the nuclear fuel inside the plant up to the reactor is: the entrance gate, the auxiliary portico, the equipment lock, the cask opening area, the new fuel storage area, the refueling machine, the spent fuel pool, and the reactor core.

In both Units the Spent Fuel Pools are equipped with fuel storage racks of two different designs. The first group, named Region 1, or compact racks, is designed to receive fresh and irradiated fuel assemblies at maximum reactivity for the specified core design, without taking credit for burnup. The second group, named Region 2 or supercompact racks, is designed to receive fuel assemblies that have reached a certain minimum burnup.

The compact and supercompact racks, made of stainless steel, have boron coupons between the storage cells in Angra 1. In Angra 2 the compact and supercompact racks use borated steel plates as the construction material of the cells. The technical specifications have curves of discharge burnup versus initial enrichment to direct the storage of fuel assemblies in region 2 because the smaller center-to-center distance of the cells.

Structures, components, and systems are designed and located such that appropriate periodic inspection and testing are performed.

In both units, all storage places are supported by criticality safety studies. Criticality in new and spent fuel storage areas is prevented both by physical separation of fuel assemblies, by boron shields and by borated water as appropriate.

The evaluated multiplication factors of the fuel storage configurations include all uncertainties arising from the applied calculation procedure and from manufacturing tolerances. The factors are less than or equal to the adequate upper bound margin of subcriticality (1-deltaK) under normal operation and all anticipated abnormal or accident conditions.

The criticality evaluation codes used by the ELETRONUCLEAR are all codes accepted by the international industry and also licensed by CNEN.

The storage capacity is shown on table G.1 below:

Table G.1. Spent fuel storage capacity at Angra – Number of fuel assemblies

	Angra 1	Angra 2
New Fuel Storage Room	45	75
Region 1 Spent Fuel Pool	252	264
Region 2 Spent Fuel Pool	1000	820
Reactor Core	121	193

Assuming a regular lifetime of 32 operating cycles for each unit and that in each cycle 1/3 of the core is replaced, then Angra 1 has enough storage capacity for its entire lifetime and Angra 2 has storage capacity for about 14 cycles.

Both units have redundant residual heat removal systems fed by redundant electrical safety buses, with provisions from the plant house load supply, redundant external electrical supplies and redundant Diesel generators. The sources of cooling water are closed circuits, cooled by seawater open circuits.

Instrumentation in the cooling and purification systems of the fuel pools detects radiation and excessive or low temperatures, emitting alarms to prompt the operator for actions.

Each unit is designed for a regular lifetime of 32 operating cycles. According to the national electric power demand, the refuelling policy is to operate with 11 equivalent full power monthly cycles, with an one-month refuelling outage. Studies are being carried out to increase the cycle lengths gradually up to 18 months, since longer cycles reduce waste generation and doses during refuelling outages. Shutdowns, refuelling and startups of the plants are conducted in such a way to reduce the amount of radioactive waste generated (see also items D.1.1.1 and D.1.2.1).

The role of the ELETRONUCLEAR on the nuclear fuel management can be summarized as follows:

- Definition of operating strategy
- Definition of core composition
- Procurement of fuel manufacturing together with manufacturers
- Follow up of fuel manufacturing
- Transport of new fuel from the factory to the site
- New fuel reception on site
- Fuel storage on site
- Fuel operation
- Refueling Operations

The supply of the fuel for nuclear power plants is planned several years in advance. In-core fuel management provides the basic data for this long-term planning. For this purpose, several burnup cycles have to be calculated in advance. The corresponding core loading schemes, or loading patterns, have to be determined considering safety-related and operational requirements as well as economic aspects. The main results of long-term fuel management are the required numbers of fuel assembly reloads and their enrichments for future cycles.

Of special interest in the long-term fuel management are the equilibrium cycles. To calculate the equilibrium cycles, the same loading pattern is used for several successive cycles. The equilibrium cycle is reached when the characteristic parameters do not change significantly from cycle to cycle. The most important characteristic parameters are:

- Type of loading strategy
- Number and enrichment of the fuel assembly reload
- Natural length of the cycle
- Average discharge burnup for the fuel assemblies
- Availability of storage places. In this sense, the interdependence of spent fuel (non-returnable to the reactor core) management is to be defined with CNEN.

G.2.2. Research reactors

See item D.2.

G.3. Article 6. SITING OF PROPOSED FACILITIES

Siting requirements for the existing spent fuel storage facilities at reactor sites are the same for siting the nuclear power plants or research reactors, respectively.

If the decision is taken to store fuel in "dry storage" on site, new detailed requirements will have to be established by CNEN.

G.4. Article 7. DESIGN AND CONSTRUCTION OF FACILITIES

Design and construction requirements for the existing spent fuel storage facilities at reactor sites are the same for design and construction of the nuclear power plants or research reactors.

The spent fuel storage racks are easily installed and removed. They are manufactured from stainless steel. Their purpose is to receive and store fresh and spent fuel assemblies as well as any core inserts, like control rods, primary and secondary sources and flow restrictors to be inserted into fuel assemblies.

The storage racks consist of load bearing structure supporting non-load bearing absorber cells. The load bearing structures comprise:

- The lower support structure (base plate)
- Rack foot
- Centering grid
- Steel channels

The non-load bearing structures are provided with features to assure safe subcriticality, each fuel assembly position is provided with one absorber cell. The absorber cells are made of neutron absorbing sheets with grooved edges. The absorber sheets are manufactured from a boron-alloyed austenitic stainless steel.

The absorber cells are fixed in the rack structure by means of welded clamps. To facilitate the insertion of the fuel assembly into the absorber cell, the upper part of the cell is provided with lead-in slopes, or chamfers and, where applicable, with guide for the refueling machine centering device.

Only about 40% of the volume of a fuel assembly consist of fuel rods; the remaining volume is filled by water.

By plant design the storage and management of spent fuel assemblies can be enhanced by fuel assembly consolidation to reduce volume. For this purpose, the fuel rods can be removed from the fuel assembly structure and packed as densely as possible into a canister. The canister can be stored and handled like a fuel assembly. In this way the fuel rods of two fuel assemblies can be consolidated to occupy the space required for one in a specified number of storage cells.

If the decision is taken to store the fuel in “dry storage” on site, new detailed requirements will have to be established by CNEN.

G.5. Article 8. ASSESSMENT OF SAFETY OF FACILITIES

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil [3].

G.5.1. Nuclear Power Plants

For the Angra 1 and Angra 2 plants, both a Preliminary Safety Analysis Report (PSAR) and a Final safety Analysis Report (FSAR) were prepared. The FSARs followed the requirements of US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs.

Chapter 9 of the FSAR contains the information related to spent fuel storage on site, including cooling requirements, subcriticality requirements, and radiation protection aspects.

These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 800).

G.5.2. Research Reactors

The design and additional modifications of the Brazilian Research Reactors have been made in accordance with IAEA Safety Standards, Safety Guides and Safety Practices of IAEA Safety Series, in particular Safety Guide 35-G2 (Safety in the Utilization and Modification of Research Reactors), Safety Guide 35-S2 (Code on the Safety of Nuclear Research Reactors: Operation), Safety Series 116 (Design of Spent Fuel Storage Facilities), and Safety Guide 117 (Operation of Spent Fuel Storage Facilities). Such documents present the fundamental principles of safety for research reactors and associated facilities for handling, storage and retrieving of spent fuel before it is reprocessed or disposed of as radioactive waste. The adoption of these principles assure that the spent fuel represents no hazard to health or to the environment, and the maintenance of the following conditions for the spent fuel:

- Subcriticality
- Capacity for spent fuel decay heat removal
- Provision for radiation protection
- Isolation of radioactive material.

G.5.3 Nuclear Fuel Cycle Facilities

INB has the following manufacturing units:

- Uranium Concentrate Unit – URA, located in the municipality of Caetité, state of Bahia;
- Ore Treatment Unit – UTM, located in the municipality of Caldas, State of Minas Gerais
- Nuclear Fuel Factory - FCN, located in the municipality of Resende, state of Rio de Janeiro, consisting of the following units:
  - FCN – Components and Assembly
  - FCN – Reconversion (UF_6 to UO_2 Conversion) and Pellets
  - FCN – Enrichment
- Heavy Minerals Processing Unit – UMP, located in Buena, state of Rio de Janeiro,
- Interlagos (USIN) and Botuxim Plants, located in the state of São Paulo.

To ensure building and operation of facilities in accordance with the safety principles required by national and international authorities, all facilities owned by INB are subject to nuclear licensing procedures with the Brazilian Nuclear Energy Commission. To this effect, a Preliminary Safety Analysis Report and a Final Safety Analysis Report are prepared and submitted in accordance with regulatory guide CNEN NE 1.04 – "Licensing of Nuclear Installations", which is further supplemented by regulatory guide CNEN 1.13 – "Licensing of Uranium and/or Thorium Mining and Milling Facilities", in the case of uranium ore mining and milling operations.

Additionally, all such facilities go through an environmental licensing process, including an Environmental Impact Study in which the safety conditions relating to the environment and the population are discussed.

For nuclear facilities, this process is conducted by IBAMA; in the case of the UMP, this is the responsibility of the state environmental body Fundação Estadual de Meio Ambiente (FEEMA); and in the case of USIN and Botuxim sites, by the state-run environmental agency Companhia de Tecnologia de Saneamento Ambiental (CETESB).

G.6. Article 9. OPERATION OF FACILITIES

Operational requirements for the existing spent fuel storage facilities at reactor sites are the same for operating the nuclear power plants or research reactors.

Detailed limits and conditions for operations (LCOs) are established for the nuclear power plant spent fuel pools, including the related surveillance requirements and the actions to be taken in case of deviations.

G.7. Article 10. DISPOSAL OF SPENT FUEL

G.7.1. Fuel from Nuclear Power Plants

The technical solution regarding reprocessing or disposal of spent fuel has not been taken in Brazil. This solution may take some time, until international consensus is achieved. Meanwhile, Brazil continues to monitor the international situation.

For Angra 1, 2 and future unit 3 an additional wet storage facility for spent nuclear fuel is foreseen, in order to complement the current on-site storage capacity of Plants. This facility will be under ELETRONUCLEAR responsibility as an initial storage facility.

G.7.2. Fuel from Nuclear Reactors

The situation of research reactors was discussed in item D.2.1

On November, 2007, 33 spent fuel elements stored in the pool of the IEA-R1 reactor and containing uranium of US origin were shipped back to Savannah River Laboratory, South Carolina, USA. This operation, which was very similar to the one concluded in 1999, when 127 spent fuel elements were shipped back to the USA, used a different transport cask (LWT) supplied by the US company NAC.

Section. H - SAFETY OF RADIOACTIVE WASTE MANAGEMENT

H.1. Article 11. GENERAL SAFETY REQUIREMENTS

General safety requirements for the management of radioactive waste are established in regulation CNEN-NE-1.04 Licensing of Nuclear Installations [3] and CNEN-NE-6.05. Management of Radioactive Waste in Radioactive Installations [6]. Additional requirements for safety in nuclear facilities are established in regulation CNEN -NE- 1.26, Operational Safety in Nuclear Power Plants [8].

H.2. Article 12. EXISTING FACILITIES AND PAST PRACTICES

H.2.1.Nuclear Power Plants

H.2.1.1. Gaseous Waste

To minimize the radiation released to the environment and to prevent the formation of explosive mixtures due to high hydrogen concentration, the gases are continuously removed from the primary systems and processed in the Gaseous Waste Processing System, before being discharged to the environment.

In Angra 1, the Gaseous Waste Treatment System removes the fission gases and stores them in the gas decay tanks. The discharge of these gases to the environment is not frequent, occurring as a function of operational tests. The safety criteria are the assumption of 1% of fuel failures being released to the Reactor Coolant System.

In Angra 2, in order to avoid a release of radioactive gases to the building atmosphere and subsequently to the environment, or the formation of explosive mixtures due to any high concentration of hydrogen that could arise inside the tanks in the auxiliary systems, the Gaseous Waste Disposal System removes such gases by continuous purging with nitrogen and processes the dissolved gases released from the reactor coolant. To fulfill the required functions, the gaseous system has the following tasks:

- To retain radioactive gases until they have largely decayed before discharging then to the exhaust air stack.
- To prevent any release of radioactive gases from the components into the building atmosphere.
- To limit the hydrogen and the oxygen concentrations in the connected components in order to prevent the formation of explosive mixtures and to reduce the presence of oxygen in the reactor coolant, which would lead to corrosion in the reactor coolant system.

- To operate with the Hydrogen Reducing System, following a loss of coolant accident.

In Angra 2, the gaseous effluents are released continuously through the vent stack, depending on the ventilation system pressure.

H.2.1.2. Liquid Waste

The Liquid Waste Processing and Storing Systems in Angra 1 and in Angra 2 are designed to collect the active and inactive liquid waste produced in the controlled area, treating them when necessary. After that, they may be discharged from the power plants in accordance to the safety rules established by nuclear and environmental authorities (CNEN, IBAMA and state regulators).

According to the activity and the chemical characteristics of the liquid waste, the following processes are provided for treatment:

- Evaporation
- Mechanical filtration (Angra 2 only)
- Ion exchange deionization using mixed-bed filters
- Chemical precipitation (Angra 2 only)
- The Liquid Waste Processing and Storing Systems are designed to collect the liquid waste arising from the controlled area to specific storage tanks, and to separate different types of liquid waste for further processing.

The systems are sufficiently automatic to minimize the human intervention, consequently reducing the occupational doses. The capacity is determined by the amount of liquid waste arising from the controlled area during normal plant operation and outages.

The liquid waste is collected separately in two groups of storage tanks, in accordance with its chemical and radiochemical composition (waste holdup tank, floor drain tank and laundry tank in Angra 1 and high activity group tanks, low activity group tanks and laundry tank belong of this group in Angra 2).

In Angra 2 the Liquid Waste Processing and Storing Systems are designed to process approximately 20,000 m^3 of liquid waste per year.

To assure the protection of the workers, of the population and of the environment against the effect of the ionizing radiation, the treated liquid waste intended for discharge is collected in monitoring tanks. Recirculation and discharge pumps are connected to the monitoring tanks to mix the liquid waste or to return it to the storage tanks.

Before discharge from the monitoring tanks, samples are taken for analysis in the laboratory. Based on the results of the analysis the radiation protection supervisor decides whether the discharge may be made. The discharge, as function of the gamma spectrometry (in Angra 1) or the activity concentration (total gamma as equivalent Cs-137) and monthly gamma spectrometry monitoring samples (in Angra 2), is performed in accordance with the technical specification for the plants, based on CNEN and IBAMA regulations and on the environmental legislation.

The released activity is monitored on-line. If the maximum allowable value of activity concentration for undiluted discharge water is exceeded an alarm is triggered and the discharge is automatically interrupted.

To optimize doses to Public Individuals, CNEN sets an authorized limit of 0,25 mSv/year for each plant.

H.2.1.3. Solid Waste

To reduce the potential of migration and dispersion of radionuclides and to minimize the dose to the environment, both plants are equipped with Solid Waste Treatment Systems. These systems process the spent resins, the concentrated liquid waste and the solid waste produced in the operation and maintenance of the plants, and confine them in special packages.

In Angra 1, the concentrates, spent resins and contaminated filters from the purification systems are immobilized in cement and conditioned in liners and special 200-liter metallic drums, within the prescribed requirements for transportation and storage. The non-compacted wastes are conditioned in special metallic boxes. In Angra 2, these wastes are immobilized in bitumen and conditioned in special 200-liter metallic drums.

In both plants, the compressible solid waste is compacted by a hydraulic press, and conditioned in special 200-liter metallic drums.

All the waste forms must fulfill the requirements for final disposal established by CNEN regulations.

To minimize the accumulation of solid radioactive waste, the entrance of materials in the controlled area is limited and controlled. Also, all the material collected in the controlled area is monitored and segregated, according to its physical and radiological features. Whenever possible, such material is decontaminated and reused or released as non-radioactive waste.

The solid radioactive waste produced in Angra 1 is stored in an on-site initial storage facility. This facility is composed of three installations, called Storage Facility 1, Storage Facility 2, with module 2A under operation and module 2B under commissioning (See Fig. E.2) and Storage Facility 3, a new storage building, that is in the final stage of construction and commissioning.

In Angra 2, all the produced waste is stored in a compartment inside the plant, called in-plant storage facility (UKA Building).

All packed radioactive waste is monitored to assure that the surface dose rates for transportation do not exceed the established values in regulation CNEN-

NE-5.01 [15] and the resulting occupational exposures are in accordance with the values established in regulation CNEN-NE-3.01 [12].

Up to 1999, the radioactive concentrate produced in the evaporator unit and the spent resins of Angra 1 were packed in 200 liter drums. As the mixture was not homogeneous, the immobilization process was considered improper, because the matrix was not in accordance with the established standard of the regulatory body.

The new Solid Waste Processing System for Angra 1, encapsulates the concentrates and spent resins in cement, inside 1 m^3 shielded liners. The new system, besides generating a more homogeneous product, reduces the occupational dose during the operational process, due to improved shielding.

Storage Facility 1 was built in 1981, with a design capacity for 2432 drums, being 1488 of low level activity and 944 of medium level activity.

As the construction of a national repository in Brazil is still under discussion, drums are being stored in the inspection and backup areas destined to damaged drums to increase the storage capacity of Storage Facility 1.

Thus, the Storage Facility 1 stores now 5239 packages. As the medium activity area is totally occupied, the medium activity drums are being stored in the low activity area. This fact contributes to increasing the dose rate at the Storage Facility 1 external walls. Another restriction is the impossibility of visual inspections in all stored drums.

These and other non-conformities were pointed out, with subsequent recommendations, in the IAEA Inspection of May 2000, through the report Safety of Processing and Storage of Radioactive Waste from the Angra 1 Nuclear Power Plant. To fulfill these recommendations a new storage facility (Storage Facility 3) was planned and is now in its final stages of construction and commissioning.

In 1992, Storage Facility 2A was built with the capacity to store 621 liners. The remote operation capability was improved to minimize occupational doses. In December 2007, this Storage Facility held 728 packages.

After the operation authorization for Storage Facility 3, the packages will be redistributed among the three buildings, in accordance to a rearrangement program to be authorized by CNEN.

The inventory of waste stored at Angra site is presented on Tables H.1 and H.2.

Table H.1. Waste Stored at Angra Site – Angra 1

Waste	Packages	Location
Concentrate	2855	Storage Facility 1/ Storage Facility 2
Primary Resins	694	Storage Facility 1/ Storage Facility 2
Filters	449	Storage Facility 1
Non- compressible	772	Storage Facility 1/ Storage Facility 2
*Compressible	511	Storage Facility 1
Secondary Resins	357	Storage Facility 1
TOTAL	5841	*(Includes 203 Inactive drums)*

* In 2006, the NPP supercompacted 1938 waste drums from Angra-1.The pellets (crashed drums) were placed inside special metallic boxes (B-25) with 2500 liters of capacity.

Table H.2. Waste Stored at Angra Site – Angra 2

Waste	Quantity (drums)	Location
Concentrate	142	In Plant Storage
Filters	2	In Plant Storage
*Compressible	58	In Plant Storage
TOTAL	202	*(Total Capacity1644)*

* In 2006, the NPP supercompacted 89 waste drums from Angra-2.The pellets (crashed drums) were placed inside special metallic boxes (B-25) with 2500 liters of capacity.

H.2.2. INB

The INB units store low activity nuclear material. The waste produced is minimized due to the high value in the nuclear content of the material processed. The recovery of uranium in all phases of the process is a constant objective not only due to the economic value, but also to avoid the presence of hazardous effluents. The material inventory is presented below, although not all this material is “radioactive waste” in the sense of the Convention.

H.2.2.1. Fuel Element Factory (FCN)

The waste is packed in 200-liter metal drums with metal cover and rubber seal. Only 102 drums have been produced so far. They contain contaminated material (gloves, shoes, tools, filters) containing UO_2 (with up to 4.0% enrichment) in the powder form.

The drums are stored inside the production facility. A storage facility is under construction within FCN protected area. After it is finished and licensed by CNEN, all the material stored in the production plant will be transferred to this storage area. All the waste is considered low-level solid radioactive waste (SBN – Table 2, CNEN- NE-6.05 [6])

H.2.2.2. Interlagos Plant (USIN) and Botuxim Storage Facility

In 1992, the Usina Santo Amaro (Santo Amaro Mill - USAM) was deactivated. USAM used to process monazite sand for the separation of rare earth elements. Works were developed in this area to subsidize the decision-making process aiming to the remediation of the area, with the objective of releasing the areas for unrestricted use. Mathematical models were applied for the dose calculation, considering different scenarios of area occupation. The dose criterion used was of 1 mSv/year in the critical group for the more conservative occupation scenario, in agreement with the possibilities of occupation of the area, located in an urban environment. The need to store the waste generated by the decommissioning process led to the choice of the USIN and Botuxim sites as interim storage facilities.

The area of USIN has about 60 000 m^2. The site, located in an urban industrial area and unused at the time, had 3 storage facilities. Storage Facilities B and C have been disassembled. Storage Facility A, with 2060 m^2, has been renovated to receive the waste originated from the USAM decommissioning. This process initiated in 1993.

Although belonging to the same company as USAM, the USIN site was not under regulatory control by CNEN, because the process of rare earth separation that used to take place in USIN did not involve significant amounts of radioactive elements, since they were eliminated in previous stages of the process at USAM. At a given moment of the operational period of USIN, however, some leakage of the material stored led to the contamination of the area surrounding Storage Facility A and also to radioactive contamination of groundwater. From 1998 to 2002, the area was partially decontaminated. This operation generated 170 plastic drums with radioactive material. The other 1,717 plastic drums stored in USIN were generated during decontamination of the USAM facilities.

INB intends to complete the site remediation after CNEN's approval of the Decontamination Plan, as described in section F.6.3.3.

Besides this occurrence, the USIN site has received large amounts of the light fraction of monazite sand, as landfill to the swampy areas around the storage facilities. As a result of these landfills, activity concentrations up to 33000 Bq of ^{228}Ra per kg of soil could be measured. The decision to clean-up the area in order to release it for unrestricted use has already been taken by CNEN, and the operator has decided to keep that area under regulatory control and to use it as a temporary waste repository for the decommissioning waste coming from USAM.

Besides the storage of waste, Storage Facility A is also used to store radioactive material (Table H.3) that can still be used as a source for nuclear material and other applications, such as the byproducts of the USAM process, mainly sodium phosphate and a material called Cake II (Torta II), composed basically of thorium hydroxide concentrate. The inventory of Cake II awaits development of improved technology to allow its economical use.

Table H.3. Types and amounts of material stored in Storage Facility A

Packages (100 liter plastic drums)	
Cake II	3283
Mesothorium	760
Non-Contaminated Trisodium Phosphate	760
Contaminated Trisodium Phospate	69
Radioactive Waste (clothes, equipment, wood, soil)	1887
Total	**6759**
Maritime Containers (30 m^3 capacity)	
Contaminated press-filter canvas	3.5
Contaminated wood	1.5
Contaminated metal parts	7
Other materials	3
Total	**15**
Metal Boxes (1m^3 capacity)	**6**

The area of the Botuxim storage facility has about 284,000 m^2, where there are 7 silos with ca. 3,500 ton of Cake II stored (Table H.4)

Table H.4. Amounts of Cake II stored in Botuxim.

Concrete silo number	**Mass (ton)**
Silo 1	321.48
Silo 2	376.93
Silo 3	374.97
Silo 4	504.32
Silo 5	479.33
Silo 6	778.85
Silo 7	664.19
Total	**3500.07**

H.2.2.3. Poços de Caldas Industrial Complex (CIPC)

The first uranium mine of Brazil has finished operation and is under preparation for decommissioning. As the licensing process took place before the present radiological protection criteria were established in Brazil, there was no previous planning for the decommissioning phase. The main areas that will need attention include the open pit mining area, the waste rock piles and the tailings dam. Up to this moment, the whole area is still under control by the operator. Radiological control is maintained at effluent discharge points, including at the waste dam and at the treatment units for the water drained from the mining area and from the waste rock piles. At CIPC, the following materials and/or by-products are considered tailings, radioactive waste, or raw material:

1 – Mesothorium, stored in different conditions, namely:

- a – Disposed of in the waste dam during the 1980's: there are around 13,000 fifty-liter drums corresponding to 1,300 tons of this product.
- b – Stored in five (5) silos excavated in a clay bank at the slope of the CIPC waste dam: there are 2,700 fifty-liter drums, corresponding to 280 tons of the material. The silos are lined and covered with a three-meter thick layer of clay and soil. This operation was performed in 1987.
- c – Placed in a trench at the slope of the waste dam, in 1984: there are 5,750 fifty-liter drums, corresponding to a total of 600 tons of mesothorium. This trench is covered with a two-meter thick layer of clay and soil.

2 – Cake II

- a – Approximately 11,000 tons of Cake II (wet base) are currently stored in sheds, packed in 200-liter drums (19,400 units) and 100-litre plastic drums (16,250 units). Other 1,734 tons of bulk Cake II, which were placed in four concrete silos, are now being treated.
- b – Additionally, there are 1,600 200-liter drums of Goianite Cake II resulting from experiments for the extraction of rare earths from Goianite mineral, which presents a low thorium content; as well as 3,560 200-liters drums of Cake II, corresponding to 534 tons, stored in silos close to the CIPC waste dam.
- c – Finally, there are 824 200-liter drums (124 tons) of Inaremo, named after the process used by Nuclemon for extracting rare earths from Goianite. Inaremo is characterized by a very low thorium content, being a neutralized waste.

3 – Thorium

- a – Approximately 80 tons of ThO_2, resulting from Cake II processing in two periods: In 1990, 32.9 tons were disposed of in a pond; in 1995/1996, 46.58 tons were stored in 148 concrete containers.

H.2.2.4 Lagoa Real Complex – Uranium Concentrate Unit (URA)

The Uranium Concentrate Unit (URA) is located at the uraniferous province of Lagoa Real in the Center-South region of Bahia state. The ore bodies have average U_3O_8 concentrations of about 0.3%. Mining activities are developed at an open pit cast and expected to continue for over 16 years. Uranium extraction is made by the Heap Leach method. The efficiency of solubilization of this method is estimated to be about 70%. The exhausted ore is disposed of in piles along with the waste rocks from the mining activities. The leachate is captured in holding tanks that are lined with geo-synthetic membranes (HDPE). The liquor is then pumped to the milling unit where uranium is isolated by means of organic solvent extraction and then precipitated as ammonium di-uranate.

The licensing process was focused only on the aerosol and gamma exposure pathways, because the facility is not supposed to release any liquid effluent to the environment, since all the processed water has to be pumped back to the process. Thus, no major impacts are expected in the local water river that is not perennial. On the other hand, subsequent facts showed that impacts into the aquifers need attention since these water bodies are also the source of water to local communities. Besides the influence of mining activities on groundwater, other pollutant sources have to be assessed like the waste-rock/leached ore piles as well as the leaching tanks. In order to assess any impact into groundwater, a monitoring program is carried out by the mining operator under regulatory surveillance. Groundwater samples are collected monthly from monitoring wells placed close to the area of direct influence of the facility and close to the population groups living at the site surroundings. Runoff samples are also collected close to the main sources to determine the concentrations of dissolved radionuclides, assessing the drainage contribution to groundwater pollution.

Data from the environmental monitoring program carried out by the mining operator, under regulatory surveillance, are collected from around 30 sampling sites and comprise the following media: groundwater; rainwater; aerosol; radon; gamma exposure (TLD); sediments; soils; pasture; corn; bean; milk; manioc and manioc flour.

The objectives of the monitoring control are: 1) to keep under control the radionuclide fluxes from mining and milling activities to atmosphere and groundwater compartments, according to the release limits prescribed in the nuclear licensing, 2) to assess the potential impacts of the pollutant sources by means of mathematical simulation and 3) to establish the overall environmental management strategy for the uranium production.

H.2.3. Navy Facilities

As mentioned above, the amounts of waste generated by the naval program are very small. The waste generated in the controlled areas is stored in identified containers. The containers are transferred to the Radioactive Waste Storage Facility within CEA. Handling, storage and accounting are under responsibility of the Radiation Protection Division. Liquid waste is treated in a thermo-solar evaporator and the sludge is later classified as solid waste.

The storage facility is a metallic structure, with asbestos tile roof and the capacity for 256 two hundred-liter drums. There is a drainage system to avoid flooding. The ventilation is natural, and equipments for fire protection and physical protection are available. The current inventory is presented on table H.1.

Table H.5. Waste Inventory at CEA

Type of Waste	Mass (kg)	Number of Drums
Plastic	774.5	17
Paper	3,575.9	34
Evaporator Sludge	2,543.2	20
Other	1,519.5	38
TOTAL	**8,413.1**	**109**

H.2.4. CNEN Institutes

H.2.4.1. IPEN

IPEN has been storing the radioactive waste generated in its own installations since the beginning of operations in 1956.

The Radioactive Waste Laboratory (LRR) is responsible for receiving, treating and temporarily storing radioactive waste generated at IPEN, as well as those generated at many other radioactive facilities all over the country. The main features of the laboratory include units for: waste reception and segregation; decontamination; liquid waste immobilization and conditioning; in-drum compaction of compressible solids; spent sealed source and lightning rod disassembly; primary and final waste characterization; storage of untreated and treated wastes. The existing facility, an Integrated Plant for Treatment and Storage of Radioactive Waste, has a total built area of 1450 m^2 and comprises the following units:

- *Changing rooms and radiation protection control*: To allow controlled access to the working area.
- *Reception and segregation unit:* To receive, classify and distribute the waste to proper treatment. If necessary, waste segregation is carried out.
- *Liquid waste storage and treatment/conditioning unit*: Equipped with suitable containers or devices for operational storage and pre-conditioning of liquids, either for immobilization or for release to the retention tanks for further discharge to the sewage system.

- *Cementation unit:* Cementation was the process chosen for conditioning and encapsulating some kinds of wastes such as liquids, wet solids, including ion-exchange resins and activated carbon generated in the reactor operation, sludge, biological and some non-compressible waste.
- *Compaction unit:* Equipped with a 10-ton hydraulic press. Compressible solids are collected in 60 liter transparent polyethylene bags and pressed into 200 liter metallic drums. The volume reduction factor is about 4-5.
- *Lightning rod dismantling unit:* Provided with a three-cell glove-box, where ^{241}Am sources are removed from the devices and packaged in metallic containers (see Figure H.1).
- *Disused source encapsulation unit*: Designed to handle source activities up to about 4 TBq ^{60}Co equivalent. Sources will be withdrawn from original shielding or device and encapsulated in a retrievable package for interim storage (see Figure H.2).
- *Analytical and radiochemical laboratories:* For characterization of primary wastes and waste forms.
- *Storage facility.* For interim storage of drums containing treated waste (see Figure H.3).

The wastes managed at IPEN are characterized by a wide diversity in nature, forms, radionuclide contents and activities, so that, for some types of waste, specific methods of treatment and conditioning had to be developed.

In general, solid and liquids wastes are treated and packaged in 200 liter steel drums, as follows:

- Compressible solids: segregation at the generator installation, compaction and package.
- Non-compressible solids: dismantling and encapsulation in concrete.
- Wet solids: chemical conditioning and immobilization in cement.
- Liquids: Wastes of short half-lives are discharged to the sewage system as liquid effluents after temporary storage for radioactive decay; releases meet the proper radiation protection standards. Wastes of longer half-life are immobilized in cement matrix.

Lightning rods with ^{241}Am sources were manufactured in Brazil until 1989. In that year, CNEN issued a resolution lifting the authorization for manufacturing of such devices. Since then, radioactive lightning rods are being replaced by regular lightning rods. The radioactive lightning rods removed are delivered to IPEN or to other installations of CNEN. The estimated amount of lightning rods to be collected is about 80,000 pieces. From this amount, IPEN has already collected about 16,000 and dismantled 13,000 units. Smoke detectors are also dismantled and about 23,500 units have been treated until now.

Figure H.1. Lightning rod dismantling glove-box

Disused sealed sources represent for IPEN and CNEN by far the largest waste problem from non-power applications, specially due to the long lived radionuclides such as ^{226}Ra and ^{241}Am. Sources with low activity or low exposure rate received until 1993 are already conditioned and immobilized in cement as well as the ^{226}Ra needles collected up to that date, meaning in the last case about 1000 needles or 200 GBq. Currently, this process has been replaced by packing the sources in a retrievable package. The spent sealed sources dismantling and conditioning unit is currently under construction. In total, LRR has received about 10,000 sealed sources and treated 40% of them.

The facilities for waste management are located inside IPEN, as part of its several nuclear and radioactive installations, properly certified by CNEN.

Figure H.2. Hot cell designed to handle sources (under construction)

Figure H.3. Interim Storage of Treated Waste at IPEN

H.2.4.2. CDTN

CDTN's waste treatment and storage facilities and its support laboratories are shown on Table H.6. Figures H.4 and H.5 show some CDTN facilities used to treat and to store the waste.

Besides the radioactive waste generated at its own laboratories, CDTN has received disused sealed sources from other users, like industries, hospitals and universities. These sources include radioactive lightning rods, smoke detectors, nuclear gauges and teletherapy units, which are stored at CDTN's intermediate storage facility. The main nuclides are ^{60}Co, ^{137}Cs, ^{226}Ra and ^{241}Am.

The strategy devised and implemented for the management of radioactive waste at CDTN is based on the standard CNEN-NE-6.05 and takes into account the available infrastructure. The main aspects of the management program are:

- registry of the waste and disused sealed sources inventory using an electronic database;
- waste generation minimization by an adequate segregation and characterization;
- volume reduction by chemical treatment for the aqueous liquid waste and compaction and cutting for solid waste;
- cementation of sludge arising from the chemical treatment and immobilization of the non compactable solid waste in cement/bentonite matrix;
- quality control of the final product in order to guarantee safety during storage and to minimize doses to workers and individuals of the public.

Table H.6. CDTN Waste Treatment Facilities

Facilities	Characteristics
Chemical treatment	200 L batch, main components: tanks, filters, pumps, control panel and sample system
Cementation, out-drum mixture	200 L batch, main components: tanks, mixer, pump, automatic weighing system and control panel
Compaction	16 t press
Cutting/shredding	Cutting mill, output 80-130 kg/h
Lightning rod dismantling	Glove box equipped with unbolting system, electrical scissors and other tools
Nuclear gauge dismantling	Hot cell with shielded windows, manipulators, pneumatic system, and control panel
Package testing	Facilities for Type A and Type B package testing
Heater system	Tank with heater device for about 600 L solution
Supporting laboratories	**Main equipment sets**
Chemical treatment	Lab hood with filtration system, pH meters, analytical scale, pumps, jar-test equipment, magnetic stirrers
Cementation	Lab hood, glove box, lab oven and diverse equipment sets for physical-chemical and mechanical testing
Thermodifferential analysis	Room with the suitable equipment to carry out the analysis.
Storage facility	**Description**
Intermediate storage building for treated wastes and disused sources	450 m^2 surface hall with control system for effluents, fence, natural ventilation, appropriate lighting and alarm system
Liquid waste storage	90 m^2 surface hall with control system for effluents, shelves, appropriate lighting and ventilation.
Solid waste store	4 m^2 room.

Segregation is carried out taking into account the physical, chemical and radiological characteristics of the waste. The liquid waste is segregated into aqueous or organic and the solid waste into compactable and non-compactable. Besides, waste containing short-lived radionuclides is segregated from the ones with long-lived radionuclides, the former being stored for decay and then released from radiological control. Each waste package is identified according to the origin and type of waste it contains. Figures H4 to H7 show some CDTN facilities to treat and store the waste.

Figure H4. a) Chemical Treatment, (b) Cementation and (c) Compaction.

After being monitored, the segregated waste is transferred to the treatment facilities. All relevant data, like origin, composition, volume or weight, chemical contaminants are registered in a specific form – GUIARR.

Figure H.5. Intermediate Storage Facility Building

Regarding sealed source, lightning rod and smoke detector management, the guidelines are:

- To provide suitable conditioning of brachitherapy and teletherapy sources. The later ones are stored in their original shields;
- To dismantle the lightning rods, smoke detectors, and nuclear gauges and to remove the source in order to reduce the stored waste volume. The sources from the gauges are assessed for possible further use.

A glove box for ^{241}Am lightning rods and smoke detectors dismantling is already operating at CDTN (Fig. H.6). A hot cell for dismantling nuclear gauges is in operation at Laboratory for Treatment of Sources (Fig. H.7). The removed sources are checked for leaks and their activity is determined for possible reuse.

Figure H6. Lightning rod dismantling Facility

Figure H7. Hot Cell for Dismantling Nuclear gauges

Regarding ^{226}Ra sources, they are conditioned in such a way that retrievability is maintained. The sources are inserted in leak-proof stainless steel capsules, which are placed in lead shields; once loaded, the shields are put inside the cavity of an internally shielded 200-liter drum.

The waste containing packages are identified, monitored and stored at CDTN's intermediate storage facility. The relevant data about the prepared packages are stored in a specific form – GUIART. The information of both forms – GUIARR and GUIART – is used as input to the CDTN's waste electronic database. With this robust database, complex searches can be performed and all information about the stored waste inventory can be easily retrieved.

Another database – named SISFONTE – contains data about the sealed sources from other users received and stored at CDTN. Among other features, this database performs an on-line update of the activity stored.

H.2.4.3 IEN

IEN is storing the radioactive waste generated in its own installations and at other radioactivity users, such as hospitals, industries and research centers. The existing facility is now being adjusted for more elaborated treatment processes. There are only two basic units, the compression and the storage units. The compression unit has a 2-ton hydraulic press.

All the strategy for the management of radioactive waste at IEN is based on the standard CNEN-NE-6.05 and takes into account the available infrastructure.

There is only a simple waste characterization, TRING, whenever possible, reducing its volume, so it can be packaged in a 200-liter steel drum and storing at the proper unit. Liquid waste is simply identified and stored in a different area expecting a treatment unit to go into operation.

H.2.5. Research Institutions

The Program for Waste Management in Research Institutions (Programa de Gerenciamento de Rejeitos em instalações de Pesquisa - PROGER) started in 1996 with the objective of controlling the radioactive waste management in research institutions throughout Brazil, and to establish common procedures and standards.

Through partnership, information and training of personnel from these institutions, the main lines of action of PROGER are to establish common procedures and best practices, which improve the workers' safety, protect the environment and prevent radiological hazards. In 1999 PROGER was implemented at the University of Brasilia and, as a result, adequate facilities were constructed and proper working procedures were established to manage and control the waste generated in research activities. The model has also been extended to other research institutions. CNEN also routinely assesses Radiological Protection Plans and Safety Assessment Reports from research institutions, in support of the issuance of the Authorization for Operation of these institutions.

H.2.6. Waste Repository at Abadia de Goiás

For the repository of the waste from Goiânia accident, also the 0,3 mSv/y dose constraint defined by the Regulatory Body based on regulation CNEN-NE-3.01[12] was used during the design of the installation. As the installation contains two buildings, each one related to different activity concentration of ^{137}Cs in the waste, as already described in this report. The design basis for the first repository (Waste Group 1) a dose limit of 0,05 mSv/y has been applied to critical members of the public while a level 0,25 mSv/y was used to the main repository, in agreement with the Technical Instruction CNEN IT-01/91[16].

H.3. Article 13. SITING OF PROPOSED FACILITIES

H.3.1. Nuclear Power Plants

The On-Site Storage facility was built at the north side of the Angra site. This area is part of the southeastern part of the Brazilian Platform. Studies made in 1982 had demonstrated that there is no sign of failure occurrence or another tectonic activity in the region of Itaorna beach, since the inferior cretacic period.

Given the geologic formation of the region, predominantly crystalline rock, there is little indication of underground waters. Due to the geology and the morphology, composed by granites and residuals soils, the region has some damage associated to the high pluviometric rate.

In order to improve the safety of the upstream slopes of the storage facilities areas, a contention gabion walls and soil nails with gunite concrete were performed, as well as superficial draining system was implemented.

Specifically, the hillside where the storage facility is located was technically certified for stability and safety conditions.

The Storage Facility 1 of the storage facility was built in 1981. The Storage Facility 2 is composed by the old Storage Facility 2A constructed in 1992 and a new Storage Facility 2B now under commissioning.

To erect the Storage Facility 2B, IBAMA, the national environmental agency, required an Environmental Impact Study, which was submitted and accepted. The Environmental Operational License was issued in 2007.

To improve the waste management facilities, a Monitoring Building is being planned. This building will be constructed between Storage Facilities 1 and 2 and will hold all the equipments and operations related to the new system of waste packages measurement (Gamma Segmented Counter System) for the waste isotopic inventory determination. Also, a third storage facility (Storage Facility 3) is being constructed (It is in the final stage of construction and commissioning).

In addition, the storage facility for the old steam generators, which will receive the replaced steam generators from Angra 1 is being constructed close to the site dock and within the site boundary. The replacement is planned for 2009.

H.3.2. Intermediate and Low Level Waste Repository (under planning)

The site selection process for waste repositories requires a series of sequential activities: the identification of regions of interest, of preliminary areas, of potential areas, and of candidate-sites. The selection should take into account 4 factors: ecological, geological, physiographic and socio-economical.

Some regions of interest for a low and intermediate radiation level waste repository were identified in Brazil. Potential areas were identified in two of these regions. The process was temporarily halted, pending the approval of a specific law on nuclear waste. With the approval of Law n. 10.308, in 2001, establishing the responsibilities, funding and licensing process for waste repositories, the work can now proceed.

For the low level waste resulting from the operation of Angra-1, 2 and future Angra 3 nuclear power plants and from the use of radionuclides in medicine, industry and research, a technical discussion about the necessity of construction of a single national near surface vault repository (for all this LLW) or two different repositories are being analysed (one near surface vault for the LLW resulting from the nuclear power plants operations and a second one type borehole or vault near surface repository for the medical, industrial, etc LLW). The location and design have not yet been selected.

It is worth mentioning that political and psycho social aspects related to the subject of radioactive waste disposal (“Not in my backyard syndrome”) contribute enormously to the difficulties faced by the Brazilian Government in the establishment of a national waste management policy.

H.4. Article 14. DESIGN AND CONSTRUCTION OF FACILITIES

Design criteria and conception of the radioactive waste facilities are based on a comprehensive survey done on the volume and physic-chemical and radiological characteristics of the waste to be received and managed in the life of the facility, and an estimation of the future demand.

H.4.1. Nuclear Power Plants

Angra waste is mixed with cement or bitumen before transfer to the On-site Storage Facility. This operation is performed under requirements for protection of the workers, the public and the environment, according to approved plant procedures.

All packed radioactive waste are monitored to assure that the surface dose rate, for transportation, does not exceed the established values in regulation CNEN-NE-5.0 [15] and the resultant occupational exposure and contamination are in accordance with the values established in regulations CNEN-NE-3.01 [12] and CNEN-NE- 6.05 [6].

The storage of the waste is done according to a layout established previously, to reduce the dose rate in external areas of the building.

The possibility of the environmental contamination in terms of the storage is remote, since all the waste is in the solid form and is conditioned in certified containers. For additional precaution the units of storage are equipped with ventilation systems to assure negative pressures (including high efficiency filtering system) and internal drains directed to sumps subjected to inspections and release control.

The inventory control of the stored waste is made with the aid of validated managing software. The data bank includes information on the physical, chemical, radiological and mechanical features of the packed waste.

Periodic visual inspections are performed to verify possible alterations in the stored packed waste. Moreover, monthly inspections are performed on the general conditions of the building and the installations.

For Storage Facility 2 and Storage Facility 3, the following systems are installed:

- Remote automatic visual inspection equipment;
- On-line external radiation monitoring system;
- Ventilation system to assure negative pressures, including high efficiency filtering system;
- Internal and external drainage systems.

The storage facility for the old steam generators, which is under construction, will also be equipped with on-line radiation monitoring system, ventilation system and drainage systems.

H.4.2. INB

At INB all waste after monitoring go through a selection step in order to be separated in different drums according to their characteristics, solids that can or can not be compacted and liquids. After the selection the waste is packed up in identified drums and they are stored within the facility.

All drum radioactive waste are monitored to assure that the surface dose rate, for transportation, does not exceed the established values in regulation CNEN-NE-5.0 [15] and the resultant occupational exposure and contamination are in accordance with the values established in regulations CNEN-NE-3.01 [12] and CNEN-NE- 6.05 [6].

H.5. Article 15. ASSESSMENT OF SAFETY OF FACILITIES

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil [3].

H.5.1. Nuclear Power Plants

For the Angra 1 and Angra 2 plants, both a Preliminary Safety Analysis Report (PSAR) and a Final safety Analysis Report (FSAR) were prepared. The FSARs followed the requirements of US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs.

Chapter 11 of the FSAR deals with radioactive waste management issue, including waste generation, treatment, in plant storage and the radiation protection aspects.

These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 800).

H.5.1.1. Onsite Storage Facility

Before the startup operation of Angra 1 the documentation for the installation of the Storage Facility 1 of the On-Site Storage Facility, establishing the design, security and radiological protection plans, was submitted and approved by CNEN. The Storage Facility 1 was built in 1981. Later, the Storage Facility 2A module was also approved by CNEN built and built in 1992.

To erect the Storage Facility 2B, besides the CNEN license, IBAMA, the National Environmental Agency, required an Environmental Impact Study, which was submitted by ELETRONUCLEAR and evaluated by IBAMA. The Operational Licence for Storage Facility 2 was issued in December 2007.

The safety and environmental licensing process for the construction of the Monitoring Building and the Storage Facility 3 is under way. This process include as minimum:

- A safety evaluation submitted to the Nuclear Regulatory Body
- An environmental impact study
- An environmental impact report
- A set of Public Hearings for discussions with the Public and local and state Organized Society Members.

ELETRONUCLEAR expects the IBAMA Operational License for the Storage Facility 3 in 2008.

H.5.2. Other Facilities

H.5.2.1. Fuel Cycle Facilities

The management of radioactive waste is considered a part of the Safety Analysis Report of all fuel cycle facilities. The information submitted is evaluated by CNEN during the licensing process.

H.5.2.2. Radioactive Waste Repositories

As mentioned above, the environmental licensing process of any waste repository in Brazil is responsibility of the Brazilian Environmental Agency (IBAMA). When radioactive waste is involved, CNEN acts in accordance with IBAMA, assisting this institution in nuclear matters.

In the implementation phase of the National Repository for Radioactive Waste, the Waste Management Division (DIREJ) of CNEN will be called upon to perform the evaluation of the Safety Analysis Report of the installation.

Two projects were implemented by CNEN, in the field of safety assessment of final disposal facilities. The first project had the assistance of the IAEA. The second is being conducted within the Federal University of Rio de Janeiro.

The project with IAEA aims at improving the national capability for assessing the safety of waste disposal facilities, and for this purpose, a multidisciplinary expert group was created and was trained in safety assessment methods, including the use of the relevant computer codes as well as laboratory and field measurements techniques.

In 2002 the International Atomic Energy Agency (IAEA) launched a co-ordinated research project in the field of safety assessment for near surface radioactive waste disposal facilities (ASAM – Application of Safety Assessment Methodologies for Near Surface Waste Disposal Facilities) with the participation of Brazilian experts. The primary objectives of the project were: to investigate the application of safety assessment methodologies used for post-closure safety assessment, in particular the methodology developed under the IAEA's ASAM project, to a range of near surface disposal facilities; and to develop practical approaches to assist regulators, operators and other specialists in their review of such safety assessment.

In 2006, the Repository Safety Assessment Group, created in 2004 within the CNEN, was promoted to an official "Section" under the Radioactive Waste Division. The Repository Safety Assessment Section has since then reviewed a number of safety assessment reports originated from nuclear and radioactive facilities across the country. This Section has also developed a publication and training material that conveyed the principles of safety assessment to regulated agents and research institutions, thus disseminating the safety assessment culture among the operators of nuclear and radioactive facilities, in order to improve the technical quality of the safety assessment reports.

H.5.2.3. Safety Assessment of Goiânia Repositories

CNEN conducted two safety assessments of the Goiânia repositories, one in the year 1995 and another one in the year 2002, as described below.

The First Safety Assessment (1995)

A robust model or screening model was developed considering that one of the main scenarios for the prediction of the impact of a near surface repository is related with the water pathway. The following scenarios related with the water pathway were considered:

(a) water ingestion;

(b) ingestion of contaminated vegetables due to water irrigation;

(c) ingestion of contaminated animal;

(d) inhalation of contaminated soil due to irrigation;

(e) external irradiation due to contaminated soil.

The dose factor was calculated considering a steady concentration of 1000 Bq/m^3 in the water well, the scenarios above, resulting in:

- Annual Effective Dose Equivalent = 4.19×10^{-5} Sv;
- Effective Dose Equivalent Commitment = 2.93×10^{-3} Sv.

Three pathways were also considered for intrusion. The following hypotheses were considered for the geosphere:

- The establishment of an Institutional Control Period;
- The continuous linear degradation of the cap, after construction of the repository allowing a higher infiltration rate each year (after 30 years the cap would completely fail);
- The infiltration rate at the surface of the cap would be only a function of the water balance between water fall and evapotranspiration;
- The unsaturated zone thickness bellow the repository bottom at the beginning of the analysis was neglected;
- The concentration inside the repository in the water phase, each year, was calculated taking into consideration the adsorption coefficient of the waste (k_d) and the available quantity of water, which is a function of the water balance and the permeability of the cap.

Two cases were studied:

- Model 1: Neglecting the permeability of the top of the vault due to the concrete thickness and applying Darcy law on the bottom of the repository to calculate the flow to the water table;
- Model 2: Neglecting the permeability of the top and bottom of the vault and considering that all the water infiltrated each year leaches the waste based on the adsorption coefficient and flows to the aquifer.

A plume model was used in the aquifer.

Re-Assessment of the Goiânia Repositories (2002)

The source term considered on this model was conservative: an annual leaching fraction of the waste considers that all the water that enters in the repository leaves the disposal and enters the geosphere (neglects cap and the engineered barriers).

The unsaturated zone thickness below the landfill was considered only at the end of the analysis, based on a transit time.

The model adopted for the saturated zone, to be coupled with the source term, takes into consideration the well-known one dimensional transport equation including dispersion, retention and decay of the contaminant in the aquifer.

The same data for the geosphere and biosphere used in the 1995 safety assessment was used in the 2002 assessment.

For modelling the biosphere, two kinds of scenarios were considered:

(a) Intrusion on the site resulting in: (i) direct inhalation of particulate due to contaminated soil, (ii) deposition on vegetables and ingestion by man; (iii) deposition on vegetables, ingestion by animals, meat consumption by man; (iv) deposition of grass, ingestion by the cow, transfer to milk and ingestion by man; (v) ingestion of contaminated soil due to resuspension and (vi) external dose due to the radioactive hazardous materials.

(b) A residential scenario, that is, the existence of a house near the site (at the border) using water from a well, resulting in: (i) Irrigation, re-suspension and inhalation; (ii) direct consumption of the water well – ingestion; (iii) irrigation of vegetables and consumption by man; (iv) irrigation of vegetables, consumption by animals, consumption of contaminated meat by man; (v) surface water contact, transfer to fish and to man; (vi) irrigation of vegetables, consumption by animals, transfer to milk and ingestion by man; (vii) irrigation and accidental ingestion of contaminated soil; (viii) irrigation and external exposure in the case of radioactive

It should be pointed out that an agriculture scenario can only occur when the engineering barrier is completely destroyed (the concrete is transformed in sand and mixed with the waste). Many countries establish a period between 300 and 500 years for the complete transformation of the concrete barriers, although cracks and modification on its permeability can occurred before this period of time. The results showed that, after approximately 280 years, the doses related to a probable agriculture scenario would be lower than the established limit for intrusion of 1 mSv/y. It should also be pointed out that on the post drilling scenario analysis a limit of 1 mSv/y is used, resulting in the necessity of establishing an institutional control period of 50 years, confirming the results obtained in 1995.

Based on a discovery scenario, a limit dose for intruder of 5 mSv is applied due to a single acute dose and an institutional control period of 40 years would be necessary (in the case of no waste dilution). Under the assumption of 0.25 dilution factor no institutional control period is necessary in this case.

The safety re-assessment of the Goiânia repositories confirmed the results obtained in 1995, as follows:

- The water pathways related to a possible residential scenario near the site is negligible when considered the retention factor (transit time of ^{137}Cs) of the unsaturated zone (natural barrier). The maximum concentration below the repository, at any time, would be under the maximum allowed value of

25000 Bq/m^3 – (6,8 x10^{-7} Ci/m^3), that could result in a dose for an individual of the critical group of 0.25 mSv/y;

- The consumption habits of the individual of the critical group was over estimated when compared to the real consumption habits of the population nearby the site today;
- Three intrusion scenarios were considered and the most critical one would be the agriculture scenario. If this is assumed to happen only after the complete degradation of concrete (300 to 500 years), it would be of no importance, since after 280 years the doses would be lower than the allowed limit of 1 mSv/y. If in the case of Goiânia the concrete transforms into sand before the usual time of 300 to 500 years, an institutional control period of approximately 280 years would be necessary;
- If one neglects this possibility (degradation of concrete in time lower than 300 years) the most important scenario would be the post drilling scenario and an institutional control period of 50 years would be necessary;
- It should also be pointed out that the results of seven years of environment monitoring plan (EMP) at the site proved that it is very unlikely to find in the future concentrations of ^{137}Cs in the aquifer which will be dangerous to the population living near the site (Concentrations lower than the detection limit of 200 Bq/m3 - 5.4x10^{-9} Ci/m^3 were obtained until today).

Finally, it is important that, before the end of the institutional control period of 50 years, a new evaluation of the safety of the Goiânia repositories be conducted by CNEN, based not only on the probably improved local data such as: (i) geosphere information (ii) demographic grown information; (iii) variation of possible consumption habits by the population, but also based on the improving capability and knowledge of CNEN.

H.5.3. INB

The solid and liquid waste generated at INB-Resende is placed in proper drums, which are duly identified and are temporarily stored in proper rooms in the site. There is a low activity initial waste storage facility under CNEN licensing process, according to regulation CNEN NE 6.05, where all solid and low activity liquid waste generated by the plant will be stored. This storage is located within the old material storeroom building of the Conversion and Pellets Factories. It was designed in two modules. The Module I has been already built with an area of 325 m^2 , subdivided in two areas: area 1 and area 2. The access to both areas is done through different gates.

In the area 1, drums of solid wastes will be stored in proper positions with maximum design capacity of 444 drums. In the area 2, drums of liquid waste will be stored with maximum design capacity is 120 drums.

The second Module II would have an available area of approximately 238m^2, suitable for future modular expansion. The design capacity will be 336 and 96 drum of solid and liquid waste, respectively.

The access to Module I will be done through an access control point that shall be always used when the drum storage process is being carried out. Near storage area there is a cloakroom and a shower room, which are to be used in event of accidents with contamination of the skin and body of occupationally exposed individual.

The referred storage civil building project, as well as its ventilation/exhausting system, is currently under CNEN review for formal approval.

H.6. Article 16. OPERATION OF FACILITIES

The responsible for the safety of the radioactive waste facilities is the operator. Information on the conduct of operation is submitted to CNEN in the corresponding Safety Analysis Report, and is reviewed during the licensing process. The operation is subject to CNEN regulatory inspection program, and periodical reports have to be submitted according to regulation CNEN – NE -1.14 [5] and specific licensing conditions.

H.7. Article 17. INSTITUTIONAL CONTROL AFTER CLOSURE

H.7.1. Repository at Abadia de Goiás

In 1988, the IRD/CNEN, through its Department of Environmental Radiological Protection began the implementation of the Environmental Monitoring Program around the interim storage facility for the radioactive waste from the decontamination of the areas affected by the radiological accident of Goiânia.

Due to the need of characterizing the area that would site the repository, the results obtained in that Program for the period between 1988 and 1992 were used as a pre-operational Program for the repositories.

IRD/CNEN continued with the environmental monitoring program until 1996, when the responsibility for the program was transferred to the Regional Center of Nuclear Sciences of the West-Center (CRCN-CO) of the District of Goiânia.

The program includes a TLD net around the site, and analyses of samples of surface and groundwater, soil, sediments, pasture and milk to determine the quantity of ^{137}Cs.

IRD/CNEN implemented a monitoring control program in 1998, including auditing records related to site monitoring and the duplicate sampling program, that includes all environmental media included in the monitoring program performed by CRCN-CO. Results of this program control program atest the good performance of the laboratory in charge of the monitoring program and the integrity of the repository.

Although not required by regulation, the laboratory of CRCN-CO participates from the National Intercomparison Program sponsored by IRD/CNEN.

The results are presented regularly at the annual environmental monitoring report and indicate a good performance.

The repository structures are not supposed to have any release of radioactive material. Therefore, no operational level on activity concentration was defined for the installation. Any increase of the background levels shall be considered as a violation of the integrity of the repository and will demand further investigation of the situation.

According to an agreement formalized between CNEN and the Goiás State, this control will be maintained over the next 50 years, with the possibility of being extended for another 50 years.

Section I – TRANSBOUNDARY MOVEMENT

I.1. Article 27. TRANSBOUNDARY MOVEMENT

The Brazilian policy related to transboundary movements of spent fuel and radioactive waste follows international practices. According to this policy, no radioactive waste shall be imported into the country.

The following section describes a case of shipment of spent nuclear fuel from a research reactor to the original supplier country.

I.1.1. Shipment of IPEN spent fuel to the original supplier country

After 40 years of the IEA R-1 reactor operation, 127 Spent Fuel Assemblies (SFA's) had been stored at the facility, being 40 in a dry storage and the other 87 in the reactor storage pool. In 1996, CNEN started negotiation with US-DOE to return the SFA's of IEA-R1 to USA. Finally, in 1998, an agreement was achieved between CNEN and US-DOE and in November 1999 the shipment was successfully performed. This section describes the operational and logistic experience of the SFA's transport.

I.1.1.1. Companies Contracted for the Transport Operation

The contract between CNEN and DOE was signed in 1998. Edlow International Co. and the German Consortium formed by Nuclear Cargo & Services (NCS) and Gesellschaft fur Nuklear-Service (GNS) were hired to perform the transport. Tec Radion Comercial Ltda (TRION) was subcontracted by Edlow to provide the necessary infrastructure for loading, transporting within Brazilian territory, and customs documents.

The German Consortium provided 4 transport casks (two GNS-11 and two GNS-16), one transfer cask, equipment and experts to handling their equipment. IPEN performed the necessaries tasks to fulfill the Brazilian legislation requirements, such as: the export license, a detailed Transport and Security Plan, safeguards documents, as well as operational and radiological protection support for the entire operation.

I.1.1.2.Transport Equipment Description

The transport casks were designed in a "sandwich" construction. The cylindrical cask consisted of the following components: inner liner with inner liner bottom, lead filling, wall with bottom plate, side wall cover sheet with spacer wire, head ring, primary lid and protective plate. The maximum weight of the cask was 13230 kg. The capacity of each cask was 33 spent fuel assemblies.

I.1.1.3. Fuel Cutting Equipment

Before the beginning of the loading operation, 19 control fuel assemblies were cut 1.27 cm from the cut line to the interior fuel plates. The cutting operation of the five control fuel assemblies stored in the dry-storage was performed in the first floor of the reactor building. For cutting the 14 control fuel assemblies stored in the reactor pool, an underwater saw was used. This tool was specially designed and constructed in Brazil under supervision of Edlow/Trion.

I.1.1.4. Loading and Transportation

On September 16, 1999, four containers, two with the GNS-11 casks and two with equipment, arrived at IPEN. The two GNS-16 casks arrived on October 7. German experts, supported by IPEN technicians and the transportation company staff hired by Edlow/Trion, removed the equipment from the containers and placed it on a truck, which were transported to the reactor building.

On September 21, the rotary lid was positioned on top of the first transport cask to be loaded, and some cold tests, with a dummy element, were performed. A transfer cask, 4-ton weight was used to transfer the assemblies from the wet storage to the transport cask. The SFAs were lifted from the storage racks inside the reactor pool with a special tool and positioned inside a plastic tube located on a metallic platform located at 2 meters from the pool surface. The transfer cask was submerged inside the reactor pool over the assembly to be removed. The assembly was guided to one of the 33 positions of the cask. After the cask loading, a water tank was positioned above the cask and filled with 4000 liters of water. Finally, the cask was closed and the water was drained from it and from the water tank. This operation was repeated for the 87 assemblies stored in the wet storage. For the other 40 SFAs stored in the dry storage, the transfer cask was not used.

On October 15 the four GNS casks had been loaded with a total of 127 Brazilian spent fuel assemblies. Then, decontamination procedures were performed. On October 20 all the equipment and cask were removed from the reactor building to the containers. The casks were sealed and controlled by safeguards inspectors from ABACC (Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials) supervised by IAEA.

On November 3, the transport operation was initiated after approval from the Brazilian regulatory bodies (Nuclear and Environmental). The licenses were issued by CNEN and IBAMA (Environmental Brazilian Agency), which required documents relative to transport, radiation, physical protection, and an environmental impact evaluation. Also the GNS 11 and GNS 16 certificates issued by American and German authorities had to be revalidated in Brazil. Opposition from environmental organizations, local politicians and harbor union demanded a comprehensive public information work, including debates and press briefing, to overcome this opposition and avoid legal action against the operation.

On November 4 at down, a huge convoy consisting of 5 trucks (one spare) escorted by Federal, State and County Police arrived in the harbour of Santos. It is also worthy to note that the highway and the main avenues and streets in São

Paulo and Santos were closed for traffic during the operation. Loading trucks were available at strategic places, to be used in case of need. Loading of the containers in the ship was concluded in 42 min. Before and during all shipment operation, the workers were monitored by the CNEN radiation protection personnel. At 4:50 am, the ship left the harbour escorted by boats of the federal police. At the exit of the harbour, these boats were replaced by a frigate of the Brazilian Navy, which followed the ship until a distance of 200 miles away from the Brazilian coast. At this point the Brazilian responsibilities over the fuel were terminated.

I.1.1.5. New Shipment of Fuel to USA

On November 2007, 33 spent fuel elements stored in the IEA-R1 reactor pool and containing uranium of US origin were shipped back to Savannah River Laboratory, South Carolina, USA. This operation, which was very similar to the one of 1999, when 127 spent fuel elements were shipped back to the USA, used a different transport cask LWT supplied by American company NAC.

I.1.2 Packing and Repatriation of US-originated sources

In 2007, the USA accepted for repatriation sources produced there that were no longer in use and were stored at IPEN and CDTN facilities. This activity was carried out by staff constituted of personnel from both institutes and from Los Alamos National Laboratory (LANL) Off-Site Source Recovery Project (OSRP). After a work plan and a training course, these sources were put into special form capsules and packed into 200-liter Type A shipping containers, or into other containers approved for shipment to the USA. The containers were shipped together with the IPEN spent fuel described in I.1.1.5 (see Fig. I.1). A total of 113 sealed sources from IPEN and 41 from CDTN were repatriated.

Figure I.1. Container loading with encapsulated sources

Section J – DISUSED SEALED SOURCES

J.1. Article 28. DISUSED SEALED SOURCES

All the disused sealed sources that are not returned to the manufacturer have been or will be dismounted from its device or shielding for further disposal. Meanwhile, disused sources are stored in interim storage facilities at CNEN Institutes.

J.1.1. Disused Source Storage

The inventory of disused sources stored at CNEN institutes in March 2008 is presented on Table J.1. The occupational rate of the storage facility is also presented.

Table J.1. Disused sources in storage

Institute	Number of Sources	Total Volume (m^3)	Total Activity (Bq)	Occupation Rate (%)
IPEN	149,727*	172	5.07×10^{14}	~99
CDTN	15,204**	133	1.7×10^{14}	~27
IEN	7,567	114	7.60×10^{12}	~99

* This includes 141,320 ^{241}Am and ^{226}Ra sources from lightning rods and smoke detectors and excludes 113 neutron sources repatriated to USA

**This includes 13,670 ^{241}Am and ^{226}Ra sources from lightning rods and smoke detectors

IRD/CNEN performs a biannual inspection on every authorized radiotherapy installation, comprising the verification of source inventory, the safety of the storage area and radiometric survey of the area. It is usually recommended that unused sealed sources be transferred to CNEN, but there are some disused sealed sources stored in hospitals, mainly brachytheraphy sources.

Nuclear medicine installations have usually just weak calibration sources. Disused sources are stored in the installation but the main concerns are towards the quality of those sources still in use.

J.1.2 Program for Collecting of Disused Sources and Radioactive Waste

After the large radiological accident in Goiânia with a disused ^{137}Cs source in 1987, CNEN contacted all users of radioactive material in the country to participate in the effort to solve the problem of the disposal of disused radioactive sources.

Periodically, CNEN conducts regional operations to collect radioactive waste from several radioactive installations. This waste includes disused sources from medical, industrial and agricultural applications.

Two big campaigns were conducted, one in 1998 in the South Region and another in 1989 for the Northeast to collect disused radioactive sources. For this operation, an especial truck (Fig. J.1) and Type A containers (Fig. J.2) were purchased. Since then, smaller campaigns have been conducted in all national territory. In 2001 a campaign was conducted in the Central-West region and in 2002, two campaigns, one for the Northeast and another for the South regions, were carried out.

In the recent years, experts from the CNEN recovered thousands of spent sources, as shown on detail on Tables J.2 and J.3

Table J.2. Number of Recovered Spent Sources Collected in 2006-2007 at IEN

RAD	Type of Source	Quant.	Activity-unitary (mCi)]	Total Activity (mCi)	Date of Storage
Sr-90	Sealed source	1			24-01-07
Am-241	Lightning rod	13	0.57	7.41	Jan./Dec.-07
Am-241	Smoke Detector	1340	0.005	6.70	Jan./Dec.-07
Ra-226	Lightning rod	4	0.44	1.76	Jan./Dec.-07
Ra-226	Smoke Detector	70	0.44	30.80	05-09-07
Mo-99	Sealed source	38			05-01-07
Cs-137	Sealed Source	59		1487.06	Jan./Dec.-07
C-14	Sealed Source	2		0.002	28-02-07
Co-57	Sealed Source	1	100.0	100.00	28-02-07
Co-60	Sealed Source	3		110240.00	Jan./Dec.-07
Ir-192	Sealed Source	1	113.5	113.50	25-05-07
Ur-92		1			15-10-07
Am-241	Lightning rod	410	0.57	233.70	Jan./Dec.-06
Am-241	Smoke Detector	341	0.005	1.71	Jan./Dec.-06
Ra-226	Lightning rod	18	0.44	7.92	Jan./Dec.-06
TOTAL		**2302**		**112,230.56**	

Table J.3 – Number of Recovered Spent Sources Collected in 2006-2007 at CDTN

RAD	Type of Source	Quant	Activity-unitary (mCi)]	Total Activity (mCi)	Date of Storage
Cs-137	Density Gauge	6	100-200	850	06-01-06
Cs-137	Density Gauge	3	50-200	300	16-01-06
Cs-137	Density Gauge	6	100-200	1100	03-02-06
Cs-137	Level Gauge	3	250	750	21-02-06
Cs-137	Level Gauge	10	0.25-109	270	16-03-06
Cs-137	Density Gauge	3	100	300	21-03-06
Kr-85	Thickness Gauge	2	400	800	12-04-06
Cs-137	Density Gauge	4	100-200	600	07-06-06
Sr-90	Ophthalmic Aplicator	1	10	10	21-11-06
Cs-137	Density Gauge	8	100-2000	4400	19-12-06
Am-241	Lightning rod	96	1.5	144	31-12-06
Ra-226	Lightning rod	1	1.0	1.0	31-12-06
Sr-90	Sealed source	1	50	50	04-01-07
Cs-137	Level Gauge	2	100	200	05-01-07
Cf-252	Process Analyzer	2	13-59	71	05-01-07
Cs-137	Brachytherapy Source	120	100	3200	05-01-07
Sr-90	Ophthalmic Applicator	2	10-20	30	05-01-07
Co-60	Teletherapy	1	6710000	6710000	10-04-07
Kr-85	Thickness Gauge	1	400	400	20-04-07
Co-60	Teletherapy	1	2752000	2752000	11-05-07
I-129	Calibration source	1	0,00005	0,00005	06-06-07
Cs-137	Calibration source	1	0,04	0,04	27-06-07
Ra-226	Calibration Source	7	0,02	0,14	06-09-07
Cs-137	Density Gauge	14	8,8-2000	8200	06-09-07
Am241-Be	Calibration Source	1	50	50	06-09-07
Kr-85	Thickness Gauge	2	400	800	14-09-07
Am241-Be	Moisture Gauge	2	100	200	27-09-07
Co-60	Teletherapy	1	4292000	4292000	26-10-07
Cs-137	Density Gauge	12	200-1000	6700	30-11-07
Fe-55	Alloys Analyzer	2	40	80	30-11-07
Cm-244	Alloys Analyzer	1	30	30	30-11-07
Co-60	Density Gauge	18	5-21	226	30-11-07
Cs-137	Density Gauge	14	1-20	60	21-12-07
Co-60	Level Gauge	2	0,4	0,8	21-12-07
Am-241	Lightning rod	42	1.5	63	31-12-07
Ra-226	Lightning rod	1	1.0	1.0	31-12-07
TOTAL		**394**			

In November 2007, 41 sources were sent back to USA: three ^{239}Pu-Be, 21 ^{241}Am-Be, five ^{252}Cf, 10 ^{137}Cs and two ^{241}Am-Be - ^{137}Cs sources. The total activity was 4.72 GBq (127.7 mCi) in October 2007.

The types of sources collected include small radium needles, lightning rods, and large sources used in radiotherapy. The sources are later transferred to the storage facilities existing at CNEN institutes (see Fig J.3).

Fig J.1 CNEN truck for disused source collection

Fig J.2. Type A waste containers

Fig J.3 Disused source storage at CDTN

Section K. PLANNED ACTIVITIES TO IMPROVE SAFETY

Safety culture requires a questioning attitude and a search for excellence. Therefore, notwithstanding the good safety record, nuclear operators and regulators in Brazil are constantly working on safety improvements.

In the area of legislation, at present a bill of law is under discussion establishing administrative and monetary penalties to all nuclear facilities and services in cases of non-compliance. This is expected to strengthen the enforcement powers of CNEN.

K.1. IMPROVEMENTS IN THE POWER PLANTS

Concerning to the radioactive waste management at Angra site, an aggressive waste reduction program was carried out in order to minimize waste volume generation (mainly in compactable, non-compactable and spent resins).

Also, an Isotopic Waste Characterization Program is being developed aiming the final disposal.

Concerning the initial storage, the present storage facility (Storage Facility 2) is being expanded in a second block and a third initial storage facility (Storage Facility 3) is under construction.

The replacement of the two steam generators of Angra 1, foreseen for the beginning of 2009, will improve the plant safety margins and, as a byproduct, will provide a revised safety analysis, with newer methods and codes. The subject of radioactive waste is an important aspect.

The old steam generators and the radioactive wastes directly produced by the replacement works will be stored in an on-site initial storage facility, which is under construction.

K.2. IMPROVEMENT IN THE RADIOACTIVE WASTE AREA

CNEN has developed a systematic approach for radioactive waste management in Brazil, aimed at harmonizing waste management approaches across the country. Still, some potential improvements have been identified, namely:

- The need to select the site and implement the National Repository for Radioactive Waste, providing final disposal for low- and intermediate level radioactive waste;
- The development of public acceptance and democratic participation programs for waste repositories;

- The development of a unified and standardized database that records the national radioactive waste inventory;
- Increasing of the capacity of CNEN institutes to treat and store radioactive waste;
- Training, recruiting and retention of human resources, in light of the forecasted resurgence of nuclear activities in the country and of the foreseen reduction of the labour force in the field, due to retirements and lack of retention;
- The need to review the regulatory approach for the research installations, performing a closer surveillance of their waste management activities;
- The development of a regulatory body which is independent of all its regulated agents.

The main challenge is certainly the establishment of a National Repository for Radioactive Waste. The Project involves several specialties in different professional fields. In each one of them CNEN and other Brazilian institutions have different degrees of accomplishment. A coordinated effort is being carried out to make possible to have the repository operational in the second decade of 21st century.

K.3. New waste storage facility at IPEN

The existing storage for treated waste will be restructured and will receive 650 m^2 of extra area. In 2007, CNEN issued a preliminary authorization for building new storage area and IPEN applied for construction license. The next phase will be hiring the company to carry out construction work.

K.4. Plans for decommissioning USIN

At present, according to section F.6.3.3, there is no decommissioning plan for USIN. Notwithstanding, INB is waiting for the position of CNEN to start the site cleanup work.

K.5. Plans for a Brazilian Radioactive Waste Enterprise

Radioactive waste in Brazil is generated at a number of facilities across the country that use radioactive material as regulated in the specific standards issued by CNEN. These facilities are classified as Nuclear Facilities or Radioactive Facilities, depending on the case.

Also, radioactive material may be generated due to other specific activities as the application of isotopes in the medicine, industry, agriculture and research, and occasionally due to decontamination process following radiological incidents.

The Brazilian laws regulating this activity establishes that the responsibility for the final guard of this radioactive waste shall be of the Federal Government and it will be carried out by the Brazilian Nuclear Energy Commission, CNEN.

Due to the increase in the applications of the nuclear energy, the waste has been accumulated throughout the recent years in temporary storage known as initial storage facilities managed by the generated facility under the supervision and inspection of the local regulatory authority.

Some of this waste has been transferred to the so-called intermediate storage facilities in the Research Institutes of CNEN.

The Brazilian long-term government program establishes the implementation of a Radioactive Waste Management Policy. One of its tasks is the implementation of a state company responsible for the radioactive waste management called Empresa Brasileira de Gerenciamento de Rejeitos Radioativos – EBRR (Brazilian Enterprise for the Management of Radioactive Waste).

It is recognized that an autarchy like CNEN does not have the necessary flexibility, dynamism and budgetary freedom for being efficient in managing this scope of activities.

Also, aiming at giving finance support for operating the EBRR, the Brazilian law (Lei 10.308/01) specifies provisions for applying the "polluter pays" principle by allowing CNEN to charge the facility generating radioactive waste with corresponding taxes.

It is proposed to gather these resources in a fund to be created (Fundo Nacional de Rejeitos Radiativos – FNRR), in order to provide the means for operating the EBRR. The financial resources so obtained shall be applied at market interest to assure the maintenance of the repositories during their operational lives.

The EBRR would be a stock company having the Government the majority of the votes. In the company capitalization phase the Government shall provide the majority of the capital resources. It is expected that this phase shall last up to the beginning of operation of the first repository for low and intermediate level wastes.

A feasibility study was carried out on the implementation of EBRR based on the following scenarios.

- In the initial phase, the company shall be only responsible for the management of the low and intermediate level wastes. The high level wastes, consisting basically of the spent nuclear fuel residues are not the initial scope of the EBRR until the decision on the use of open or closed cycle scenario by the Brazilian Nuclear Policy.
- The oldest nuclear plant in operation in Brazil, Angra 1, shall be decommissioned by 2040. Since it has sufficient space to store the whole

spent fuel until then, the initial operational phase of EBRR shall not be involved with high level radioactive waste over the short term.

- The minimum EBRR capital would be sufficient for the construction of the first repository of low and intermediate level wastes and corresponding expenses with EBRR during that initial phase.
- The capital provider would be the Federal Government. A set of different possibilities for providing that support is analyzed in the feasibility study of EBRR. Among those, it is also considered that the resources could come through the tariff of the energy generated by Nuclear Power Plants.
- The capacity of the first module of the repository is evaluated for 30 years of activity of the sector.
- The time of construction of the first module of the repository is estimated in 5 years. It is not considered in that time the site selection and approval. The impact in the energy tariff in that case is not significant.

The strategy to create the EBRR comprises in an initial operation using CNEN installations and personnel. Gradually, according with its expansion, EBRR shall become independent of CNEN.

These plans are currently under Government review.

K.6. FINAL REMARKS

Brazil has demonstrated that the Brazilian nuclear power programme and the related nuclear installations has met the objectives of the Convention.

Based on the safety performance of nuclear installations in Brazil, and considering the information provided in this National Report, the Brazilian nuclear organizations consider that their nuclear programs have:

- achieved and maintained a high level of safety in the area of spent fuel and waste management on its nuclear and radiological installations;
- established and maintained effective defenses against potential radiological hazards in order to protect individuals, the society and the environment from harmful effects of ionizing radiation;
- prevented accidents with radiological consequences and is prepared to mitigate such consequences should they occur.

Therefore, Brazil considers that its nuclear programme has met and continues to meet the objectives of the Join Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

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Annex 1

Present Inventory

The following table presents the inventory of radioactive waste in Brazil as of the end of March 2008.

Source/ Type	Present Situation	Inventory as of March 2008	Treatment	Interim Storage	Final Disposal (proposal)
ANGRA I NPP					
Spent Fuel	Storage inside reactor pool (Spent fuel pool)	650 fuel assemblies	Waiting for decision concerning reprocessing. Under Brazilian regulation is not considered waste.	Inside reactor pool	Deep geological disposal
Filters	Stored in 200 l drums at plant site	449 packages/ 93.4 m^3 / 2.3E+13 Bq	Cementation and encapsulation in steel drums	At plant site	Brazilian repository
Evaporator concentrates	Stored in 200 l drums and 1000l liners at plant site	2855 packages / 878.1 m^3 / 5.3 E+12Bq	Cementation and encapsulation in steel drums/shielded liners	At plant site	Brazilian repository
Non-compressibles	Stored in 200 l drums and 1000 l metallic boxes at plant site	772 packages/ 438.3 m^3 / 1.2 E+13 Bq	Cementation and encapsulation in steel drums/metallic boxes	At plant site	Brazilian repository
Resins	Stored in 200 l drums and 1000 l liners at plant site	1051 packages/ 345.4 m^3 / 2.3E+14 Bq (considering 357 packages or 74.3 m^3 from secondary system resins)	Cementation and encapsulation in steel drums/shielded liners	At plant site	Brazilian repository
Compressibles	Stored in 200 l drums at plant site	511 drums/106.3 m^3 / 1.9E+12 Bq	Encapsulation in steel drums	At plant site	Brazilian repository
ANGRA II NPP					
Spent fuel	Storage inside reactor pool (Spent fuel pool)	272 fuel assemblies	–	–	Deep geological disposal
Filters	Stored in 200 l drums at plant site	2 drums / 0.4m^3			Brazilian repository
Evaporator concentrates	Stored in 200 l drums at plant site	142 drums / 28.4 m^3 / 1.6 E+10 Bq	Betuminization and encapsulation in steel drums	At plant site	Brazilian repository
Compressibles	Stored in 200 l drums at plant site	58 drums / 11.6 m^3 / 3.5 E+11 Bq	Betuminization and encapsulation in steel drums	At plant site	Brazilian repository

Source/ Type	Present Situation	Inventory as of March 2008	Treatment	Interim Storage	Final Disposal (proposal)
RADIONUCLIDE APPLICATIONS IN MEDICINE, INDUSTRY AND RESEARCH					
Waste generated by radioactive installations, research institutes (including those belonging to CNEN) and lightning rods	Stored in the institutes of CNEN: IPEN(SP), CDTN(MG) and IEN(RJ)	IPEN:583m^3/5.07E+14Bq CDTN: 133m^3/1.7E+14Bq IEN: 114m^3 / 7.6E+12Bq	According to type of waste	Institutes of CNEN	Brazilian repository
FUEL CYCLE INSTALLATIONS					
Poços de Caldas Mining and Milling Industrial Complex – uranium and thorium concentrates	Stored in shed and trenches	7250 m^3 / 119288GBq (3224 Ci) (Low level waste)	-	-	-
Poços de Caldas Mining and Milling Industrial Complex – Mesothorium	Talings dam	1500 ton (Low level waste)	-	-	-
Poços de Caldas Mining and Milling Industrial Complex – Mesothorium	Trenches	880 tons (Low level waste)			
Poços de Caldas Mining and Milling Industrial Complex – Waste Generated in the Process	Tailings dam	2 111 920 tons (Low level waste)			
Poços de Caldas Min.&Mill. Industrial Complex – Calcium Diuranate (DUCA)	Tailings dam and Mine Pit	120 000 tons (197 tons of U_3O_8)			
Poços de Caldas Mining and Milling Industrial Complex – Contaminated Filters and Other Materials	Isolated areas on the site	Approximately 50 tons (Low level waste)			

Source/ Type	Present Situation	Inventory as of March 2008	Treatment	Interim Storage	Final Disposal (proposal)
Poços de Caldas Mining and Milling Industrial Complex – thorium (ThO_2)	Pond and 148 concrete containers	79.48 tons (Low level waste)			
INB Nuclear Fuel Factory – FCN Resende: Filters of the ventillation system, filters of the air conditioned system, and filters of portable dust vacuum cleaners)	Disposed of in 7 - 200 liter drums, temporarily inside the Reconversion plant	454 kg (Low-level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Non compactable waste (metal pieces, wood, glass, plastic pieces, and others)	Disposed of in 24 200-liter drums, temporarily inside the Reconversion plant	1681 kg (Low-level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Compactable solids (plastic sheets, gloves, clothes, and others)	Disposed of in 39 200-liter drums, temporarily inside the Reconversion plant	3139 kg (Low level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Refractory material (bricks)	Disposed of in 7 200-liter drums, temporarily inside the Reconversion plant	2064 kg (Low level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Dried lime cake	Disposed of in 19 200-liter drums, temporarily inside the Reconversion plant	3379 (Low level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Dried ammonium fluoride cake	Disposed of in 2 200-liter drums, temporarily inside the Reconversion plant	449 kg (Low level solid waste)			
INB Nuclear Fuel Factory – FCN Resende: Pieces of molybdenum	Disposed of in 2 100-liter drums, temporarily inside the Reconversion plant	116 kg (Low level solid waste)			

Source/ Type	Present Situation	Inventory as of March 2008	Treatment	Interim Storage	Final Disposal (proposal)
MONAZITE SAND PROCESSING INSTALLATIONS					
Interlagos Facility (USIN/SP) – uranium and thorium concentrates	Stored in plastic drums	325 m^3 /5069 GBq(137Ci)	-	-	-
Interlagos Facility (USIN/SP) – – Mesothorium	Stored in plastic drums	39 m^3 / 222 GBq(6Ci)			
Interlagos Facility (USIN/SP) – Others contaminated matrial	Stored in plastic drums, maritime containers and metal boxes	1585 m^3			
Botuxim Desposiy (São Paulo) uranium and thorium concentrates	Stored in concrete silos	2,190 m^3/ 32856 GBq(888Ci)	-	-	-
RADIOLOGICAL ACCIDENT IN GOIÂNIA					
Low level wasts (^{137}Cs) below exemption level	Final disposal concluded	1525 m^3 / 2 Ci	Encapsulation in steel and concrete drums	Open air at Abadia de Goiás	Great Capacity Conteiner (CGP)
Low level waste (^{137}Cs) above exemption level	Final disposal concluded	1975 m^3 / 1338 Ci	Encapsulation in steel and concrete drums	Open air at Abadia de Goiás	Goiânia Repository

Annex 2

LIST OF RELEVANT CONVENTIONS, LAWS AND REGULATIONS

2.1. Relevant International Conventions of which Brazil is a Party

Convention on Civil Liability for Nuclear Damage (Vienna Convention). Signature: 23/12/1993. Entry into force: 26/06/1993.

Convention on the Physical Protection of Nuclear Material. Signature:15/05/1981. Entry into force: 8/02/1987.

Convention on Early Notification of a Nuclear Accident Signature: 26/09/1986. Entry into force: 4/01/1991.

Convention on Assistance in Case of Nuclear Accident or Radiological Emergency. Signature: 26/09/1986. Entry into force: 4/01/1991.

Convention on Nuclear Safety. Signature: 20/09/1994. Entry into force: 24/04/1997.

Convention n. 115 of the International Labor Organization. Signature: 7/04/1964.

Join Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Ratification: 14/11/2005.

2.2. Relevant National Laws

Decree 40.110 of 1956.10.10 - Creates the Brazilian National Commission for Nuclear Energy (CNEN).

Law 4118/62 of 1962.07.27 - Establishes the Nuclear Energy National Policy and reorganizes CNEN.

Law 6189/74 of 1974.12.16 - Creates Nuclebras as a company responsible for nuclear fuel cycle facilities, equipment manufacturing, nuclear power plant construction, and research and development activities.

Law 6.453 of 1977.10.17 - Defines the civil liability for nuclear damages and criminal responsibilities for actions related to nuclear activities

Decree 1809 of 1980.10.07 - Establishes the System for Protection of the Brazilian Nuclear Programme (SIPRON).

Law 6938 of 1981.08.31 - Establishes the National Policy for the Environment (PNMA), creates the National System for the Environment (SISNAMA), the Council for the Environment (CONAMA) and Brazilian Institute for the Environment (IBAMA).

Law 7781/89 of 1989.06.27 - Reorganizes the nuclear sectors.

Decree 99.274 of 1990.06.06 - Regulates application of law 6938, establishing the environmental licensing process in 3 steps: pre-license, installation license and operation license.

Decree 2210 of 1997.04.22 - Regulates SIPRON, defines the Secretary for Strategic Affairs (SAE) as the central organization of SIPRON and creates the Coordination of the Protection of the Brazilian Nuclear Programme (COPRON).

Law 9.605 of 1998.02.12 – Defines environmental crimes and establishes a system of enforcement and punishment.

Decree 3719 of 1999.09.21 – Regulates the Law 9.605 and establishes the penalties for environmental crimes.

Law 9.765 of 1998.12.17 – Establishes tax and fees for licensing, control and regulatory inspection of nuclear and radioactive materials and installations.

Decree 3833 of 2001.06.05 – Establishes the new structure and staff of the Brazilian Institute for the Environment (IBAMA).

Law 10.308 of 2001.11.20 – Establishes rules for the site selection, construction, operation, licensing and control, financing, civil liability and guaranties related to the storage of radioactive waste.

2.3. CNEN Regulations

NE 1.04 - Licenciamento de instalações nucleares - Resol. CNEN 11/84 - ***(Licensing of nuclear facilities).***

NN 1.14 - Relatórios de operação de usinas nucleoelétricas - ***(Nuclear power plant operation reports).***

NE 1.16 - Garantia da qualidade para a segurança de usinas nucleoelétricas e outras instalações - Resol. 15/99 - ***(Quality assurance and safety in nuclear power plants and other facilities).***

NE 1.17 - Qualificação de pessoal e certificação para ensaios não destrutivos em itens de instalações nucleares - ***(Personnel qualification and certification for non-destructive testing in nuclear power plants components).***

NE 1.18 - Conservação preventiva em usinas nucleoelétricas - ***(Nuclear power plant preventive maintenance).***

NE 1.19 - Qualificação de programas de cálculos para análise de acidentes de perda de refrigerante em reatores a água pressurizada - Resol. CNEN 11/85 - ***(Qualification of programs for coolant loss accident analysis in pressurized water reactors).***

NE 1.20 - Aceitação de sistemas de resfriamento de emergência do núcleo de reatores a água leve - ***(Acceptance criteria for emergency core cooling system of light water reactors).***

NE 1.21 - Manutenção de usinas nucleoelétricas - ***(Maintenance of nuclear power plants).***

NE 1.22 - Programas de meteorologia de apoio de usinas nucleoelétricas - ***(Meteorological programme for nuclear power plant support).***

NE 1.25 - Inspeção em serviço de usinas nucleoelétricas - ***(In service inspection of nuclear power plants).***

NE 1.26 - Segurança na operação de usinas nucleoelétricas - ***(Operational safety of nuclear power plants).***

NE 1.28 - Qualificação e atuação de órgãos de supervisão técnica independente em usinas nucleoelétricas e outras instalações - Resol. CNEN-CD N^{o}.15/99 de 16/09/1999- - ***(Qualification and actuation of independent technical supervisory organizations in nuclear power plants and other installations)***

NN 1.01 - Licenciamento de operadores de reatores nucleares - Resol. CNEN 12/79 - ***(Licensing of nuclear reactor operators).***

NN 1.06 - Requisitos de saúde para operadores de reatores nucleares - Resol. CNEN 03/80 - ***(Health requirements for nuclear reactor operators).***

NN 1.12 - Qualificação de órgãos de supervisão técnica independente em instalações nucleares - Resol. CNEN 16/85 - Revisada em 21/09/1999 - ***(Qualification of independent technical supervisory organizations for nuclear installations).***

NN 1.15 - Supervisão técnica independente em atividades de garantia da qualidade em usinas nucleoelétricas - ***(Independent technical supervision in quality assurance activities in nuclear power plants).***

NE 2.01 - Proteção física de unidades operacionais da área nuclear - Resol. CNEN 07/81 – revised by Resol. 06/96 ***(Physical Protection in nuclear facilities).***

NN 2.02 **–** Controle de materiais nucleares - Resol. CNEN 11/99 ***(Nuclear material control).***

NE 2.03 - Proteção contra incêndio em usinas nucleoelétricas - Resol. CNEN 08/88 - ***(Fire protection in nuclear power plants).***

NN 3.01 - Diretrizes básicas de proteção radiológica - Resol. CNEN 48/2005 - ***(Radiation protection basic directives). January 2005***
NE 3.02 - Serviços de proteção radiológica - ***(Radiation protection services). August 1988***

NE 3.03 - Certificação da qualificação de supervisores de radioproteção - Resol. CNEN 09/88 – Revisada em 01/09/95, Modificada em 16/10/97 e 21/09/99 - ***(Certification of the qualification of radiation protection supervisors). September 1999***

NE 5.01 - Transportes de materiais radioativos - Resol. CNEN 13/88 - ***(Transport of radioactive materials). August 1988***

NE 5.02 - Transporte, recebimento, armazenamento e manuseio de elementos combustíveis de usinas nucleoelétricas - ***(Transport, receiving, storage and handling of fuel elements in nuclear power plants). February 2003***

NE 5.03 - Transporte, recebimento, armazenagem e manuseio de ítens de usinas nucleoelétricas - ***(Transport, receipt, storage and handling of materials in nuclear power plants). February 1989.***

NE 6.02 Licenciamento de instalações radiativas ***– (Licensing of radioactive installations). July 1998***

NE 6.05 - Gerência de rejeitos radioativos em instalações radiativas - ***(Radioactive waste management in radioactive facilities). December 1985. (Currently under review)***

NE 6.06 – Seleção e escolha de locais para depósitos de rejeitos radioativos. - ***(Site Selection for radioactive waste storage facilities).- December 1989***

NN 6.09 – Critérios de aceitação para deposição de rejeitos radioativos de baixo e médio níveis de radiação - ***(Acceptance criteria for disposal of low and intermediate level radioactive wastes). – Setember 2002***

IN-DRS 010 – Rev. 03 –- Requisitos de segurança para depósitos finais de rejeitos radioativos de baixo e médio níveis de radiação ***(Safety requirements for low and intermediate level radioactive waste disposal facilities) – May 2007***

2.4. CONAMA Regulations

CONAMA – 01/86 - Estabelece requisitos para execução do Estudo de Impacto Ambiental (EIA) e do Relatótio de Impacto Ambiental (RIMA) - ***(Establishes requirements for conducting the environmental study (EIA) and the preparation of the report on environmental impact (RIMA)) -*** (23/01/1986).

CONAMA-28/86 - Determina a FURNAS a elaboração de EIA/RIMA para as usinas nucleares de Angra 2 e 3 - ***(Directs FURNAS to prepare an EIA/RIMA for the Angra 2 and 3 nuclear power plants) -*** (03/12/1986)

CONAMA-09/86 - Regulamenta a questão de audiências públicas - ***(Regulates the matters related to public hearings) -*** (03/12/1987).

CONAMA-06/86 – Institui e aprova modelos para publicação de pedidos de licenciamento - ***(Establishes and approves models for licensing application) -*** (24/01/1986).

CONAMA-06/87 – Dispõe sobre licenciamento ambiental de obras de grande porte e especialmente do setor de geração de energia elétrica - ***(Regulates environmental licensing of large enterprises, specially in the area of electric energy generation) -*** (16/09/1987).

CONAMA-237/97 – Dispõe sobre os procedimentos a serem adotados no licenciamento ambiental de empreendimentos diversos - ***(Establihses procedures for environmental***

licensing of several types of enterprises) - (19/12/1997).

2.5. SIPRON Regulations

NG-01 - Norma Geral para o funcionamento da Comissão de Coordenação da Proteção do Programa Nuclear Brasileiro (COPRON) - ***(General norm for the Coodination Commission for the Protection of the Brazilian Nuclear Programme).*** Port. SAE Nr. 99 of 13.06.1996.

NG-02 - Norma Geral para planejamento de resposta a situações de emergência. **- *(General norm for planning of response to emergency situations).*** Resol. SAE/COPRON Nr.01 of 13.06.1996.

NG-03 - Norma Geral sobre a integridade física e situações de emergência nas instalações nucleares - ***(General norm for physical integrity and emergency situations in nuclear installations).*** Resol. SAE/COPRON Nr. 01 of 19.07.1996.

NG-04 - Norma Geral para situações de emergência nas unidades de transporte - ***(General norm for emergency situations in the transport units).*** Resol. SAE/COPRON Nr. 01 of 19.07.1996

NG-05 - Norma Geral para estabelecimento de campanhas de esclarecimento prévio e de informações ao público para situações de emergência - ***(General norm for establishing public information campaings about emergency situations).*** Port. SAE Nr. 150 of 11.12.1992.

NG-06 - Norma Geral para instalação e funcionamento dos centros de resposta a situações de emergência nuclear - ***(General norm for installation and functioning of response center for nuclear emergency situations).*** Port. SAE Nr. 27 of 27.03.1997.

NG-07 - Norma Geral para planejamento das comunicações do SIPRON ***(General norm for SIPRON communication planning).*** Port. SAE Nr. 37 of 22.04.1997.

NG-08 – Norma Geral para o planejamento e a execução da proteção ao conhecimento sigiloso ***(General norm for planning and execution of classified knowledge protection)****.* Port. SAE Nr. 145 of 7.12.1998.

NI-01 – Norma Interna que dispõe sobre instalação e funcionamento do Centro para Gerenciamento de Emergência Nuclear ***(Internal norm on the installation and operation of the national Center for Nuclear Emergency Management).*** Port. SAE Nr.001 of 21.05.1997.

Diretriz Angra-1 - Diretriz para elaboração dos planos de emergência relativos a unidade 1 da Central Nuclear Almirante Alvaro Alberto - ***(Directive for the preparation of emergency plans related to Unit 1 of Almirante Alvaro Alberto Nuclear Power Plant - Angra 1).*** Port. SAE Nr.144 of 20.11.1997.

Annex 3
List of Abbreviations

Abreviation	Portuguese	English
ABACC	Agência Brasileiro - Argentina de Contabilidade e Controle de Materiais Nucleares	Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
ALARA	Tão baixo quanto razoavelmente exeqüível	As Low As Reasonable Achievable
AOI	Autorização para Operação Inicial	Initial Operation License
AOP	Autorização para Operação Permanente	Permanent Operation License
BSS	Padrões Básicos de Segurança (da IAEA)	Basic safety Standards (of IAEA)
CEA	Centro Experimental de Aramar	Aramar Experimental Centre
CDTN	Centro de Desenvolvimento de Tecnologia Nuclear	Nuclear Technology Development Center
CGRC	Coordenação Geral de Reatores e Ciclo do Combustível	General Coordination for Reactors and Fuel Cycle
CICP	Complexo Industrial de Poços de Caldas	Poços de Caldas Industrial Complex
CNEN	Comissão Nacional de Energia Nuclear	National Commission for Nucelar Energy
CTMSP	Centro Tecnológico da Marinha em São Paulo	Navy Technology Center in Sao Paulo
DIREJ	Divisão de Rejeitos Radioativos	Radioactive Waste Division
DIRR	Deposito Inicial de Rejeitos Radioativos	Radioactive Waste Initial Repository
DRS	Diretoria de Radioproteção e Segurança Nuclear	Radiological Protecion and Nuclear Safety Directorate
EIA	Estudo de Impacto Ambiental	Environmental Impact Study
ETN	ELETRONUCLEAR - Eletrobrás Termo Nuclear LTDA.	Eletrobrás Thermal Nuclear LTDA.
FEEMA	Fundação Estadual de Estudos do Meio Ambiente	State Foundation for Environmental Studies
FSAR	Relatório Final de Análise de Segurança	Final Safety Analysis Report
IAEA	Agência Internacional de Energia Atômica	International Atomic Energy Agency
IBAMA	Instituto Brasileiro de Meio Ambiente	Brazilian Institute for the Environment
ICRP	Comissão Internacional de Proteção Radiológica	International Commission on Radiological Protection
IEN	Instituto de Engenharia Nuclear	Nuclear Engineering Institute
IPEN	Instituto de Pesquisas Energéticas e Nucleares	Institute for Energy and Nuclear Research
IRD	Instituto de Radioproteção e Dosimetria	Radiation Protection and Dosimetry Institute
MCT	Ministério de Ciência e Tecnologia	Ministry for Science and Technology
OSTI	Órgão de Supervisão Independente	Independent Supervision Organization
PSAR	Relatório Preliminar de Análise de Segurança	Preliminary Safety Analysis Report
RIMA	Relatório de Impacto Ambiental	Environmental Impact Report
RR	Reator de Pesquisa	Research Reactor
SFA	Elemento Combustível Usado	Spent Fuel Assembly
SIPRON	Sistema de Proteção do Programa Nuclear	System for the Protection of the Nuclear Program
USAM	Usina de Santo Amaro	Santo Amaro Processing Plant
USIN	Usina de Interlagos	Interlagos Processing Plant
USNRC	Comissão de Regulação Nuclear dos Estados Unidos	United States Nuclear Regulatory Commission

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Ministério de Relações Exteriores (MRE)

Rio de Janeiro - Brazil
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CNEN
Comissão Nacional
de Energia Nuclear

IBAMA
MMA

ELETRONUCLEAR

Ministério da
Ciência e Tecnologia

Ministério do
Meio Ambiente

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