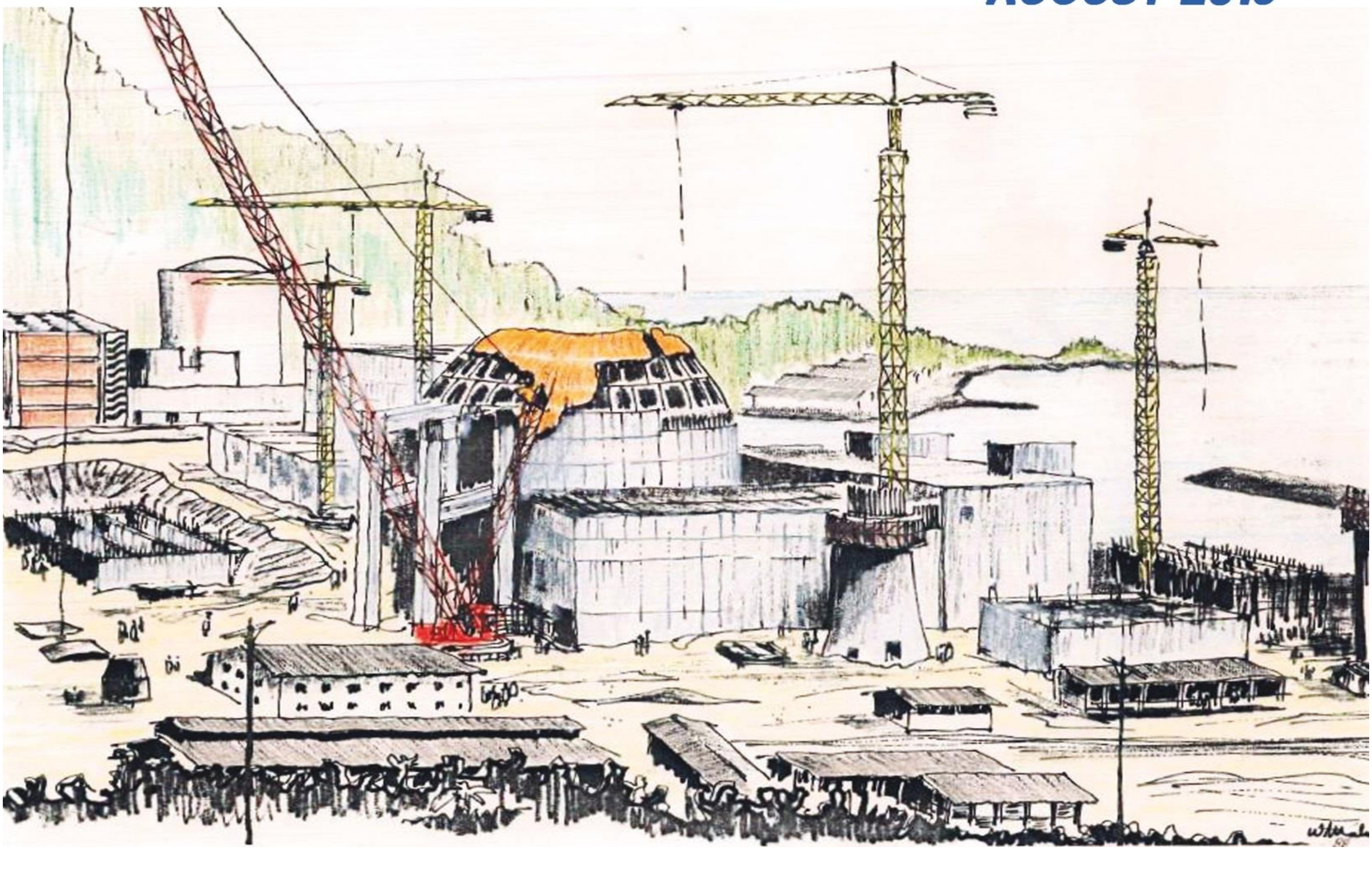
SEVENTH NATIONAL REPORT OF BRAZIL FOR THE NUCLEAR SAFETY CONVENTION

AUGUST 2016



CONVENTION ON NUCLEAR SAFETY
REPORT BY THE GOVERNMENT OF THE FEDERAL REPUBLIC OF BRAZIL
FOR THE
SEVENTH REVIEW MEETING IN MARCH/APRIL 2017

AUGUST 2016

FOREWORD

On 20 September 1994 the Convention on Nuclear Safety was open for signature at the headquarters of the International Atomic Energy Agency in Vienna. Brazil signed the Convention in September 1994, and deposited the instrument of ratification with the Depositary on 4 March 1997.

The Convention objective is to achieve and maintain a high level of nuclear safety throughout the world. One of the obligations of the Parties to the Convention is the preparation of a periodical National Report describing the national nuclear program, the nuclear installations involved according to the Convention definition, and the measures taken to fulfill the objective of the Convention.

Brazil has presented periodically its National Report prepared by a group composed of representatives of the various Brazilian organizations with responsibilities related to nuclear safety. Due to the implications of the Fukushima nuclear accident in 2011, an Extraordinary National Report was presented in 2012 and in the Sixth National Report, presented in 2014, an update of the Extraordinary Report related to lessons learned from the Fukushima accident was included. Since then, the information related to the Fukushima's subjects became a part of the National Report.

This Seventh National Report includes relevant information for the period of 2013/2015 and is an update of the Sixth National Report in relation to the Convention on Nuclear Safety articles.

Following the recommendations of the Sixth Review Meeting and the Extraordinary Meeting, the information is provided according to the Guidelines Regarding National Reports (INFCIRC/572-Rev5) and the corresponding Summary Reports, which established a different structure for the Report and requested additional information.

The authors decided to prepare the Seventh National Report of Brazil as a self-standing document, with some repetition of the information provided in the previous National Reports so that the reviewers do not have to consult frequently the previous documents.

The executive summary presents the level of fulfillment of the obligations of the Convention on Nuclear Safety by Brazil. Based in these considerations it can be concluded that Brazil has achieved and has maintained a high level of safety in its nuclear installations. The Brazilian nuclear safety-licensing regime has proved to be effective in implementing and maintaining strong defenses against potential radiological hazard in order to protect individuals, society and the environment of the harmful effects of ionizing radiation, to prevent nuclear accidents with radiological consequences and prompt to act effectively in the case of an emergency. Consequently, Brazil has achieved the objectives of the Convention on Nuclear Safety.

PREFÁCIO

Em 20 de setembro de 1994 a Convenção sobre Segurança Nuclear foi aberta para assinaturas na sede da Agência Internacional de Energia Atômica, em Viena. O Brasil assinou a convenção em setembro de 1994 e ratificou-a através do decreto legislativo n. 4 de 22 de janeiro de 1997, depositando o instrumento de ratificação em 4 de março de 1997.

O objetivo da Convenção é alcançar e manter o alto nível de segurança nuclear em todo o mundo. Uma das obrigações das Partes da Convenção é a preparação, a cada 3 anos, de um Relatório Nacional descrevendo o programa nuclear nacional, as instalações nucleares existentes, e as medidas tomadas a fim de cumprir o objetivo da Convenção.

O Brasil tem apresentado periodicamente seu Relatório Nacional preparado por um grupo composto de representantes de várias organizações brasileiras relacionadas à segurança nuclear. Devido às implicações do acidente nuclear de Fukushima em 2011, um Relatório Nacional Extraordinário foi apresentado em 2012 e no Sexto Relatório Nacional, apresentado em 2014, uma atualização do Relatório Extraordinário referente às lições aprendidas do acidente de Fukushima foi incluída. Desde então, as informações relacionadas aos assuntos de Fukushima se tornaram parte dos Relatórios Nacionais.

Este Sétimo Relatório Nacional do Brasil atualiza a informação contida no Sexto Relatório Nacional para o período de 2013 a 2015 em relação aos artigos da convenção sobre Segurança Nuclear.

Seguindo as deliberações da Sexta Reunião de Revisão e da Reunião Extraordinária, as informações são apresentadas segundo o Guia para Elaboração dos Relatórios Nacionais (INFCIRC/572-Rev5) e os respectivos Relatórios Sumários que modificam um pouco a estrutura usada nos relatórios anteriores e requerem informações adicionais.

Os autores decidiram preparar o Sétimo Relatório Nacional do Brasil como um documento completo, com alguma repetição das informações contidas nos outros Relatórios Nacionais de maneira que os revisores não tivessem que consultar freqüentemente os relatórios anteriores.

No sumário executivo é apresentado o grau de cumprimento das obrigações da Convenção sobre Segurança Nuclear pelo Brasil. Com base nessas considerações pode-se concluir que o Brasil alcançou e vem mantendo um alto nível de segurança em suas instalações nucleares. O regime de licenciamento e segurança tem se demonstrado efetivo em implementar e manter defesas efetivas contra o perigo radiológico potencial, a fim de proteger os indivíduos, a sociedade e o meio ambiente de possíveis efeitos nocivos da radiação ionizante, evitando acidentes nucleares com consequências radiológicas e mantendo-se preparado para agir efetivamente em uma situação de emergência. Consequentemente, o Brasil alcançou os objetivos da Convenção sobre Segurança Nuclear.

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NATIONAL REPORT OF BRAZIL FOR THE CONVENTION ON NUCLEAR SAFETY

A. INTRODUCTION

A.1. The Brazilian nuclear policy

The Brazilian Federal Constitution of 1988 states in articles 21 and 177 that the Federal Government has the exclusive competence for managing and handling all nuclear energy activities, including the operation of nuclear power plants[1]. The Federal Government holds also the monopoly for the survey, mining, milling, exploitation and exploration of nuclear minerals. All these activities shall be solely carried out for peaceful uses and always under the approval of the National Congress.

The CNEN-Comissão Nacional de Energia Nuclear (National Commission of Nuclear Energy) was created in 1956 (Decree 40.110 of 1956.10.10) to be responsible for all nuclear activities in Brazil. Later, CNEN was re-organized and its responsibilities were established by the Law 4118/62 with amendments determined by Laws 6189/74 and 7781/89. Thereafter, CNEN became the Regulatory Body in charge of regulating, licensing and controlling nuclear energy, and the nuclear electric generation was transferred to the electricity sector.

The national policy for the nuclear sector is implemented through the Plan for Science and Technology (Plano Plurianual de Ciência e Tecnologia - PPA), which establishes quantitative targets that define the Government strategy. Among these targets one can mention the National Nuclear Power Policy which guides research, development, production and utilization of all forms of nuclear energy considered of strategic interest for the Country in all aspects, including scientific, technological, industrial, commercial, energy production, civil defense, safety of the public and protection of the environment.

The Nuclear Program has the aim to increase the participation of nuclear energy in the national electricity production and involves continuous development of technology for the design, construction and operation of nuclear industrial facilities related to the nuclear fuel cycle, which requires improvements on human and financial resources.

[1] In this Report the terms Nuclear Installation and Nuclear Power Plant are used as synonyms, in accordance with the definition adopted in the Nuclear Safety Convention (Art. 2 - i).

A.2. The Brazilian nuclear power program

A.2.1 – Nuclear Power Plants

Currently, Brazil has two nuclear power plants in operation (Angra 1, 640 MWe gross/610 MWe net, 2-loop PWR and Angra 2, 1370 MWe gross /1300MWe net, 4-loop PWR), and one under construction (Angra 3, 1400 MWe gross/1330 MW net, 4-loop PWR). Angra 3 construction was postponed in 1983, restarted in 2009 following a decision of the Federal Government and stopped again in September, 2015 (see Article 6). 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.

As it was the case in other countries, the Fukushima accident highlighted the need to reassess not only domestic nuclear safety standards, but also the overall level of participation of nuclear power in the Brazilian energy matrix. Since then, renewed domestic discussions have been taking place on the previous long-term planning studies on energy policy that outlined the convenience of building four new nuclear power plants in Brazil.

The National Energy Plan 2030 (Plano Nacional de Energia – PNE 2030), issued by the Ministry of Mines and Energy of Brazil through one of its organizations, the Energy Research Enterprise (Empresa de Pesquisa Energética – EPE), presents alternatives for the resumption of the Brazilian Nuclear Plan that includes new power plants up to 2030. ELETRONUCLEAR, jointly with EPE, has worked in the selection of suitable sites for the deployment of new nuclear power plants in the Northeast, Southeast and South of the country. This work is presently in hold.

Currently, the company awaits the release of the National Energy Plan 2050 (PNE2050), which is expected to be issued by the government. This document will determine the updated Brazilian energy planning for the next decades and will establish the future contribution of nuclear energy.

The construction of nuclear power plants in Brazil has required considerable effort in qualifying domestic engineering, manufacturing, supplier and construction companies, in order to comply with the strict nuclear technology and requirements. 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.

According to the 10-year Energy Expansion Plan – PDE 2022 approved on January 24, 2014, by the Ministry of Mines and Energy, issued by the EPE – Brazil´s Energy Research Company, Angra-3 would enter in commercial operation by June 2018. However, due to the unexpected stopping of the construction, the Plant schedule is postponed and the end of the construction depends on a commercial renegotiation with the Contractors (see Article 6).

A.2.2 – Research Reactors (RR)

Brazil has 4 research reactors operating at CNEN's institutes and 1 under licensing process. For details and technical data see Annex III.

A.2.2.1 - The IEA-R1 Research Reactor

The IEA-R1 is the largest research reactor in Brazil (Figure 1), 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, and it is located at the Institute for Energy and Nuclear Research (IPEN), in the city of São Paulo. 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. After that, the IEA-R1 was uprated to 4.0 MWth (until July 27, 2011) and nowadays is operating at 4.5 MWth (from August 01, 2011) with a 64-hour cycle per week. The reactor originally used 93% enriched U-Al fuel elements. Currently, it uses 20% enriched uranium (U3O8-Al and U3Si2-Al) fuel that is produced and fabricated at IPEN. The reactor is operated and maintained by the Research Reactor Center (CRPq) at IPEN, São Paulo, which is also responsible for irradiation and other services.


Fig.1 - IEA-R1 – Pool of Reactor and Reactor Building

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 institutes also use it for academic and technological research. The main applications of the reactor is 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 I-131, P-32, Au-198, Na-24, S-35, Cr-51 and labeled compounds for medical use. After 1980, it started producing 99mTc generator kits from the fission of 99Mo imported from Canada. This production is continuously increasing, with the current rate of about 17,000 Ci of 99mTC per year. The 99mTc 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 I-131, P-32, Cr-51 and Sm-153 are also produced at IPEN.

Since 2001, a concentrated effort has been made in order to upgrade the reactor power to 4.0 - 4.5 MWth and 5 MWth by 2015. One of the reasons for this decision was to produce 99Mo at IPEN, thus minimizing the dependence on the international market.

A.2.2.2 - The IPR-R1 Research Reactor

The IPR-R1 TRIGA Mark I is a pool type Reactor and has been operating for 56 years at Nuclear Technology Development Center (CDTN), at Campus of Federal University of Minas Gerais (UFMG), in Belo Horizonte. The IPR-R1 is a pool type nuclear research reactor, with an open water surface and the core has a cylindrical configuration (Figure 2). The first criticality was achieved in November 1960 and operates at 100 kW and under demand. The integrated burn-up of the reactor since its first criticality is about 2 GW.h. Due to the low nominal power, spent fuel is far from being a problem, except for ageing concerns.

There was not fuel element replacement so far. Some laboratories, which give support to the IPR-R1, were renewed especially for increasing and improving the reactor applications. The IPR-R1 is mainly used for neutron activation analysis, experiments and applied research, as well as for the production of some radioisotopes, like Co-60, Au-198, Ir-192, Mn-56, Na-24 etc, that are used in the stainless steel industry, and environmental research activities. Additionally it is also employed for training purposes, including the Brazilian NPP operators.

Fig.2 - IPR-R1 – Control Room and NPP Operator Training Course

A.2.2.3 - Argonauta Research Reactor

The third Brazilian RR is named Argonauta (Figure 3), and is located at the Institute of Nuclear Engineering (IEN) on the campus of the Federal University of Rio de Janeiro, in the city of Rio de Janeiro. The first criticality of the reactor was reached in February of 1965.

The reactor is a pool type and can operate at a maximum power of 1kW during one hour or 500 W continuously. It is usually operated in the range of 170 to 340 W. The accumulated burnup of the reactor since its first criticality is less than 1% and due to its low nominal power, storage of spent fuel is not a problem. It is used for training purposes, research, samples irradiation and for the production of some radiotracers for industrial use.

Fig.3 - IEN-R1-Argonauta

A.2.2.4 - IPEN/MB-01 Research Reactor

The most recent Brazilian RR is IPEN/MB-01 (Figure 4), also located at the Institute for Energy and Nuclear Research (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 November 9, 1988. From that date to March 2011, the reactor operated more than 2,587 times in order 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 × 108 n/cm2.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 UO2 pellets inside.

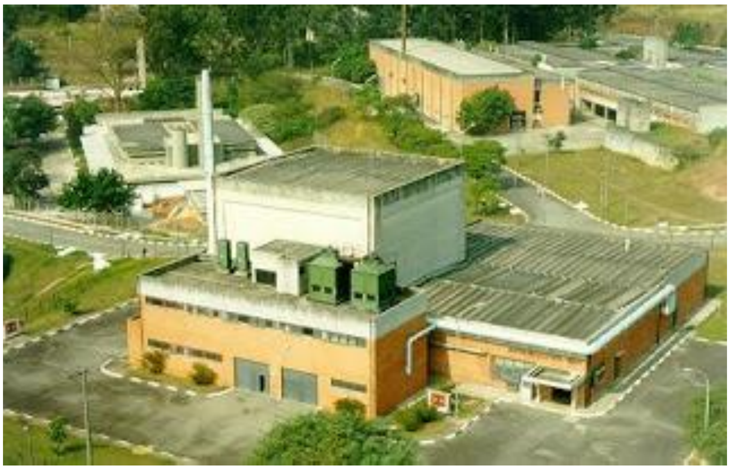

Fig.4- IPEN/MB-01-Research Reactor

The pins are manually inserted into a perforated matrix plane, making it possible to have 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 rod 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.

Although the Brazilian Research Reactors are used for different purposes, all the operations shall be done by operators licensed by the Regulatory Body (DRS/CNEN).

A.2.2.5 - The Brazilian Multipurpose Research Reactor – The RMB Project

Brazil has an ongoing project to build a Multipurpose Research Reactor (RMB), open pool type with a primary cooling system through the core. With a maximum power of 30 megawatts and powered by uranium silicate enriched up to 19.9%, it will have a neutron flux of over 2x1014 neutrons per square centimeter per second. Upon completion of its conceptual project, the reactor site was chosen and environmental impact assessments were already conducted. CNEN and IBAMA have issued the Local Approval in 2015. The Australian research reactor OPAL (Open Pool Australian Light water Reactor) projected by Argentina and built in Australia are being used as initial references for the RMB project. The basic engineering projects are under way, benefiting of the cooperation with Argentina, see Annex III.

This reactor will enable the production of radioisotopes for application in medicine, industry and environment; irradiation testing of advanced nuclear fuels; irradiation and materials testing and, if possible, to conduct fundamental scientific research with a beam of neutrons in various fields of knowledge. The layout can be seen bellow in Figure 5.

Concerning the treatment and storage of radioactive waste, a dedicated facility will be constructed to the handling, processing and safe storage of all radioactive waste produced by the multipurpose research reactor. The waste storage facility has been designed to accommodate all the low- and intermediate-level waste produced throughout the whole RMB operational life, set in 50 years.

Fig.5 - RBM Project – Layout of the main buildings

For the spent fuel elements, the RMB design will also have space to store all the produced material during the reactor lifetime of 50 years. In addition, the holding time of this irradiated fuel can span more 50 years, reaching a total storage time of 100 years.

A.2.4 Other Nuclear Installations

Brazil has established a nuclear power utility / engineering company Eletrobrás Termonuclear S. A. (ELETRONUCLEAR), a heavy components manufacturer, Nuclebrás Equipamentos Pesados (Nuclebrás Heavy Equipment - NUCLEP), a nuclear fuel manufacturing plant (Fábrica de Combustível Nuclear - FCN) and a yellow-cake production plant belonging to Indústrias Nucleares do Brasil (Nuclear Industries of Brazil - INB). Brazil has also the technology for Uranium conversion and enrichment, but, up to now, have done it in a small scale. There are also private engineering companies, research and development (R&D) institutes and universities devoted to nuclear power development. Over 15,000 individuals are involved in these activities. Brazil ranks sixth in world Uranium ore reserves, which amounts to approximate 310,000 t U_3O_8 in situ, recoverable at low costs.

Related to the nuclear fuel cycle, Uranium mining activities developed in the mine of Caetité have had an annual output of 400 tons of yellow cake, which is enough to meet the needs of both Angra 1 and Angra 2. Reconversion, pellet production and fuel fabrication for both plants is performed 100% in Brazil by INB. The enrichment facility in operation, Resende, has an installed capacity that accounts for 6% of the fuel used in the two power plants. Whereas full capacity in the enrichment process at national level has not yet been achieved, the goal of the Nuclear Industries of Brazil (INB) continues to be achieving self-sufficiency, as is already the case in the subsequent phases of the nuclear fuel cycle.

A.3. Commitment to the Nuclear Safety

Brazil was always committed to conduct its nuclear program in compliance with its own safety regulations and best international practices. Brazil has participated actively in the development of the Convention on Nuclear Safety, and has signed, ratified and implemented it since the first review meeting.

The National Reports presented until today have demonstrated compliance with the Convention objectives. The reviews, comments and recommendations in the various review meetings have assisted Brazil in improving even further the level of safety.

Both Brazilian Regulator (CNEN) and Operator (ETN) have actively participated in international forums or events related to nuclear safety. During 2015 Eletronuclear created a Safety Oversight Committee to do an independent assessment of the NPP’s safety.

Due to this approach, the Brazilian installations have never had a serious safety problem, although continuous improvement in safety is being a permanent goal. There are always partially solved or new safety related issues to be worked out, mainly after Fukushima accident, as will be showed in the present Report.

A.4. Structure of the National Report

This Seventh National Report has been prepared by Federal Republic of Brazil to meet the requirements of Article 5 of the Convention on Nuclear Safety[1]. In the first part it describes the national nuclear program, the nuclear installations involved according to the Convention’s definition and the measures taken to fulfill the obligations and follows the new Guidelines Regarding National Reports (INFCIRC572/Rev5/Jan2015)[2]. In addition, Brazil has used a number of other sources to present information related to the compliance with the convention (CNS). These include:

1) Summary Report of the President of the Sixth Review Meeting, regarding the key safety issues discussed at the Sixth review meeting;

2) Report of the President of the Sixth Review Meeting, regarding the key safety issues discussed at the Sixth review meeting;

3) The Vienna Declaration on Nuclear Safety: On principles for implementation of objective of the Convention on Nuclear Safety to prevent accidents and mitigate radiological consequences;
4) The Template to Support the drafting of National Report under the Convention on Nuclear Safety referring to relevant IAEA Safety Requirements;
5) Additional recommendations for the preparation of National Reports for the 7th Review Meeting;
6) Generic Safety Observations Report – Report of the IAEA Secretariat to the Seventh Review Meeting of Contracting Parties to the Convention on Nuclear Safety; and the
7) Written and verbal questions raised (and the answers given) on the Brazilian Report to Sixth Meeting of Convention and on the presentation made at the review meeting in April 2014.

Part B presents a summary of the national report, highlighting the main safety issues, and addressing the recommendations from previous meeting to all Parties and especially to Brazil. Part C presents an article-by-article review of the situation in Brazil, highlighting the new information related to the period 2013-2015. Following the approach used since the first reports the Seventh National Report of Brazil has been prepared as a self-standing document, with some repetition of the information provided in the previous Reports so that the reviewers do not have to consult frequently the previous documents. An additional Part D was prepared summarizing the current status of the Action Plan related to the implementation of lessons learned from the Fukushima accident.

Since Brazil has only two nuclear power plants in operation, more plant specific information is provided in the report than is recommended in the new Guidelines [2]. This was purposely done for the benefit of the reader not familiar with the current Brazilian situation.

The report also includes three annexes providing more detailed information on the nuclear installations, the Brazilian nuclear legislation and regulations, and general information about research reactors.

B. Summary

B.1 Important safety issues

Below are presented updated information related to some important safety issues reported in the Sixth Brazilian National Report:

1) The independence of the regulatory body: As mentioned in previous Reports, a draft legislation proposing the creation of an Independent Agency was prepared by CNEN and was under review by the relevant ministries. Due to political changes in Brazil, in 2015, there were some changes in high level organizational positions in CNEN and in INB. This fact led the new top managers to ask back the draft legislation for a revaluation. In this context, CNEN is proposing the creation an interministerial group for discussion and review of the current Brazilian Nuclear Program, including a discussion of the most appropriate model for a Brazilian Nuclear Regulatory Agency. So this subject is still pending. (See Article 8(2))

2) The situation of PSA of Angra 1 and Angra 2: This item has progressed significantly, as described in Article 14(1). All planned studies for Angra 2 (fire, shutdown, external events and seismic, level 2) have been completed and verified in December 2015. (See Article 14(1))

3) Periodical Safety Review (PSR): since the first PSR, completed in 2005 for Angra 1, it has become an established process. The first PSR for Angra 2, covering the first 10 years of plant operation, was completed in November, 2012, and the second Angra 1 PSR, in July of 2014. (See Article 14(1))

4) Updating of the design of Angra 3: All safety relevant differences of the newest versions of the German Plants (country supplier of the technology), inputs from Angra 2 operational experience, other standards required by CNEN as well as lessons learned from the Fukushima event are being incorporated to the Angra 3 design. A full scope of PSA studies for the design phase (internal events and flooding, fire, shutdown, external events and seismic, level 2) is in the final phase of development. A development of a new Digital I&C Systems is undergoing by Areva. (See Article 6, 14(1))

5) The implementation of a quality management system at CNEN: in the period the DRS contracted a specialist organization to map all its processes. This work finished in the mid of 2015. Particularly in the General Coordination for Reactors and Fuel Cycle (CGRC) the routine

activities are procedural. In the 2012-2015 period, procedures for induction and initial training of new employees and retraining for the staff were developed. Also the procedure for safety assessment was updated. There is still work to be performed to establish an integrated program, although many of the elements of quality management have already been implemented for many years so far. (See Article 8)

6) <u>Fukushima Response Plan</u>. As for the entire nuclear industry the most important safety issues in the 2013 – 2015 period were the planning and implementation of actions in response to the Fukushima accident (see item B.5 and section D).

7) <u>The consideration of severe accidents in the plant analysis and procedures</u>. This item has progressed significantly, as described in Article 14(1).

8) <u>Simulator status</u>. The full scope simulator and its training documentation for Angra 1 NPP, were completed in June 2015, including the training of instructors. (See Articles 6, 11 and 12).

9) <u>Licensing of new sites for new plants</u>. This issue is on hold since no application for new sites is anticipated in the near future. During the 2013-2015 period CNEN has issued the Site Approval for a Multiprpoposal Research Reactor and for an Independent Interim Storage of Spent Fuel which are located in previous approved sites for other installations. (See Article 17)

10) <u>Spent fuel storage.</u> The policy adopted with regard to spent fuel from nuclear power plants is to keep the fuel in safe storage until a technical, economic and political decision is reached about reprocessing and recycling the fuel, or disposing it as such. Therefore, spent fuel is not considered radioactive waste in the sense of this Convention. The spent fuel storage capacity of the pools of the plants is limited and, according to the design of these plants, the fuel assemblies stored for a longer time have to be transferred for complementary storage facilities. The exhaustion of the storage capacity of the pools, in a recent estimate, is expected to 2021. A Dry Type Spent Fuel Complementary Storage Unit of CNAAA, called UAS started a licensing process. (See Article 19)

11) <u>Emergency management</u>. Lessons learned from the Fukushima event have indicated the need of more investment in the area of Emergency Planning, as for instance, upgrading of the emergency centers and increasing the realism of the exercises. An Action Plan is undergoing to address these new insights. (See Article 19)

12) The assessment of safety culture. This is a continuous program. It has been carried out periodically by ELETRONUCLEAR, since the occurrence of the first company safety culture self-assessment in 1999, with the assistance of the IAEA. Further safety culture assessment was included in the 2011 OSART mission in Angra 2 NPP by IAEA decision, despite the company request of performing a separate SCART mission. Eletronuclear planned for 2016 an IAEA workshop on fostering and maintaining safety culture during relevant organizational changes. (See Article 19 and Article 8(1).9 for aspect related to Regulatory Body)

13) Ageing management and life extension. Programs for ageing management are in place in both Angra 1 and Angra 2 Plants and are being expanded to meet present-day requirements. In particular, for Angra 1, a large program is being implemented with the support of the Plant Designer, to allow application for life extension in 2019-2020 (end of original lifetime is 2024). The performed replacement of Steam Generators and RPV head are part of this program. ETN asked for an IAEA Pre-SALTO Mission in order to evaluate its capacity to develop this task. (See Article 14 (2))

B.2. Future safety activities

Future safety activities relate mainly to:

- Long Term Operation (LTO) and ageing management: Angra 1 NPP is 32 years old and ETN will face a huge task to demonstrate that the plant can run for 10 to 20 years more. Consequently CNEN will have to prepare itself to review the License Renewal application. (see item b.3 13), Articles 6, 7, 14 and 19);

- Knowledge management – maintain competence and knowledge. (See item B.3.5 and Article 8);

- Completion of the Fukushima Response Plan. (See item B.5 and Article 8);

- Completion of design and construction of Angra 3 power plant and the associated licensing process; (See items B.1 4) and B.3 7), Articles 6, 7, 8, 9, 11, 16, 17 and 18);

- Finish the Second RPS of Angra 1 assessment; (See item B.1 3) and Article 6 and 8);

- Development and licensing of new digital control and protection systems and the computerized control room. (See items B.1 4) and B.3 7), Articles 6, 8, 12, 14 and 18).

B.3. Topics from previous meeting

Important topics from previous meetings that have some implication for Brazil are the following:

1. The independence of the regulatory body: See item B.1 and Article 8 (2).

2. Transparency: CNEN is a governmental organization and as such is subject to Access to Information Act (Law 12.527/11), this law regulate the right of the public to acess information and establishes the principle of maximum disclosure of information held by public authorities, and secrecy as an exception. The exceptions are linked with proprietary information, security-related information and sensitive information. (See Article 7(2)(ii) B) to transparency in IBAMA and 8(1).10 to CNEN)

3. Safety Oversight within Licensees: The Operating Organization (ELETRONUCLEAR) has established a third safety committee, called Independent Safety Oversight Committee (COSIS), established at the highest company level, comprising representatives of all directorates, reporting directly to the Company Board. (see the Article 10)

4. The assessment of safety culture: see item B.1.12) above and Article 8(1).9.

5. Knowledge management – maintain competence and knowledge: CNEN started in 2013 with support of IAEA a project to capture and retain key knowledge need for regulatory process of Brazilian nuclear fuel cycle installations (Nuclear power plants, research reactors and other installations). The project encompasses three major areas: assessment of key knowledge (existing and needs), development of strategy to capture and retain key knowledge needed for the regulatory process of the nuclear fuel cycle installations in CNEN, and development and implementation of methodology (i.e. Mechanisms and tools) for identifying, capturing and disseminating lessons learned and good practices in key regulatory competence areas, see item 8(1).6 in Article 8(1) and Article 11(2) about Licensee program.

6. Quality and availability issues in the supply of materials and services: The Operanting Organization implemented an obsolescence programme. This programme includes proactive strategy for reliability and availiability, focusing on Structures, Systems and Components important to safety (SSCs), procedures to manage obsolescence and organizational arrangements for the implementation. (See Article 14 (2))

7. Instrument & Control (I&C) systems: CNEN has signed an agreement with European Commission to provide technical cooperation to improve the capacity to carry out review and assessment of the safety of digital I&C systems as part of the licensing process of Angra 3 NPP, in construction, and modernization of Angra 1 and Angra 2, in operation. This agreement is still undergoing and one of its results was a development of internal guideline for Digital I&C assessment. CNEN has been also participating in international workshops for IAEA standard revisions and workshop with NRC on activities for DI&C. (See also Article 18(2)).

8. Long Term Operation: see item B.1.13) above and Article 14(2).

9. Reduction of radioactive releases: lessons learned from the Fukushima event have indicated the need to install Hydrogen Passive Catalytic Recombiners (PAR) inside Containment and Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity in case of BDBA like core melt causing high pressure inside the containment, this action make part of the Eletronuclear Fukushima Response Plan, see item B.5, Article 18(1) and part D.

10. Severe accident management / Emergency Preparedness: (action from the Eletronuclear Fukushima Response Plan, see item B.5 and part D.

11. Bilateral Cooperation Issues and Regional Activities. CNEN has Bilateral Cooperation Agreement with Gesellschaft Für Anlagen und Reaktorsicherheit (GRS) of The Federal Republic of Germany for the exchange of Technical information and Cooperation in Regulatory and Safety Research Matters. Under this agreement three Workshops were held in the period 2013 to 2015. In 2015, CNEN started a new Project with European Commission, Project BR3.02/12 - “Support to the Nuclear Safety Regulator of Brazil” and it is dedicated to the enhancement and strengthening of the nuclear safety regulatory regime in Brazil in compliance with international criteria and practices. The Consortium RISKAUDIT IRSN/GRS was chosen by European Commission to carry out this project. This Consortium is composed of the following members: Institut de Radioprotection et de Sûreté Nucléaire (IRSN–France), Gesellschaft Für Anlagen und Reaktorsicherheit (GRS - Germany) mbH, Radiation and Nuclear Authority (STUK-Finland) and TECNATOM S.A. (Spain). (See Article 8)

12. International Cooperation between Regulatory Bodies. CNEN is a member of The Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO). The FORO is an association created in 1997 with the aim of promoting radiological, nuclear and physical

security at the highest level in the Latin American region. Today the FORO is composed of radiological and nuclear regulators from Argentina, Brazil, Chile, Colombia, Cuba, Spain, Mexico, Paraguay, Peru and Uruguay. The main objective of FORO is to provide an environment for the exchange of experiences and the development of joint activities related to common problems, in order to achieve the strengthening of the capacity and competence of its members. The FORO believes that one of the instruments for achieving its objectives is to set technical programmes which should be harmonized with the plans of the International Atomic Energy Agency. The basic pillars on which this program is based are: a common technical program that gives priority to national and regional needs, and development of a knowledge network. CNEN also has a Cooperation Agreement with USNRC in the area of safety analysis, including the use of Computational Codes (CAMP and CSARP). (See Article 8)

13. Peer Reviews. ELETRONUCLEAR has regularly requested Peer Review missions performed by the WANO and the IAEA, as they aim to identify industry best practices concerning safety and reliability in plant operation. ELETRONUCLEAR adhered to these review programs from their inception, and since 2004 has established policy of performing a complete internal (self-assessment) and external evaluation at 3-year cycles, alternating IAEA OSART and WANO Peer Reviews. In 2013, ETN asked for an IAEA Pre-SALTO Mission in order to evaluate its capacity to develop this task, see Articles 14 (2) and 19 (7).

B.4. - Additional Recommendations for the preparation of National Reports for 7Th Review meeting

B4.I. - Challenges identified by the Special Rapporteur

B4.I.1 - How to minimize gaps between Contracting Parties' safety improvements? (Articles 6, 14)

According to the Law 6.189/74, the License for construction and authorization for the operation of nuclear facilities will be conditioned to adapt to newly emerging conditions necessary for safe installation and preventing the risk of accidents arising from its operation.

CNEN Standard CNEN-NE-1.14[6] requires that the Operating Organization systematically carry out the assessment of internal operating experience as well as other plants. The operational experience should be examined in order to detect any warming signs of possible adverse trends to safety. The Operating Organization shall maintain channels of communication with designers, manufacturers and other organizations for not only the feedback of operational experience as well as obtaining, if necessary, update the changes and advice in the event of equipment or abnormal events faults.

The Operating Organization, ELETRONUCLEAR (ETN), integrates the PWR Owners Group of Westinghouse, with focus on the following objectives:

- Support safe and reliable plant operations,
- Provide an effective regulatory interface,
- Effectively leverage the resources of its members, including Westinghouse and Areva NP,
- Provide a forum for joint discussions and resolution of issues common to more than one member,
- Provide a mechanism for allocating costs and resources relative to resolution of owners group issues, whether performed Westinghouse, Areva NP, or others,
- Provide an effective interface with NEI, EPRI, INPO and other industry groups and owners groups on industry issues,
- Share best practices and lessons learned among US and International Members.

ETN is also a member of WANO and systematically peer reviews are conducted as mentioned in item B.3.13) above and Article 19(7).

Other important aspects, in our point of view, is to increase the participation of CNEN in various forums and projects, where specific subjects are discussed and its status are presented for each country. (See item B.3.11), B.3.12 and Article 8).

As a suggestion, the IAEA could organize specific discussions among regulator from countries that has the same NPP designer. For example: Workshops or meetings among “Westinghouse regulators”, “GE Regulators”, “KWU Regulators” “VVER Regulators”, and so on.

B4.I.2 - How to achieve harmonized emergency plans and response measures? *(Article 16)*

It should be noted that, due to the particular geographical location of the Angra plants, no radiological impact is expected in any neighboring countries, even in the improbable event of a major release. Notwithstanding that fact, Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological

Emergency, and a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident (See Article 16 and Annex III).

In spite of this, Brazil has sought to improve its emergency preparedness, more specifically, CNEN started in 2015 the Project BR3.01/12 supported by RiskAudit under UE assistance to:

- Advise CNEN on the selection of relevant information related to emergency situations, to be made available in CNEN's Headquarters Emergency Room in Headquarters on-line and in real time.
- Support CNEN to further enhance the functionalities of the ARGOS-BR code in order to deal with Brazilian Emergency Planning Zones (EPZs).

On the area of emergency preparedness, CGRC is an active member of the ARGOS consortium and participate on the yearly seminar to share experience with other international users.

Harmonize emergency plans and response measures are not easy tasks since there are differences among national legislations and the organizations involved in each country. In some countries there are few organizations to respond an event while in others there are a lot of them, including different governmental levels as municipality, state or federal. In spite of that a good practice could be the improvement of regional cooperations.

B4.I.3 - *How to make better use of operating and regulatory experience, and international peer review services?* (Article 19)

Brazil participates actively in the IRS and IRSRR and the operator undergoes peer review regularly, as mentioned above and has increased the number of Reports during the period 2013-2015. (See Article 19 (7)). The operational experience feedback process in Brazil comprises two complementary systems: one performed by ELETRONUCLEAR, processing both in-house and external information, and one performed by CNEN.

ELETRONUCLEAR has adhered to IAEA and Wano peer review programs from their inception, and and more recently asked for a Pre-SALTO mission as a part of its preparation for Anra 1 NPP license renewal, see table 7 and 8 in Article 19.

In 2009, an IAEA's expert reviewed the CGRC's processes against some IAEA documents related to regulatory activities. The conclusion was that the CGRC's processes were consistent with the IAEA recommendations, but there were room for improvements. At that time, 36 recommendations were done and about two third of that were already implemented. However, some are still pending, mainly those one related to standardization of some processes. The status of each subject is somehow described along this Report.

CNEN is planning to request in the near future an IRRS mission in Brazil.

As a suggestion the IAEA should discuss an improvement on the treatment of small or near missing events, to make a better use of them.

B4.I.4 - How to improve regulators' independence, safety culture, transparency and openness?

As evidenced in Article 8 (2) the regulatory function of CNEN is separated from its promotion function and it also independent from Operating Organization. As shown above, CNEN has made efforts to increase its regulatory independence. As mentioned in B.1 and Article 8 (2) there is a proposal to create an interministerial group with all organizations involved in the Brazilian Nuclear Program to review the program and in particular to discuss the better model for a fully independent nuclear regulatory body.

The better way to improve regulatory effectiveness is still the international cooperation. Benchmarking among Member States with similar Nuclear Programs would be a good practice.

B4.I.5 - How to engage all countries to commit and participate in international cooperation?

There are a lot of good IAEA's initiatives in terms of cooperation. As a suggestion for further enhancement, the IAEA should increase the participation of the developing countries as observers in peer reviews and stimulate regional cooperation.

B.4.II. Implementation of the Vienna Declaration on Nuclear Safety

B.4.II.1- *New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.*

Although new plants are not scheduled, these concepts are being incorporated into the draft standard being developed by CNEN, as a part of the EC

Project, with the support of STUK (Finland), GRS (German) and CNS (Spain), and it incorporates new concepts like Design Extension Condition and distinguishes between new design and operating plants. For future plants, the project shall include in their design basis the condition of accidents leading to core melt. Their systems and procedures must be capable to keep core cooling, to maintain the integrity of the containment and to minimize the release of fission products into the environment while keeping stable the long term plant conditions.

The development process of this new draft standard was based mainly in the following documents: **Safety of Nuclear Power Plants: Design,** *IAEA* Safety Standards Series No. NS-R-1 and its successor SSR–2/1, **Design of Reactor Containment Systems for Nuclear Power Plants,** *IAEA* Safety Standards Series No. NS-G-1.10; **Radiation Protection Aspects of Design for Nuclear Power Plants Safety Guide,** *IAEA* Safety Standards Series No. NS-G-1.13, 2005; **Deterministic Safety Analysis for Nuclear Power Plants Specific Safety Guide,** *IAEA* Safety Standards Series No. SSG-2, 2010; **Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants Specific Safety Guide,** *IAEA* Safety Standards Series No. SSG-4, 2010; **Safety of Nuclear Power Plants: Operation, IAEA Safety Standards Series No. NS-R-2; Severe Accident Management Programmes for Nuclear Power Plants Safety Guide,** *IAEA* Safety Standards Series No. NS-G-2.15, 2009; **Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants,** *Safety Standards Series No. NS-G-2.2,* 2000; **Recruitment, Qualification and Training of Personnel for Nuclear Power Plants,** *Safety Standards Series* No. NS-G-2.8, 2002 and **WENRA harmonization Issue: Emergency Operating Procedures and Severe Accident Management Guidelines,** 2005.

B.4.II.2.- *Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.*

DRS/CNEN carries out a set of activities in its regulatory control process as described in Articles 7 and 14 in order to obtain reasonable warranty that the design basis or licensing basis are adequate to promote the plant safety and protection of the public and environment. To accomplish with this objective CNEN relies in the systematic review provided by RPS and, regular peer reviews from IAEA and WANO are also part of the operator strategy. By the RPS, the operational experience, the improvements and updates implemented in the norms and standards used in licensing base are evaluated to identify possible gaps and necessary improvements in safety aspects of NPPs.

B.4.II.3.- *National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the CNS.*

The standard CNEN-NE-1.04 - Licensing of Nuclear Installations [36] requires in the item 6.5 Technical Standards and Codes that: 6.5.1 Items must be designed, manufactured, assembled, built, tested, and inspected according to standards compatible with the technical importance of the safety function to be performed. 6.5.2 In applying the requirements of section 6.5.1, Brazilian updated codes and standards should be adopted. In the absence of appropriate Brazilian standards, Codes, Guides and Recommendations of the IAEA should be used preferably, and in their absence, international standards or standards of technically developed countries, provided that such standards and regulations are accepted by CNEN.

In addition, IAEA safety documents and USNRC rules are used as the basis of the development of national standards.

B.5. Status of implementation of Fukushima Action Plan

As soon as it was identified the magnitude of the accident occurred in March, 11th 2011 at the Fukushima Daiichi Nuclear Power Station in Japan, the Board of Directors of Eletronuclear decided in March, 16th 2011 to constitute a Technical Committee, coordinated by the Presidency, counting on senior staff members of all company's Directorates, with responsibility of following the accident evolution and measures taken to control it, to follow the recommendations from international organisms related to nuclear, environmental, industrial, and radiological safety as a consequence of the accident, and also to help the Executive Board on nuclear safety related matters resulting from the event.

On April, 19th 2011, Eletronuclear responded to the World Association of Nuclear Operators Significant Operating Experience Report (WANO SOER 2011-2) issued in March 2011, including the results of the recommended verifications regarding Angra 1 and Angra 2 NPPs capability to face beyond design basis accidents, with emphasis on station black out, flooding and fire hazards.

CNEN evaluated the preliminary information about the accident occurred at the Fukushima Daiichi Nuclear Power Station in Japan and on May 13, 2011, CNEN issued a document nr. 082/11-CGRC/CNEN formally requiring Eletronuclear to develop a preliminary safety assessment report, including a specific set of technical aspects taking in account the Fukushima accident. These included:

1. Identify the major design differences between Fukushima and Angra Units;
2. Identify possible external initiating events (extreme) and the internal potential cause a common mode failure;
3. Control of concentrations of hydrogen in the containment;
4. Ensuring electricity supply emergency power;
5. Fulfillment of the requirements of station blackout;
6. Service water system, cooling chain;
7. Procedures for severe accidents;
8. Access to buildings and controlled area of the reactor after an severe accident
9. Development of Probabilistic Safety Analysis Level 1, 1 and 2;
10. Performance of "stress tests"
11. Emergency planning

Eletronuclear provided to CNEN a technical report, in July 2011, with a preliminary evaluation of the above listed topics.

Along the second half of 2011 the ETN Technical Committee referred above developed an Action Plan with planned initiatives to be developed to respond to the Fukushima event. This Plan, named Response Plan to Fukushima, was approved by the Executive Board of the company in November 2011 and shortly thereafter, submitted to CNEN, then revised in January 2013, in the light of new obtained information.

It had 56 initiatives, comprising studies and projects, divided into three areas of evaluation: protection against risk events, cooling capacity, and limitation of radiological consequences. Some of these actions were already in progress, as part of Eletronuclear's continuous safety improvement programs.

The action plan included studies and projects to be accomplished by 2016, with an estimated investment of about US$ 150 million. Eletronuclear has invested R$ 55 million Reais by the end of 2015.

On September 2011, in Madrid (Spain) the Foro-Iberoamerican (FORO), an Association of Iberoamerican Radiological & Nuclear Regulatory Authorities created in 1997, on the initiative of its member states, owners of NPPs, decided to conduct a re-evaluation of their NPPs in response to the Fukushima Daiichi accident, like Stress Tests (STs) assessments (EU stress test) carried out under the leadership of ENSREG. In this first Technical Meeting, CNEN together with CSN (Spain), ARN (Argentine) and CNSNS (Mexico) have defined the scope and methodology that was applied in the "FORO – Stress Test" (In Spanish).

On January 2012, CNEN, issued a letter, 012/12-CGRC/CNEN formally requiring Eletronuclear to develop a complementary assement in according to “FORO – Stress Test” specification.

The performance of the Stress Tests for Angra 1 and Angra 2 was completed in March 31st, 2012. Based on the Stress Tests results mobile equipment to provide additional means to withstand a prolonged Blackout, comprising diesel generators, diesel driven pumps, compressors and associated connection fixtures, were specified and purchased. This equipment is presently stored close to the Plants.

The “REPORT ON THE STRESS TEST ASSESSMENT OF THE UNITS OF THE ALMIRANTE ALVARO ALBERTO NUCLEAR POWER STATION FOR THE CONDITIONS OF THE FUKUSHIMA ACCIDENT” – DT-006/12, issued on March 29th, 2012, encompasses the two units in operation at Angra site. The evaluations have been performed engaging specialists with deep knowledge of the site characteristics and specialists in the design and dynamical behavior of each plant.

In according to procedure adopted by FORO, Brazil, Argentine, Spain and Mexico carried out a Cross-Peer-Review on the National Reports (Action Plan). On June 2012, in Buenos Aires (Argentina), Argentina, Brazil, Mexico and Spain held a technical meeting dedicated to discuss the results of the Cross-Peer-Review and submit the result to the scrutiny of other FORO Countries member that do not have nuclear power plants (Chile, Uruguay, Peru and Cuba). Finally, the joint review conducted by experts appointed by the member countries resulted in a Final Report (In Spanish). This report contain the assessment carried out in each nuclear power plant and the regulatory position regarding these assessments, as well as the implementation schedule of the improvements arising as a result of the Licensee evaluation made by or at the request of Regulatory body.

The Final Report was approved by the FORO Plenary and presented at the Second Extraordinary Meeting of the Nuclear Safety Convention dedicated to the lessons learned from Fukushima.

On June 2014, in Mexico City (Mexico), experts appointed by the member countries of the Forum (Argentine, Brazil, Mexico, Spain, Uruguay, Chile, Peru and Cuba) held the Third Technical Meeting dedicated to follow-up to verify the status of implementation of improvements includes in National Reports (Actions Plan).

Eletronuclear has also carried out a strong exchange of technical information participating and/or collaborating with many different Brazilian organizations (government, regulator, technical support organizations, vendors, service providers and other stakeholders) involved in maintaining and enhancing nuclear safety, and efforts made to achieve and maintain or strengthen a high level of nuclear safety in these organizations.

In addition Eletronuclear participated and in certain instances led discussions through the media and directly with the several organizations, including governmental and public in general through seminars and open meetings. Besides, international organizations, such as GDFSuez, AREVA, Westinghouse, Rosatom and others were invited to discuss with Eletronuclear professionals aspects related to the Fukushima event and improvements needed.

Monitoring of ongoing initiatives in other nuclear power plants, together with other international organizations, indicates the adequate alignment of actions undertaken by Eletronuclear in response to the accident at Fukushima Daiichi to what has been practiced by the nuclear industry worldwide.

For this Seventh National Report, the areas of assessment were converted into topics indicated by the Convention guidance documents for the Extraordinary Meeting of 2012 and their current status of implementation is presented in an additional part D.

B.6. Conclusions

At the time of the sixth review meeting of the Nuclear Safety Convention, Brazil had demonstrated that the Brazilian nuclear power program and the related nuclear installations met the objectives of the Convention. During the period of 2013 – 2015, Brazil has continued the operation of Angra 1 and Angra 2 in accordance with the same safety principles.

Based on the safety performance of the nuclear power plants in Brazil, and considering the information provided in this Seventh National Report, the Brazilian nuclear organizations consider that its nuclear program has:

- Achieved and maintained a high level of nuclear safety in its nuclear installations;
- Established and maintained effective defenses in its nuclear installations 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.
- Improved the conditions for on-site and off-site management of emergency situations in alignment of actions undertaken in response to the accident at Fukushima by the international nuclear industry.

Therefore, Brazil considers that its nuclear program related to nuclear installations has met and continues to meet the objective of the Convention on Nuclear Safety.

C. REPORTING ARTICLE BY ARTICLE

ARTICLE 6 – EXISTING NUCLEAR INSTALLATIONS

Brazil has two nuclear power plants in operation (Angra1, 640 MWe gross/610 MWe net, 2-loop PWR and Angra 2, 1370 MWe gross/1300 MWe net, 4-loop PWR). A third plant (Angra 3, 1400 MWe gross/1330 MW net, PWR, similar to Angra 2) had the construction postponed in the mid-eighties. By a Governmental decision the Angra 3 NPP project has resumed, and construction activities restarted in 2009. The Construction Permit was granted by CNEN in May 2010. Because of contractor problems and a political decision, construction was interrupted again in September 2015 (see section 6.3 of this Article).

Angra 1, 2 and 3 NPPs are located at a common site, near the city of Angra dos Reis, about 130 km from Rio de Janeiro. More details about these units can be found in Annex 1, as well as at the ELETRONUCLEAR home page www.eletronuclear.gov.br. In addition, the governmental decision included a discussion for a new nuclear power plant site that would add up to 4.000 MWe to the national electrical grid by the year 2030.

6.1 - Angra 1

Site preparation for Angra 1, the first Brazilian nuclear unit, started in 1970 under the responsibility of FURNAS Centrais Elétricas SA. The actual construction of the plant began, however, 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. For the erection work, Westinghouse contracted a Brazilian company, Empresa Brasileira de Engenharia S.A. (EBE). For the supply of the containment steel structure and the civil works not included in the Westinghouse contract, FURNAS contracted directly, respectively the Chicago Bridge & Iron Company and Construtora Norberto Odebrecht S.A, a Brazilian contractor, which eventually also became contractor of the civil works of Angra 2.

CNEN granted the Construction License for the plant in 1974 and the Operating Licence 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 absorbed all the operating personnel of

FURNAS, and part of its engineering staff, and the personnel of the engineering and design company Nuclebrás Engenharia (NUCLEN).

Since 2009, when Angra 1 Steam Generators were successfully replaced after an outage of 5 month, the power limitation of 80% to slow down tube degradation imposed by operation of the older SGs was no longer necessary and the plant returned to the grid with a new gross unit power of 640 MWe. The Plant has been since then operating without any problems associated with the new SG, with good trends of the WANO Availability Performance Indicator, as shown in Table 1 below.

Table 1 - Angra 1 Plant Availability

Year	Energy Generation (MWh)	Accumulated Energy (MWh)	Plant Availability (%)
2001	3.853.499,20	37.499.392,40	82,94
2002	3.995.104,00	41.444.496,40	86,35
2003	3.326.101,30	44.770.596,70	73,30
2004	4.124.759,20	48.895.356,90	90,05
2005	3.731.189,70	52.626.546,60	81,61
2006	3.399.426,40	56.025.973,00	74,88
2007	2.708.724,00	58.734.697,00	60,65
2008	3.515.485,90	62.250.182,90	77,49
2009	2.821.494,71	65.071.677,61	58,01
2010	4.263.040,75	69.334.717,90	77,26
2011	4.654.487,03	73.989.204,93	89,58
2012	5.395.561,26	79.384.766,19	97,26
2013	3.947.626,43	83.299.601,58	71,20
2014	4.989.574,57	88.289.176,15	88,71
2015	4.102.089,90	92.391.266,06	73,68

Angra 1 current license expires in 2024 and Eletronuclear started the negotiation with CNEN focusing the preparation for a license renewal application of Angra 1. The basis will be CNEN-NE-1.04[3] and CNEN-NE-1.26[7], US NRC 10 CFR 54, NUREG-1801 and NEI 95.10 as well as the IAEA NS-G-2.12.

6.1.1 - Main safety improvements at Angra 1

The original steam generators, a Westinghouse D3 model, presented progressive tube degradation. Nearly 20% of the tubes were plugged at the time of replacement. This problem required periodic ECT inspections of all generators tubes and repair (sleeving) or plugging of tubes, which yielded longer refueling outages or additional outages specifically for tube testing and repair. The new steam generators, also designed by Westinghouse and assembled at the Brazilian company NUCLEP, are larger than the old ones, having 5428 tubes each (instead of 4674), and were manufactured with Inconel 690 instead of Inconel 600. The feedwater nozzles were moved to the upper part of the steam generators and the thermal power output was increased from 941 to 1000 MWth per unit. In 2009, Angra 1 replaced its steam generators.

In this review period, the most significant modification in the Angra 1 plant was the replacement Reactor Pressure Vessel (RPV) head in early 2013, based on results of the industry indicating that some of its materials, mainly Inconel 600, were susceptible to primary water stress corrosion cracking. This replacement was preventively done once neither reportable flaws nor leakage was detected in the RPV head.

In addition to the Steam Generator and RPV head replacements, several programs for improvement of safety and reliability listed in the previous National Reports, and confirmed by the findings of the Angra 1 Periodic Safety Review (PSR), were concluded, as follows:

- Program to minimize Inconel 600 alloy stress corrosion cracking problems, substituting or repairing/reinforcing equipment/components using Inconel 600 in welds or parts, as for instance follow up of condition, preservation and planning for replacement of the Reactor Pressure Vessel (RPV) head;
- Reduction of generation and volume of radioactive waste, as well as enlargement of storage capacity for this waste;
- Reduction of snubbers;
- Obsolescence related activities, such as modernization of I&C and modernization of fire detection system;
- Evaluation and monitoring of thickness of secondary side energy-carrying pipes.

Some selected plant modifications, important for safety and/or reliability implemented in the period were:

- Installation of a digital main feedwater control system (Ovation® Digital I&C Platform) in 2013;
- Replacement of the full Reactor Protection System electronic circuit cards due to ageing;
- Replacement/repsir of the rubber coating application in the boxes of the condenser;
- Upgrade of Turbine Control System (Ovation® Digital I&C Platform);

- Installation of 20 Hydrogen Passive Catalytic Recombiners (PAR) inside Containment (action from the Eletronuclear Fukushima Response Plan);
- Use of adavanced fuel 16 NGF, with cladding of zirlo;
- Replacement of the electronic cards of the Control Rods Drive Mechanism System and the sequencers of emergency diesel generators.

Other noteworthy achievements in the 2013 – 2015 period were:

- Implementation of the new Technical Specification for Angra 1, version in Portuguese, following the format and content of NUREG 1431;
- Development, installation, testing and commissioning of the new Angra 1 full scope simulator;
- Completion of the review of the Environment Radiological Control Manuals;
- Completion of the stages of development, training and preparation for implementation of the Angra 1 Severe Accident Management Guidelines (SAMG), version in Portuguese - (action from the ETN Fukushima Response Plan);
- Completion of the second Angra 1 PSR in July 2014, covering the period 2004 -2013(see Article 14);
- Updating of Emergency Events Classification, using as reference the NEI 99-01, “Methodology for Development of Emergency Action Levels” Revision 5, 2008.

Human performance follow-up and improvement committees established during the previous review period continue to provide initial and refreshing training on the use of human error prevention tools as well to monitor trends in personnel performance, as can be seen in Article 12.

In March 2014, IBAMA issued the unified Operation License nr. 1217/2014 for the Almirante Álvaro Alberto Nuclear Power Site – CNAAA authorizing the operation of Angra 1 and Angra 2 NPPs, as well as the Waste Management Center – CGR and ancillary facilities for ten years. For more details concerning this process, see Article 17(2).

6.2 - 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, at present Areva ANP.

Considering that one of the objectives of the Agreement was a high degree of domestic participation, Brazilian-German engineering company Nuclebrás Engenharia S.A. - NUCLEN (now ELETRONUCLEAR, after merging with the nuclear branch 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.

Furthermore, great efforts were dedicated to qualify Brazilian engineering firms and local industry to comply with the strict standards of nuclear technology.

Angra 2 civil works started in 1976. However, from 1983 on, the project suffered a gradual slowdown due to financial resources reduction. In 1994, the financial resources necessary for its completion were defined and in 1995, a bid was called for the electromechanical erection which started in January 1996.

Hot trial operation was started in September 1999. In March 2000, after receiving from CNEN the Authorization for Initial Operation (AOI), initial core load started, followed by initial criticality on 17 July 2000, and first connection to the grid on 21 July 2000. The power tests phase was completed in November 2000. Angra 2 NPP has been operating at full power since mid-November 2000, and began the commercial operation on February 1st, 2001.

Due to legal constraints imposed by the Brazilian Public Ministry related to the environmental licensing (see Article 7(2), Angra 2 was operating based on an Authorization for Initial Operation (AOI) issued by CNEN that was extended for periods of 8 months. On June 15th 2011, CNEN issued the Authorization for Permanent Operation with conditions to be fulfilled during operating life. One of these conditions was the performance of a Periodic Safety Review (PSR) each 10 years, as stated at CNEN-NE-1.26[7]. The first PSR was started in July 2011 and concluded in November 2012 with the issuance of the Global Report of Periodic Safety Review for CNEN approval.

Angra 2 operational record for the period 2001/2015, as measured by the WANO Availability indicator, is shown in Table 2 below.

As reported in the previous National Reports, and illustrated in Table 2, Angra 2 had a very good performance in its first three years of operation. In the two subsequent years, the plant performance has declined due to a series of problems with major secondary side components, such as main transformer, electric generator, main condenser and the motors of the main recirculating water pumps.

These problems have been addressed, their root causes have been identified and measures for their elimination have been or are being implemented. The positive trend resulting from the actions taken is reflected in Table 2 above by the plant availability factor, which has shown steady improvement beginning in 2006 reaching values of the best operating plants in the following years.

Table 2 - Angra 2 Plant Availability

Year	Energy Generation (MWh)	Accumulated Energy (MWh)	Plant Availability (%)
2001	10.498.432,70	13.121.084,70	93,90
2002	9.841.746,20	22.962.830,90	91,50
2003	10.009.936,10	32.972.767,00	91,30
2004	7.427.332,20	40.400.099,20	74,60
2005	6.121.765,30	46.521.864,50	64,50
2006	10.369.983,90	56.891.848,40	89,00
2007	9.656.675,00	66.548.523,40	85,73
2008	10.488.288,90	77.036.812,30	90,11
2009	10.153.593,49	87.190.405,79	92,24
2010	10.280.766,54	97.471.172,56	88,09
2011	10.989.764,07	108.460.936,63	99,09
2012	10.645.229,04	119.106.165,67	92,06
2013	10.692.555,33	129.798.721,00	90,15
2014	10.444.932,54	140.243.653,54	88,83
2015	10.707.070,63	150.950.724,17	90,60

6.2.1 - Main safety improvements at Angra 2

Angra 2 NPP belongs to the 1300 MWe Siemens-KWU PWR family, with 4 x 50% redundant safety systems, with consequent physical separation of trains. The plant has also a high degree of automation of the reactor control, limitation and protection systems, complying with the 30 minutes non-intervention rule and a very reliable emergency power supply system, consisting of 2 independent sets of 4 Diesel generators each. A separate, fully protected building is provided to host the Emergency Control Room and the required water and energy (batteries and 2nd set of Diesel generators) supplies to shut down and maintain the cooling of the plant, in case of major natural or man-made hazards.

Angra 2 status is the one of a modern NPP, as a result of a consistent program of upgrading that has been carried on along the construction years, with implementation of all safety related modifications added to the German reference plant Grafenrheinfeld, as well as most improvements built in the newest German KONVOI plant series.

Several ongoing programs for improvement of safety and reliability being conducted at the Angra 2 Plant are:

- Evaluation and planning for substitution of electrical and I&C equipment due to obsolescence;

- Reliability Centered Maintenance program;
- Improvement of operating performance of major plant equipment including identification and elimination of design and maintenance weaknesses;
- Improving the calculation of the thermal power through reconciliation of data.

Some selected modifications, important to safety and/or reliability, in the period 2013 – 2015, are:

- Completion of interconnection of the bus bars of the Emergency Power Supply D2 (power supply by small Diesel Generator set) with the bus bars of the Emergency Power Supply D1 (power supply by the large Diesel Generator set) **-** (action from the ETN Fukushima Response Plan);
- Installation of Hydrogen Passive Catalytic Recombiners (PAR) inside the Angra 2 Containment (action from the ETN Fukushima Response Plan);
- Replacement of the existing Reactor Control system (non-safety) by a digital Control System (Teleperm XS);
- Enlarging the Bleed capacity of the reactor coolant system Bleed & Feed equipment, including dedicated I&C and power supply for better response to beyond design events - (action from the ETN Fukushima Response Plan);
- Modernization of the RPV level measurement;
- Modernization of the aeroball measuring system.

Other noteworthy achievements in the 2013 -2015 period are:

- An expanded PSA scope comprising studies for Shutdown, Internal Fire, External events and Seismic and Level 2, was completed in December 2015, through a contract with the Plant Supplier. The Angra 2 Internal events, level 1+ PSA study has undergone its third revision. More details are given in Article 14(1);
- The development, testing and exercise for integration with Emergency Planning of the Severe Accident Management Guidelines (SAMG) of Angra 2 was completed in December 2015 (action from the ETN Fukushima Response Plan).

In the area of Operational Experience the systematic for collection, trending and reporting of minor events and near-events has been developed and implemented for both Plants. The established external operational experience committees evaluate significant event reports from USNRC, WANO, INPO and VGB as well as Plant Supplier Information Notes making recommendations for plant implementation when pertinent.

WANO sponsored best practices from the nuclear industry, such as Operational Decision Making procedures, as well as comprehensive familiarization with human performance error prevention tools and training in their use have also been developed and implemented for both plants.

A hardware and software upgrade of Angra 2 full scope simulator is undergoing and is scheduled for 2016, including the substitution of the old hardware and former operational system as well as the models of the most relevant systems which has been completed successfully after a long Verification &Validation period.

6.3 – Angra 3

In June 2007 the Federal Government through its National Council for Energy Planning approved the restart of construction of Angra 3 after a 23-year interruption.

For the actual restart of construction, two licenses were 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) Report.

Concerning the Construction License, in accordance with the original concept, Angra 3 was planned to be a twin plant of Angra 2, using the same licensing bases. This concept had been submitted to and approved by the Brazilian nuclear licensing authority – CNEN, considering “Angra 2 as-built” as the reference plant for Angra 3. This concept was used by ELETRONUCLEAR as basis for preparation of the first version of the Angra 3 PSAR, submitted to CNEN.

Later in 2008, along the process of evaluation of the Angra 3 PSAR for issuance of the Construction License, the original licensing bases were questioned by CNEN, and a review of the applicable regulations was requested, with the goal of comparing the original requirements with the corresponding current requirements.

As a result of this review it was identified that in most of the cases the original requirements did not change. Where there were changes, in most of the cases it could be shown that the design in accordance to the original requirements allowed sufficient margins to accommodate the new requirements. In the case where the design did not fulfil the new requirements plant modifications were done.

The PSAR has been revised to include the results of the regulation review and, after several rounds of evaluation, the plant safety concept was considered acceptable. Angra 3 Limited Construction License was issued by CNEN in 1st of July of 2009.

On May 25th, 2010 CNEN issued the Construction License with a list of 56 Conditions to be fulfilled before the Authorization for Initial Operation.

These conditions are splited in eight areas as follows:

[1] Six (6) general conditions

[2] One (1) condition related to civil construction area

[3] Eight (8) conditions related to mechanical area

[4] Three (3) conditions related to electrical area;

[5] Six (6) conditions related to I&C area

[6] Four (4) conditions related to safety analysis area

[7] One (1) condition related to human factors engineering

[8] One (1) condition related to physical protection

Some highlights of these conditions are:

- Submittal of the test procedures including the acceptance criteria and commissioning programs, before the start of each test.
- Submittal of the detailed design for each of the safety related buildings, for CNEN approval and release, before construction begins;
- Availability of an Angra 3 specific full scope simulator for operator training before core loading;
- Development of Angra 3 specific levels 1 and 2 PSA that shall be functional before Initial Operation;
- Submittal for approval of the concept for control of Severe Accidents.

The preparation of Final Safety Analysis Report, including a new chapter 19 (Severe Accidents and Probabilistic Safety Analysis), is under way at ELETRONUCLEAR, in order to be submitted to CNEN two years before the Authorization for Initial Operation.

The training of plant operators was already initiated.

With respect to Angra 3 environmental license, IBAMA proposed in 1999 the Terms of Reference for the preparation of the development of the EIA/RIMA. The EIA/RIMA Reports for Angra 3 where prepared under the responsibility of ELETRONUCLEAR and submitted to IBAMA in May 2005.

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

The Preliminary License for Angra 3 was issued by IBAMA, through Preliminary License No. 279/08 of 24th of July 2008, subjected to 65 conditions, as follows:

- 5 conditions of general character, related to aspects of the project and obligations of the Owner, such as environmental monitoring, conservation areas, etc;
- 60 specific conditions, related to:
    - Support to the surrounding Counties directly affected by the project, in providing the infrastructure needed to accommodate the increase in permanent and variable population;
    - Submittal of the Basic Environmental Plan, that allows follow up of the construction activities relative to control and monitoring of the impacts of the construction on the environment;
    - Start up of the planning for development of a Final Radwaste Repository, to dispose the plant radioactive waste;
    - Submittal of a regional “Insertion Plan” of social character, with the goal of providing better living conditions for the population of the areas affected by the project.

The content of these conditions emphasizes planning and preparation for the project installation phase.

IBAMA issued the Installation License No.591/09 for the Angra 3 project in the 5th of March 2009, with additional conditions, as follows:

5 general conditions related to aspects of the project and obligations of the Owner (same as for the Preliminary License);

46 specific conditions related basically to meeting of the planning and deadlines presented by the Owner in response to the conditions of the Preliminary License.

In December 2009, IBAMA issued the first amendment to the Angra 3 Installation License Nr.591/09 including a new specific requirement related to the Paraty-Cunha Road implementation.

At the time of the issuing of the combined environmental operational licence for the site, the specific Installation License No.591/09 was revised again and generating a second amendment with set of 33 exclusive new requirements for Angra 3 plant construction.

The Brazilian environmental laws establish that at least 0.5% of the overall cost of a project with potential harmful effects on society and environment shall go to environmental compensatory measures. It is expected that of the order of 4-5% of the total cost of the Angra 3 project will be spent to comply with the above referred conditions.

Unfortunately, in September 2015, the Angra 3 construction was stopped as a result of a bribery investigation being carried out which involves several national main construction contractors, including those contracted to perform the electromechanical erection of this unit. Until all these matters are clarified the activities for construction are frozen.

The present activities at the Angra 3 construction site are associated with the preservation of the buildings partially constructed and the equipment already installed as well as the storage and preservation of the national and international supplies being delivered. Additionally, activities related to maintenance and storage of the regulatory documentation are in place.

Concerning the status of construction of the plant first concrete for the reactor base plate was poured following CNEN issuing of the Construction License, on June 1st, 2010. By December 2015 around 70% of the civil construction work has been completed. At this date the reactor building was built up to the elevation of 19 meters high. The spherical steel containment bottom part has floated for positioning and securing in place and its erection is 50% done.

The turbine building is close to completion with its crane already installed still missing are the condensers. The installation of the tanks that are civil construction dependent is being done. At the moment the borated water storage tanks have been mounted in the reactor building annulus, as well as several tanks in the reactor auxiliary building.

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 was 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.

The training program for the first 260 people hired specifically for Angra 3 of a total of 520 authorized to compose the Plant staff, to cover the different Plant disciplines is essentially completed, including licensed and non licensed operators and engineers and technicians for all Plant disciplines. Because of the interruption of construction most of this personnel is being assigned to different areas of the existing Plants, mainly to Angra 2.

Most of the required engineering is essentially available since for standardization reasons Angra 3 is to be as similar as possible to Angra 2.

Plant construction was planned for 66 months duration, from reactor base plate first concrete to the end of the power tests and start of commercial operation.

However, some delays were already accumulating along the construction period and a new schedule will have to be established after solution of the existing problems.

6.3.1 - Main safety improvements at Angra 3

The reference plant of Angra 3 NPP is Angra 2 NPP, as built, but also incorporating into the design the up-to-date requirements of rules and standards, in force at the time of the application to the Construction License in 2003, as well as some design modifications made in structures and systems so as to increase the protection and the capability of the plant to resist design basis accidents. Some additional improvements were introduced to withstand beyond design basis accident scenarios. Moreover, as regards the differences from Angra 2 that are important to withstand these scenarios, Angra 3 is being built at an elevation that is one meter higher than the one of Angra 2.

A tornado hazard study was prepared for Angra 3 design taking into consideration a probability of occurrence of 10-7/year, as required by the American guideline of the NRC, RG 1.76, “Design Basis Tornado and Tornado Missiles for Nuclear Power Plants” (2007). The hazard assessment indicated a maximum tornado wind speed of 209 km/h for the site. However, considering the maximum occurrences in the region, equivalent to the EF3 category, ELETRONUCLEAR conservatively adopted 242 km/h as the design speed for tornadoes (average between the limits of the EF3 category), also similarly to the design tornado established for the Region III in the United States. The corresponding tornado missiles have been also adopted in the design.

The seismic event SSB (combination of Burst Pressure Wave – BPW with SSE effects) is being applied for the design of all safety related structures, systems and components (class I and IIA civil structures; class 1 or 2A systems and components). The design concept, which is based on the KWU PWR 1300 MW Standard Model, includes an increased staggered defense-in-depth configuration, which does not only provide highly redundant safety systems to cope with design basis accidents, but in addition it provides a further line of defense consisting of dedicated ultimate safety features. By use of these ultimate safety features, some specific events can be coped with, like loss of main control room (including absence of operators for up to 10 hours) and station blackout. In addition, these features provide a robustness reserve even for beyond design basis external events.

The low probability external events SSB and Tornado were raised to “classical” design basis accidents against the previous consideration as “design extension” events in Angra 2. This concept represents an upgrade when compared to the one adopted for the reference plant (Angra 2), where some safety related SSC´s where designed only for SSE and not for SSB (e.g., Switchgear Building – UBA, Large Diesel Generator (D1) Building - UBP). This upgraded concept is conservatively adopted, and can be considered as an additional safety margin in the defense-in-depth line.

As referred in the previous paragraph all Unit 2 safety design features are being maintained in the safety design concept for Unit 3 (as for instance: decoupling between Emergency Feed Building - ULB and Switchgear Building - UBA; internal flooding protection, design criteria of up to 10 hours for SSB and up to 2 hours for SSE).

In Angra 3 the emergency power supply consists of two sets of Diesel generators:

- Emergency Power Supply D1 (4 x 50% large Diesel Generators) which supplies the power for all safety related systems in case of Loss of Off-site Power (LOOP);
- Emergency Power Supply D2 (4 x 50% small Diesel Generators) which supplies the power in case of LOOP and loss of D1 emergency Diesel Generators for the minimum required set of safety related systems (reactor protection system, emergency control room, emergency feedwater system, emergency residual heat removal chain and the main steam blowdown stations). The D2 emergency Diesel generators could be called “SBO Diesels”, in order to reflect on international requirements.

Even considering the above mentioned situation, an additional power supply installation for Angra 3, consisting of a Diesel Generating Set, similar to the DG of one redundancy of the Emergency Diesel building - UBP, shall be included in the plant design, due to the following points:

- The applied edition June/1999 of Standard KTA 3701, introduced in item 3 (2) d) a new requirement regarding an independent power supply installation, additionally to the two offsite connections;
- Requirement for energy supply 72 hours after an external event where the external energy supply (525 kV and 138 kV) fails (KTA 3701, App.C, item C 2.4).

Therefore, ELETRONUCLEAR decided to include the UBN structure with one DG Set including all necessary supporting systems. This DG Set is air cooled and is designed with the same safety requirements of the UBP building (resistant to SSB, tornado and TNT explosion).

This additional diesel generator can also replace one of the 4 diesel generators of the Emergency Power Supply D1 in case of maintenance.

The initiatives of ELETRONUCLEAR's Fukushima Response Plan focus on the plants in operation, Angra 1 and Angra 2. The results of the studies related to site conditions have been basically completed, except the evaluation of the resistance of the wave breaker, in front of the Plants sea water intakes, to waves produced by extreme sea conditions. Need for minor interventions in the site infrastructure as well as in the plants, have been identified. Part of the initiatives related to design improvements in Angra 2, mainly in relation to beyond design basis accidents, is already considered in Angra 3 design. Other design modifications in Angra 2, resulting from specific issues addressed in connection with the Fukushima accident, such as the possibility of connection of mobile equipment, will be afterwards incorporated in Angra 3 design.

The following recent improvements, all related to control and mitigation of beyond design events, including Severe Accidents, are being implemented in Angra 3:

- Hydrogen Reducing System, which reduces the Hydrogen content in the containment continuously by means of PAR's (Passive Autocatalytic Recombiners) during normal operation, design basis accidents (DBA) as well as after beyond design basis accident (BDBA);
- Nuclear Sampling System for the Containment Sump and Atmosphere, which is designed for the purpose of obtaining high quality samples of the containment atmosphere even after a BDBA. In addition also the containment sump can be sampled after BDBA.; Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity in case of BDBA like core melt causing high pressure inside the containment;
- The Primary Side Bleed & Feed, to remove core heat in case of BDBA, has its capacity increased and the bleed valves are powered by dedicated batteries to be available in case of Station Black-out (SBO);
- The Secondary Bleed & Feed, to remove primary side heat in case of BDBA, has the bleed valves powered also by batteries to be available in case of SBO (including the loss of the D2 emergency Diesel generators called “SBO-Diesels”).

6.4 Research Reactors

In this Seventh National Report Brazil decided to voluntarily submit some information related to Research Reactor, which are overall described in A.2.2 and in Annex III.

ARTICLE 7 - LEGISLATIVE AND REGULATORY FRAMEWORK

Article 7 (1) Establishing and maintaining a legislative and regulatory framework

Brazil has established and maintained the necessary legislative and regulatory framework to ensure the safety of its nuclear installations. The Federal Constitution of 1988 specifies the distribution of responsibilities among the Federal Government, the States and the Municipalities with respect to the protection of the public health and the environment, including the control of radioactive materials and installations (Articles 23, 24 and 202). As mentioned in item A.1, the Federal Government is solely responsible for nuclear activities related to electricity generation, including regulating, licensing and controlling nuclear safety (Articles 21 and 22). In this regard, the Comissão Nacional de Energia Nuclear (National Commission for Nuclear Energy - CNEN) is the Brazilian nuclear national regulatory body, in accordance with the Brazilian Legislation, see Annex II.2.

Furthermore, the constitutional principles regarding the protection of the environment (Article 225) require that any installation that may cause significant environmental impact shall be subject to environmental impact studies. More specifically, for nuclear facilities, the Federal Constitution (Article 225, paragraph 6) states that a specific law shall define the site of any new nuclear facility. Therefore, nuclear installations are subject to both a nuclear licence by CNEN and an environmental licence by the Brazilian Institute for Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA), which is the national environmental agency, with the participation of state and municipal environmental agencies as stated in the National Environmental Policy Act (Law 6938/81) and the Supplementary Law 140 of 08 December 2011. These principles were established by the Federal Constitution of 1988, when Angra-1 was already in operation, and Angra-2 was in construction. Hence, the licensing of these power plants followed slightly different procedures, as described later on in this Report.

Brazil has also signed several international conventions (see Annex II.1) that, once ratified by the National Congress, become national legislation, and are implemented through CNEN regulations.

Article 7 (2) (i) National safety requirements and regulations

By the Law 4118/62, with alterations determined by the Laws 6189/74 and 7781/89, CNEN became the Regulatory Body in charge of regulating, licensing and controlling nuclear energy. Since 2000, CNEN is under the Ministério de Ciência, Tecnologia e Inovação (Ministry of Science, Technology and Inovation - MCTI).

CNEN responsibilities related to this Convention include, among others:

- Preparation and issuance of regulations on nuclear safety, radiation protection, radioactive waste management and physical protection;
- Accounting and control of nuclear materials (safeguards);
- Licensing and authorization of siting, construction, operation and decommissioning of nuclear facilities;
- Regulatory inspection of nuclear installations;
- Acting as a national authority for the purpose of implementing international agreements and treaties related to nuclear safety activities;
- Participating in the national preparedness, and response to nuclear emergencies.

Under this framework, CNEN has issued regulations related to radiation protection, licensing process of nuclear power plants, safety during operation, quality assurance, licensing of operational personnel, reporting requirements, plant maintenance, and others (see Annex II for a list of relevant CNEN regulations).

The licensing regulation CNEN NE 1.04[3] establishes that no nuclear installation shall be constructed or operated without a licence. 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 licence.

There are several requirements regarding BDBA distributed in different standards in Brazil. The Regulatory Guidelines for Elaboration and use of NPP Safety Probabilistic Analysis has a specific requirement about the use of PSA in Severe Accident Management Program. The CNEN standard CNEN-NE-1.26[7] - Operational Safety in Nuclear Power Plants has requirements about development of instructions and procedures to manage the plant under severe accident condition; other specific requirements were included as conditions of the Renewal of Permanent License of Angra 1, issued in 2010, and the Permanent License of Angra 2, issued in 2011; these conditions are related with the implementation of a SAMGs that will be supported by a PSA with specifications: PSA Level 1 and 2, Fire PSA, Low Power and Shutdown PSA and External Events PSA. In addition, a Chapter 19 has been included in FSAR to treat aspect related to Severe Accident and PSA. CNEN issued a specific standard format to this Chapter 19 in 2010.

Under the project the project “Nuclear Safety Cooperation with the Regulatory Authorities of Brazil” – (Project BR3.01/09) CNEN, in collaboration with the European Commission (EU) and RISKAUDIT finalized in 2013, was compiled great part of all these requirements in a specific draft standard. (See Article 8)

Article 7 (2) (ii) System of licensing

A) Nuclear Licensing Process

The nuclear licensing process is divided in several steps:

- Site Approval;
- Construction Licence;
- Authorization for Nuclear Material Utilization;
- Authorization for Initial Operation;
- Authorization for Permanent Operation;
- Authorization for Decommissioning;
- Regulatory Control Withdrawal.

Federal Law 9.756 has been approved in 1998 establishing 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 plants to be licensed.

For the construction licence, 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, including resident inspections.

For the authorization for initial operation, CNEN reviews the construction status, the commissioning program including results of pre-operational tests, and updates its review and assessment of plant design based on the information submitted in the Final Safety Analysis Report (FSAR). At this time CNEN also licenses the reactor operators in accordance with regulation CNEN-NN-1.01[5]. Startup and power ascension tests are closely followed by CNEN inspectors and hold points at different power levels 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 shall 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.

Brazilian nuclear power plants are licensed for a period of 40 years in accordance with the rule CNEN NE-1.04[3], ‘Licensing of Nuclear Installations’, issued by, the Brazilian regulatory board: Comissão Nacional de Energia Nuclear (CNEN). PSRs are conducted in accordance with CNEN NE-1.26, ‘Safety in Operating Nuclear Power Plants’[7], consistent with IAEA Safety Guide No. SSG-25, ‘Periodic Safety Review of Nuclear Power Plants’. A comprehensive AMP at Angra NPP is being developed with the objective of coordinating operations, maintenance and engineering actions to control under acceptable limits the effects of ageing to maintain integrity and functional capability of SSCs important to safety the way that the licensing basis of the plants are maintained during the period of the current operating license and during the period of LTO, as defined in IAEA Safety Reports Series No.57, ‘Safe Long Term Operation of Nuclear Power Plants’. The AMP implementation project at Angra counts on the technical support of the designers of both plants. During the initial phase, technical visits of Westinghouse and Areva and the development of a pilot project for a mechanical system (by Westinghouse) contributed to the first assessments of the available documental infrastructure and of the proposed methodology for the development of AMP processes.

The Severe Accident Management Programs were required during first PSRs, for both plants in operation. For more detail, see Art. 14(1), and Art. 19(4). For Angra 3, under construction, this aspect has been included as a condition in the License Construction. For more detail see Article 14(1). With the support of European Commission (Project BR3.01/09) CNEN reviewed some parts of the developed SAMGs for Angra 1 and 2, see Article 8.

The full implementation of the Severe Accident Management Programs is not yet finished because this process has been extended to include several issues related to the Fukushima Accident.

Reporting requirements are also established through regulation CNEN-NN-1.14[6]. These reports, together with a system of regulatory inspections performed by resident inspectors and headquarters personnel, are the basis for monitoring safety during plant operation.

Other governmental bodies are involved in the licensing process, through appropriate consultations. The most important ones are the Brazilian Institute for Environment and Renewable Natural Resources - IBAMA, which is in charge of environmental licensing and the Gabinete de Segurança Institucional da Presidência da República (Institutional Cabinet of the Presidency of the Republic - GSI/PR) with respect to emergency planning aspects.

B) Environmental Licensing of Angra 1, 2 and 3.

IBAMA was created by Law 7735 in 1989, it is linked to the Ministry of Environment (MMA), and has the responsibility to implement and enforce the National Environmental Policy (PNMA - Brazilian Law 6938 of 1981). The PNMA's goals are to preserve, improve and recover environmental quality to ensure conditions for social and economic development and the protection of human dignity. The PNMA established the National System for the Environment (SISNAMA), which is composed by the National Council for the Environment (CONAMA) and executive agencies at the federal, state and municipal levels.

Environmental licensing is a legal obligation required prior to the installation of any project or activity that exploits natural resources and has a significant potential to pollute and/or degrade the environment. The enforcement of environmental licensing is shared by the environmental agencies of Brazilian Municipals and States, and IBAMA at the federal government level. IBAMA is the agency tasked with the licensing of large projects involving impacts on more than one Brazilian State and activities of the oil and gas sectors on the continental shelf. IBAMA is also responsible to carry out the licensing of the environmental component of activities and projects related to prospecting, mining, producing, processing, transporting, storing and disposing of radioactive materials at any stage or using nuclear energy in any of its forms and applications.

The regulation of nuclear activities remains with the Federal Government. The *nuclear licensing* and the *environmental licensing* processes are independent, parallel, and complementary acts. CNEN, a federal organization, through its Directorate of Radiation Protection and Nuclear Safety, is the Regulatory Body in charge of *nuclear licensing*, which consists of regulating, licensing and controlling nuclear activities in Brazil, enforcing Nuclear Safety, Security and Safeguards. IBAMA is responsible for the environmental licensing of any installation with potentially significant socioenvironmental impact and risk, including the nuclear installations.

In the environmental licensing process, possible direct and indirect impacts of a project imposed to the external environment and communities are assessed. These include: the physical aspects (geology, hydro-geology, climate, water availability), atmospheric emissions (radioactive and conventional), and generation and control of effluents, and solid waste (radioactive and conventional); the interactions with biotic system (marine and terrestrial fauna and flora) and possible incorporation (bioaccumulation, toxicity); and the socioeconomic and health implications to the human populations in the vicinity of the project. The main guidelines for the implementation of the environmental licensing are expressed in Law 6938 of 1981, Supplementary Law 140 of 2011, CONAMA Resolutions 001/86 and 237/97, and IBAMA's Normative Instruction nº184/2008 and n° 01/2016. These guidelines discipline the environmental licensing for projects with potentially adverse effects on the environment, following three main steps:

- Prior License (LP), granted at the preliminary planning stage, approving the general concept of the installation and location, evaluating its environmental feasibility, and establishing the basic requirements and conditions for the next implementation phases;
- Installation License (LI), authorizes the construction of the facility in accordance with the approved specifications, programs and projects - including measures that are considered essential to protect the environment and human populations;
- Operation License (LO) – authorizes the operation of the facility, after successful completion of the construction and commissioning activities and the verification of the effective fulfilment of the Installation License conditions, and the effective implementation of measures to protect the environment and human populations during operation.

Among the requirements for issuing a Prior License, three technical reports should be presented by the project's proponent to provide IBAMA with a comprehensive set of information to support the decision-making process, such as:

- An Environmental Impact Study (EIA) - EIA was established by the National Environmental Policy - PNMA (Federal Act No. 6938/1981) and by the Brazilian Federal Constitution (Article 225). EIA is required for projects or activities that may potentially cause significant environmental degradation. Brazilian environmental legislation provides a guideline to an EIA that includes: technological and location alternatives of the project, environmental diagnosis of the affected areas, identification and assessment of the environmental impacts caused by the implantation and operation of the activity, definition of limits of the geographical area directly and indirectly affected by the project, definition of mitigation actions for the identified impacts, and identification of strategies for environmental monitoring in the affected area. EIA should also consider other governmental plans and programs planed to the same area, to evaluate the compatibility between projects;
- An Environmental Impact Report (RIMA) - The RIMA is a document that summarizes the information presented in the Environmental Impact Study. Contents should be presented in clear, non-technical, and accessible language to facilitate stakeholders' understanding;
- A Quantitative Risk Assessment (EAR) - The EAR is applied by the environmental agency to assess the industrial/conventional risks associated to the operation of projects and activities potentially harmful to people and the environment. The EAR also guides the implementation of risk management programs and emergency plans originated by any non-nuclear accidental event. It is important to stress that, in Brazil, the National Commission for Nuclear Energy (CNEN) is the sole agency responsible for the assessment of nuclear risk and safety.

Notwithstanding, the conclusions and recommendations of CNEN are relevant to the decision making process of the environmental agency.

Transparency is one important requirement for the environmental licensing process. Public participation is ensured by legislation through public hearings prior the issuing the Prior License (CONAMA Resolution 09/87). The legislation also establishes that information about any public hearing, license application and decisions of the environmental agency should be made available to the public in official newspapers and local press.

Environmental Licensing of Angra-1, 2 and 3 Radioactive Waste Storage Facilities

The beginning of construction of Angra-1 and 2, including the radioactive waste stored on-site, occurred before the creation of IBAMA. The operation of Angra-1 started in 1981, before the current environmental regulation was established. At that time, the State of Rio de Janeiro's Foundation for Environment Engineering (FEEMA), the Rio de Janeiro environmental state agency, issued an Installation License (on September 15th 1981).

Since 1989, IBAMA is the legal authority for environmental control of nuclear installations in Brazil; and since 1997, following the publication of the CONAMA Resolution 237/97, IBAMA is also the legal authority for environmental licensing of nuclear power plants and radioactive waste storage facilities. Given this legal setup:

- The environmental licensing of Angra-1 and the Radioactive Waste Storage Facility 1 and Facility 2-A was performed through an "adaptive licensing", in accordance with IBAMA requirements, to adjust the facility to the current environmental regulations. This process defined the necessary environmental studies to be carried out and presented to IBAMA as requirements to issuing an Operation License. Subsequently, in March 2009 the report "Environmental Control Plan – PCA" was submitted to IBAMA;
- The environmental licensing of Angra-2 was performed as required by CONAMA 237/97, which involved the preparation by the facility's owner of an Environmental Impact Study (EIA) and a Report on Environmental Impact (RIMA). These documents were submitted to IBAMA for environmental impact evaluation. They also served as a basis to define environmental plans and programs that are detailed in a Basic Environmental Project (PBA). Two public hearings were performed in the period of 1999-2000. Based on the technical evaluations and inputs from stakeholders and the public, IBAMA issued a special License for Initial Operation (commissioning) in 2000. In March 2001, Brazil's Federal Public Prosecution intervened in the environmental licensing and a Statement of Commitment (Termo de Compromisso de Ajustamento de Conduta – TCAC) that laid down a series of conditions to be met by Eletronuclear (mostly centered on the improvement of the emergency

plan) was signed by IBAMA, Eletronuclear, and the Public Prosecution. In June of 2006, IBAMA issued a report (Parecer Técnico Nº 015/2006 – COEND/CGENE/DILIC/IBAMA) concluding that all of such conditions were met;

- The radioactive waste from the nuclear power plants are stored in four storage facilities, the Radioactive Waste Storage Facilities 1, 2 & 3 at the Radioactive Waste Management Centre (CGR) and the Storage Facility for the two old (replaced) steam generators from Angra-1;
- IBAMA issued the Preliminary License No. 279/08 for Angra-3, in July 2008. In March 2009, after an evaluation of compliance of conditions of the Preliminary License Nº 279/08, IBAMA issued the Installation License Nº 591/09 for Angra- 3;
- The Project of the Complementary Unit of the Storage of Irradiated Fuel – UFC was modified by Eletronuclear in 2015 and its Environmental Study will be reviewed.

It is noteworthy that in 2011 IBAMA started up a process to unify the environmental licensing processes of the units in operation at the CNAAA, with the exception of Angra-3 that is currently under construction. In March 2014, IBAMA issued a Joint Operating License (LO N° 1217/2014) that encompasses the operation of Angra-1, Angra-2, the Radioactive Waste Management Centre, and the Storage Facility for the replaced old steam generators. Concomitantly, the Installation License for Angra-3 was reviewed to adjust it to the Joint Operating License of the CNAAA.

In March 2014, IBAMA issued the Combined Environmental Operation License nr. 1217/2014 for the Almirante Álvaro Alberto Nuclear Power Site – CNAAA authorizing the operation of Angra 1 and Angra 2 NPPs, as well as the Waste Management Center – CGR and auxilliary facilities for ten years.

As already mentioned the issuance of the combined environmental operational licence for the site in March 2014, the specific Installation License Nr.591/09 was revised again and generated a second amendment with a set of 33 new requirements for Angra 3 plant construction.

Article 7 (2) (iii) System of regulatory inspection and assessment

The General Coordination for Reactors and Fuel Cycle (CGRC) is the CNEN branch responsible for the licensing and control of the Angra 1, 2 and 3 nuclear power plants and the research reactors. This branch is composed by four divisions in charge of the following areas: Resident Inspection, Engineering and Materials, Safety Analysis and Radiation Protection and Meteorology (see Article 8(4)). With the advice of these divisions a regulatory inspection and audit program is established annually for each plant by CGRC.

The regulatory inspections are composed by routine inspections performed by the resident inspectors in according to CGRC's schedule, complemented by specific inspections or audits performed by the technical staff from the CNEN's Headquarters.

The inspections can be scheduled or reactive, depending on the performance of the Plant. During the outages some people from the headquarters join the Resident Inspection Team. An Inspection Report with the objective, scope and findings is issued and posted to the operator asking corrective actions. During 2013-2015, CGRC conducted 32 inspections in Angra 1, 30 in Angra 2, 6 in Angra 3 and 7 related to the whole plant organization. Additionally Waste Storage and Management, Environmental Protection Program and Physical Protection are subjects covered by others departments inside the Directorate for Nuclear Safety and Radiation Protection (DRS) which conduced 8 inspections in the period.

Complementary to field activities, operation follow up is performed also based on licensee reports, as required by regulation CNEN-NN.1.14 [6].

CNEN's regulations establish the documentation, as Safety Analysis Reports, Plans, and Programmes and so on, that shall be submitted to the Regulatory Body for assessment. The safety assessments are carried out by a specialist or group of specialists (internal or external), following a specific procedure. If there is a need for additional information it is requested to operator and in case of a document does not attend the regulations it is informed to the operator that is necessary to revise it.

The specialists positions are internally revised, approved by the correspondent Division and shall be endorsed by CGRC.

Article 7 (2) (iv) Enforcement of applicable regulations and terms of licences

Enforcement powers are given by the legislation that created CNEN (Law 4118/62 with alterations determined by Laws 6189/74 and 7781/89). These laws explicitly establish that CNEN has the authority "to enforce the laws and its own regulations".

Enforcement mechanisms are included in CNEN regulations, such as the power to impose conditions, suspend activities up to withdraw a licence. However, up to now, no legal actions were required to ensure enforcement. Usually, CNEN establishes conditions which are met by the licensee in due time. CNEN monitors implementation of these conditions and whenever delays occur some new corrective actions or compensatory measures can be imposed. New evaluations are performed to ensure that safety is not been compromised.

ARTICLE 8 - REGULATORY BODY

Article 8 (1) Establishment of the regulatory body

As mentioned before (as discussed in item A.1 of Introduction and in article 7), 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 installations.

Other governmental bodies are also involved in the licensing process, such as the Brazilian Institute for the Environment and Renewable Natural Resources.

8(1).1 - Legal foundations and statute of the regulatory body

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

8(1).2 - Mandate, mission and tasks;

CNEN’s mission is: "To ensure the safe and peaceful use of nuclear energy, develop and make available nuclear and related technologies for the well being of the population".

The Deliberative Committee (CD), see Figure 6, is composed of five (5) members, one of whom is the CNEN’s President. The President and the other Members of the CD shall be appointed by the Executive Government, among persons of good moral character and administrative capacity in scientific or technical fields. Members of the CD shall be appointed for a period of five (5) years, provided their renewal.

The CD shall:

- Advise the formulation process of the National Nuclear Energy Policy;
- Deliberate on policies, plans and programs;
- Approve rules and regulations of the CNEN;
- Issue authorization for the construction and operation of reactors and nuclear fuel cycle facilities;
- Make proposals on treaties, agreements, conventions or international commitments on nuclear energy etc.

8(1).3 - Authorities and responsibilities

The information related to this topic are included in the item 8(1).1 and Article 7(2)(i).

8(1).4 - Organizational structure of the regulatory body (CNEN)

The structure of CNEN is presented in Figure 6. The Organizational part of CNEN that has the Regulatory Body functions is formed by the Board (Deliberative Commission – CD), by CNEN’s President and the main organizational unit involved with the licensing of nuclear power plants, the Directorate for Radiation Protection and Nuclear Safety (DRS).

The Directorate for Nuclear Safety and Radiation Protection (DRS) responsibilities between others are**:**

- Issue regulations, licenses and permits/authorizations (which must be approved by CD); monitor and control their application.
- Oversight the nuclear and radioactive facilities.
- Require and monitor the implementation of actions related to the radiological safety of workers, the public and the environment.
- Require and monitor the implementation of actions related to the radiological safety of workers, the public and the environment.
- Require operators of nuclear or radiological installations to perform safety demonstration studies.
- Authorize and accredit professionals to carry out activities with nuclear material or radioactive sources in nuclear or radiological installations.
- Order the suspension of nuclear or radiological activities that are not adequately licensed.
- Order the decommissioning of nuclear and radiological installations.
- Issue notifications requiring the regularization of nuclear and radiological activities and installations.
- Require and receive information from regulated agents concerning the production, imports, exports, processing, transportation, transfer, storage, distribution, allocation and trading of services and materials subject to the nuclear authority regulation.
- Prepare and approve nuclear and radiological emergency plans, mandatory for regulated agents; give technical guidance and collaborate with the agencies in charge of the civil defense emergency plan.

- Monitor, assist and supervise the implementation of international diplomatic compromises assumed by the Brazilian government in the areas of radiation and nuclear safety, security and safeguards.
- Apply safeguards to nuclear materials and facilities / installations.
- Provide technical support to the Deliberative Commission of CNEN.
- Gather and consolidate data on national reserves of nuclear ores and provide the Deliberative Committee of CNEN with criteria for fixing their prices for trading purposes among companies and agencies of the Federal Administration.

Directorate for Research and Development (DPD) is mainly in charge of running CNEN institutes, which operate the research reactors, produce radioisotopes and conduct basic research. The institutes may also provide some specialized support to DRS in the licensing process, provided there is no conflict of interest involved. DPD is in charge of the design and construction of the future Multipurpose Research Reactor. DPD is also working in the site selection and design of a national repository for low and medium level waste.

The General Coordination of Reactors and Fuel Cycle Facilities (CGRC) responsibilities are:

- Perform licensing and control activities of nuclear Reactors and Fuel Cycle facilities.
- Monitor the compliance of nuclear installations with technical regulations and standards on radiation protection and safety, through inspections and assessment of the Licensee’s safety performance.
- Carry out the nuclear and radiological safety assessment of nuclear reactors and conduct the process of elaboration of technical information related to the issuance of operation permits / authorizations.
- Issue professional licenses for operators and certificates for radiation protection supervisors, and qualify Independent Technical Supervisory Agencies to develop activities in the areas of nuclear power reactors, research reactors and prototypes/ testing facilities.
- Provide technical support in nuclear and radiological safety assessment of nuclear, radioactive, minerals and industrial installations, and deposits of radioactive waste.
- Coordinate the regulatory response actions to emergencies in nuclear installations.
- Provide support, if requested, to licensing processes conducted by other governmental regulatory agencies.
- Propose and implement actions aimed at the optimization of licensing, inspection and control of nuclear installations.

- Propose update and the development of new regulations.

The CGRC branch is composed by four divisions, in charge of the following areas: Resident Inspection, Engineering and Materials, Safety Analysis and Radiation Protection and Meteorology. With the advice of these divisions a regulatory inspection and audit program is established annually for each plant by CGRC.

The Division of Resident Inspection, located at plant site, makes continuous verification of the plants compliance with its Technical Specifications (TS), which establishes the limiting conditions for operation of each plant. Strict adherence to these specifications is essential for operational safety. Additionally, the division makes use of a set of inspection procedures to inspect the plant periodic tests, maintenance activities and use of maintenance rule, housekeeping, inspection of control room, evaluation of operational significant events, aspects of radiological protection, management and generation of waste, among others. Every six months, an Inspection Report is prepared containing the main inspections findings for each plant. It also supports the inspection and audits performed by the other divisions at the plant.

The Division of Engineering and Materials makes continuous verification of compliance with regulatory requirements in the following subjects: Civil, Mechanical, Electrical and I&C, Materials and Chemical Engineering and Quality Assurance. These activities are done through development of audits, inspections and safety assessments of the documents submitted by the licensee.

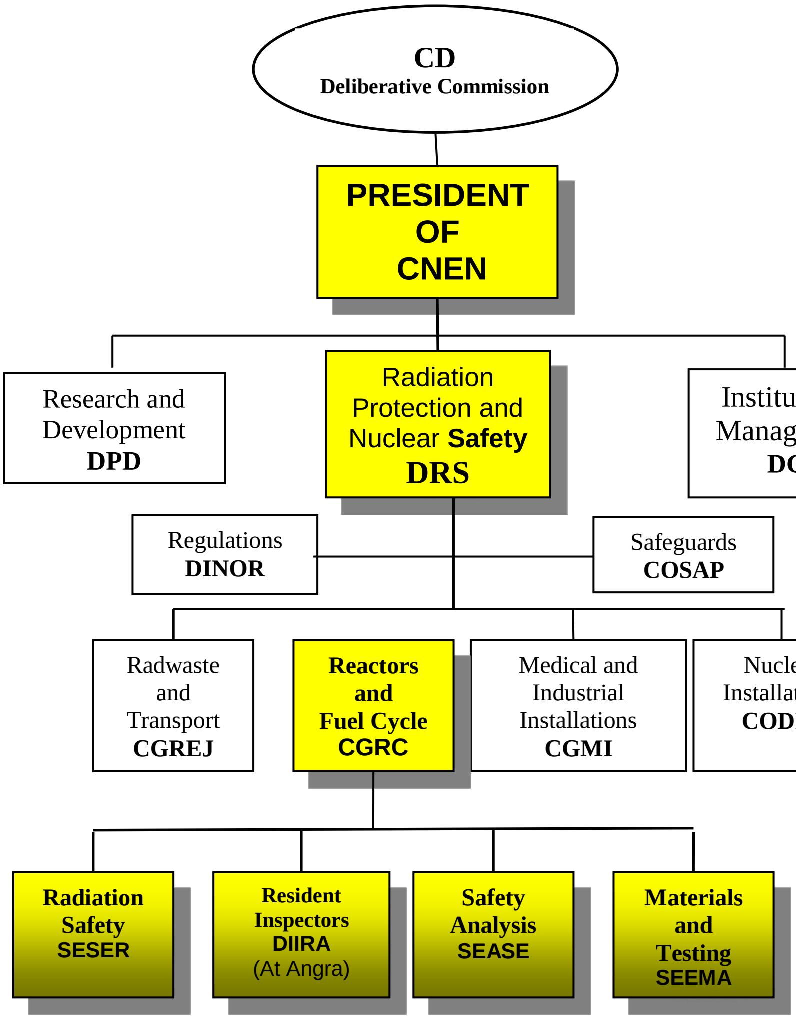

Fig. 6 – CNEN Structure (simplified)

The Division of Safety Analysis makes continuous verification of compliance with regulatory requirements in the following subjects: Probabilistic safety Assessment (PSA), Termo-Hidraulic Analysis, Transient and Accident Analysis, Severe Accident, Human Factor Engineering, Core Physic, Fuel Performance and Criticality Analysis. These activities are done through development of audits, inspections and safety assessments of the documents submitted by the licensee.

The Division of Radiation Protection and Meteorology makes continuous verification of compliance with regulatory requirements in the following subjects: Radiation Protection, Radioactive Effluents Processing, Meteorology and Emergency Preparedness. These activities are done through development of audits, inspections and safety assessments of the documents submitted by the licensee.

The four division above provide CGRC with the necessary technical support in decision-making activities regarding the development of policies, rulemaking, procedures and administrative controls.

8(1).5 - Development and maintenance of human resources over the past three years;

Adequate human resources are provided to CNEN. A total staff of 2200 people, of which 85% are technical staff, is available at CNEN and its research institutes. Forty eight percent (48%) of the staff are university graduates, 16% having a master degree and 15% having a doctoral degree. DRS staff is about 300 people. CGRC itself comprises 56 people, 46 of which are technical.

In the period, CGRC staff registered a loss of 10 professionals, mostly due to retirement and has received 12 new professionals, through a public hiring process or transfer from another area of CNEN. By the end of 2015, the staff qualification shows 20 holding a Ph.D. degree, 26 holding a M.Sc. or equivalent in nuclear science or engineering, and 10 administrative.

8(1).6 - Measures to develop and maintain competence;

CNEN is constantly evaluating its staff needs, considering the new licensing projects and the retirement of staff.

The maintenance of the staff is still a challenge because of the high age average. CNEN is claiming for new public hiring process based on national contest, as required by Brazilian legislation, to recruit new employees. Whenever a contest is held specific job description is prepared for each function and candidates are supposed to demonstrate both academic training and some experience in the specific field.

Initial training, Induction course, is done, including basic concepts on nuclear safety, radiological protection, legal aspects, functions, processes and roles of the regulator, PWR’s technology, emergency planning, safety analysis and inspections. One week's technical visit to the NPP, tutored by the Resident Inspection Division, is part of the initial training. Depending on the employee function, some of them attends the NPP Systems Course. On-the-job training is used in an individual basis and is tutored by experienced staff. National academic or technological institutions are used for complement the staff competence and international cooperation projects also are used for training of new staff and retraining of more experienced staff. A three year initial evaluation is included in the recruitment process.

The CGRC technical staff receives nuclear general training and specific training according to the field of work at national and international organization, including both academic training and courses attendance, technical visits, participation in workshops, and on technical committee meetings mostly sponsored by IAEA and European Commission.

Also there is a technical cooperation agreement with German GRS to exchange information on the areas of operational events, PSA and Severe Accident.

On the area of emergency preparedness, CGRC is an active member of the ARGOS consortium and participate on the yearly seminar to share experience with other international users.

The Table 3 show the set of training course and tutoring attended in the period of 2013-2015 within cooperation project between CNEN and European Community entitled: “Training and Tutoring for experts of the NRAs and their TSOs for developing or strengthening their regulatory and technical capabilities”, the multi-country projects MC3.01/10, MC3.01/11 and MC3.01/13.

Concerning training courses sponsored by the IAEA:

- “Train-the-Trainers Workshop on INES", Vienna, Austria, 07 – 11 October 2013 - 1 Expert, and
- “Training Workshop on the Development of Severe Accident Management Guidelines Using the IAEA’s SAMG-D Toolkit", Vienna, Austria, 19–23 October 2015 – 1 Expert.

Table 3 – Course and Tutoring attended by CNEN at the multi-country projects MC3.01/10, MC3.01/11 and MC3.01/13.

“Safety Assessment I” (ENSTTI) • Safety assessment approaches for deterministic analyses with respect to FSAR, Emergency Operating Procedures (EOP) and Severe Accident Management Guidelines (SAMG) application in pressurized water reactors; • FSAR grade licensing analyses, based on RELAP5 - requirements, visualization, evaluation and documentation; • Severe accident analysis based on MELCOR - model development principles, etc.	February - Mars/13 Trnava/Slovakia	2 Experts
“Radiation Protection and Regulatory Emergency Preparedness”	Mar/13 – Belgiun	2 Experts
“Safety Assessment II” (ENSTTI) • Reliability theory and applications;	Mar/13 – Cologne/German	3 Experts

• Probabilistic safety assessment; • Probabilistic uncertainty analysis; • Risk-informed decision making. • PSA level 1 including reliability analysis; • PSA level 2 including severe accident assessment.	y	
Review and Inspection of I&C systems. (ITER-Consult)	22 – 26 Apr/13 Helsinki/Finland	1 Expert.
Training Course on ‘’ Requirements and safety evaluation of PSA for NPP’’ (ITER-Consult)	Mai/13 Ljubljana/Slovenia	2 Experts
Regulatory Control of Nuclear Site Evaluation and Inspection during the Siting, Construction and Operation. (ENSTTI)	31 May -08 Jun/15 Fontenay-aux-Roses/France	1 Expert
“Introduction to Nuclear Safety” (ENSTTI)	03-28 June/13 Munich/Germany	2 Experts
“Safety in NPP – Assessing Nuclear Installations with respect to Fire Safety in Design and Operation” (ENSTTI)	9-14 Nov/13 Cologne/Germany	1 Expert
Design Conduct, reporting and follow up of inspection programmes related to reactor structures and components important to safety” (ENSTTI)	27 Sept – 05 Oct/14 Fontenay-aux-Roses/France	1 Expert
Inspection of I&C (Instrumentation and Control)	11 – 19 Oct/14 Rome/Italy	1 Expert
Safety in PWR, BWR, CANDU, VVER, RBMK for Regulators and Licensors (ENSTTI)	17 – 21 Nov/14 Bologna/Italy	1 Expert
SOFIA Simulator Training – PWR Operations, Physics and Safety (ENSTTI)	1 – 5 Dez/14 Fontenay-aux-Roses/France	3 Experts
Legal Criteria related to Radioactive Nuclear Installations (ENSTTI)	19 – 23 Jan/15 Paris/France	1 Expert
Evaluation of Safety Analysis Reports for Research Reactors and Nuclear Power Plants. (ENSTTI)	Apr/15 Berlin/Germany	1 Expert
Design conduct, reporting and follow up of inspection programmes for environmental and occupational radiation in nuclear installations. (ENSTTI)	20 – 24 Apr/15 Fontenay-aux-Roses/France	3 Experts

"NPP siting regulatory requirements & licensing" (ITER-Consult)	9 – 17 May/15 Rome/Italy	1 Expert
Investigation, reporting and follow up of operating events. (ENSTTI)	1 – 5 Jun/15 Fontenay-aux-Roses/France	1 Expert
Requirements and safety evaluation of NPP SAR" (ITER-Consult)	6-11 July in Ljubljana/Slovenia	2 Experts
Tutoring about "Requirements and safety evaluation of NPP SAR" (ITER)	13 Jul – 06 Sept/15 Ljubljana/Slovenia	1 Experts
''Severe Accident Phenomenology" (ENSTTI)	6-10 July/15 Stockholm/Sweden	2 Expert
"Nuclear power reactor technology and nuclear power plant safety from a regulatory perspective" (ITER-Consult)	5 – 9 Oct/15 Mannheim, Germany	2 Experts
Tutoring "Nuclear power reactor technology and nuclear power plant safety from a regulatory perspective" (ITER-Consult)	12 Oct– 4 Dec/15 Mannheim, Germany	1 Experts
" Models and Methods for Advanced Reactor Safety analysis" (ITER-Consult)	23 – 27 Nov/15 Pisa/Italy	1 Expert
Management of Spent Fuel & Radioactive Waste. (ITER-Consult)	28 Nov – 06 Dec/15 Paris/France	1 Expert

Institution: European Nuclear Safety Training and Tutoring Institute-ENSTTI and ITER-Consult.

CNEN started in 2013, with support of IAEA, a project related to Building Capacity through Knowledge and Quality Management (KQM) Programme. The project encompasses three major areas: assessment of key knowledge (existing and needs), development of strategy to capture and retain key knowledge needed for regulatory process of the Brazilian nuclear installations nuclear fuel cycle installations, and development and implementation of methodology (i.e. Mechanisms and tools) for identifying, capturing and disseminating lessons learned and good practices in key regulatory competence areas.

There were two workshop in CNEN's Headquarters in Rio de Janeiro, the first one was held in November, 2013 and was more related to the fundamentals, concepts, definitions, strategy, tools and mechanisms of a Capacity Building and a KQM Programme. The second Workshop occurred in August, 2015 more focused in practical examples, discussions and diagnosis. In both workshop the attendance was over 80 % of the staff.

Based on the discussions the CGRC created at the end of 2015 a Working Group to propose a plan to develop a KQM Programme.

In parallel to the IAEA initiative the CGRC participate from 2012 to 2015 in a project of the FORO Iberomerican for Regulators related to Nuclear Regulatory Competences, which led to the publication of a document together with IAEA , IAEA-TECDOC-1794 (in Spanish), *Guía para la Elaboración de un Programa de Creación y Desarrollo de Competencias de Reguladores de Reactores Nucleares.*

8(1).7 - Developments with respect to financial resources over the past three years;

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

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

The DRS´s budget has had a small evolution in the period, arising from R$ 8.308.953,00 in 2013 to R$ 9.870.103,00 in 2015. This budget is strictily to carry out CNEN's regulatory function (rulemaking, safety assessment and oversight) and does not include the costs of salaries and infrastructure which are covered by extra-budget resources.

8(1).8 - Statement of adequacy of resources.

From the above mentioned item it can be seen that the finantial resources are adequate to cover DRS needs.

8(1).9 - (Quality) management system of the regulatory body;

As mentioned in Summary of the National Report, CNEN is still lacking a comprehensive and systematic Management System, although elements of quality management have already been implemented for many years. Routine processes are well mapped and described in internal procedures. These includes the receiving licenses applications, internal distribution of review tasks, review procedures, preparation of individual evaluation reports, consolidation of evaluation reports and preparation of draft resolution submitted to the Deliberative Commission. Inspection activities are also guided by internal procedures. Non routine activities are done in ad ad-hoc basis. There is a lack of a systematic internal review process (internal audits).

Safety culture is a subset of the wider organizational culture within an organization. Many practices which are used internationally to improve organizational effectiveness aim to promote the unity of purposes among the employees, motivating them to achieve organizational goals. The concepts of Mission, Vision, Goals and Values are often used to achieve these desired requirements.

To implement the safety and quality policies inside the Brazilian nuclear regulatory body, CNEN has issued a safety policy[8] and quality assurance policy statements[9] in December 1996, which is based on the concept of Safety Culture. In according with this policy, a project was launched for the development of a quality management system applicable to the main regulatory functions: rulemaking, licensing and control, review and assessment, inspection and enforcement. Soon it was recognized the importance of considering the cultural aspects inside regulatory organization. Different from operating organizations, a failure in human behavior of a regulatory staff can not directly challenge the safety of nuclear installations.

A consistent regulatory strategy, however, may have a stronger influence over plant safety performance. If an adequate set of shared values can promote attitudes and behaviors of the individuals towards organizational goals, a selected set of regulatory principles define the consistency of regulatory strategies.

Currently, the regulatory review and control activities related safety culture in Operating Organization is carried out by Resident Inspectors (verification) and by analysis of Operational Experiences (analysis of operational events reports). However, is necessary develop a regulatory process based in safety indicators, to categorize deficiencies associated with the operational safety of nuclear power plants, and so prioritizing regulatory inspection efforts or escalating enforcement actions over plant operators, in order to be consistent with the application of the concept of safety culture to regulatory bodies, warranting attention to issues proportionally to their safety significance.

Regarding CNEN verification of Safety Culture, all meetings and activities inside the NPP site are open for CNEN resident inspectors. The inspectors have direct access to all documents, reports, control room and also access to all managers and supervisors. In this way, the inspectors monitor the daily routine of the plant. In this case, the inspectors can check the attitude of workers and top management, allowing the understanding and the verification of application of the Safety Culture concepts. Other opportunity to check some aspect related to Safety Culture consists in conducting a global assessment of Reports of Operational Events. When systemic deficiencies are detected the regulatory body requests a meeting with plant senior management.

8(1).10 - Openness and transparency of regulatory activities including actions taken to improve transparency and communication with the public.

CNEN is a governmental agency and as such is subject to Access to Information Act (Law 12.527/11), this law regulates the right of access to public information and establishes the principle of maximum disclosure of information held by public authorities, and secrecy as an exception. The exceptions are linked with proprietary information, security-related information and sensitive information.

Questions can be done in the Government Website and it has 30 days to be answered.

CNEN makes availiable at http://www.cnen.gov.br all information related to nuclear activities and the national policy, the public.

Public consultation is part of the standard and regulations development process and has the objective of improving the Transparency of nuclear regulations elaboration process, allowing the participation of interested parties such as professional associations directly involved, organizations interested in its application and the general public.

8(1).11 - External technical support.

CNEN makes some use of its institutes (TSOs), for example, The Institute of Energetic and Nuclear Research (IPEN), the Nuclear Energy Institute (IEN), the Radioprotection and Dosimetry Institute (IRD) and the Development Center of Nuclear Technology (CDTN). These Institutes are also the main actors in the national nuclear safety research and development activities.

As an example, in the review of Angra 1 PSA, CNEN/DRS established a Working Group composed of four representatives of DRS divisions and three engineers from IPEN. In the review of aspects related to Human Factors, CNEN/DRS established a Working Group composed of six representatives of DRS divisions, one engineers from IPEN and two engineers from IEN.

CNEN/DRS also uses IRD as a TSO in regulatory inspections in radiation protection and environmental monitoring.

At the international level, CNEN/DRS has used the support of Riskaudit under an EC Technical Cooperation Project:

- **BR – EC Project BR3.01/09 (BR/RA/01)**
  - ✓ Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN)
  - ✓ November 2013 - Finalized

- Strategy for maintaining and enhancing the capacity and regulatory capabilities of CNEN and its practical implementation
- Safety of digital instrumentation and control (I&C) systems,
- Severe accident management (SAM);
- Emergency preparedness and response
- Operational experience
- Safety of new fuels

- **BR – EC Project BR3.01/12 (BR/RA/02)**
  - Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN)
  - June 2015 - started
  - Strengthened capabilities for Probabilistic Safety Analysis assessment:
    - to support CNEN in the enhancement of the most important Probabilistic Safety Assessment (PSA) regulatory issues – regulatory activities, requirements and guidance update, computer code issues;
    - to support CNEN in the reviewing process of the PSA documents to be submitted by the utility ;
  - Enhanced capabilities for the assessment of the Deterministic Safety Analysis for Angra-2/3:
    - to support CNEN to perform an independent uncertainty and sensitivity analysis to quantify uncertainties associated with the Angra-2 Loss of Coolant Accident evaluation model with a best estimate code, in the licensing process of power-upgrade and new fuel design;
    - to support CNEN in the development of a methodology for fuel design safety analysis involving specific computer codes;
  - Improved assessment of ageing management and long term operation:
    - to transfer knowledge and know-how to identify the appropriate parts which must be evaluated in the Periodic Safety Review (PSR) as far as long term operation is concerned, and on the way to carry out such evaluation;
    - to support CNEN in the improvement and the application of specific requirements for Brazilian NPPs based on the existing documents developed by the FORO and other existing documents in other countries
  - Improved emergency preparedness:

- to advise CNEN on the selection of relevant information related to emergency situations, to be made available in its emergency room in CNEN Headquarters on-line and in real time, and to advise CNEN about similar computerized infrastructure used in other countries and regarding the concept and the development of the interface with the operational information available at the NPP main control rooms;
- to support CNEN to further enhance the functionalities of the ARGOS-BR code in order to deal with Brazilian Emergency Planning Zones (EPZs);

➢ Enhanced follow up capabilities for Severe Accident Management:

- to support CNEN in the assessment of the Severe Accident Management Programs (SAMP) for Angra-2 and 3, possibly including the capacity to review and/or revise MELCOR nodalisations used in Angra-2;

➢ Enhanced follow up capabilities for the assessment and commissioning of systems with digital I&C in Angra-2 and/or Angra-3:

- to support CNEN in specific safety analyses, inspections and commissioning in support of the licensing of the digital I&C systems, the man-machine interface and the information systems important to safety.

8(1). 12 - Advisory committees.

The DRS has established four Advisory Committees:

- Advisory Committees on Civil Engineer;
- Advisory Committees on Radiological Protection;
- Advisory Committees on Decommissioning.
- Reactors Operators Licensing Board.

The Advisory Committees on Civil Engineer has the purpose to evaluate solutions and support the licensing activities of the DRS in civil engineering, mainly for evaliuation of the civil design of Angra 3, and is composed of four representatives of DRS divisions and four engineers of TSOs.

The Advisory Committee on Radiological Protection has the purpose to promote the assessments related to radiological protection actions, procedures and detection equipment used by CNEN’s inspectors it also control the individual dose from CNEN’s employees. It reports to the Director of DRS. This committee also performs the licensing of Radiation Protection Supervisors, according to the CNEN’s standards.

The Advisory Committees on Decommissioning has the purpose to develop a draft of regulatory standard on the management of financial reserves for decommissioning of nuclear power plants.

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and test in simulator. It is responsible for all technical activities to support the issue of an Operator Reactor License.

8(1). 13 – International Activities.

In accordance with the Brazilian Legislation, CNEN conducts international activities related to statutory mandates, international treaties and conventions, international organizations, bilateral relations, and research.

8(1). 13.1 - IAEA

CNEN actively participates in many IAEA Committees: CSS –-Commission on Safety Standards, NUSSC - Nuclear Safety Standards Committee, WASSC - Waste Safety Standards Committee, TRANSCC - Transport Safety Standards Committee, RASSC - Radiation Safety Standards Committee, EPReSC - Emergency Preparedness and Response Standards Committee, NSGC - Nuclear Security Guidance Committee and INSAG – International Safety Advisory Group.

CNEN is an active member of the IRS and IRSRR systems and contributes yearly with the presentation of events on the general meetings.

CNEN staff participates in many IAEA Technical Meetings (11), Conferences (1), and Courses (2).

8(1). 13.2 - Bilateral Cooperation Issues and Regional Activities.

CNEN has Bilateral Cooperation Agreement with Gesellschaft Für Anlagen und Reaktorsicherheit (GRS) of The Federal Republic of Germany for the exchange of Technical information and Cooperation in Regulatory and Safety Research Matters. Under this agreement three Workshops were held in the period 2013 to 2015. In 2015, CNEN started a new Project with European Commission, Project BR3.02/12 - “Support to the Nuclear Safety Regulator of Brazil” and is dedicated to the enhancement and strengthening of the nuclear safety regulatory regime in Brazil in compliance with international criteria and practices. The Consortium RISKAUDIT IRSN/GRSwas chosen by European Commission to carry out this project. This Consortium is composed of the following members: Institut de Radioprotection et de Sûreté Nucléaire (IRSN–France), Gesellschaft Für Anlagen und Reaktorsicherheit (GRS - Germany) mbH, Radiation and Nuclear Authority (STUK-Finland) and TECNATOM S.A. (Spain).

The **Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC)** is a binational agency created by the governments of Brazil and Argentina, responsible for verifying the pacific use of nuclear materials.

8(1). 13.3 - International Cooperation between Regulatory Bodies.

CNEN is a member of The Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO). The FORO is an association created in 1997 to promote nuclear and radiological safety, and physical security at the highest level in the Ibero-American Region.

Today the FORO is composed of radiological and nuclear regulators from Argentina, Brazil, Chile, Colombia, Cuba, Spain, Mexico, Paraguay, Peru and Uruguay. The main objective of FORO is to provide an environment for the exchange of experiences and the development of joint activities related to common problems, in order to achieve the strengthening of the capacity and competence of its members. IAEA is the scientific reference organism of FORO and participate in all the technical activities.

The Brazil took part of the following FORO's projects:

- Project PREEV (2009 – 2011),
- Project “Iberoamerican stress tests” (2011 – 2017),
- Project on development of Regulatory Bodies competences in Nuclear Safety (2012 – 2014).

As a consequence of the decision of the German Government to phase out from nuclear power, in 2013 a KWU Regulators Club was established by regulators from Germany, Netherlands, Spain and Switzerland with the purpose to share experience among them. The Brazilin Regulator (CNEN) joined this Club in 2014.

Article 8 (2) Status of the regulatory body

The relation amongst regulatory organizations and operators is shown in Figure 7.

8 (2).1 - Place of the regulatory body in the governmental structure

The following summarizes the relationships among the Federal Government Organization:

- MCTI: Ministry of Science, Technology and Innovation.

The MCTI has the following competencies: national policy of scientific research, technology and innovation; planning, coordination, supervision and control of the activities of science and technology; development policy for IT and automation; National biosafety policy; space policy; nuclear policy and control the export of sensitive goods and services. The Nuclear Energy National Commission (CNEN) is a branch of MCTI.

- SIPRON: System of Protection of the Brazilian Nuclear Program

The SIPRON has the duty, between others, to coordinate the necessary actions, in the governmental level, to meet permanently the safety and security needs of the Brazilian Nuclear Program (PNB) and plan as well as coordinate the necessary actions in case of nuclear emergencies which aim to protect people, workers and the environment.

- MMA: Ministry of Environment.

This Ministry is basically responsible for the National Environment Policy. The Brazilian Institute of Environment and Renewable Natural Resources, known by the acronym IBAMA, is a Federal Agency and it is responsible for implementing the National Environmental Policy, developing various activities for the preservation and conservation of the natural heritage, exercising control and supervision of the use of natural resources, also granting environmental permits for projects of their competence. (See item 8(2).3)

- MME: Ministry of Mines & Energy.

In 2003, Law n° 10.683 defined the competencies of the MME in several areas, including electric power, as well as nuclear. The Ministry has some related companies such as Eletrobras, which controls, between other companies, Eletrobrás Termonuclear S/A (Eletronuclear) which aims to design, build and operate nuclear power plants in Brazil. Currently it operates the Almirante Álvaro Alberto Nuclear Power Station located in Angra dos Reis, with total capacity of 2007 MW.

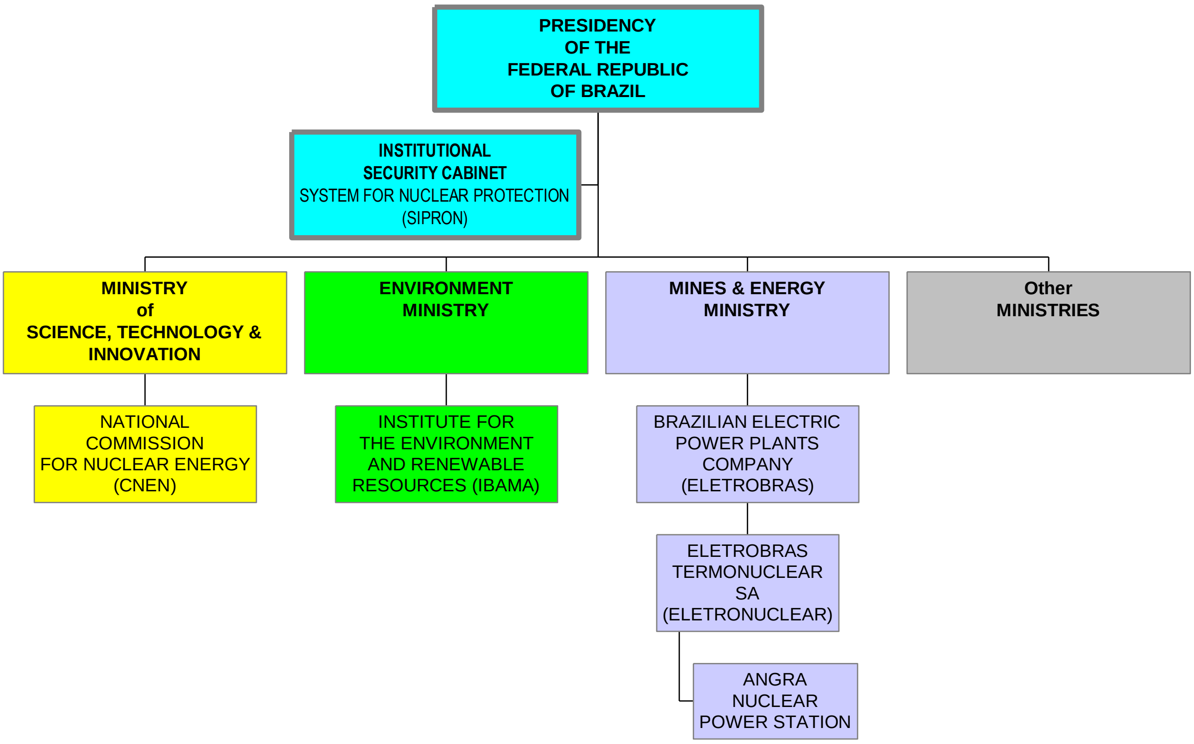

Fig. 7 – Brazilian organizations involved in nuclear power plant safety

8 (2).2 - Effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

The separation between the functions of the regulatory body (CNEN) and the organization concerned with the utilization of nuclear energy for electricity generation (ELETRONUCLEAR) is provided by the structure of the Brazilian Government in this area. While CNEN is linked to the Ministry of Science, Technology and Innovation (MCTI)**,** ELETRONUCLEAR is fully owned by ELETROBRAS, a national holding company for the electric system, which is under the Ministry of Mines and Energy (MME).

There is a discussion to create an independent nuclear regulatory agency. The reason for this proposal is not a deficiency in the existing regulatory system, but rather a perspective of expansion of the nuclear energy sector. The proposal is based on the existing structure of the Directorate of Radiation Protection and Nuclear Safety (DRS) of CNEN, adapted to the existing Law for Regulatory Agencies.

As mentioned in the Summary, CNEN has prepared a draft legislation for the creation of the independent regulatory agency. This proposal was sent to the concerned ministries, but CNEN's new leaders asked it back for further discussions which are in progress. Meanwhile DRS and CGRC are proceeding with the licensing review of the installations, including the research reactor of DPD/CNEN, as an effectively independent organization.

One of the new features in the proposed legislation is the formal inclusion of financial sanctions in order to face non compliances in a graded approach.

8 (2).3 - Other governmental bodies are also involved in the licensing process: IBAMA

The Law 7735 created IBAMA in 1989, which is responsible to implement and enforce the National Environmental Policy (PNMA - Brazilian Law 6938 of 1981). The structure of IBAMA is presented in Figure 8. The main organizational units involved with the regulation and control of nuclear power plants is the Directorship of Environmental Licensing (DILIC) and the Directorship of Environmental Control (DIPRO).

The Directorship of Environmental Protection (DIPRO) represents IBAMA in the CCCEN and in the COPREN, which are two multi-stakeholders committees to act in the response of an eventual Nuclear Accident in the CNAAA.

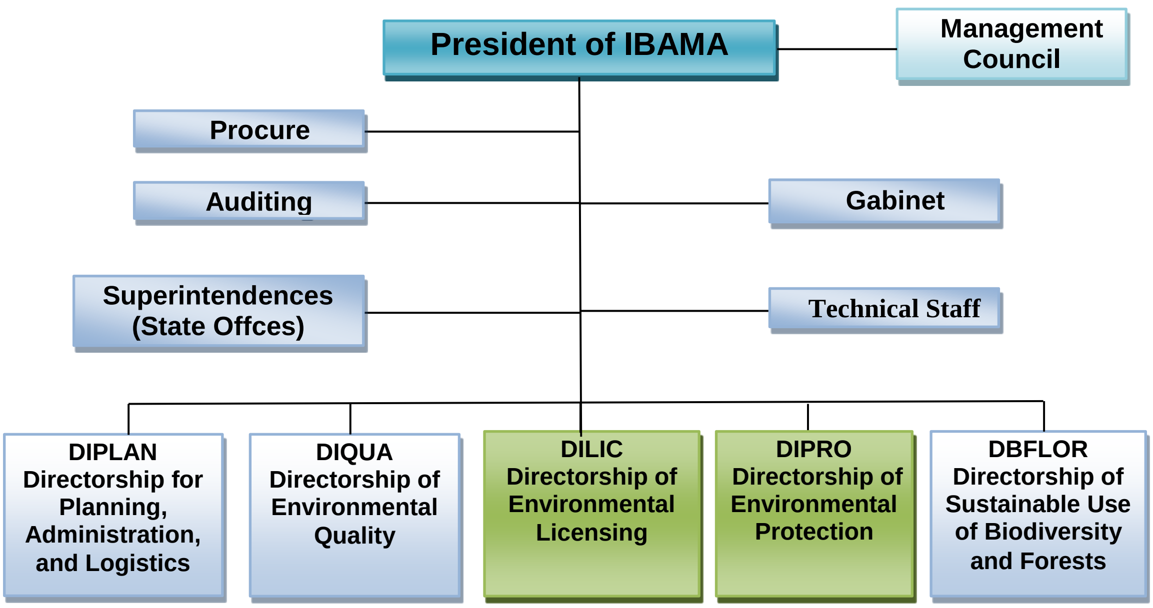

Fig. 8 - IBAMA Structure

Three divisions of the Directorship of Environmental Licensing (DILIC) carry out the environmental licensing of nuclear activities and facilities: the Coordination of Electrical Power, Nuclear and Pipelines (COEND); the Coordination of Mining and Civil Infrastructure Projects (COMOC); and the Coordination of Ports, Airports and Waterways (COPAH). The structure of DILIC is presented in Fig. 9.

COEND performs the environmental licensing of the Nuclear Power Plants, the Nuclear Fuel Factory, the Nuclear Research Centers (CNEN and Navy), the Radioactive Waste Deposits, the Transportation of Radioactive Materials, and, after the enactment of the Federal Law 140/2011, any other radioactive facility. Also observe that:

- With respect to Nuclear Fuel Factory, COEND has also unified the environmental licensing of the three units in operation and issued the Operation License N° 1174/2013 to the complex that encompasses the activities of component manufacturing, fuel elements assembly, uranium enrichment, UF6 reconversion, and chip manufacturing.
- Recently, the CNEN's Directorate for Research and Development (DPD) started up the environmental licensing process for two new facilities, also under IBAMA's COEND: 1) COEND issued the Term of Reference to the Environmental Impact Study (EIA) and the Report on Environmental Impact (RIMA) of the Repository for Low and Intermediate Level Waste in March 2016; and 2) the Brazilian Multipurpose Reactor (in 2010). After the technical evaluation of the Environmental Impact Study (EIA) and gathering of supplementary information the IBAMA issued the Prior License (LP N° 500/2015) in July 2015.

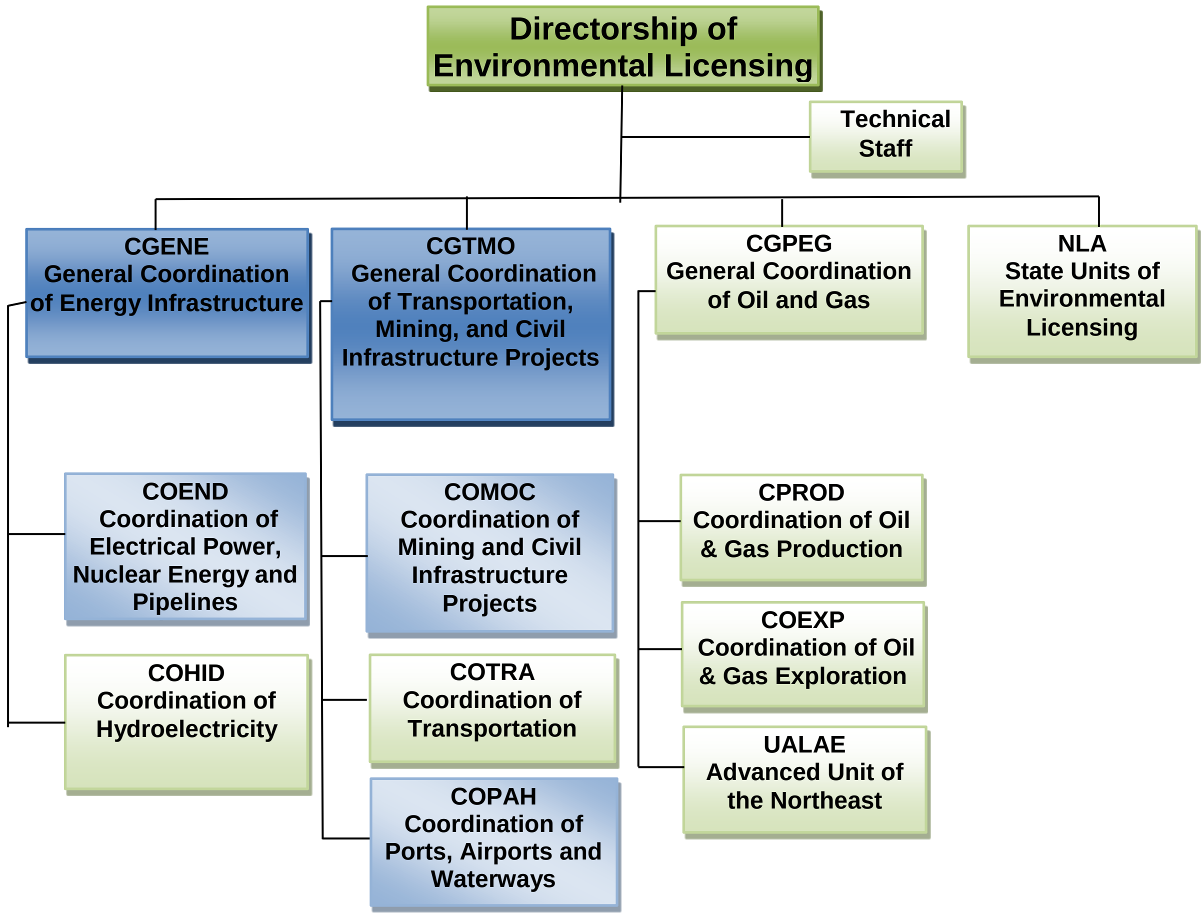

Fig. 9 - DILIC Structure

- In February 2016 IBAMA issued the Normative Instruction No. 01/2016, which established the criteria for the licensing of radioactive facilities.

COMOC carries out the environmental licensing of uranium mines in the municipalities of Santa Quitéria and Caetité and the decommissioning activities of the Ore Treatment Unit of Poços de Caldas (UTM):

- The Santa Quitéria Project consists of the exploration and processing of phosphate ore associated with uranium in a deposit owned by INB (Brazilian Nuclear Industries). In March, 2014, COMOC received the Environmental Impact Study (EIA) and the Report on Environmental Impact (RIMA). After the technical evaluation of the Environmental Impact Study (EIA), the IBAMA asked supplementary information to complement the evaluation in 2015. These studies will provide IBAMA with the technical information for the decision about the Prior Licensing (LP) of this enterprise.

- The Caetité unit of concentrate uranium (URA) comprises two mines and a processing plant, whose final product is U3O8 in the form of ammonium diuranate (yellow cake). In April, 2015, COMOC issued the Installation Licence (LI 1057/2015) of the Engenho mine in the site.
- The Ore Treatment Unit of Poços de Caldas (UTM), is currently undergoing decommissioning. COMOC has approved the conceptual project of the unit's decommissioning. INB has yet to present the executive project to be evaluated and approved by COMOC.

COPAH performs the environmental licensing of the Brazil's nuclear submarine. In April 2010, IBAMA issued the LP 351/2010, and In December 2014, IBAMA issued the LI 1031/2014 to this project.

Article 9 – RESPONSIBILITY OF THE LICENSE HOLDER

The Brazilian legislation defines the operating organization as the prime responsible for the safety of a nuclear installation.

Moreover, in according to Article 4 of the law 6.453, regardless of fault, the civil liability for nuclear damage repair caused by a nuclear accident is an exclusive responsibility of the nuclear facility operator. This law has adapted to the three principles of Vienna Convention (1963): (i) the risk of nuclear damage; (ii) liability for nuclear damage; (iii) the amount of insurance to cover the nuclear damage.

In fulfilling its legal obligation, the Operating Organization has established adequate safety policies, organizational structure and procedures which reflect its commitment to safety, see Article 10.

More specifically, the CNEN's Safety Policy[8] and the regulation CNEN-NE-1.26- Operational Safety in NPP [7] define the operating organization as the prime responsible for the safety of a nuclear installation.

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-NN-1.14 [6]. 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 headquarters staff take place every year, focusing on specific topics or operational events.

Article 10 - PRIORITY TO SAFETY

At CNEN

CNEN has issued its Safety Policy[8] and Quality Assurance Policy Statements[9] in December 1996, which are based on the concept of Safety Culture.

The main principals of the CNEN's Safety Policy are:

- The legislation and rules shall determine safety objectives and establish the features to assure their implementation;
- The responsibilities shall be clear determined and the safety issues shall be treated by their merits without undue pressure;
- CNEN shall seek resources to performance its mission;
- The international exchange of safety information shall be encouraged by the Government;
- CNEN recognizes that the primary responsibility for safety rests with the operating organizations. Thus, CNEN should ensure that regulatory requirements are clear and contemplate a sufficient degree of flexibility to avoid undue restriction;
- The standards adopted by CNEN shall require appropriate levels of safety but without discarding the inevitable residual risk;
- Controversial topics shall be managed by CNEN in an open way. Individuals and institutions shall have the opportunity to express an opinion on them.

CNEN has established in its regulatory standards requirements to be met by the applicants or licence holders based on safety principles, defense-in-depth, ALARA concepts, quality assurance and human resources management. According to regulation CNEN-NE-1.26 [7] the licensee shall establish an organizational structure with qualified staff and managers to deal with technical and administrative matters using principles of a Safety Culture.

At ELETRONUCLEAR

ELETRONUCLEAR is a company resulting from the merger, in 1997, of the nuclear portion of the electric utility FURNAS and the nuclear design and engineering company NUCLEN, both with almost 40 years of experience in their field of activities. Both companies had already policies aiming the priority to nuclear safety. The current organization structure of ELETRONUCLEAR is presented in Figure 10, which is essentially the same as presented in the previous National Report.

ELETRONUCLEAR, as the owner and operator of the Angra 1 and Angra 2 plants, issued a company safety policy initially based on the INSAG 4 document, since its foundation, occurred in 1997, stating its commitment to safe operation. This policy was revised in 2004, becoming an “Integrated Safety Management Policy”, and revised again between 2012 and 2015, keeping the same content but expressed in an easier way to understand, as follows:

> *“We are committed to generate electricity with high standards of safety, reliability and environmental responsibility. So all of us, leaders and employees, we have to conduct our activities in an integrated manner, always giving priority to safety, which includes primarily the nuclear safety.*
>
> *Other topics are also part of our integrated safety such as quality assurance, information security, physical protection, industrial safety, health and radiological protection of occupational workers and the general population, and care for the environment.*

This was expanded into 7 principles, as follows:

> *PRIORITY: Nuclear safety is a priority. It is more important than the productivity and economy and is not to be compromised for any reason.*
>
> *PRESENCE IN THE FIELD: The frequent presence of the leaders in the field activities, the processes of communication and decision-making reinforces our commitment to safety.*
>
> *RESPONSIBILITY: The responsibility for our safety should be clearly defined and the various legal requirements met.*
>
> *TRAINING: All of us, employees and service providers, must be qualified and aware of various aspects of integrated safety necessary to carry out our work properly.*
>
> *PREVENTION: Risks to health, safety and environmental impacts must be prevented, minimized or eliminated.*
>
> *COMMUNICATION: Our communication processes, internal and external, should be transparent and efficient so that any unsafe condition identified will be promptly informed.*
>
> *CONTINUOUS IMPROVEMENT: We seek continuous improvement of our practices related to integrated management of safety.”*

These principles establish the commitment and actions of the higher and middle management as well as of the individuals toward safety.

To support this policy several permanent programs were created, such as, enhancement of safety culture and human performance, assessment of internal and external operating experience, self-assessments and external assessments (OSARTs and WPR), nuclear oversight committees, among others.

Strict adherence to this policy is firstly verified at the plant level by the Plant Operation Review Committee (CROU). The second and higher level of adherence to this policy is verified by the Nuclear Operation Analysis Committee (CAON), the supervisory committee with the responsibility to review and approve all important aspects related to the plants safety, reporting to the Operations Directorate level. The members of this Committee are the Plants Managers and the Heads of Engineering, Safety, Licensing, Quality Assurance and Training, under the coordination of the Site Superintendent (SC.O). The CAON meets regularly four times a year, and has as many extraordinary meetings as needed (on the average 8 times a year).

CAON is supported, in its plants safety oversight task, by a subcommittee, composed with members from Operations, Design and Support Engineering, Maintenance, Safety Analysis, Training and Quality Assurance. This committee reviews the operational experience reports, the Plants Safety committees meeting minutes as well as the Plants modifications documentation and takes any identified safety related issue to the CAON for scrutiny. This subcommittee also provides the CAON with a yearly evaluation of the Plants safety status.

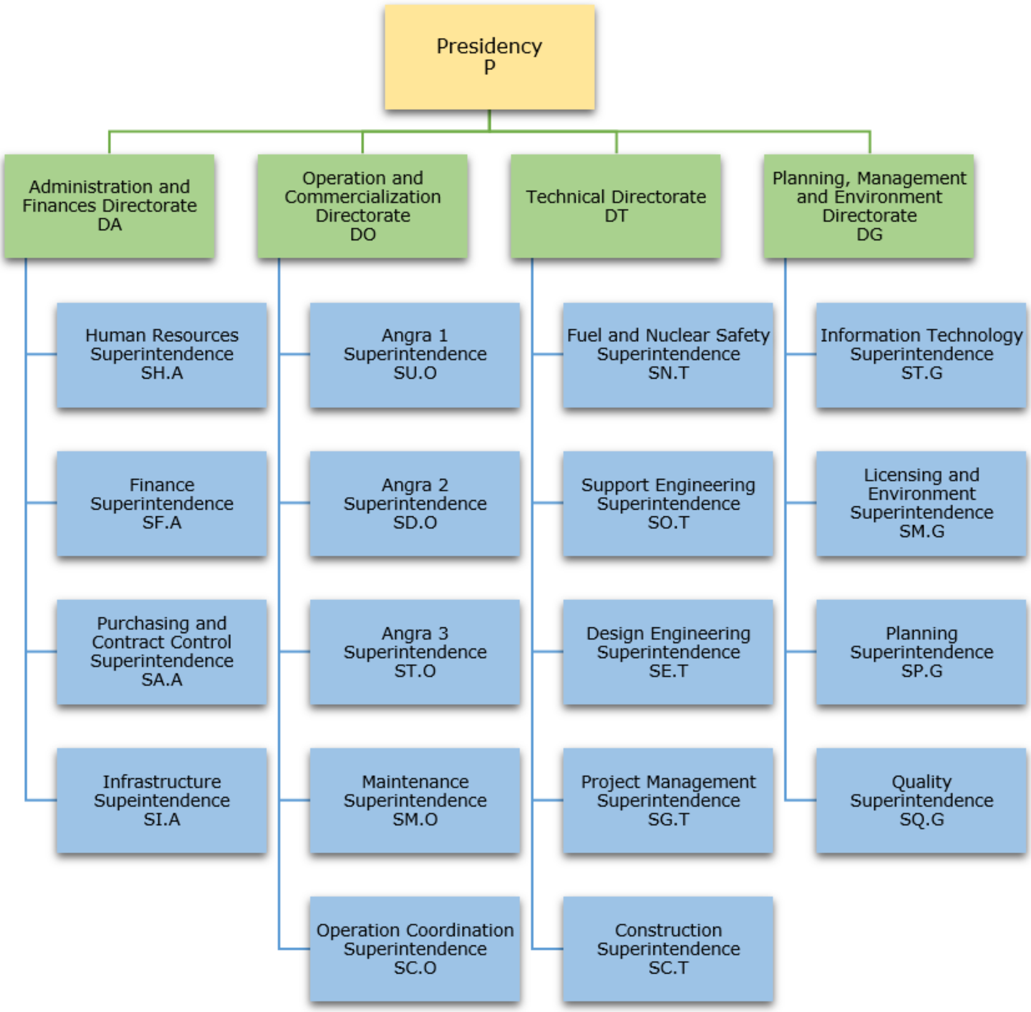

Fig. 10 – ELETRONUCLEAR Organization Chart

A third safety oversight committee, Independent Safety Oversight Committee (COSIS), established at the highest company level, comprising representatives of all directorates, was created to provide independent oversight, reporting directly to the Company Board.

The nature of the subjects under the COSIS review may range from CNAAA and Headquarters performance indicators, reported events, performance audits and plant safety reviews by either national or international bodies, results and recommendations of CROU and CAON, among others. The committee also has the autonomy to set up working groups for specific investigations of matters of interest related to the nuclear power plants safety.

The creation of COSIS is also aligned with the objectives of the WANO Performance Objectives and Criteria (PO&C) establishing that an independent oversight provides the senior leaders (if necessary through the Administration Council) a continuous perspective on Eletronuclear power plants and corporate performance compared with the industry, with main focus on nuclear safety, plant reliability and efficiency of emergency responses.

Following the line of the merged companies, a strong Quality Assurance (QA) unit was established, at ELETRONUCLEAR, from the beginning in 1997, at the level of superintendence, with the responsibility of monitoring all design, construction and operation activities and coordinating/supervising the plants nuclear and environmental licensing. This superintendence responded formally to the Technical Director at headquarters. With start of operation of the second Plant, in December of 2000, it was identified the need of a Quality Assurance unit inside the Operation organization. To meet this need the original QA superintendence was split in two units in 2003, one at headquarters, under the Technical Director and one on site, under the Operation and Production Director. This area was reorganized in 2007, keeping its previous characteristics of one unit at the Site and one unit at Headquarters, however now subordinated to a single Directorate independent of the production areas, the Planning, Management and Environment Directorate (see ELETRONUCLEAR Organization Chart, Fig. 10).

In 2011, ELETRONUCLEAR began a joint work with IAEA in the Project RLA9060 – Enhancing Operational Safety in Nuclear Installations. This project that has its additional scope funded by European Commission – Enhancement of Safety Culture, involves not only Brazil, but also Mexico and Argentine. From this work, 8 Peer Visits involving 26 Participants (among which 16 Brazilians) identified 53 Good Practices (49 for Brazil) that are under development and adjustment to be applied in a routine basis. Besides, a web platform (LASCN – Latin American Safety Culture Network) is being created by the project to sustain experience and information sharing between counterparts. As a consequence, ELETRONUCLEAR developed a Corrective Action Program which captures all inputs from deficiencies and allows a link to the associated actions. For the company, this was a step in the direction of implementing a Nuclear Oversight process, inspired in one of those good practices observed as well as improving its communication process based on benchmarking with partners of this project.

Eletronuclear is currently using the Pendencies Management System (Sistema de Gestão de Pendências – SGP), a corporate system for items pending of corrective actions, related to several areas of the company. It stores and maintains data on pending and deficiencies items detected through several internal and external processes, providing functions that enable the planning, monitoring and recording solutions. Moreover, it provides information that enables the preparation of reports, charts and indicators, serving as a large repository of operational experience and troubleshooting.

The SGP was implemented in 2004. The software (available in the company’s intranet to all employees) was built in a partnership between Eletronuclear and the Federal University of Rio de Janeiro. Since then and as a result of audits to which the system is submitted, it has been revised to improve efficiency and the integration of organizational units in their corrective actions programs.

The SGP has several processes as inputs. They include the CNEN's findings, WANO and OSART recommendations, Nuclear Operations Review Board (NORB) and Plant Operation Review Committee (PORC) resolutions and internal pendencies from: Quality Assurance; PSA; Periodic Safety Review; Radiation Safety; Industrial Safety; Operating Experience and Human Performance Committees and Environmental Safety.

Monthly, the Operations Directorate demands a meeting when all pending issues, its established goals and action plans are discussed and updated. All organizational unit managers to which SGP is related are present in this meeting.

As an effort to evolve to an effective Nuclear Oversight Program, Eletronuclear took several steps to detect the processes that should be reviewed and upgraded and feed this important program. The SGP is being considered as a starting point to this project. That was confirmed through a gap analysis conducted within the IAEA Project Regional Latin America, RLA 9060.

In September 2013, it was held at the Duke Power Company, in North Carolina (USA), a technical exchange mission sponsored by the IAEA (RLA 9060) focusing on Corrective Action Program for which Eletronuclear sent an expert. On this occasion, aspects concerning the operation and management of the program at this institution were discussed as a benchmark to the upgrade of the company SGP.

ARTICLE 11 - FINANCIAL AND HUMAN RESOURCES

Article 11 (1) Financial resources

ELETRONUCLEAR is a state-owned company of closed capital controlled by ELETROBRAS, an open capital company which holds the control of all the federal public companies of electrical energy in Brazil.

Until the year 2012, the company had as its revenue source the sale of electrical energy to its related counterpart FURNAS, generated by its plants Angra 1 and Angra 2, through a long term contract of electrical energy supply.

From January 1st 2013 onwards, as established by the government, the revenue of ELETRONUCLEAR due to the electrical energy generated by the Angra 1 and Angra 2 is composed by quotas from all the companies of public distribution service of the National Interconnected System – SIN. The Electrical Energy National Agency - ANEEL established the conditions for the commercialization and the calculation methodology of the annual quota to each distributing company. These quotas are proportional to the sum of consumers´ load of each distributing company.

The company has been keeping adequate resources for the operation and maintenance of the plants of Angra 1 and Angra 2, as can be visualized from the examples presented in Table 4, where a detailed comparison of the executed budgets for the years 2013 to 2015 is presented:

Table 4. Comparison of ELETRONUCLEAR budget from 2013 to 2015. Values in million R$

Items	YEARS		
	2013	**2014**	**2015**
Primary Costs			
Angra1 & 2 Personnel (salaries + benefits)	486	723	735
Angra1 & 2 Fuel	299	309	287
Other services, subcontractors and materials	629	559	674
Investments			
Angra 1 & 2 Upgradings (including engineering)	151	193	197
Angra 3 Site Maintenance and Construction	1482	1777	1728

As it can be seen from the above Table, the primary costs have been kept at about the same level along these three years, with the exception of personnel costs, about 50% higher. This sharp increase in personnel costs in 2014 and 2015, was caused by the payment of the incentives to personnel that joined the Early Retirement Program (about 620 employees), imposed by the Holding company Eletrobras. This personnel left the company along these two years.

The impact of the loss of such a large number of experienced personnel is briefly discussed in item 11(2).

As far as Investment Costs the program of Plant upgrades has had an increase of about 30% from 2014 on, and kept at this level in 2015, in such a way to continue to ensure a safe and reliable operation of the Plants.(see Article 6).

Also the expenditures for Angra 3 construction have shown an upward trend from 2013, indicating the larger amount of activities being performed with the construction evolution until December 2015, when the construction activities were stopped.

The company keeps in a Brazilian Federal Public Bank an exclusive investment fund whose use is restricted to the future financing of the decommissioning activities of the plants of Angra 1 and Angra 2 Plants, under the ownership of its holding (ELETROBRAS), as determined by the CNPE – National Board of Energy Politics.

The annual sums destined for this fund are formed from monthly contributions and have coverage in the rates structure during the same period of depreciation of the plants (3,3%/per year). The present estimated decommissioning costs are 432 million dollars for Angra 1 and 531 million dollars for Angra 2.

The main instrument to ensure the necessary financial resources in the event of a radiological emergency is the Special Fund for Public Calamities (Fundo Especial para Calamidades Públicas – FUNCAP), it is provided for emergency assistance in response actions to disasters, in according to Art. 148, paragraph I, of the Brazilian Constitution, "The Federal Government by supplementary law, institutes compulsory loans to meet extraordinary expenses resulting from public calamity, foreign war or the imminence thereof."

Article 11 (2) Human resources

Human resources are available for ELETRONUCLEAR from its own personnel or from contractors. Currently ELETRONUCLEAR has a total of 1947 employees on its permanent staff and a few long-term contractors, which supply additional personnel. From this total, 725 have a university degree, 866 are technicians and the remainder 356 administrative personnel.

Before getting to this number, in the review period, ELETRONUCLEAR had a great reduction in its staff employees resulted from the personnel reduction imposed by the holding company Eletrobras to all its subsidiaries, through an Early Retirement Program. About 600 employees joined this program and left the Company along 2014 and 2015.

Once the Retirement Program was announced, CNEN asked to ETN to present the actions that would be taken to face the losses of experienced employees. The Program was discussed with CNEN and meetings between high level managers were done in a regular basis.

The most significant losses occurred in the Eletronuclear Headquarters staff with a reduction of about 40% of its experienced personnel from engineering, commercial and administrative areas. The Operation and Commercialization Directorate was the least affected numerically (less than 20% losses) and had the additional possibility of replacing lost personnel in the operating plants by personnel hired and trained for Angra 3. Managerial positions were fulfilled with the regular substitution planning.

In order to minimize the impacts caused by the loss of experienced employees that joined the retirement program, it was launched in 2014 the Substitutes Preparation Program – PPS providing information to minimize the risk of human performance factors arising from unplanned outputs.

The following steps and respective instruments developed to support each step (with their respective results) are described below:

1. STEP 1: **Mapping of competences** (SKA: skills, attitudes and knowledge) necessary and likely to be developed in the context of the PPS.

   RESULTS:

   → Creation of data collection instruments;

   → Search for survey of SKA;

   → Delphi Technique application to construction of scenarios;

   → Mapping of the SKA which are vacant positions;

   → Mapping of skills gaps of likely successors.

2. Step 2: **Planning of training**, development and education relating to PPS.

   RESULTS:

   → List of learning actions for development of SKA;

   → Drawing up the plan of training;

- → Development and education to the PPS, including instructional objectives and instruments of data collection for evaluation of actions.

3. Step 3: **Implementation of educational actions** and transfer of knowledge.

   RESULTS:

   → Definition of educational actions;

   → Creation of an Organizational Socialization Program and Organizational Integration Program.

4. Step 4: **Evaluation of actions of training**, development and education and other to be developed under the PPS.

   RESULTS:

   → Instruments of evaluation in five phrases: reaction, learning, impact on behavior in office, impact on organizational outcomes and return on investment, being the first three implanted in the short term and the last 2 in the medium term.

5. Step 5: **Eletronuclear Training Management Model**, Development and Education.

   RESULTS:

   → Model Eletronuclear in management of training, development and education, having as focus actions routed to the retention of employees.

In 2016, in order to replace the personnel lost in areas were own personnel is required in accordance to CNEN and Labor Ministry guidelines, ELETRONUCLEAR was authorized to promote a public examination with the purpose of occupying the vacancies left in three specific job positions in the company: occupational health physician, field operator and security specialist.

Implemented in 2010, the Organizational Climate Survey had the objective to analyze the employee`s perceptions of their work environment, about aspects like communication, leadership and that sort of thing. Comparing the result of the first survey conducted in 2010 (when the favorability index was 65,51%), the level of satisfaction has been increasing and in 2015 the result has achieved 68,81%. This instrument helped the Human Resources area to monitor the internal atmosphere of the organization and address plans to interfere more directed in some specific points.

Eletronuclear continues to keep an agreement with the Brazilian Coordination for Improvement of High Level Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES) to provide scholarships to graduate programs in public or private institutions that have courses in the nuclear area.

The Human Performance Program was implemented in 2007 and since then, it has been increasing in terms of actions and areas. The goal of the Program is to systematize actions in order to promote the improvement of employees working at Eletronuclear so as to reduce human errors and error-related events. One of the basic methodologies is the reduction of human errors through the comprehension of the reasons why the errors occur and the conscience and perception of emotional and behavioral factors with also the use of error prevention tools.

The human resources representatives at Human Performance Program are the Psychologists from the Eletronuclear permanent staff. They participate in the initiatives from this program so as described below:

- Basic trainings applied to all new employees including disciplines as error theory, error precursors, and error prevention tools.

- Application of the Human Performance Module inside the Outage Training to an average of 1500 contractors from Angra 1 and Angra 2 NPPs over the last three years, before their respective refueling outages.

- Application of Team Work Training for operator, chemical and maintenance areas. This training was structured to develop skills and attitudes for a good relationship, communication and integration of the team.

- Attendance of daily safety dialogue from maintenance area. The main objective is to draw attention to the error precursors and reinforce the errors prevention tools. Besides that, some subjects as leadership, motivation, conflict resolutions can be discussed as well.

- Behavioral aspects are observed on training operators in order to give them emotional support and develop necessary skills for the exams.

- Participation in simulators training to follow-up behavioral aspects (teamwork, leadership, communication, decision-making processes, error precursors, etc.) for the operator’s staff from Angra 2.

- Participation in the plants Human Performance Committees. In committees, it is discussed the strategies to reduce the human errors and the effectiveness of the initiatives. One of the contributions of the psychologists is the development of the newsletters covering topics such as communication, teamwork and motivation.

Since 2011, the psychologist staff of Eletronuclear has been effectively included in the root-cause analysis group working at the plants Angra 1 and Angra 2 analyzing all kind of events, even those that are not at first related to human errors. The goal is to verify if the event is related to human error and, if so, determine the causes of the problem and how they should be treated, seeking to avoid repetition or recurrence of events in the future. In 2015, 52 events occurred in Angra 1 and 63 in Angra 2 were analyzed.

Activities related to qualification, training and retraining of plant personnel are performed by the Training and Simulator Department of ELETRONUCLEAR, which reports to the Site Superintendent.

Four main facilities are available for training in the Plants personnel residential village, located at about 14 Km from the site: a general training center, a full scope simulator facility for Angra 2, a brand new full scope simulator facility for Angra 1, and a maintenance training center. Two Interactive Graphic Simulators (IGS) are available to support classroom training.

These facilities have been expanded in 2010 with the construction of two new blocks (~700 m^2) for classroom and mechanical, electrical and I&C maintenance labs training to support identified needs of better practical maintenance training and additional classroom space for the Angra 3 personnel.

As reported in the previous Brazilian National Reports, Angra 1 operators have done their simulator training abroad, in simulators of similar plants.

Following the successful replacement of the Angra 1 Steam Generators completed in June 2009 and the possibility of extend the life of the plant, in operation since 1985 and in order to fulfill CNEN's requirements, the original decision of installation of a plant specific simulator was confirmed by the Company Board.

The contract for the supply of a replica full scope simulator for the Angra 1 Plant was signed in February 2012, after an international bid process.

The simulator development was done on schedule with completion of site acceptance tests by end of February 2015. After about 4 month for training of instructors in the operation of the simulator and preparation and running of the simulator training material, the simulator was available for use in July 2015.

The Angra 2 full scope simulator is available on site for operator training since beginning of 1985. This simulator was originally used to provide external training services until start of training of the first group of Angra 2 operators, in 1995. The first group of Angra 2 control room operators was licensed in the beginning of 2000.

This simulator has undergone periodical partial upgrading of the hardware (basically the computers) at about every 10 years, as well as adaptation of the models and control room to take in account changes in the Angra 2 plant. In spite of still providing a good simulation performance, its original software used for the plant modeling had considerable limitations compared to today software.

A contract for a major software and hardware upgrade was signed in mid-2009 involving substitution of the computers and of the old operational system, provision of a new instructor's station with modern features, review of the models programming language and provision of new models for the core, primary system and containment. This upgrade took longer than expected and was finally completed by end of 2013 after a long verification and validation period.

In the period under review (2013 to 2015), the initial and re-qualification, training programs performed for the Angra 1 power plant operators, allowed 43 operator licenses to be renewed and 3 new licenses to be granted.

For Angra 2, in the same period, 39 new operators completed successfully their training program and received their licenses and 57 operators completed the training requirements for license renewal.

The process for acquisition of the Angra 3 simulator, which will feature the same digital instrumentation that will be installed in the Plant as well as a separate module that allows simulation of severe accident , has been temporarily interrupted awaiting for a decision on the new Plant construction time schedule.

In the meantime, the future Angra 3 operators are being trained in the Angra 2 simulator, taking advantage of the similarity between the Angra 2 and 3 plants. These operators will be licensed for Angra 2 so that they will be able to acquire practical control room experience in Angra 2 before going to Angra 3.

A final simulator-training period will be applied when the new Angra 3 simulator is available to allow these operators to familiarize themselves with the Angra 3 computerized control room, which is the most important difference between the two plants.

As indicated above the first group of 22 Angra 3 operators have completed their initial training using the Angra 2 simulator and passed the written, oral and simulator examinations obtaining their licenses for Angra 2.

Simulator training load is at least 60 hours per year for each individual. The composition of control room teams is specified in plant administrative procedures. The minimum control room team comprises a Shift Supervisor (who must hold a current Senior Reactor Operator - SRO license), a Shift Foreman (also a SRO), a Reactor Operator (who must hold a Reactor Operator – RO license) and a Balance of Plant Operator (also a RO). Although not required by CNEN, all Angra 1 Shift Supervisors are graduated engineers with five years of academic education.

The requirements for organization and qualification of the Angra 1 and 2 staff are established in Chapter 13 of the respective FSAR. Implementation and updating of these requirements is subject of CNEN audits of the licensee training and retraining program and examination of new operators to comply with the regulations CNEN-NN-1.01[5] and CNEN-NE-1.06[10].

According to regulation CNEN NN 1.01[5], besides the Control Room shift personnel, the Head of the Operation department must also hold an SRO license. Additionally, Radiation Protection Supervisors must also hold a special license issued by CNEN, according to regulation CNEN-NN-7.01 [11].

Aside from the requirements of the regulations, it has been a permanent policy of the Operation and Production Directorate to occupy important management positions at the plants with licensed or former licensed operators. In particular, the Plant Manager, the Deputy Plant Manager, the head of Operation Department and the heads of Technical Support and Maintenance for both Plants are currently licensed SRO. Furthermore, key engineers belonging to Technical Support and Outage Planning are receiving SRO training and certification with the dual purpose of acquiring a better knowledge of the operation processes and improving of interfaces between these areas and operations.

Specialized training is also provided for personnel belonging to the different plant areas. Maintenance technicians follow qualification and re-qualification programs tailored to their field of activity. Chemistry and radiological protection technicians follow extensive on-the-job training on a yearly basis aimed at a continuous updating of basic concepts learned during their initial technical training. The fire brigade and security personnel are trained according to the requirements established by related CNEN regulations.

A detailed training program for the Angra 3 future staff was developed in 2008, as well as the planning for the needed training infrastructure. Hiring of personnel has started in beginning of 2009 followed by the implementation of the referred training program. To date all 266 new hired employees have received specific training to occupy their future positions in the Angra 3 staff organization. The training duration depends on the specific position to be occupied by the trainee, varying from 1-2 month up to 2 years for licensed operators.

The authorization for hiring of the remaining 245 new employees to complete the needed Angra 3 staff is in hold.

Technical visits and reviews of ELETRONUCLEAR training programs and training center by experts from the International Atomic Energy Agency (IAEA), the Institute for Nuclear Power Operation (INPO) and the World Association of Nuclear Operators (WANO) continue to provide valuable contribution to the identification and implementation of good practices of the nuclear industry for enhancing the quality of the training activities.

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.

In the specific case of reactor operators, CNEN has established regulations related to their authorization[5] and their medical qualification[10]. CNEN conducts written and practical examinations for Reactor Operators and Senior Reactor Operators before issuing each individual authorization.

Similarly, CNEN certifies the qualification of radiation protection supervisors (RPS) by issuing licenses with a validity of five years.

In the period 2013 – 2015, CNEN has issued a total of 35 licenses for Angra 1, 3 new operator licenses (3 SRO) and 32 renewals (18 RO and 14 SRO), and a total of 108 licenses for Angra 2, 39 new licenses (15 RO and 24 SRO) and 69 renewals (19 RO and 50 SRO).

The standard CNEN-NN-1.01 – *Licensing of Nuclear Reactor Operators* also establishes the criteria for inactive or active licences.

This certification process is representing a substantial demand on CGRC manpower and it will increase with the increasing number of operating plants.

Article 12 - HUMAN FACTORS

12.1 - Regulatory requirements and organizational issues

The Brazilian nuclear regulation was and is still strongly influenced by the model used in the United States Nuclear Regulatory Commission, particularly with regard to stages of the licensing process. One consequence of this influence was the incorporation into PSAR and FSAR of the so called human factors engineering (Chapter 18). The NUREG-0711, Revision 3, Human Factors Engineering Program Review Model, has been adopted as a reference for the safety evaluations, taking into account the technological differences between Westinghouse and Siemens/KWU (AREVA) designs. The human factors engineering approach to be presented in PSAR and FSAR is composed by the following topics, in accordance with NUREG-0711 (the twelve elements of the HFE program's review model):

1. Human factors engineering program management;
2. Operating experience review;
3. Functional Requirements Analysis and Function Allocations;
4. Task Analysis;
5. Personnel Qualification and Quantification (Staffing and Qualification);
6. Treatment of important Human Actions (Human Reliability Analysis);
7. Human – System Interface Design;
8. Procedures Development;
9. Training Programs Development;
10. Human Factors Verification and Validation;
11. Design Implementation.
12. Human Performance Monitoring.

The Regulatory Framework related to Human Factors is based in the following main documents (among others referenced in the NUREG-0711 that must be used):

1. NUREG-0700, Rev.2, Human-System Interface Design Review Guideline, May 2002, (U.S. Nuclear Regulatory Commission).
2. NUREG-0711, Revision 3, Human Factors Engineering Program Review Model, 2012, (U.S. Nuclear Regulatory Commission).
3. NUREG-0737, Supplement 1, Requirements for Emergency Response Capability, 1989, (U.S. Nuclear Regulatory Commission).
4. NUREG-0800, Standard Review Plan (SRP).
5. NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (U.S. Nuclear Regulatory Commission).
6. NUREG/CR-4227, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, 1985.

7. NUREG/CR-5439, Human Factors Issues Associated with Advanced Instrumentation and Controls Technologies in Nuclear Plants, 1990.
8. NUREG/CR-5908, Vol.1, Advanced Human-System Interface Design Review Guideline, (U.S. Nuclear Regulatory Commission), 1994.
9. Regulatory Guide 1.97, Instrumentation for Light-Water-Cooled Nuclear Power Plants to Asses Plant and Environs Conditions During and Following an Accident, Rev.3, (U.S. Nuclear Regulatory Commission), revision 4, June 2006.
10. NUREG/CR-6751 - The Human Performance Evaluation Process (HPEP): A Resource for Reviewing the Identification and Resolution of Human Performance, (2001).

12.2 - Human factors in the design.

Angra 1

Concerning the human factors engineering design considered in the Angra 1 Plant, being an early Westinghouse, type PWR, with two-loop, was designed at a time when human factors were not formally and systematically taken as a prime issue in nuclear safety. Following the accident at Three Mile Island, in 1979, and still before beginning of operation, a critical review of the Angra 1 plant design with respect to man-machine interface was undertaken. This resulted in numerous modifications in the control room, including the installation of the Angra 1 Integrated Computer System (SICA), which encompasses a Safety Parameter Display System (SPDS) and a Critical Safety Function (CFS) monitoring program.

The Federal University of Rio de Janeiro in a partnership with the applicant developed the SICA. The hardware and software of this Integrated Computer System is upgraded in 3 to 4 years intervals, for better equipment performance and increase of features, such as number of monitored parameters, frequency of data acquisition, among others.

At the same time, plant emergency operating procedures were greatly improved in their format, which now incorporate double columns, the left one with the expected action and the right one with actions to be taken in case of inadequate response.

A new layout of the control room was implemented considering ergonomic aspect and operational experience.

The Angra 1 Plant has a new simulator recently installed. Since 2015, this simulator has been used for training of the operators to be licensed, as well as the requalification of operators of the plant operation staff. The acceptance of this simulator was submitted to CNEN and all documentation for qualification were based in the standard ANSI/ANS 3.5- Simulators for Operators Training.

Angra 2

The family of German PWRs, to which Angra 2 belongs, was designed giving great importance to HFE safety and operational aspects. The most important feature is known as the “30 min rule”, by which the plant I&C is designed to meet the requirement of automatic accident control for the first 30 minutes, to allow sufficient time to the operators to plan their subsequent manual actions for accident control.

In the operational aspects, repetitive and routine operations have been automated to relieve operators of boring tasks and so reducing the possibility of human errors. The long operational experience of these plants, as well as the first 15 years of operation of Angra 2, confirm the effectiveness of their HFE.

Among the improvements of the man-machine interface that have been introduced relative to the Angra 2 original design, the most important was the addition of a Integrated Computer System (SICA) for extension of the scope of the plant Safety Parameter Display System (SPDS) and for monitoring of the Critical Safety Functions (CSF). This was done subsequently to the plant commissioning.

This system was further improved, with a substantial increase in the number of monitored variables, following the replacement of the Angra 2 plant process computers. This improved version was also installed in the Angra 2 simulator.

12.3 - Methods and Programmes

The basic requirements concerning human factors and organizational issues important to safety for the Brazilian Plants are established in the different chapters of their Final Safety Analysis Reports (FSAR). Under “Conduct of Operations” and “Administrative Controls” the plants organization structure, qualification and training program requirements for plant personnel, types of procedures required, etc., are established. The consideration of Human factors in the design is treated in the FSAR I&C chapter, as for instance, implementation of automation to help and relieve operators from performing repetitive tasks or for allowing adequate time for complex actions as well as the design of the Man-Machine-Interface of the Main Control Room.

For the Angra 2 plant an additional chapter “Human Factor Engineering” was prepared **and incorporated in the FSAR**, which details the several aspects of human factors taken into account in the design of this plant.

These basic requirements contemplate Brazilian nuclear regulations and the regulations of the Country supplier of the plant, when no specific Brazilian regulation exists. Complementation of these requirements, to take into account newer knowledge or experience, is achieved by internal programs for enhancement of safety culture and human performance, feedback from internal and external operational experience as well as from Regulator requests.

As reported in previous National Reports a safety culture (SC) enhancement program based on an IAEA supported in-house SC self-assessment was developed beginning in 1999-2000 and has become a permanent program at Eletronuclear S.A. Training on SC concepts is provided since then on the New Employee initial training program and refreshed yearly in the in the periodic retraining for plant access.

Since 2007 the Human Performance Program has been improved and can be considered a key role in terms of reinforcement of safety culture in the company. In the beginning the objective was to train every employee in the human performance fundamentals on the use of error prevention tools. After this, the retraining has been developed under the responsibility of the immediate leader. This approach was chosen to allow the involvement in all the levels of the company with the principles of Human Performance. For the new employees and contractors the basic training continues being conducted by the psychological and technical professionals, to provide uniform guidance related to Human Performance.

In response to a CNEN requirement of establishing a Human Factor Engineering program for Angra 1 following the American licensing guidelines of NUREG-0711, Human Factor Engineering (HFE) Program Review Model, and was incorporating in this program a new FSAR chapter (chapter 18), as established in NUREG-0800 Standard Review Plan. Then, an evaluation of the Angra 1 HFE was developed along 2011 and 2012. The expertise for developing this program has been provided through a Cooperation Protocol between Brazil and the European Commission. This work was completed providing an overall review of the Angra 1 HFE aspects, in particular of the Main Control Room. No major discrepancy was found. Some upgrade recommendations have been issued for displays in the main control room. As required, a FSAR chapter 18 was prepared and has been sent to CNEN.

As already informed in the previous National Report, for Angra 2, CNEN requirements concerning HFE evaluation were basically the same reported above for Angra 1. That is, the preparation of a chapter 18, in accordance to NUREG 0800 following NUREG 0711. Although Angra 2 was designed following basically German standards, it was agreed in the licensing process to adopt the above NUREGs for itemization and format, with the contents and criteria from the actual plant design documentation. The developed chapter 18 was approved with a series of conditions, most of them fulfilled before criticality and some for later compliance.

These last requirements have been incorporated in a HFE verification program using the Angra 2 full scope simulator and analytical evaluations the results, obtained by comparing the required and available times for manual operator action for a set of critical transients/accidents, resulted in no operator overload, indicating the adequacy of the Angra 2 HFE design, including the main control room Man-Machine Interface (MMI).

The above mentioned HFE verification program is not yet concluded, as there are still CNEN open questions concerning the human reliability analysis developed for the Angra 2 level 1+ PSA and operator behavior in case of beyond design events including severe accidents. Work is being done on both fronts; the actions involved however are of long duration, such as developing a Level 2 PSA and the respective human reliability analysis, which were recently concluded.

The main finding in the field of HFE in the recently completed Angra 2 PSR was, as for Angra 1, the lack of a systematic approach for treating these aspects in the plant modifications process.

CGRC audit periodically the following programmes:

- Qualification Program for Engineering and Technical Support Staff;
- Implementation of the Job and Task Analysis Training based on the Systematic Approach to Training (SAT);
- Instructor Qualification and Managers Training Systematization.

In the case of Angra 2, the subjects related to the Cognitive Task Analysis (using the Angra 2 simulator to obtain the time spent to perform operational tasks) and Human Reliability Analysis has been analyzed by CNEN, according to the following standards "Time response design criteria for safety-related operator actions"(ANSI/ANS 58.8 – 1994), "Good Practices for Implementing Human Reliability Analysis" (NUREG-1792, USNRC, 2005) and "Evaluation of Human Reliability Analysis Methods Against Good Practices" (NUREG 1842, USNRC, 2006).

The standard CNEN-NN-1.01 – Licensing of Nuclear Reactor Operators[5] requires the qualification of the simulators used in the training of nuclear reactor operators. Such qualification is evaluated by CNEN. Angra 2 has a specific simulator installed in the Training Center near the plant. The training of the Angra 1 operators has been performed at the Almaraz plant simulator (TECNATOM, Spain) that was adapted to this task, until May 2015. Since then, the entire Angra 1 Operator's retraining program has been performed in the new simulator in Mambucaba Training Center.

Severe Accidents Procedures are presupposed in the Standard CNEN-NE-1.26 –Operational Safety in Nuclear Power Plants[7]. This kind of procedure requires firstly an analysis of the design vulnerabilities to the severe accidents to be performed by means of a Probabilistic Safety Assessment (PSA) coupled with a Human Reliability Analysis (HRA). This requires in turn the elaboration of the FSAR chapter 19 - Severe Accidents for Angra 1, 2 and 3, according to the review and acceptance criteria described in the NUREG-0800 (March 2007) and NRC Regulatory Guide 1.200 (March 2009).

Regarding Angra 3, the FSAR chapter 18 was evaluated by CNEN and yielded several findings when compared to the acceptance and review criteria of the NUREG-0711 and German Standards. Particularly, the use of digital technology implies in several new safety issues compared to the technology utilized in the past. The computerized control room is much more integrated with the instrumentation and control systems and is necessary to investigate carefully the influence of the digital architecture on the staff behavior (human actions) during the operational events occurring in the control room. The CNEN review activities aim to verify that accepted HFE principles are incorporated during the design process and that the human-system interfaces reflect a state-of-the-art HFE design. The findings mentioned above need to be cleared to guarantee the commitment in the previous sentence.

12.4 - Self-assessment of managerial and organizational issues by the operator;

Self-assessments, including organizational aspects, are performed for all main plant areas, on a regular schedule and in preparation for the external reviews, OSART or WANO Peer Review (WPR) every three years, for each plant (see Article 19(7)), where the managerial and organizational aspects at plant management level are also evaluated.

The first WANO Corporate Peer Review was requested by Eletronuclear to evaluate managerial and organizational aspects of the Company as a whole, focusing on the level and adequacy of the alignment between the company headquarters in Rio and the plants site, about 200 km away, at Angra. This Corporate WPR was performed in July 2007 with a follow up mission in 2009.

As a consequence of the Post Fukushima Action Plan, and following a new schedule established by WANO for this type of Peer Review, a second WANO Corporate Peer Review was held in 2014. The results showed that there is the need to improve the existing communication within the corporate levels, in order to guarantee a better alignment of targets, and to promote a more efficient resource allocation on programs and projects.

The final report also showed that senior leaders acknowledged that the monitoring and oversight organisation should use independent nuclear safety assessments more effectively. As a result, an Independent Nuclear Safety Oversight Committee (COSIS) reporting to the Executive Board was created, see Article 10 for more details. A program implemented by the company to enhance management skills was developed and identified as strength.

12.5 - Feedback of experience in relation to human factors and organizational issues.

The feedback of experience with respect to human factors and organizational items is performed mainly through the evaluation of operational events where there is the presence of human and organizational failures and periodic audits performed in the training and requalification system of licensed and non-licensed personnel.

12.6 - Regulatory review and control activities.

Organizational aspects have been addressed by CNEN using the HPEP method. In the Operational Experience area, CNEN has evaluated operational events to identify programmatic causes to determine whether a deficiency in a program, policy or practices for managing work activities allowed barriers to fail. Angra-1 and Angra-2 operators retraining program, which are approved and audited by CNEN in function of requirement in the standard CNEN-NN-1.01[5], incorporates this operational experience.

For the review of Operational Events involving Human Failures, CNEN has adopted the review process described in the NUREG/CR-6751 - The Human Performance Evaluation Process (HPEP): A Resource for Reviewing the Identification and Resolution of Human Performance, (2001).

The Regulatory Framework related to nuclear power plants simulators is based in the following requirements included in the Articles 81, 82 and 83 of the Standard CNEN-NN-1.01 (Resolution CNEN/CD No. 170 of April 30, 2014) and ANSI/ANS-3.5-2009, "Nuclear Power Plant Simulators for use in Operator Training and Examination", which is adopted by CNEN to assess compliance with Article 82 of the Standard CNEN-NN-1.01:

"The request of the acceptance of a simulator, as mentioned in Article 81 should be made by the operator organization at least six (6) months in advance by means of an application containing the following information:

I - statement that the simulator features meet the training plan submitted to CNEN;

II - Detailed description of the simulator, specifying, if any, the main differences to the unit for which it will be used, and

III - detailed description of the tests and their results that prove the similarity of the simulator to the unit for the utilized scenarios. "

The ANSI/ANS-3.5-2009 requires to perform the following simulator tests associated with their respective requirements and criteria (items 3.4 and 4.4 of the Standard): 1) Verification tests; 2) Validation tests and 3) Performance tests. In addition, the standard requires the physical fidelity tests (3.2.1 and 4.2.1) and capacity test of the simulator instructor station (items 3.3 and 4.3).

Validation tests required by paragraph 4.4.2 of ANSI/ANS-3.5-2009 are performed to compare the results of the simulation models with the installation data. Criteria for meeting the requirements of these tests are described in items of section 4.1 of ANSI/ANS-3.5-2009, in particular the items 4.1.3.1 - Steady State, 4.1.3.2 – Normal Evolutions and 4.1.4 – Malfunctions. The scope of the tests must meet the set of events listed in item 3.1 - Simulator Capabilities, in particular the items 3.1.3.1 - Operation Steady State, 3.1.3.2 - Normal Evolutions and 3.1.4 - Malfunctions. To document the results of these tests the pattern described in Appendix A.4 of ANSI/ANS-3.5-2009 must be followed.

The ANSI/ANS-3.5-2009 defines four types of performance tests in 4.4.3: 1) Operability Test; 2) Simulation test based on specific training scenarios; 3) Reactor Core Performance Test and 4) Post-Event Tests.

ARTICLE 13 - QUALITY ASSURANCE

The requirements for quality assurance programs for any nuclear installation in Brazil are established in the respective licensing regulations. Specific requirements for the preparation and implementation of programs are fully described in the Standard CNEN-NN-1.16 Quality Assurance for Safety in Nuclear Power Plants and Other Installations[12], with the addition of the concept of independent inspection and expertise where applicable.

ELETRONUCLEAR has established its quality assurance programs for Angra 1 and Angra 2, in accordance with the above-mentioned requirements and with the Standard CNEN-NE-1.26 Operational Safety in Nuclear Power Plants[7]. The corresponding procedures have been developed and are in use. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the FSAR of each unit.

For Angra 3, ELETRONUCLEAR prepared a quality assurance program applicable to the construction and assembly phases in accordance with the Standard CNEN-NN-1.16 [12]. After the commissioning phase, this program will include the requirements of the Standard CNEN NE-1.26 [7], as already established for the first two units.

The quality assurance system in use is also extended for non-safety-related activities.

At present, the departments responsible for Quality Assurance belong to a Quality Superintendence, which reports to the Planning, Management and Environment Directorate. This Superintendence comprises two Quality Assurance Departments, one of them, the Institutional Unit is located in Rio de Janeiro; and the other, responsible for Quality Assurance in Operations, is located in the site, in Angra dos Reis.

The Quality Assurance Superintendence, according to its respective attributions established in proper documents, is responsible for the verification of implementation of ELETRONUCLEAR Quality System, by means of internal and external audits and surveillances, which are performed in accordance with written procedures. Audit and surveillance reports are formally distributed to the organizations responsible for the areas object of the audits/surveillances.

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.

CNEN has monitored closely the quality assurance activities of Angra plant, trying to focus more on results than on the formalities. In the beginning of 2000, special audits where carried out where quality aspects were discussed directly with the plant management, rather than with the QA group. These audits have identified some problems related to the lack of a grading system for the findings, both from CNEN inspections and ELETRONUCLEAR internal QA audits, a consequent lack of prioritization of their resolution, and a consequent long time for the closing of minor problems.

CNEN required ELETRONUCLEAR to establish and implement a system for management of corrective actions as an additional license condition at the time of the renewal of the Authorization for Initial Operation (AOI).

This system is already implemented by Eletronuclear, so called Pendencies Management System (“Sistema de Gerenciamento de Pendências – SGP) and can be accessed from the corporate Intranet and is subjected to audit by Quality Assurance. More details of this System are described in Article 10.

ARTICLE 14 – ASSESSMENT AND VERIFICATION OF SAFETY

Article 14 (1) Assessment of safety

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

As required, a Preliminary Safety Analysis Report (PSAR) and a Final Safety Analysis Report (FSAR) were prepared for the Angra 1 and Angra 2 NPPs. The FSARs followed the US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs. These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 0800).

Licensing regulation CNEN NE 1.26, Operational Safety in Nuclear power Plants [7], requires that a Periodical Safety Review (PSR) be performed for each operating nuclear power plant at 10-year intervals.

Each Plant Modifications has to be assessed to verify the maintenance of the Design Basis and Quality Requirements.

14(1).1 - Angra 1

Periodical Safety Review (PSR)

The first Brazilian Periodical Safety Review (PSR) was performed for Angra 1 in the 2004-2005 period, following the requirements of CNEN standard NE 1.26 and the guidelines of the IAEA Safety Guide NS-G-2.10. Strong points and opportunities for improvement have been identified, for which action plans have been developed and executed.

The second Brazilian PSR was performed for Angra 1 in 2014 based on CNEN Standard CNEN-NE-1.26 – Safety Operation in Nuclear Power Plants and the guidelines of the IAEA Safety Guide SSG-25 - Periodic Safety Review for Nuclear Power Plants, issued in March 2013.

The evaluation, covering the period from January 1st 2004 to December 31st 2013 was held between July 2013 and July 2014 by a multidisciplinary team of Eletronuclear and Tecnatom, company hired for this purpose. Six (06) evaluation areas have been established for 14 Safety Factors (FS). In order to evaluate these FS assessments generated 33 evaluation reports.

It is noteworthy that the evaluations, studies and implementation made after Fukushima event were widely considered along the holding of the second RPS Angra 1.

These six main areas encompass all items of IAEA Safety Guide SSG-25 and CNEN - NE 1.26[7], that are, plant design; systems, components and structures condition; equipment qualification; ageing; safety analyses (deterministic and probabilistic); risk analysis (hazards); plant performance; operational experience (national and international); organization and administration; human factors; procedures; emergency preparedness; and radiological impact in the environment.

Strong points, some deficiencies and opportunities for improvement have been identified, for which action plans have been developed.

The main deficiencies identified were related to documentation updating, full completion of the Environmental Qualification program, completion of the planned PSA scope, timing for conclusion of the evaluations of the Operational Experience Program and lack of a process for immobilization of contaminated lube oil, none of them of high safety significance.

The main conclusion of the PSR was that in these 10 years, the plant Angra 1 continued to operate within the safety standards and keeping current important functions for operational safety, meets the operating conditions to complete their lifetime. For all the scope evaluated, no deficiencies that could hinder the continued safe operation of the plant were identified.

Deterministic Analysis

In the previous review period an extensive scope of new deterministic safety assessments have been performed for the Angra 1 NPP, for the licensing of the Steam Generator replacement project. The whole Safety Analysis chapter of the Angra 1 FSAR, covering the plant transients and accidents, was revised. A new LB-LOCA analysis was performed, consisting in the development of a realistic evaluation model for the LB-LOCA, using the Westinghouse methodology that encompasses the WCOBRA/TRAC code with the ASTRUM methodology for uncertainty calculation.

ELETRONUCLEAR has also submitted to CNEN approval the documentation relative to the use of a new fuel design (Westinghouse 16x16 Next Generation Fuel – 16NGF, jointly development by Westinghouse, Korea Nuclear Fuel-KNFC and Indústrias Nucleares do Brasil) and a power increase. All this major design changes required additional safety analyses. The evaluation process carried out by CNEN was finalized in 2009. The first reload (one third of the core) of this new fuel was done in the 2014 refueling outage.

Probabilistic Safety Assessment (PSA)

Although a full Probabilistic Safety Assessment (PSA) was not a formal licensing requirement at the time, a preliminary level 1 study was performed in

1983/85 for Angra 1 using generic plant data. This study indicated a strong contribution of the reliability of the Emergency Diesel-Generator system to the total risk, which supported the decision to install two additional Diesel-Generator sets at Angra 1. Additionally, the surveillance interval of seven check valves of the High Pressure Safety Injection (HPSI) system was reduced, to increase system reliability, and therefore reduce this system contribution to the total risk.

A new study was concluded in 1998 (revision 0) and revised in 2000 (revision 1), consisting of a detailed level 1 PSA, for the Angra 1 plant, in accordance with the methodology described in NUREG/CR-2300, “PRA Procedures Guide”. This study has been evaluated by CNEN, with the assistance of IPEN staff, and several new requirements were sent to ELETRONUCLEAR in the period 2003-2009.

This PSA has suffered several partial and full revisions, being presently in its revision 4, issued in December 2014, with the purpose of periodic update of data, incorporation of relevant Plant changes as well as to fulfill CNEN requirements. The periodic update contemplates new plant data and changes in the Plant hardware and procedures, such as modifications associated with the steam generators replacement, as well as advances in modeling, as for example the incorporation of a state of the art model for analysis of the behavior of the pump seals in case of total loss of cooling, new modeling of ECCS valves and main control room cooling, and a reevaluation of the PSA human reliability analysis using state of the art EPRI HRA Calculator.

Several important findings, leading to upgrading of plant hardware and operational procedures, arose from this second PSA study.

The implementation of hardware and/or procedural measures, originated from the results of the above referred PSA study, led to a considerable reduction of the calculated Angra 1 Core Damage Frequency (CDF), down to the range of low 10^{-5} per reactor.year.

The major routine application for this PSA is Configuration Risk Management (CRM), which consists on the identification of the allowable plant configurations for on-line maintenance planning, based on evaluation of the risk rate and the weekly cumulative risk resulting from the different plant configurations associated with the maintenance program.

Another routine application is the screening and when pertinent, evaluation of the impact on the overall plant risk, of all proposed plant modifications.

As a further application, the Angra 1 level 1 PSA has been used to support the development of the Maintenance Rule, which consists in orienting the maintenance program to emphasize maintenance of the components that have more influence on the plant risk, in accordance with the NUMARC 93-01 Revision 2.

In early 2006 a reprogramming of the planned PSA studies for both plants, based on CNEN requirements and recommendations of the Angra 1 PSR, was performed, based on more realistic evaluation of the timing and available resources. The scope, for both plants, included PSA level 1+, including fire and internal flooding at power, shutdown and low power states, as well as level 2 PSA, involving development of eight major studies, for which it was assumed an average of 24 month for performance of each study. This scope was later extended to include External events PSA. Completion of the whole program is planned for 2015- 2016.

The main PSA development activities for the Angra 1 plant performed to date within this program were:

- Extension of the existing level 1 study to level 1+; completed in December of 2006;
- Model improvements for the above PSA study, including pump seal LOCA, review of reliability of high pressure safety injection valves, evaluation of reliability of the control room air conditioning; completed in 2008;
- Preparation of the revision 0 of the Angra 1 Fire PSA, performed jointly with EPRI, using the state-of-the-art methodology of EPRI TR-1011989 (NUREG/CR-6850), EPRI/NRC-RES “Fire PRA Methodology for Nuclear Power Facilities”; started in February 2007 and completed in August 2010.
- Issuing of the Angra 1 level 1+, internal events PSA 3rd overall revision in 2012;
- Issuing of revision 1 of the Angra 1 Plant Fire PSA study, in beginning of 2013, incorporating refinement of rooms modelling which is being applied in the revision of the Angra 1 Fire Hazard Analysis, to evaluate the associated risk reduction of each of the proposed modifications to improve the Plant fire protection;
- Issuing of the Angra 1 level 1+, internal events PSA 2nd, 3rd and 4th overall revisions in 2010 – 2014 period;

Severe Accident Assessment

Development, under a contract with Westinghouse, of Severe Accident Management Guidelines (SAMG) for Angra 1, based on the Westinghouse Owners Group (WOG) SAMG methodology. The revision 0 of these SAMG was completed in end of 2009. The process of verification, validation, training and integration into the Emergency Planning framework (see Article 19(4), for more details) was recently completed.

In that case, the Angra 1 SAMG have been developed adapting the generic Westinghouse Owners Group (WOG) SAMG to the specific details of the Angra 1 Plant. This is the usual approach for Westinghouse designed Plants and for other type of Plants that have developed generic guidelines. It is justified by the fact that the generic strategies of the WOG SAMG were developed and validated for the Westinghouse designed PWR.

In the process of validation of the Angra 1 specific SAMG which is underway, ten (10) Angra 1 specific calculated severe accident scenarios were used to perform a table top exercise for verification of the full applicability of the developed SAMG to Angra 1.

14(1).2 - Angra 2 NPP

For the Angra 2 plant, the licensing process was started in accordance to the German licensing procedure. Such process foresaw a series of partial approvals. For each step, a large amount of the actual design and licensing data has been supplied for analysis to the Brazilian licensing authorities. No comprehensive licensing document such as a PSAR was adopted in this procedure. This approach turned out not to be practical; CNEN had already licensed Angra 1, along the line of US NRC procedures. It judged that to use two different approaches for licensing would be too time and resources consuming. Accordingly, it requested to have a FSAR following US NRC Regulatory Guide 1.70, to be able to use the Standard Review Plan methodology as done for the first plant. Preparation of an FSAR for Angra 2 was a major task, which involved extensive adaptation and revision work internally and extensive exchange of information with CNEN. Along the licensing period CNEN has submitted approximately 800 requests for information, which were answered by ELETRONUCLEAR. Through such a review, optimization of safety calculations, clarification of limit conditions of operation, and other relevant matters have been addressed. As far as applicable, the FSAR has been revised to incorporate the modifications derived from these improvements. On the basis of this revision ELETRONUCLEAR was granted the Authorization for Initial Operation.

Periodical Safety Review (PSR)

As reported in previous National reports, because of problems independent of Plant performance involving the Public Ministry, the Angra 2 Plant had been operating on an Initial Operation License, renewed yearly. In June of 2011, after approximately 10 years of operation, Angra 2 Permanent Operation License was issued. One of the conditionings of this License, reinforcing the requirements of the standard CNEN-NE-1.26[7], was the performance of the first Angra 2 PSR. The final Angra 2 PSR report, including the plant global safety assessment, was delivered to the Regulator in end of November of 2012, covering the 2001 – 2010 review period, however, the evaluations, studies and implementation made after Fukushima event were widely considered.

The assessments were performed by a multidisciplinary company team from design and support engineering, safety analysis, operations, maintenance, radiation protection and quality assurance, led by a Board appointed committee.

About 10 man.years were necessary to complete this work. Having available the experience acquired with the performance of the Angra 1 PSR, beingAngra 2 a fairly new Plantwith a modern documentation system and having available the Plant design knowledge (ETN was the Plant architect engineer), led to a substantially lower effort than the required for the first Angra 1 PSR, which was a turnkey plant delivered in the early eighties.

The detailing of the work followed the guidelines of the IAEA guide NS-G-2.10. A check was done against the draft of the new revision of this Guide, DS 426, later issued as Safety Guide SSG-25.

The 13 Safety Factors (SF) of the NS-G-2.10 guide have been assessed, as for the Angra 1 PSR, plus an additional one, Severe Accident Management, included as a consequence of the lessons learned from the Fukushima accident. This work resulted in 33 individual assessment reports and one final PSR report containing the summary of the assessments and the Plant global evaluation.

Strengths and weaknesses of each SF have been identified. The weaknesses have been subdivided in Deficiencies and Improvement Opportunities. The Deficiencies have been classified from 1 to 5 in accordance to their decreasing importance to safety. The impact to safety of each individual Deficiency as well as of the whole set of Deficiencies on the operation of the plant over the elapsed assessment period as well as for the subsequent operation of the plant have been evaluated.

No class 1 deficiencies (high safety importance) have been identified. The final conclusion of the first Angra 2 PSR was that the plant operated safely along its first 10 operation years and that no relevant safety problem was identified that could impact the subsequent operation of this plant.

Action plans have been developed and submitted to CNEN for elimination of the 14 deficiencies identified, which were basically: lack of procedure (checking of fire penetrations) or poor compliance with some existing safety related documentation procedures, need to encompass the several ageing management activities in a systematic ageing management program in accordance to the latest IAEA guidelines, development of immobilization processes for contaminated lubricating oil and residual mud from systems clean up and long permanence time of quality assurance corrective action requests.

The PSR for Angra 2 was evaluated by CNEN and some requests were issued. The main conclusions were related to preparation of an Integrated Ageing Management Program, update the Severe Accident Guides considering specific data from Angra 2 Probabilistic Safety Assessment, Reestructure the FSAR's Chapter 18 in accordance with updated version of NUREG 0711 and NUREG 0800.

Deterministic Safety Assessment

The safety assessment, with the purpose of demonstration of the adequacy and safety of the plant design bases, included both deterministic and probabilistic approaches to safety analysis. The deterministic approach followed the traditional western methodology of using qualified, internationally accepted, conservative computer codes and assumptions for the analysis of a large set of postulated events, established in national/international guides and regulations, ranging from minor transients to a large loss of coolant accident (LOCA).

An exception to the above mentioned conservative approach was the Angra 2 large break LOCA Analysis which was performed following the "best estimate" methodology approach using of a "best estimate code" of the RELAP5 MOD2 family, coupled with uncertainty evaluation. This analysis was evaluated by CNEN with the assistance of two international consultants, the German institute GRS (Gesellschaft fur Anlagen und Reaktorsicherheit) and the University of Pisa. The verification and acceptance of these analyses was performed through independent calculations done by the CNEN with the support of the University of Pisa.

For the Angra 2 also, a major scope of deterministic safety assessments, covering plant transients and accidents, has been performed in the previous review period, to support the licensing of a 6% increase of Angra 2 power, together with a fuel design change (HTP - high thermal performance fuel with M5 cladding). Reanalysis of the LB-LOCA with uncertainty quantification was part of the assessment.

Probabilistic Safety Assessment (PSA)

For the Angra 2 plant, a preliminary evaluation of the core melt frequency, as well as the probabilistic analysis support for development of Accident Management countermeasures and other evaluations requiring probabilistic insight have been done taking the German Risk Study (DRS) as well as PSA results of German sister plants, as a basis, and adapting their models for the main design differences between these plants and Angra 2. The validity of this approach is based on the similarity of the plant designs all belonging to the standard 1300 MWe German PWR design.

The estimated Angra 2 core damage frequency (CDF) for internal events, obtained from this approach was on the range of mid10^{-6} /reactor.year, compatible with the CDFs for 6 German sister plants, all in the 1 to 3 x 10^{-6} /reactor.year range.

The at-power specific level 1+ PSA for Angra 2, considering internal events and flooding, was developed in the 2005 – 2008 period by an external contractor. Revisions of this study have been incorporated in the previously mentioned PSA development program.

To date, three revisions of this study have been performed. The Regulator also requested to increase the set of Level 1 PSA studies for Angra 2 to include Low Power and Shutdown, Internal Fire and External Events as well as Level 2.

The main PSA development activities for the Angra 2 plant performed within this program were:

- Conclusion of revision 0 of the level 1+ PSA of Angra 2 by an external contractor, in mid-2008;
- Conclusion of revision 1 of this PSA, performed internally, in mid-2009, with implementation into the model of the identified required modifications;
- Revision 2 of this PSA was completed by end of 2013, and revision 3 by end of 2015;
- Conclusion of the development of application of the Angra 2 Risk Monitor, using the above PSA model, for Configuration Risk Management of on line maintenance of this Plant. The Angra 2 risk monitor is being routinely used by the Operation and the maintenance planning group;
- Support to the development of the Reliability Centered Maintenance program for the Angra 2 Plant. The development of this program is presently completed and it is being applied.
- The referred scope of PSA studies requested by the Regulator was finalized using a contract signed with plant supplier AREVA, in December 2015.

Some of the main insights resulting from the Angra 2 level 1+ PSA for internal events and flooding were:

- The existing procedure of Feed and Bleed from the Secondary side for the beyond design event of total loss of feedwater is too complicated resulting in a too large probability of human error and failure of the procedure;
- Connecting the bus bars of the 4 redundancies of the two existing Emergency Diesel 1 (large Diesels) and 2 (small Diesels) power supply nets, in such a way that in case of failure of a Diesel 2 of one or more redundancies, the bus bars of these redundancies are fed by the corresponding Diesel 1 bus bar redundancies, is an effective risk reduction measure. This feature already exists in the German plants of the Angra 2 family but was not implemented in Angra 2;
- Provision of double secured power supply for some critical secondary side valves, required for DBA and BDBA accident control will contribute effectively to risk reduction.

The CDF values obtained for the Angra 2 plant in PSA revisions 1 and 2 were in the low 10-5 per reactor.year, which, when compared to the CDF of its German sister plants, was almost one order of magnitude higher.

After completion of revision 3, which incorporated in the PSA model the above referred safety features, installed in the Plant in the meantime, the corresponding CDF was reduced to $3.3x10^{-6}$ / reactor.year, in the same range of its sister plants.

Similarly to Angra 1, this PSA has been used routinely for maintenance planning in order to ensure a safe plant configuration during maintenances, to evaluate the risk impact of plant modifications, to support the Reliability Centered Maintenance program and eventually to support justifications to exceptions to the Technical specifications, as for instance extended emergency Diesel unavailability times during the 10 years revision of this equipment.

CDF results and insights from the recently completed scope of PSA studies (fire, shutdown, seismic/external events and level 2 were :

- The CDF for internal fire yielded a very low $3.7x10^{-7}$/year, indicating that the consistent physical separation of Plant redundancies (4x50%), as well as the existing fire detection and extinguishing systems provide a sturdy fire protection design;
- The CDF for external events (excluding seismic) of $1{,}2x10^{-5}$/year is dominated by loss of Ultimate Heat Sink (UHS) due to intake water blockage from organic material (48,5%) and from the combination of Loss Of Offsite Power (LOOP) and of UHS, caused by strong wind and organic material (35%). This is consistent with the Angra site characteristics;
- The CDF for seismic PSA yielded a value of $1.1x10^{-5}$/year, which seems to be high for a low seismicity country as is Brazil. This study still needs further refinement as it was based on a preliminary Probabilistic Seismic Hazard Analysis and still used conservative assumptions in case of lack of some detailed equipment or building data. The evaluation of building and equipment fragilities indicated that the Plant can withstand earthquakes with a PGA of up to 0,4g, (design Safe Shutdown Earthquake, PGA= 0,1g), indicating existence of substantial margins against seismic events;
- The CDF for shutdown, $4{,}5x10^{-5}$/year, is one order of magnitude higher that of its sister plants. This can be tracked down to large differences in reliability data for residual heat removal system valves, between the Angra 2 Level 1 internal events PSA used as reference and the corresponding reliability data considered in Germany. Some procedures available in German Plants, during outage work performance, are still to be implemented in Angra 2;
- The Level 2 PSA study yielded a Large Early Release Frequency (LERF) of $3{,}5x10^{-8}$/year, indicating that the existing features for mitigation of

Severe Accidents (passive H_2 recombiners and sturdy Primary and Secondary Bleed and Feed) are efficient in avoiding early releases.

Another important general insight arising from the ELETRONUCLEAR PSA development program is that to have a usable PSA model in accordance to up-to-dated methodology takes considerably longer than expected, even without any unforeseen problems and with available support from experienced consultants.

Severe Accident assessment

The development of Severe Accident Management Guidelines (SAMG) for Angra 2 started in April 2011, supported through a Cooperation Agreement with the European Commission. The completion of the work, including calculations, documentation, assessment, training and integration with Emergency Planning was completed in December, 2015. All generated documentation was submitted to CNEN, which also participated in the training courses and exercises. For more details see Article 19.4.

In the case of Angra 2 no generic SAMG were available for the German PWR design, therefore the corresponding SAMG required use of results from specific Angra 2 levels 1 and 2 PSA plus additional specific MELCOR SA calculations for development of the strategies and computational aids.

Regulatory review and control activities

All technical documents submitted to CNEN by the licensee go through a process of safety assessment by CGRC. The result of this process is documented on technical reports, which contain the review findings. These findings may accept the document, require further information, identify non-compliance with regulations or require further action by the licensee.

The Regulatory technical activities related to nuclear power plants and research reactors licensing are carried out by the CGRC, as specified in Article 8. In particular, these include:

- Carrying out safety evaluation and inspection of NPP and research reactors during the construction, pre-operational and operational phases, in order to qualify for CNEN's licenses;
- Following the implementation of quality assurance programmes during construction and operation of NPPs;
- Inspecting the fabrication of NPPs components;
- Examining and licensing candidates for nuclear reactor operators;
- Developing studies for evaluating accidents in NPPs.

To perform these tasks, CGRC:

- Analyzes the geographical, demographical, geological and meteorological data of the site submitted for approval by the applicant;
- Assesses the installations by analysis and control of the projects, including a detailed investigation of the normal operational state, and of the equipment and safety systems in case of accidents. This analysis with its occasional stipulation of specific conditions, constitutes the basis on which the construction license is granted;
- Supervises and conducts inspections of the construction, controlling conformity with the project analyzed, and observance of the conditions stipulated;
- Assesses the quality assurance programs of the organizations involved in planning, construction, and operation of the respective installations;
- Effects controls, in order to verify the adequate application of Quality Assurance programs;
- Effects controls to verify the various processes used in construction, and the accurate execution of tests scheduled in the project;
- Supervises the commissioning stages, and the pre-operational tests, comparing the analysis of the results with the conditions stipulated in the construction license;
- Grants the operation license for nuclear power stations;
- Issues the licenses for qualified plant operation personnel;
- Supervises the operation of nuclear installations, analyzing eventual technical modifications;
- Analyzes, supervises, and inspects all decommissioning stages;
- Establishes ecological and biological procedures and systems for radiation measurement in the vicinity of nuclear installations, aiming at a collection of data in pre-operational and post-operational stages for future comparison of cause and effect.
- Regular inspection programmes for research reactors in operation; Written and oral examination to qualify operators for power plants and research reactors.

Current projects or missions are:

- Finalize in the end of 2016 de review process of Second Angra 1 PSR;
- Start the review process of Angra 2 PSA study in August 2016, because the expected to submission by ETN to CNEN is April 2016;
- Evaluation of Severe Accident Management Programmes of Angra 1 and 2 not yet finalized;

In 2015, the CGRC started a new project (EC Project BR3.01/12, see Article 8) with support of European Commission in the reviewing process of the PSA documents submitted by Operating Organization, assessment of Angra 2 SAMGs and review the MELCOR nodalisation used by Angra 2.

Article 14 (2) Verification of safety

On the utility side, the main elements for continued verification of safety are:

- Existence of a structured permanent safety oversight process at Plant, Site and Corporate level;
- Verification of strict adherence to the safety limits, limiting conditions of operation, repair times, system operability criteria and surveillance requirements established in the Technical Specifications (see Article 19(2));
- Verification of strict adherence to the ISI program;
- Verification through PSA tools of the allowable risk for the on line maintenance plant configurations (see Article 14(1));
- Verification of the adherence to the predictive and preventive maintenance program;
- Follow up and periodic evaluation of a comprehensive set of performance and safety indicators (see Article 6);
- Verification of how safety problems from internal and external operational experience affect the safety of the Brazilian plants (see Article 19(7));
- Obtain periodic feedback of external comprehensive peer reviews (WANO, IAEA), see Article 19(7).

Ageing management program

Eletronuclear has decided for the implementation of an ageing management program at Angra Unit 1, following the requirements defined by 10 CFR 54, US License Renewal Rule, which embodies a systematic and comprehensive approach for the ageing management of systems, structures and components (SSCs) important to safety. The US ageing management approach is also consistent with the principles of the IAEA guidelines on the implementation of ageing management programs for nuclear power plants. Such decision complies with CNEN’s (Brazilian Regulatory Body) recommendations. In addition, the implementation of this program will support the application for a Licensing Renewal process of Angra 1, planned to starts in 2019.

The ageing management program is being implemented, with the assessment of Westinghouse, in four different phases: a Pilot Program (concluded in 2010); a Time-Limited Ageing Analyses (TLAA) review (concluded in 2013); an Integrated Plant Assessment (IPA) (started 2015 conclusion in 2019); and the implementation of the commitments (planned to start in 2019).

In parallel, Eletronuclear has improved at Angra 1, a set of initiatives, including studies, assessment and plant modifications, as shown below:

- Replacement of components to eliminate Copper-alloy in the secondary system;
- Readiness assessment for the implementation of an AMP (Framatome, 2002-2003);
- Ageing management assessments in the scope of the 1st Periodic Safety Review - PSR (2005);
- Identification of Alloy 600 parts and welds in the Reactor Coolant System and its connections (2007);
- Replacement of Reactor Pressure Vessel Internals Split Pins (2008);
- Replacement of Steam Generators (2009). Substitution of material tubes: Alloy 600 to Alloy 690;
- Weld overlay at the pressurizer surge line, spray line, safety valve lines, and relief valve line (2010);
- Replacement of the Reactor Pressure Vessel Closure Head (January 2013);
- IAEA Pre-SALTO Mission at Angra 1 (November 2013);
- Implementation of inspection and maintenance programs for safety related concrete structures (CONCREMAT - ELETRONUCLEAR, in course);
- Initiatives to contract technical assistance for the implementation of an Environmental Qualification Program for Electrical and I&C Equipment (in course);
- Contracting Westinghouse for the implementation an Integrated Plant Assessment (IPA);
- Studies for the implementation of Mechanical Stress Improvement Process (MSIP) for Stress Corrosion Control at Reactor Pressure Vessel Nozzles (in course);
- IAEA TSM at Angra Site (October 2016).

Upon the invitation, a peer review mission on safe long-term operation (SALTO) was provided to review programmes / activities of Angra Nuclear Power Plant Unit 1 (“the plant”). The design lifetime of this Westinghouse plant is 40 years. The plant was commissioned in 1985. Brazilian regulatory authority CNEN issued a 40-year-period license till 2024 for the plant in accordance with the rule CNEN NE-1.04[3].

The target of the plant is to follow US NRC requirements for licensing renewal and be consistent with the IAEA recommendations for long term operation (LTO). The mission reviewed completed, in-progress and planned plant activities related to long-term operation (LTO) including activities involving the ageing management of systems, structures and components (SSCs) important to safety and revalidation of time limited ageing analysis (TLAA).

The main conclusion of Pre-SALTO Mission to Angra 1 was commitment of the plant management to improving plant preparedness for LTO. In addition, the Pre-SALTO team noted that the Technological Obsolescence Management implemented by Eletronuclear as a good practice.

The Pre-SALTO team also recognized that the plant approach and preparatory work for safe long term operation generally followed the IAEA Safety Standards and international practices.

Finally, the Pre-SALTO team identified areas for further improvement. Eleven issues were raised:

- The plant initiated activities on LTO but did not develop overall framework documents on the LTO project and on the plant policy;
- Preparation of the scoping and screening process for the LTO evaluation is at the beginning stage, and extensive efforts will be necessary to establish a complete scoping and screening process;
- The effectiveness of the existing and proposed programmes to manage ageing of SCs within the scope of LTO has not been sufficiently evaluated to demonstrate the appropriateness of these programmes for safe LTO;
- Scoping of non-safety related mechanical and civil SCs whose failure could affect the function of safety-related components, has not been performed using a documented and verifiable methodology to identify spatial interactions;
- It is not clear which part of the project will be performed by the plant, which will be done by contractors and how the necessary knowledge will be transferred to the plant;
- The plant has not developed and implemented a comprehensive environmental qualification (EQ) programme;
- Several databases are considered for assessment of the SCs in a scope for LTO but the process to assure data consistency between databases is not clearly defined;
- There are no inspection procedures and ageing management programmes for concrete structures;
- Civil structures have not been defined at the component level or as commodity groups;
- There is a lack of adequate long term staffing plan for the LTO programme;
- A systematic approach for competence and knowledge management is not implemented to support the plant LTO.

The plant implemented an obsolescence programme. This programme includes proactive strategy, focus on SSCs important to safety, procedures to manage obsolescence and organizational arrangements for the implementation. The prograrnrne consists of two processes:

- RAPID - Readily Accessible Parts Inventory Database. It is a virtual warehouse and the database has information of about 100 organizations and plants worldwide. Part of this database is the Obsolete Items and Replacement Database (OIRD) with information if some organization has already solved a problem of equal or similar obsolescence;
- PKMJ contract, providing engineering consulting service to solve problems related to obsolescence - Engineered Obsolescence Solutions (EOS) and set of licenses for the use of software necessary for proactive management of obsolescence.

The plant strengthened the cooperation with Westinghouse. A meeting was held in October 2013 regarding services and spare parts. Altogether, 71 items were discussed. Several contracts were awarded to Westinghouse, including preventive maintenance and tests, digital control rod systems position indication, replacement of I&C cards for the reactor protection system (implemented during outage lPI9), I&C cards replacement for the control rod system (planned during outage lP 20, March, April 2014) and other modifications planned for outages lP 21 and lP22. It is important to mention that the bidding process is not necessary for Westinghouse spare parts and services when the SSCs was designed and manufactured by this manufacturer, which makes the procurement easier and quicker. In addition, the plant strengthened its cooperation with the similar Krsko NPP in Slovenia.

The plant achieved good results in prioritization of materials for maintenance and modifications. Daily operation focus meetings and monthly outage meetings prioritize purchasing of materials based on safety and reliability needs. In addition, the plant reduced the modifications requests backlog from an average of 120 in 2011 to 71 in 2012 and 63 in 2013.

ETN also receives PEER Reviews missions from IAEA, WANO and INPO in a regular basis, as can be seen in Table 6 – International Technical and Review Missions, Article 19(7).

Regulatory review and control

On the regulatory side, to verify the safety of the operating plants CGRC makes use of two levels of surveillance. The first is a continuous inspection of activities carried out by the division of Resident Inspection. These on site inspectors have procedures to verify the execution of several activities such as periodic tests, maintenance actions, control room activities, fire protection and housekeeping, work control, evaluation of operational events, etc. and to report any deviations. The second is the yearly Inspection and Audit Program to be implemented by the headquarters divisions of CGRC. This inspection program may be complemented along the year as necessary. All inspections and audits are documented on Inspection Reports.

Article 15 – RADIOLOGICAL PROTECTION

Radiological protection requirements and dose limits are established in Brazil in the regulation for radiological protection CNEN–NN–3.01–Basic Radiation Protection Basic Directives [13], based on the Safety Series n. 115 – International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, jointly sponsored by FAO, IAEA, ILO, OECD/NEA, PAHO and WHO. These requirements establish that doses to the public and 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 through the establishment of a Radiological Protection Program at each installation. Plant design is assessed at the time of the licensing review and by evaluating the dose records during normal operation.

The Radiological Protection Program of Angra 1 and Angra 2, included in the Final Safety Analysis Reports, sets forth the philosophy and basic policy for radiological protection during operation. The highest level policy is to maintain personnel radiation exposure below the limits established by CNEN and to keep exposures as low as reasonably achievable (ALARA), taking into account technical and economic considerations.

The present annual dose limits to workers are 20 mSv for Effective Dose and Equivalent Dose for the lens of the eyes averaged over 5 consecutive years and a maximum of 50 mSv in any single year; and an equivalent dose to the extremities (hands and feet) or the skin of 500 mSv in a year.

The actual personnel radiation doses at Angra Nuclear Power Plants continue to be much lower than the established limits. The dose distribution for workers at the Angra site demonstrates an adequate radiological protection program, with all averaged annual accumulated individual doses below 0,33 mSv and no one with radiation dose above 12 mSv in the 2013-2015. The dose distribution for the 2013-2015 period is summarized in the Table 5, shown below.

For the incoming years, efforts are in place to reduce the collective doses for Angra 1 and Angra 2, aiming to values below the industry average, by improving the ALARA planning of the activities, including source term reduction, additional shielding, and better use of the human performance tools.

A plant ALARA Commission for each Plant, composed of different groups (Operation, Maintenance, Chemistry, System Engineering and Radiological 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.

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

Table 5 – Dose Distribution for Angra 1 and Angra 2 from 2013 to 2015

Year	**2013 (TLD)**		**2014 (TLD)**		**2015 (TLD)**	
Dose Range (mSv)	**Number of Persons**		**Number of Persons**		**Number of Persons**	
	A1	**A2**	**A1**	**A2**	**A1**	**A2**
0,0 <-- 0,2	1788	2095	1683	2264	1558	2028
0,2 <-- 1,0	413	151	422	216	343	224
1,0 <-- 2,5	169	30	98	40	112	59
2,5 <-- 5,0	47	1	42	4	17	2
5,0 <-- 7,5	12	0	1	0	0	0
7,5 <-- 10	8	0	0	0	0	0
10 <-- 15	4	0	0	0	0	0
15 <-- 20	0	0	0	0	0	0
20 <-- 50	0	0	0	0	0	0
50 <---	0	0	0	0	0	0
Total of Persons	2441	2277	2246	2524	2030	2313
Highest Dose (mSv)	11,47	2,69	5,23	3,43	4,17	2,91
Median Dose (mSv)	0,00	0,00	0,00	0,00	0,00	0,00
Average Dose (mSv)	0,33	0,05	0,22	0,07	0,18	0,09
Collective Dose (person.mSv)	799,85	109,52	489,63	168,33	374,19	199,18

A1: Angra 1 NPP / A2: Angra 2 NPP
TLD: Thermoluminescent Dosimetry

The discharge limits are derived from the dose values to public individuals. The procedures for the release of plants ensure that the activity released by effluent are below these dose limits (0.25mSv/year). Similarly, values of set point detectors that monitor the effluents are derived from these discharge limits.

The reference levels for effluent´s discharge are in accordance with the reference level for dose constraint established 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's regulation CNEN-NN–1.14[6], an Effluents Releasing and Wastes Report is issued for each unit every semester, documenting the liquid, gaseous and aerosol effluents: batch number, radionuclides present and their concentration, waste quantity and type sent to radioactive waste facilities and the meteorological data in the period.

In this report, the effective dose for the critical individual is also presented. In the period of 2013-2015, the highest dose reached was $7{,}29 \times 10^{-3}$ mSv in 2014, which is much lower than the 1 mSv/year value and the dose constraint value of 0,30 mSv/year, established in regulation CNEN-NN-3.01 [13].

The IBAMA does not interfere in this subject. It only receive the manifestation of CNEN about the projects' Radiological Protection in its environment licensing process.

A Radiological Environmental Monitoring Program, based on CNEN requirements, is conducted by ELETRONUCLEAR to evaluate possible impacts caused by plant operation. This program defines the frequency, places, types of samples (sea, river, underground and rain water, fish, beach sand, marine and river sediments, algae, milk, grass, airborne, banana and soil) and types of analyses (gamma spectrometry, beta counting and tritium) 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 program are compared with the pre-operational measurements taken, in order to evaluate any possible environmental impact. Annual reports are presented to CNEN. To date essentially no impact has been detected. Typical results are presented in Table 6, for the period 2013-2015 and in Fig. 6 for the life of the site.

The Institute of Radiation Protection and Dosimetry (IRD) of CNEN conducts independent radiological monitoring program, which is further analyzed by the regulatory staff of CNEN.

Table 6 – Environmental Monitoring Program Results from 2013 to 2015

	YEAR		
	2013	2014	2015
	Measured values in mSv/30 days (10^{-2})		
I – Impact Area	8,95	9,10	8,79
C – Control Area	8,27	8,30	7,46

Impact Area: 37 measuring points within 10 km radius from the plant.
Control Area: 4 measuring points beyond 10km radius from the plant.

The radius 10 Km was defined by ELETRONUCLEAR, in agreement with CNEN, using the same concept used in the establishment of the emergency planning zones EPZ, where it was identified by calculations assuming restrictive meteorological conditions that most of the contamination following an emergency in the Angra site plants, with large external releases, would remain within the first 10 Km of the plants.

These criteria adopted by ELETRONUCLEAR are in agreement with the IAEA guidance: “In order to be effective the protective actions need to be implemented first for those located within 3 to 5 km of the nuclear power plants, followed by those located more than 5 kilometers far”

However, monitoring of the impact of the operation of the plants on the environment surrounding the site performed by the Environmental Monitoring Laboratory of Eletronuclear encompasses lab analyses and radiation exposure rates measurements (TLD) within (impact area) and also beyond (control) 10 Km radius of the site epicenter.

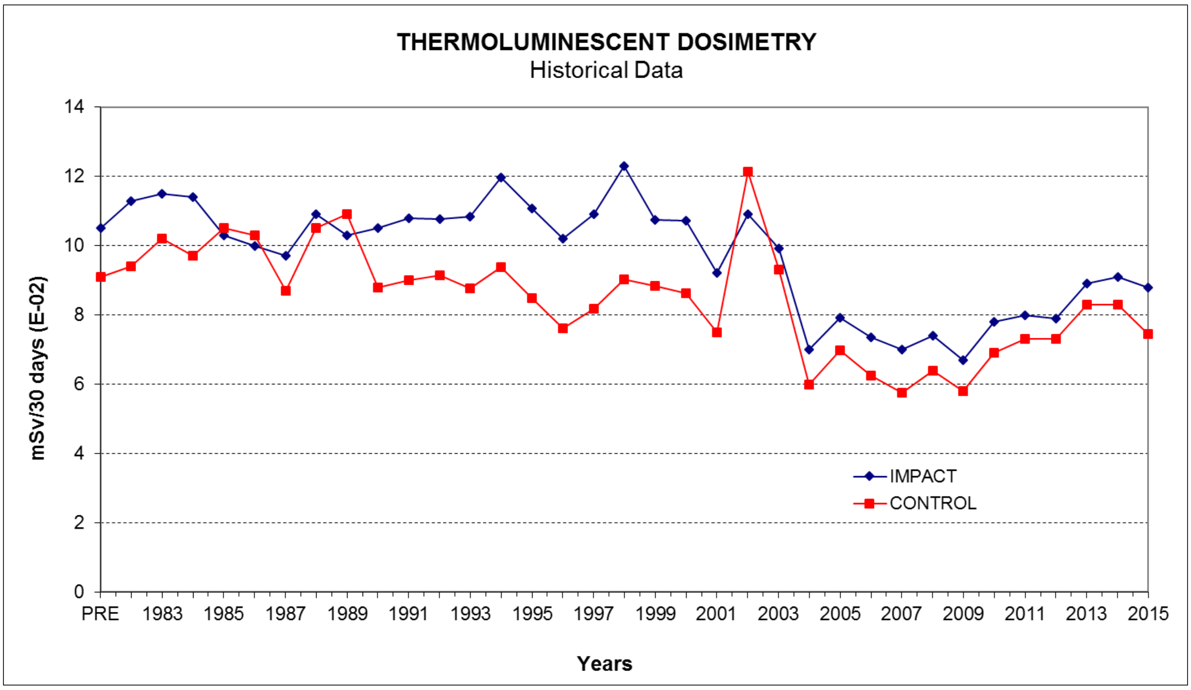

Fig. 11. – Site lifetime environmental impact

As it can be seen from the above Table 5, there is essentially no variation of the measured values in the survey periods. The average values for the Impact and Control areas measurements are statistically equivalent, indicating the absence of radiological impact from the power plants.

This is confirmed by the graph shown in Fig.11, which shows a compilation of Impact and Control measurements from the preoperational phase of the first NPP to be installed on site up to end of 2015, with two Plants in operation. The lack of data for 1985 in the Fig.11 was due to the destruction of the remote Environmental Monitoring Laboratory due to a landslide. The apparent variations in 1998 and 2001 are due to changes in monitoring places or changes in measuring instrumentation.

ARTICLE 16 - EMERGENCY PREPAREDNESS

Article 16 (1) Emergency plans and programs

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 concept.

The Emergency Planning Zone (EPZ) encompasses the area within a circle with radius of 15 km centered at the Angra1 nuclear power plant. This EPZ is further subdivided in 4 smaller zones with borders at approximately 3, 5, 10 and 15 km from the power plants. The epicenter in Angra 1, the first plant to be built in the site, was established when the original emergency plan for the site was developed before start of Angra 1 operation, in the early 80´s. This plan was verified later before start of operation of the second plant Angra 2 (located circa 500 m far from Angra 1), in early 2001, with the conclusion that the original plan remained adequate and did not need modifications following the inclusion of the second plant.

CNEN Resolution 9/69 presents the criteria for the establishment of the Exclusion Area (Area of property of licensee) and Low Population Zone requirements. The determination of the numerical values for the exclusion area and the low population area must meet the following requirements:

1 – Exclusion Area - the total radiation dose to the whole body cannot exceed 25 rem and the total radiation dose by inhalation of iodine-131 in the thyroid cannot exceed 300.rem for an individual located at a point on the outer boundary line. The time irradiation is two hours, counted from the beginning of the maximum postulated accident.

2 –Low Population Zone - the same doses limits established in the previous paragraph, cannot be exceeded for an individual located on a point of their boundary line, during the whole period of passage of the radioactive cloud resulting from the release of products fission due to the maximum postulated accident.

16(1).1 - On Site Emergency Preparedness

The On-site Emergency Plan covers the area of property of ELETRONUCLEAR, and comprises the first zone (EPZ-1, 0.5Km to about 1.5 km from the power plants). For these areas, the planning as well as all actions and protection countermeasures for control and mitigation of the consequences of a nuclear accident are under ELETRONUCLEAR responsibility.

Specific Emergency Groups (Power Plants- Units 1 and 2, Support Services, Head Office and Medical) under the coordination of the Site

Superintendent or his deputy 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.

The former meteorological data acquisition and processing system was composed of 4 meteorological towers is in place. Measurements of meteorological variables are installed and distributed at three levels in a 100 meter height tower (tower A). Wind speed and direction, temperature (DT) and humidity are measured at 10, 60 and 100 meters in this tower. Additionally, three 15 meters satellite towers (towers B, C and D), installed in the vicinity of the site, measure the wind data. Precipitation is also measured near tower A. All these data are send to a computerized system in the Technical Support Center / Control Room of Units 1 and 2, through which the follow up and calculation of the spreading of the radioactive cloud is performed. The meteorological data is automatically transferred to CNEN for emergency management.

The former four meteorological towers have been modified with relocation of two of them and installation of three new towers. In addition, an automatic meteorological data transfer to CNEN for emergency management is underway. This new data acquisition system is under implementation but not yet operational.

The Decision Support System Argos (Accident Reporting and Guidance Operational System), with a capability of making prognosis up to 72h ahead of the event, for atmospheric releases, by means of the Numerical Weather Prediction, produced in Brazil by CPTEC/INPE, has been implemented and is fully operational at CNEN headquarters. Argos was originally developed by the Danish government, but now it is managed by an International Consortium that encompasses about 14 countries.

CNEN performed an installation of seven stations to monitor the background radiation, on the perimeter between Angra dos Reis city and Paraty city. One of them, near the site, can identify radionuclides. Three new stations are going to be installed. This stations provide data for the ARGOS system.

The On-site Emergency Plan involves several levels of activation, from Unusual Event, Site Alert, Site Area Emergency up to General Emergency.

The initial notification for activation of the On-site Emergency Plan is done by the Shift Supervisor from the Control Room, who preliminarily classifies de event and notifies the Plant Manager, as Plant Emergency Group coordinator, which alerts the coordinators of the other Emergency Groups, the Site Superintendent and the Authorities (CNEN resident inspector and headquarters). The plant personnel and the members of the public inside this emergency zone 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 Superintendent, ensure the prompt actuation of the Emergency Groups. Training and exercises (5 per plant) are performed yearly for personnel on-call.

The utility made a full revision of the methodology of classification of emergency situations using the NEI-99-01, “Methodology for Development of Emergency Action Levels”, Rev 5, 2008. The Regulatory Body also made a full revision of its own emergency procedure after approval of the emergency procedure of the utility.

Emergency training and exercises for overall Plant personnel are performed yearly. Information to the public on how to behave in a situation of nuclear emergency is provided by ELETRONUCLEAR through periodic campaigns, distribution of printed information, the local press and permanent information available in the Site Information Center.

Use of SAMG, developed for both Plants, has been integrated to the emergency Planning procedures.

The On-site Emergency plan is revised every two years and a specific revision will occur before the first core load of Angra 3.

16(1).2 - Off Site Emergency Preparedness

Brazil has established an extensive structure for emergency preparedness under the so-called Brazilian Nuclear Protection System (SIPRON). Federal Law 12.731 from November 21st, 2012 establishes Sipron’s responsibilities and duties.

The Brazilian Nuclear Protection System is now organized as follows:

a) A central organization – that is the Institutional Security Cabinet of the Presidency of the Federative Republic of Brazil;
b) Three nuclear emergency response centers, and
c) Four collegiate bodies.

Both the nuclear response centers and the collegiate bodies includes organizations at the federal, state and municipal levels involved with nuclear emergency preparedness and response, as well as those involved with public security and civil defense.

Within SIPRON, the Central Organization issued a set of General Norms [14], consolidating all requirements of related national laws and regulations. These norms establish the responsibilities of each of the involved organizations and the procedures for the emergency management centers, communications, knowledge protection and information to the public (SIPRON General Norms are listed in item II.5 of Annex II).

The approach to emergency preparedness and response is based on the application of local resources in the response action to an emergency situation, utilizing mainly the resources available at the Municipality (local level response). The State and Federal Governments complement the local resources as necessary. In this way, SIPRON works in collaboration with the Municipal Government, the State Government and the Federal Government, as necessary to attend nuclear emergencies.

The exercise was upgraded, as can be seen in the examples below. The conclusion was that the upgraded actions did validate the plan. Nevertheless, discussions proceed to further improve the exercises, for example to involve even more people to participate in the evacuation by foot, as experienced in FUKUSHIMA.

Some of the improvements on the last general emergency exercise were:

- Improvement of previous and post communication with population, involving more than 5,000 people in workshop and several other interactions. Federal government communication organization participated for the first time in the exercise;
- Simulated accident extended from 1 to 2 days, including overnight activities;
- A 3rd day included in the exercise to practice and improve communication with the public;
- Inclusion of practice of public evacuation by sea and by foot (simulating road disruption) which involved more than 500 people, a number considerably higher than the previous exercises;
- Improvement of communication with the regional emergency center by providing video conference between regional, state and federal emergency centers, and
- Installation of 3 campaign hospitals in different regions around the plant (in other exercises only one campaign hospital was installed), with the medical staff actually attending more than 1,500 people of the region.

16(1).3 - Overview and implementation of main elements of national plan (and regional plan, if applicable) for emergency preparedness, including the chain of command and roles and responsibilities of the licence holder, the regulatory body, and other main actors, including State organizations.

The responsibility for the development and coordination of the External Emergency Plan (PEE) is the Civil Defense Department of the Rio de Janeiro State.

The main decisions of the emergency related to activities outside the site are taken by the Nuclear Emergency Coordination and Control Center (CCCEN) in Angra dos Reis city. CNEN and the Utility actively participate in this Center. When needed CNEN perform specific recommendations related to radiological protection of the people and the environment. This Center is activated on an ALERT situation.

The Nuclear Emergency Coordination of the State Center (CESTGEN) in Rio de Janeiro city and Nuclear Emergency Federal Coordination Center (CENAGEN) operates in Brasilia City giving support when needed. A Nuclear Emergency Information Center (CIEN) is established in the city of Angra dos Reis to support CCCEN in the communication with local citizens.

This centers' activities during an emergency are established in SIPRON General Norms[15], [16] (See also II.5 of Annex II) and is stated at the Rio de Janeiro State Plan for External Emergency, approved by the State of Rio de Janeiro Governor by Decree 41.147, of January 24th, 2008.

There are yet a navy hospital specialized for nuclear accidents in Rio de Janeiro city and a small hospital to deal with workers near the site.

Emergency Response Plans for CNEN and other involved agencies have been prepared, and detailed procedures have been developed and are periodically revised. The CNEN's Plan for Emergency Situation in Nuclear Power Reactors was updated in 2015.

This CNEN's Plan establishes a technical group to evaluate an emergency (CORAN) and a high level group (CORE) to make the recommendations for the governamental agencies, both in its headquarters in Rio de Janeiro city.

CNEN has representatives in the following emergency centers CCCEN, CESTGEN, CENAGEN, mentioned above, and NPP Technical Support Center.

IRD is a CNEN's Institute and is part of the emergency notification system coordinated by DRS. It is responsible for the implementation of field actions in response to an emergency situation. The field data collected, after preliminary analysis by IRD specialists, is sent do CNEN headquarters (CORAN), compared with the ARGOS prognosis and used to drive CNEN's recommendations (CORE) to the Emergency Centers.

IBAMA, through the Directorship of Environmental Protection - DIPRO, supports CCCEN with technical resources and equipments in the event of environmental issues during nuclear accidents at the Angra site. IBAMA was accepted as a member of CCCEN and COPREN in 2013. In 2015, DIPRO elaborated its first review of the Complementary Emergency Plan (PEC).

16(1).4 - Implementation of emergency preparedness measures by the licence holders.

16(1).4.1 - Classification of emergencies

The classification of emergency situation is done using the emergency procedure of the utility – Local Emergency Plan (PEL). This procedure uses as reference the document NEI-99-01, “Methodology for Development of Emergency Action Levels”, Rev 5.

The emergency classes are:

- Non Usual Event;
- Alert;
- Area Emergency and;
- General Emergency.

16(1).4.2 - Main elements of the on-site and, where applicable, off-site emergency plans for nuclear installations, including, availability of adequate resources and authority to effectively manage and mitigate the consequences of an accident.

The utility has an emergency group besides the control room for each utility, and other groups for infrastructure outside the NPP.

The main elements are described in Article 16(1).1 - On Site Emergency Preparedness

16(1).4.3 - Facilities provided by the licence holder for emergency preparedness (if appropriate, give reference to descriptions under Article 18 and Article 19 (4) of the Convention, respectively).

In order to comply with the Angra 2 TCAC requirements related to emergency planning ELETRONUCLEAR awarded a contract to the Federal University of Rio de Janeiro to develop a comprehensive study on evacuation and sheltering possibilities. This study addressed, through computer simulation, movement of people and vehicles in different evacuation scenarios. In addition, availability of sufficient transportation, training of drivers and suitability of sheltering installations were also evaluated. The resulting recommendations were incorporated into a long term action plan, already implemented. For this purpose, formal agreements have been signed to provide the Angra Municipality and Rio de Janeiro State civil defenses with better infrastructure for public shelters, health care and other measures related to emergency preparedness. These included an agreement between ELETRONUCLEAR and the National Transports Infrastructure Department (DNIT) to improve the BR-101 federal highway passing through the Angra site, at a cost of about 7 million US dollars provided by ELETRONUCLEAR. The work, already finished, comprised restoration of 60 km of asphalt paving, of the road drainage and emergency lanes at the road sides, slope stabilization at the road hill side, building of crossings, underpasses and pedestrian passageways as well as elimination of three road bypasses.

In the same area of emergency preparedness, in order to provide an extra mechanism to monitor the environment, CNEN has installed an On-Line Radiation Monitoring System in the emergency planning zone (EPZ). The system is composed of thirteen Geiger Müller detectors disposed strategically around the Angra site. All data are locally collected and sent to the Institute of Radiation Protection and Dosimetry (IRD) by modem connection.

16(1).5 - Training and exercises, evaluation activities and main results of performed exercises including lessons learned.

The Central Organization, SIPRON, established that a full-scale exercise should be performed biannually. On the other hand, one partial exercise should be performed between two full-scale exercises. Full-scale exercises were performed in 2007, 2009, 2011, 2013 and 2015, most of then with the presence of international observers from fifteen countries. A partial exercise was performed in 2012 and 2014 and another partial exercise is scheduled for September 2016.

In 2013, a broader, 3-days General Exercise took place, involving nearly 1500 people from the several institutions participating in the national emergency response framework. In this exercise the evacuation by sea was successfully tested; people at different places, on the beaches in the neighborhood of the Plants site have been evacuated by the Navy using large capacity (up to 500 people) diseinbarkment barges.
Furthermore, as part of the periodic exercises programme, SIPRON held, in 2014, a Nuclear Emergency Response Partial Exercise aimed at testing the effectiveness of specific parts of the nuclear power plant External Emergency Plan (PEE).

In September 2015, a broader, General Exercise took place, as every odd years, involving nearly 1600 people from several institutions participating in nuclear power plant External Emergency Plan (PEE). This was the largest exercise ever conducted in Brazil. Many features were tested like the KI distribution, maritime evacuation, the use of the Argos Code to predict the radioactive plume behavior, the sampling of water, plants and soil at simulated contaminated areas, among others.

During the full-scale exercises the activation of several shelters and the simulated evacuation of part of the population in the Emergency Planning Zone (EPZ) are tested. During the 2013 and 2015 full-scale exercise, it was simulated the potassium iodine tablets distribution to a community in the ZPE – 5 (west side).The Brazilian Health Ministry (MS) has issued in September 2012 the

Pharmaceutical Assistance Protocol in case of Radiological- Nuclear Accidents which establishes the distribution politics of Potassium Iodine tablets for the population. The amount of 200.000 tablets was purchased by the MS and is under responsibility of Angra dos Reis Municipality. All exercises are prepared, conducted and evaluated under the coordination of the GSI/PR.

There are three types of exercises performed in Angra dos Reis city and in all of them the Regulatory Body participates.

The first one is performed by the utility on the site. There are 5 exercises for each unit per year. During this exercise is verified that all groups that deal with an emergency are available with appropriate infrastructure and resources.

The second type is a communication exercise of the Brazilian Nuclear Program Protection System (SIPRON). There are at least one exercise of this type each 2 months.

The third exercise is an annual one involving all organizations that have actions off-site, including the Regulatory Body and the utility. Each organization has its own emergency plan and on this exercise, the actions are tested. This exercise consist on a scenario beginning with a Non Usual Event and has an evolution until a general emergency with evacuation of the population of the neighborhood of the site.

In odd years the exercise includes the displacement of all organizations envolved in response activities and population. In even years, the same type of exercise is performed but without personnel displacement.

On the annual exercises there are meetings before and after the exercise. In the meeting before, the recommendations and corrective actions of the past exercise are revisited and the implementation status reviewed. After the exercise a meeting is done to obtain an initial evaluation and a detailed report is issued 3 months latter.

Several space for improvements are verified in each exercise and they are recorded in the general report.

Several improvements were done after the last exercises as:

1. Scenario for the exercise of two days (48 hours);
2. Development and implementation of procedures to maintain and distribution of iodine pills;
3. Distribution of false iodine pills during exercise;
4. New resources for evacuation of population – navy ships;
5. New emergency classification methodology;
6. Redundant External Emergency Control Center with communications facilities;

7. Inclusion of health ministry in the planning and in the emergency center;
8. Development of a software simulator to train the personnel involved on the emergency;
9. Use of the ARGOS system to have a big picture of the simulated scenario and to help the decisions;
10. Use activities in the scenario for remediation phase;
11. Improvements on the Public Communication Group.

16(1).6 - Regulatory review and control activities;

The Regulatory Resident Inspection follows all real demand or exercises of the emergency plan. On each demand, the inspectors perform also an evaluation of the shift and the infrastructure needed to deal with the emergency.

Additionally an audit is performed each 6 months to verify the infrastructure and resources needed, the records of the exercises and when applicable, the implementation of corrective actions.

There are two different aspects linked to the calculation bases from the preparedness point of view. One is methodology (model), other is input data. In a complex terrain, like Angra’s, quality and quantity of input data make a noticeable difference. CNEN has been making a significant effort for improving both aspects. The model inside Argos (Rimpuff) is no different from this point of view than models used by several countries. The input data are not only a question of need, but on purpose and availability. Right methodology and good input data target the other end of the process of impact assessment, the “visible” part of the response itself, two different challenges, plume trajectory and content. To know what is in the plume (source term) without knowing where it is (trajectory) would make the response quite more difficult and complex in terms of protection actions. CNEN has been making an extensive work to address both challenges, requiring the NPPs Operator to have 7 (seven) meteorological towers in operation onsite, increasing NWP to 1 km resolution, developing statistically the met towers observations inside the NWP, applying nudging techniques to initialize the Wind Field using surface observations on real time, having INPE/CPTEC experts working together with CNEN’s experts. This has been done with cooperation of experts from all over the world. Part of this was achieved during the recent project with European Commission cooperation. The appropriate source term to be used for accidents is in intense debate, all around the world, because of the intrinsic difficulty in guessing which part of the core inventory will be available to be released in a real case. History shows that no country was able to guess precisely the source term for real severe accidents. We have been taking precautions and a conservative approach, i.e. to pre-prepare tables of nuclides most likely to be released depending on kind of accident in course, which will depend on initial information from the plant. This has necessarily to be compared to monitoring stations aftermath. Other improvement we have been seeking is to consider the actual inventory of our NPPs instead a theoretical one. And last but not least, we permanently pay attention to the debate in the international scientific community.

Article 16 (2) Information of the public and neighboring states

Regarding information to the public, SIPRON norm NG-05 [16] establishes the requirements for public information campaigns about emergency plans. The first public information campaign was conducted by FURNAS in 1982 before the first criticality of Angra 1. Several other campaigns have been conducted on a regular basis. The campaigns combine information on both on-site and off-site emergency plans, including the population living in the 15-km area around the plant. These campaigns include training courses for community leaders and public school teachers, guided tours for students from public schools to the Nuclear Plant (1520 in 2015), educational lectures in community associations and the distribution of informative material on a house-to-house basis, to local newspaper, radio, TV broadcast, buses and bus stations, schools, community association, churches, and administrative offices. These campaigns are conducted by a joint working group composed by personnel from the federal, state and municipal civil defence, state fire brigade, ELETRONUCLEAR volunteers, and CNEN and ELETRONUCLEAR technical and public information personnel.

In addition, visitors to the Site Information Center (about 16.000 in 2015), receive general information concerning, among other, nuclear energy generation, the Angra site , the operation of the Plants, as well as the site emergency plan.

At present, the siren system is tested every month, at 10:00 AM, every tenth day. A daily silent sirens test is also done. The information about these tests is included in the calendar that is distributed every year to the whole population within the EPZ-5. These calendars also present the basic information on the emergency planning to the population. Also, preceding every siren test or a general emergency exercise, specific flyers are distributed in relevant areas and handed along main routes to passing drivers and buses, and vehicles fitted with loudspeakers circulate through villages making announcements to ensure that all residents have been properly informed.

It should be noted that, due to the particular geographical location of the Angra plants, no radiological impact is expected in any neighboring countries, even in the improbable event of a major release. Notwithstanding that fact, Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, and a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident.

16(3) - Fukushima Lessons Learned

Fukushima event insights have led to modifications in the Site Emergency planning, where the most important are:

- Planning of personnel and resources for simultaneous emergency conditions in both Plants;
- Implementation of procedures for use of additional mobile equipmente for control or mitigation of the event;
- Signing agreement of prompt notification of severe weather or other severe external event conditions with the Angra dos Reis Civil Defence monitoring center and development of a procedure for response to the different events;
- Incorporation of the SAMG team to the Technical Support Center emergency staff;
- Improvement of the realism of the exercises, as far as duration, actions of the different emergency teams and use of Plant simulators to provide the actual event development;
- Expanding of the evacuation routes, with the successfully tested evacuation by sea;
- Upgrading of the emergency centers.

There is still considerable work to be done to upgrad the existing Emergency Centers, in special the ones external to the Plants to meet post Fukushima expectations. Further work is also needed to provide protection for Plant personnel and people living in the Site neighborhood, in case of early releases.

ARTICLE 17 - SITING

Article 17 (1) Evaluation of site related factors

The Brazilian siting regulation, CNEN 09/69[4] and CNEN-NE-1.04, Licensing of Nuclear Installations [3], require a site approval before the issuance of a construction authorization. The Angra site was approved for 3 nuclear power units. As established in these regulations, a site approval is issued after Regulator review and acceptance of, at least, the following information:

- General and safety characteristics of the proposed plant design;
- Population distribution, existing and planned roads, use of the area surrounding the site and distances to population centers;
- Physical characteristics of the site, including seismology, geology, hydrology and meteorology;
- Preliminary evaluation of potential effects on the environment resulting from plant construction and operation (normal and accident conditions);
- Preliminary site environmental pre-operational monitoring plan

Site related factors, in particular, those that affect nuclear safety, have been reviewed at specific times, that is, before issuance of the construction licenses for each one of the 3 nuclear power plants, during plant Periodic Safety Reviews or whenever new knowledge about external events that might affect the Angra site arose, indicating the need for such reviews.

The evaluation of all site related factors affecting the safety of the nuclear installations was initially performed for the design of the Angra 1 nuclear power plant in the 1970s. The American Weston Geophysical Corporation was involved in the geological and geophysical investigations of the region and site, together with Brazilian organizations. These investigations were reviewed during the 1980s for the design of Angra 2, the second plant to be built in this same site. The seismic catalogue and the geological faults were updated in 1998 by involving seismologists of the Institute of Astronomy and Geophysics of the University of São Paulo, considering the state of the art at that time. At that time, the installation of a seismometer was planned for the site, in order to study regional seismological aspects as micro-seismic events, analyze the propagation and attenuation of seismic waves and the crustal regional structure. This seismographic installation has been operating since the beginning of 2002.

As a preparation for the restart of Angra 3 construction, a Probabilistic Seismic Hazard Analysis (PSHA) was performed by specialists from Pontificia Universidade Católica – PUC, RJ (1999-2000), considering the previously mentioned seismic catalogue. The original horizontal Peak Ground Acceleration (PGA) of 0,1 g for Safe Shutdown Earthquake, which was deterministically adopted for the site, was confirmed by the PSHA.

In the context of the Angra 1 Periodic Safety Review (PSR), performed in 2004-2005, all external events assumed for the design of the plant structures have been reviewed. The seismic catalogue was updated considering seismic events up to December 2003. The seismic hazard analysis was updated in 2005.

The result of the PSR, as already reported in previous Brazilian National Reports, was that the original assumptions concerning seismic design response spectra, maximum floods and storms as well as off-site explosions were found to be still valid. A research on tornado events in the region (not considered in the original design basis) was also started at that time and presented a negligible probability of occurrence for the site.

A recent comprehensive review of site conditions was carried out, contemplating the newest version of the applicable regulations, in preparation for the restart of construction of Angra 3. Natural external events such as explosion, aircraft crash, meteorological and severe weather conditions, external flooding and earthquakes, as well as human made external events, were re-evaluated by experts from different research institutes in Brazil, considering the state of the art. The results of this review are presented in Article 17(3).

Furthermore, in the context of the Fukushima response Plan actions, it was again confirmed, as a first step of the evaluation, that the existing Angra Site Design Bases for external events were up to date in accordance to international practice, and that the protection measures adopted were adequate.

The second step of this evaluation consisted in determining the available margins of the existing design to accommodate extreme external events. The results are reported in Section D, specific for response actions derived from the Fukushima event.

The site related design criteria for the first two plants, Angra 1 and Angra 2, built in the Angra site are listed below:

Angra 1 was designed to resist the following external events:

- Two Earthquake levels are considered in the plant design: OBE (Operating Basis Earthquake) and SSE (Safe Shutdown Earthquake; this is also named as DBE – Design Basis Earthquake for this plant design).
- TNT explosion (20 tons) from a truck on the road close to the site, considered according to NRC RG 1.91 (1975).

Angra 2 was designed to resist the following external events:

- Two Earthquake levels are considered in the plant design: DBE (Design Basis Earthquake) and SSE (Safe Shutdown Earthquake).

- SSB load case, from the combined effects of a Safe Shutdown Earthquake (SSE) and a Burst Pressure Wave (BPW) is also considered for the main class 1 structures (structures that are required for plant shutdown and residual heat removal in case of SSE).
- TNT explosion (23 tons), considered according to NRC RG 1.91 (1978).

Both Units 1 and 2 were designed for the following external events:

- SSE level earthquake corresponding to 0,1g horizontal peak ground acceleration at the outcropping rock,
- External flooding: considering a 10000 years return period flood and that the water will accumulate on the site to a maximum height of 45 cm;
- A conservatively adopted wind speed of 45 m/s and ASCE Standards used for design.

Due to the very low probability of occurrence the following external events were not considered in the design of Units 1 and 2 at Angra site:

- Tornadoes, waterspouts and hurricanes;
- Tsunamis;
- Aircraft crash.

The corresponding Angra 3 Design Criteria for External events are presented in section 17(3).

The demographic distribution in areas that affect the emergency preparedness plan continues to be evaluated. An updating of the detailed population census in the vicinity (5-km radius) of the power plant was conducted in 1996. In addition of the 1996 data, collected by ELETRONUCLEAR, new data on population density in the vicinity of the site is available from the 2002 national census, and its update performed in 2007.

Article 17 (2) Impact of the installation on individuals, society and environment

The basic criterion concerning the impact of introducing a new industrial installation in a given site is that it should have minimum adverse effects on individuals, society and the environment.

For a nuclear power plant, the major impact is associated to the potential of radioactive releases, in normal operation or accidental conditions. Minimization of this risk is ensured by a design that adequately incorporates all levels of the "defense in depth" concept as demonstrated by deterministic safety analyses and complemented by probabilistic safety analyses.

The nuclear licensing of a new plant consists in the verification of compliance to the above criteria before issuing construction and operation licenses. These same criteria are monitored during plant operation and in particular, when performing a plant PSR, for authorization of continuation of plant operation.

Control and mitigation of Beyond Design Events are covered by symptom oriented Emergency Operating Procedures and in case of Severe Accidents, by Severe Accident Management Guidelines.

A well-structured Emergency Plan is the last level of defense in depth for protection of the population.

The level of compliance of the Brazilian nuclear power plants to the above criteria is described in the text of the different Articles of this report.

The environmental licensing for authorization of construction and operation of a new project, contemplates, besides of radiation risk covered by the nuclear licensing, all other potential adverse effects arising from plant construction and operation activities on the population and environment in the area of influence of the plant are covered by the environmental licensing.

For example, the impacts from NPPs Angra-1, 2, 3, and the Radioactive Waste Management Centre are controlled by the environmental programs monitoring, such as: monitoring waste generation, quality of the drinking water; quality of the saline waters; quality of the wastewater; monitoring of the marine fauna and flora in the operational phase; monitoring of the plankton zones (phytoplankton, zooplankton, benthos and nekton). The environmental direct influence area has been established as the radio up to 15 km from the CNAAA (Admiral Álvaro Alberto Nuclear Power Station, in Angra dos Reis), which encompasses the municipalities of Paraty and Angra dos Reis with a total of 206,845 inhabitants (data from 2010 of the Brazilian Institute of Geography and Statistics - IBGE); and indirect influence area has been established as the radio up to 50 km from the CNAAA, which cover sixteen municipalities with a total estimated of 802,749 inhabitants (IBGE - 2010).

In December 2009, IBAMA issued the first amendment to the Installation License Nr.591/2009 including a new specific requirement related to the Paraty-Cunha Road implementation.

In March 2014, IBAMA issued the unified Operation License nr. 1217/2014 for the Almirante Álvaro Alberto Nuclear Power Site – CNAAA authorizing the operation of Angra 1 and Angra 2 NPPs, as well as the Waste Management Center – CGR and ancillary facilities for ten years.

At the issuance of the unified operating license to CNAAA in March 2014, the Installation License nr. 591/2009 was revised again generating the second amendment with 33 exclusive requirements for Angra 3 plant construction.

Article 17 (3) Re-evaluation of site related factors

A re-evaluation of site parameters as well as of the external events considered in the design of the existing Nuclear Power Plants, Angra 1 and Angra 2, performed in the context of the Angra 1 Periodic Safety Review (PSR), concluded in 2005, have confirmed the validity of the original assumptions.

Similar results have been obtained from the subsequent PSRs, for Angra 2, completed in 2012 and the second Angra 1 PSR, completed in mid-2014, as well as in the first step of the evaluation performed in the scope of the ETN Fukushima Response Plan (see 17(1)).

As documented in the Angra 3 Preliminary Safety Analysis Report (PSAR) recent re-evaluations of the design criteria for external events, were performed for the new Angra 3 plant. This re-evaluation resulted in some external event design criteria differences when compared to the ones applied to Angra 1 and 2, basically due to new requirements in the present revision of the regulations applied for Angra 3.

These differences, as discussed below, do not have a substantial impact on the original site external events design criteria and are considered additional improvements agreed between CNEN and ELETRONUCLEAR to be applied for a new plant.

- All class 1 structures, systems and components shall be designed to resist a SSB load case, from the combined effects of a Safe Shutdown Earthquake (SSE) and a Burst Pressure Wave (BPW). The original horizontal Peak Ground Acceleration (PGA) of 0.1 g for SSE, which was deterministically adopted for the site, was confirmed by a Probabilistic Seismic Hazard Analysis (PSHA).

- All class 1 structures shall also be designed to resist tornado effects and an explosion from a TNT-loaded truck on the road in the vicinities. The tornado hazard analysis showed that a design for a medium EF3 (Enhanced Fujita scale) is a conservative assumption for the site.

- The maximum wind velocity was revised, taking into account the available data from CNAAA meteorological towers, Unit 3 location in the site and a 100-year-return period. Therefore, a maximum basic wind speed of 41.0 m/s was adopted and the Brazilian Standard for wind loads on civil structures shall be used to determine the characteristic wind speeds and the pressure coefficients. This revision does not represent a significant change of the site parameters adopted for Units 1 and 2, where a wind speed of 45 m/s was conservatively adopted, but other standards, such as ASCE, were used for design.

- Regarding water level (flood), precipitation and sea level were re-evaluated without significant consequences on plant design. The drainage system in the vicinity of Unit 3 is designed considering rainfalls with recurrence period of 10,000 years. Unit 3 ground-level is 1 (one) meter higher than Units 1 and 2. The access to safety buildings are placed 45 cm above ground level (+6.15 m), assuring that no flood will affect the plant operation.

- In March 2012, CNEN agreed to consider the concept of tornadoes proposed for Angra 3 in the Eletronuclear technical report SE.T/3/BP/011006 Rev.1. The conclusions from the discussions with the CNEN for Angra 3 will serve as a basis for evaluating the improvement safety measures necessary for Angra 1 and Angra 2.

- As discussed in more detail in section D, the evaluation of existing margins of the Plants design for protection against external events, performed in the scope of Angra 1 and 2 evaluations of the ETN Fukushima Response Plan, indicate that its design is sturdy and that the Plants can withstand external event magnitudes substantially higher than the limits considered in the Design Bases.

Article 17 (4) Consultation with other Contracting Parties likely to be affected by the installation

Due to the special geographical situation Angra site, no other Contracting Party is expected to be affected by the construction and operation of the nuclear power plant. Therefore, no consultation with neighboring countries is included in the licensing process.

Even so, Brazil has signed both the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, as well as a bilateral agreement with Argentina for notification and assistance in case of a nuclear accident.

ARTICLE 18 – DESIGN AND CONSTRUCTION

Article 18 (1) Implementation of defence in depth

The design of the Brazilian nuclear power plants is based on established nuclear technology in countries with more advanced programs. The licensing regulation CNEN-NE-1.04[3] formally requires the adoption of a “reference plant” which shall have a similar power rating, shall be under construction in the country of the main contractor, and shall go into operation with sufficient time to allow the use of the experience of pre-operational tests and initial operation.

Angra 1 was designed and constructed with American technology, which incorporates the concept of defense in depth, including the use of multiple barriers against the release of radioactive material. Safety principles such as passive safety or the failsafe function, automation, physical and functional separation, redundancy and diversity was also incorporated in the design.

Extensive use was made of American codes and guides such as ASME section III, ASME section XI, IEEE standards, ANSI standards and US NRC Regulatory Guides. Operating experiences from American plants, especially the fire at Browns Ferry and the accident at Three Mile Island, were incorporated through modification in the design, during the construction phase. Design review and assessment was performed through preparation of a PSAR and a FSAR, by FURNAS and its contractors, which were evaluated by CNEN during the licensing process.

Construction adopted a quality assurance program, which encompassed all activities related to safety conducted by FURNAS and its contractors and subcontractors. CNEN monitored the implementation of the quality assurance program through the regulatory inspection program and with the establishment of a resident inspector group during the construction phase.

In a similar manner, Angra 2 has been designed and constructed with German technology, within the framework of the comprehensive technology transfer agreement between Germany and Brazil. The German counterpart assumed technical responsibility for the jointly built plant during construction up to initial operation.

The plant is referenced to the Grafenrheinfeld nuclear power plant, recently shutdown definitively as a result of the German decision of abandon nuclear energy generation. The problem of long storage time of early manufactured components was dealt with by an appropriate and careful storage process, which involved adequate packaging, storage, monitored environmental conditions and a periodical inspection program. The electromechanical erection was performed by the Brazilian consortium UNAMON, which started its activities at the site in January 1996, with a strong technical support from ELETRONUCLEAR, Siemens and foreign specialized companies. A specific Quality Assurance Programme was established for the erection phase, including the main erector activities. Erection activities supervision and inspection were carried both by the main erector as well as by ELETRONUCLEAR. The electromechanical component pre-operational tests were performed in this phase, by the commissioning staff under the plant designer responsibility, as soon as allowed by the erection process.

For the Angra 3 design, the “defense in depth” concept was applied considering the concept evolution, where much more emphasis in the beyond design level is put nowadays as at the time of construction of the Angra 1 and 2 Plants, incorporating already internationally adopted beyond design measures (see Article 6, Angra 3), that in Angra 1 and 2, were or are being introduced through backfits.

The emphasis in the beyond design level, more specifically the 4th and 5th level of defense in depth that deals with accident management and confinement protection measures, that is prevention and mitigation of beyond design events including severe accidents. In spite of differences in detail, the following measures apply to the two plants in operation. The same measures will be implemented in Angra 3.

Prevention:

- PSA studies to identify and correct design and operation procedures weaknesses as well as risk management for maintenance activities (reduction of CDF);
- Symptom oriented Emergency Operating Procedures (EOP) with Critical Safety Function monitoring, including control of complex sequences in the beyond design range;
- Provision of additional means (portable Diesels, pumps, additional heat sink) and incorporation of these means into the EOPs, for the case of total loss of AC power and ultimate heat sink (post Fukushima measures still under implementation)

Mitigation:

- Severe accident Management Guidelines with incorporation of additional features (passive catalytic recombiners, filtered containment venting and containment sampling system). These measures are still being implemented.
- Incorporation of the use of SAMG in the Emergency Planning exercises (under implementation).

The following recent improvements, all related to maintain the integrity of physical containment in case of beyond design events:

- Hydrogen Reducing System, which reduces the Hydrogen content in the containment continuously by means of PAR’s (Passive Autocatalytic

Recombiners) during normal operation, design basis accidents (DBA) as well as after beyond design basis accident (BDBA).

- Nuclear Sampling System for the Containment Sump and Atmosphere, which is designed for the purpose of obtaining high quality samples of the containment atmosphere even after a BDBA. In addition also the containment sump can be sampled after BDBA.
- Containment Filtered Venting System, which vents the containment atmosphere through special filters to prevent loss of containment integrity in case of BDBA like core melt causing high pressure inside the containment.

Article 18 (2) Incorporation of proven technologies

After completion and initial operation of Angra 2 no other NPP design and construction work has been done in Brazil except design modifications for the Angra 1 and 2 plants and some work of continuation of adaptation and upgrading of the Angra 2 design documentation to Angra 3 conditions. This part of the Angra 3 design and engineering work is assigned to ELETRONUCLEAR design and engineering Superintendence (see Fig. 3) under the Technical Directorate. With the recent approval of restart of construction for the Angra 3, this unit had to be restructured and enlarged to be able to perform its scope of activities.

The most significant modifications made in Angra 1 were the steam generators replacement in 2009 and the reactor pressure vessel head replacement in 2013. The original steam generators, of the Westinghouse D3 type, had the tube bundle made of Inconel 600 as well as the penetration welds of the RPV head, manufactured by Babcock & Wilcox. This alloy turned out to be very susceptible to primary water stress corrosion leading to an international program of substitution. Although the original head had more than 12 years effective full power that ranks it as high susceptibility, no indication was found during inspections. Together with the head all control rod drive mechanisms and thermal insulation have also been replaced. The new head was made by Mitsubishi Heavy Industry and the new welds were made with alloy 690 which is not susceptible to the primary water stress corrosion cracking. In the new steam generators the tube material was also changed from Inconel 600 to the 690 alloy.

The new head was made by Mitsubishi Heavy Industry and the new welds were made with alloy 690 which is not susceptible to the primary water stress corrosion crack. The head replacement will ensure the safety and reliability of Angra 1 the long term, contributing to extending the life of the plant. The old head and the old CRDM were stored in the mausoleum with the steam generator replaced.

The new steam generators and RPV head, manufactured with updated proven technology, will ensure the safety and reliability of Angra 1 in the long term, and are an important contribution to the Angra 1 life extension programme.

For Angra 2 no major modifications as for Angra 1have been installed to date. The performed Plant modifications are related to upgrading and modernization of Plant systems, as for example, the full substitution of the conventional Reactor Control I&C (non safety) by digital I&C, to safety improvements, as the interconnection of the two sets of emergency Diesel generators, or also to beyond design measures backfitting, as upgrading of Primary and Secondary Bleed&Feed equipment or installation of passive catalytic recombiners.

Due to the long delay of Angra 3 construction, new design features, resulting from technology development, have been incorporated in the design, especially in the area of instrumentation and control, where full Digital I&C (DIC) will be installed for non safety as well as for safety I&C systems. However, only proven technology already used in other plants is being used as reference.

One major concern for Eletronuclear and possibly to other companies in countries that have German designed nuclear power plants, concerning proven technology for the coming years, results from the German decision to abandon nuclear power generation, with the last German Plant shutting down in 2022.

The proposed use of digital technology for the plant instrumentation will pose a challenge, not only to the licensee, but to CNEN as a reviewer as well.

CNEN has signed, in 2009/2010, an agreement with European Commission to provide technical cooperation to improve the capacity within CNEN to carry out review and assessment of the safety of digital I&C systems as part of the licensing process of Angra 3 NPP, in construction, and modernization of Angra 1 and Angra 2, in operation. Experiences and practices from European Reactors have been presented and discussed through workshops (4 workshops) and visit to nuclear power with upgraded DI&C (Paks NPP), licensing experiences, etc. Evaluations of concepts, criteria and general requirements of DI&C of Angra-3 described in the PSAR were carried out from 2007 to 2010, as part of License Construction issued by CNEN, see Article 8.

Guidance for assessment of quality and reliability of software and programmable electronics based on IEC standards was developed by GRS-ISTec, revision 1, July 2012. An internal guideline of CNEN, consolidating the licensing experience of I&C systems since 1981, based on the NUREG-800 approach, is under revision, balancing the experiences from US and European for digital I&C technology which is being used by new design (like EPR, AP1000), to be designed in the Angra-3 instrumentation. These experiences will be used in next phases of the safety evaluations of FSAR and commissioning activities, in compliance with of initial operation licensing requirements.

As discussed in Article 8, Digital I&C subject was incorporated in the second period (2015–2017) of the CNEN/EC Technical Cooperation Project.

CNEN has been also participating of international workshops for IAEA standard revisions and workshop with NRC of activities for Digital I&C.

Article 18 (3) Design for reliable, stable and manageable operation

The Brazilian Plants in operation or construction are of the PWR type, by far the most used concept for nuclear power generation, with designs proven through many years of operation of similar Plants.

The consideration of human factors and MMI for reliable, stable and manageable operation in the original design of the Brazilian Plants corresponded to the status of this technology in the countries suppliers of the technology (USA and Germany) at the time of the completion of the respective designs.

As mentioned in Article 12, human factor was not a major issue at the time of design of Angra 1, and several reevaluation and backfittiings were carried out in this area along the plant life. For Angra 2, more automation was already incorporated in the design, taken into account the state of the art of the technology. For Angra 3, it is expected that even more advances will be taken into account.

From the regulatory point of view, more attention will be taken with respect to these aspects, and the requirement for a Human Factor Engineering evaluation will be repeated for Angra 3.

ARTICLE 19 - OPERATION

Article 19 (1) Initial authorization

The operation of a nuclear power plant in Brazil is subjected to two formal approval steps by CNEN within the regulatory process: Authorization for Initial Operation (AOI) and Authorization for Permanent Operation (AOP).

The Authorization for Initial Operation (AOI) is issued after the completion of the review and assessment of the Final Safety Analysis Report (FSAR), and taking into consideration the results of regulatory inspections carried out during the construction and pre-operational test period. Additionally, it requires the operator to have already an Authorization for Utilization of Nuclear Materials (AUMAN), and a physical protection program in accordance with CNEN regulations, to have an emergency plan in accordance with SIPRON regulations and to have financial guarantees with respect to the civil liability legislation. In parallel, the corresponding environmental licence has to be obtained from IBAMA, in accordance with the national environmental legislation.

The Authorization for Permanent Operation (AOP), in addition to the AOI requirements, is based on the review of startup test results. Safety requirements during operation are established by regulation CNEN-NE-1.26 [7].

All the above mentioned requirements have been successfully met for the Angra 1 and 2 Plants that have 30 and 15 years of operation, respectively. The Angra 1 AOI was issued in September, 1981 and the AOP in January 1985; for Angra 2, the AOI was issued in March 2000, and the AOP, much later in June 2011, because of non-technical reasons as explained in Article 6, item 6.2.

Operation is monitored by CNEN through an established system of periodical reports [6], notification of safety related events and through the regulatory inspection during operation. A group of CNEN resident inspectors is present at the site.

In the period 2013-2015, CNEN conducted 32 inspections in Angra 1 power plant, including the following areas: Conduct of Operations, Chemistry, Radiation Protection, In-service Inspection, Physical Protection, and Implementation of the Local Emergency Plan, Event Analysis, and Monitoring of the Radioactive Effluents Release, Waste Treatment System, Fire Protection and Operators Training.

During the period 2013-2015, CNEN conducted 30 audits and inspections activities in Angra 2, concentrated in the following areas: Radiation Protection, Fire Protection, Quality Assurance, Event Analysis, Maintenance, Plant Modification and Monitoring of the Radioactive Effluents Release, Solid Waste Treatment System, Fuel Loading Cycles and Operators Training.

Additional 15 inspection covered areas of the organization common to both units, such as Meteorology Systems, Emergency Planning, Physical Protection, Waste Storage & Management and Training.

Article 19 (2) Operational limits and conditions

Limits and conditions for operation are proposed by the applicant in the FSAR, in the form of Technical Specifications. These technical Specifications are reviewed and approved by CNEN during the licensing process, and referenced in the Operation Licence document. No changes in these limits and conditions can be made by the licensee without previous approval by CNEN.

The project for adaptation of the original Angra 1 Specifications to the content and format of document NUREG 1431, Standard Technical Specifications for Westinghouse Plants, Rev. 1, was started several years ago following the practice of the American Plants. The new Angra 1 Technical Specifications were elaborated, translated to Portuguese, and after a long review period, internally and by the Regulator, have been finally approved by CNEN in beginning of 2015 and implemented at the Plant in the end of 2015.

For Angra 2, the German licensing framework did not foresee Technical Specifications in the strict USNRC sense. The equivalent documentation, called “safety specifications” in the German procedure, is part of the Operating Manual, and is much more concise than the American ones. For the sake of uniformity, CNEN required that Technical Specifications following the Standard Format of NUREG 1431 be prepared also for Angra 2. This was again a huge adaptation job with extensive revision work. Being a new document, the Angra 2 Technical Specifications are being verified in practice and several revisions have been implemented to date as the result of feedback from operation. In the meantime the Specifications have been translated into Portuguese and this translation has been validated. The Portuguese version has been reviewed by CNEN and some modifications were required and implemented.

For Angra 2, the operability criteria of the systems, as required in the Limiting Conditions for Operation (LCOs), are defined in the Test Instructions. Each Test Instruction links the results of the test with the acceptance criteria of the associated LCO. An user-friendly software was developed and implemented in Angra 2 to support the Safety Function Determination Programme required in the Technical Specifications.

As an additional tool to support the Plants concerning acceptable Plant configurations, both Plants have available risk assessment tools, based on Plant specific living internal events PSA, either on-line (Risk monitor) for Angra 2 or through daily calculations, for Angra 1. Besides routine risk evaluation these tools allow assessment of complex situations and decision-making that would be complicated using only Technical specification orientations.

Article 19 (3) Procedures for operation, maintenance, inspection and testing

Safety requirements during operation are established by regulation CNEN-NE-1.26 [7]. Additional CNEN regulations establish more detailed requirements for maintenance [17] and in-service inspection [18].

The implementation of these requirements at the plant is done through the preparation of an Operation Manual, which contains guidelines to develop, approve and control plant procedures according to the nuclear class and the Quality Assurance Program. It also contains the actual procedures for all activities to be conducted in the plant, related to operation, maintenance, inspection and testing.

An administrative procedure - Organisation of Operation Manual - provides the detailed requirements to develop, approve and control all plant procedures. In the case of surveillance procedures required by Technical Specifications or other regulations (ASME Code or KTA rules), another administrative procedure gives instructions in more details for the preparation of field procedures, implementation and control. Each Unit Operation Review Committee (CROU) approves all procedures of the respective unit. The Plant Operation Review Commission (CAON), which oversees both units, analyses and approves all nuclear safety class procedures and those that are related to the Quality Assurance Program.

All employees must follow written procedures, and each Department Manager (Operation, Maintenance, Technical Support, Chemistry, Health Physics, etc.), must assure that all tasks done under his/her responsibility are accomplished using the latest revision of the approved procedure. The Quality Assurance Department monitors and controls whether the plant organisation is using approved procedures during operation, maintenance, test and inspection.

The Operation Manual is divided into volumes according to specific areas of activity, such as: Administrative, Operation, Radiological Protection, Chemistry and Radio Chemistry, Reactor Performance, Nuclear Fuel, Instrumentation, Electrical and Mechanical Maintenance, Health Physics, Surveillance, Training, Physical Protection, Emergency Procedures, Fire Protection, Environmental Monitoring. Besides the Normal Operation Procedures, the Operation volume contains also the Abnormal and Emergency Operation Procedures for assisting in abnormal and accident occurrences, including procedures to be followed relative to the Emergency Plan. The procedures should be revised every 2 or 4 years, considering their classification as safety or quality documents.

In case of an accident evolution to core damage conditions, specific exit criteria have been incorporated in the Emergency procedures that call the guidelines of the Severe Accident Management Manual (SAM M), recently completed and tested for both Plants.

In cases where contracted companies (foreign or national) perform work in the plant, a temporary procedure is necessary. For a contracted company that develops its own procedures, a plant expert or an engineer related to the work to be performed, analyses the original procedure and sends it to the Quality Assurance to check if the acceptance criteria are achieved. A cover sheet with an approval form is attached to the procedure.

For other temporary procedures, the author writes the procedure, explains the reason for its temporary nature and establishes a validation period. Temporary procedures can be used only during the validity period stamped in the procedure.

The Work Control Group is responsible for planning all the maintenance, inspection and testing tasks in operation and outages. Inside the work package, procedures, plant modification documents, part lists and other references applicable to the task should be included. A task can be started only after discussion at the daily co-ordination meeting and the shift supervisor release.

Work control process stamps the ”Work Permit” with a “Red Line” to identify tasks related to nuclear safety equipment. In this case, quality assurance and maintenance quality control personnel ensure that approved procedures and part lists with traceability are being used. In addition, for equipment that has a "Risk of Scram", an approved procedure must be used and this procedure has a “Red Cover Sheet” to warn workers about risks and cautions to be taken.

During outages, a written and approved outage procedure controls the overall plant safety condition for inspection, testing and refueling operation.

Article 19 (4) Procedures for responding to operational occurrences and accidents

The Operation Manuals of Angra 1 and Angra 2 contain procedures to respond to anticipated operational occurrences and accidents. For abnormal conditions, procedures are used to return the plant to normal conditions as soon as practical or to bring the plant to a safe state, such as hot shutdown or cold shutdown. For accidents, Emergency Operating Procedures (EOPs) were written in accordance with latest reactor manufacturer guidelines and current international practices.

Although having different formats, both the EOPs for Angra 1 and Angra 2 are based on the same philosophy:

- If an event can be clearly identified, Event Oriented EOPs are used; e.g., for Angra 2, Event Oriented EOPs are provided for control of the following classes of accidents: LOCAs, steam generator tube rupture, secondary side breaks, overcooling transients, external impacts during plant operation with reduced inventory or at refueling.
- If the event cannot be clearly identified, Symptom or Safety Function oriented EOPs direct the operator into monitoring and restoration of the set of fundamental safety functions (Critical Safety Functions). If these

safety functions are fulfilled the plant is in a safe state. These Safety Functions are Subcriticality, Core Cooling, Coolant Inventory, Containment Integrity, and Heat Sink.

The EOP structure, taking Angra 2 as example, consists of two levels of detail. The first level includes a diagnose chart, a trends-of-plant-parameters table, an automatic actions flow diagram, a manual actions flow diagram. The second level includes an instrumentation list, detailed instructions for automatic and manual actions, explanatory remarks and diagrams and tables.

These EOPs cover accidents in the Design Basis and Beyond Design Basis up to but not including accidents with core melt (severe accidents). They assume the use of all available systems, even beyond their original design purposes and operating conditions.

These EOPs are being modified to call for specific procedures for installation and operation of mobile equipment as a means of power supply and steam generator cooling, in addition to the existing Plant systems. The work of preparation of the specific mobile equipment procedures is still underway.

Integrated Computerized Systems, added to Angra 1 and Angra 2 after initial design as a result of HFE evaluations (see Article 12), assist the operator in monitoring Critical Safety Functions (CSF) and other process variables. When a CSF (Subcriticality, Core Cooling, Coolant Inventory, Containment Integrity, and Heat Sink) is violated or there is a chance to reach the specified limits, there are approved procedures to be used to restore the CSF to normal condition. Color codes used in the Integrated Computerized System help the operators to act in an anticipated way, to avoid reaching the protection limits. These colors (green - Normal, yellow - Alert, orange - Urgent, red - Emergency) guide the operator to what procedure should be used. In case the Integrated Computerized System is not operable, there is a paper procedure that must be followed by the operator to confirm that no CSF is in the process of violation or has been already violated.

As indicated in 19(3) specific exit criteria have been incorporated in the Emergency procedures that call the guidelines of the Severe Accident Management Manual (SAM M).

Severe Accident Management Guidelines (SAMGs) have been developed for the Angra 1 plant in the 2008 – 2009 period through a contract with Westinghouse, using the Westinghouse Owner Group (WOG) concept. This concept was applied to essentially all Westinghouse PWR in the USA and abroad and was developed to address elements of USNRC Severe Accident Management Program (SECY-89-012).

The WOG SAMG provides structured guidance for: (1) Diagnosing plant conditions (2) Prioritizing response, (3) Evaluating alternatives and (4) Verifying implementation of actions, being a process for choosing appropriate actions, based on actual plant conditions.

No detailed knowledge of Severe Accident phenomena for the specific plant is required and the SAMG measures rely basically on existing equipment.

The resulting documentation consists of guidelines for the control room operators for the initial transition from the EOP to SAMG and guidelines, logic trees and computational aids to be used by the Technical Support Center staff that takes over operator orientation for management of severe accident conditions. The complete SAMG documentation also includes a set of background material with the bases for the guideline actions and of SAMG training material to be used for initial and periodic retraining.

A second contract was signed with Westinghouse to support ELTRONUCLEAR in the process of verification and validation of the Angra 1 SAMG, integration of these SAMG into the Emergency Planning (EP) documentation as well as training of the involved personnel. All the above tasks have been performed and the integration of the SAMG with the Emergency planning documentation was tested through performance of an EP exercise with activation of the Angra 1 Plant Emergency Centers Control Room and TSC. This work was completed in May 2016.

To be coherent with the approach being adopted in the development of the SAMG for the Angra 2 plant as well as to follow IAEA and international practices, additional equipment to help manage a severe accident, such as passive H2 recombiners and filtered containment venting are being procured and purchased for installation in Angra 1. Accordingly, after clear definition of this additional equipment these SAMG will have to be revised to account for it.

Preparatory work for the development of a project to provide SAMG for the Angra 2 was pursued along 2009 - 2010, taking advantage of a recently signed Cooperation Protocol between Brazil and the European Commission, in which the EC provides funding for safety improvement projects. The project was initiated in March, 2011, and involved the development of Angra 2 specific SAMG, including transfer of know how. AREVA was the selected contractor.

So far an Angra 2 severe accident calculation model using the MELCOR code has been developed and validated, the calculations for a comprehensive set of plant damage states have been performed, and the results are being analyzed. Furthermore the evaluation of the Angra 2 existing mechanical, electrical and I&C equipment with possible use in severe accident conditions has also been completed.

The next step consists in the development of simplified computational aids in form of curves or tables to allow quick identification of core or containment conditions in a severe scenario. From these results Angra 2 specific severe accident management strategies will be derived.

The following additional equipment specific for severe accident management is already being considered in the development of the Angra 2

SAMG: passive H_2 recombiners, filtered containment venting and containment sampling system.

The main tasks performed jointly by ETN and the Contractor were: developing and validation of an Angra 2 specific severe accident calculation model using the MELCOR code, performance and evaluation of calculations for a comprehensive set of plant damage states, that provided the insights for development of Angra 2 specific accident management strategies; evaluation of the Angra 2 existing mechanical, electrical and I&C equipment with possible use in severe accident conditions and development of simplified computational aids in form of curves or tables to allow quick identification of core or containment conditions in a severe accident scenario.

From the inputs of the above tasks and taking as reference the AREVA Severe Accident Guidelines from German sister Plants, the Angra 2 specific Severe Accident Management Guidelines were developed and collected in the Angra 2 Severe Accident Management Manual.

For verification of these guidelines table top exercises have been performed. Two one-week training sessions have been provided by experts from the Contractor. The final exercise of use of the developed SAMGs integrated to an Emergency Plan exercise was successfully done in November 2015. In this exercise the Control Room and the TSC were activated with the actual personnel foreseen in the Emergency Plan Manual, and an exercise unknown to the participants was run, conducted by experts from the Contractor.

CNEN, based in international experience, prescribes a systematic examination of severe accident vulnerability using PSA. In this frame, CNEN issued the technical report NT-GEDRE-01/93 specifying the safety requirements. Moreover, the Operator Organization shall issue instructions and procedures that deal with the plant under severe accidents conditions according to the CNEN-NE-1.26 Standard (10/1997).

In 2010 CNEN initiated a project (BR/RA/01), supported by the European Commission, and entitled: “Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN)”. Within this project, CNEN with support from the EC developed an internal capacity to carry out the assessments of matters related to severe accident management.

The main objective of this tasks has been reached and was developed one draft standard with regulatory requirements for severe accident management, as well as one draft guidelines to assessment of the severe accident management guidelines (SAMGs) submitted to CNEN by the ETN. This project has been started in June 2011 and was finalized in October 2013.

In 2015 CNEN initiated a second project EC Project BR3.01/12 (BR/RA/02), supported by the European Commission, and also entitled: Nuclear Safety Cooperation with the Regulatory Authorities of Brazil (CNEN). The main objective of Task 5 of this project is to support CNEN in the assessment of the Severe Accident Management Programs (SAMP) for Angra-2 and 3, possibly including the capacity to review and/or revise MELCOR nodalisations used in Angra-2.

Article 19 (5) Engineering and technical support

Engineering services and technical support are available for the operation of Angra 1 and Angra 2 within the ELETRONUCLEAR organization and supplemented by outside contractors. The technical support groups include all basic engineering disciplines: civil, electrical, mechanical, instrumentation and control, systems and components, safety analysis, stress analysis, reactor physics, and radiation protection. In this respect, the creation of ELETRONUCLEAR, combining FURNAS engineering and technical support groups with NUCLEN design capability, has significantly improved the support services available to both Angra 1 and Angra 2.

The engineering support staff is mostly involved with the design and implementation of plants modifications, derived from inputs provided by the Plants or by external operating experience.

The company has also made available experienced technical personnel to perform deterministic and probabilistic safety assessments to support Plants modifications, event analysis or Regulator requirements. Core reload calculations or mechanical and stress analysis for the Angra Plants are also performed in-house.

As referred in Article 18(2) the Company has an Engineering and Design Superintendence at Headquarters, dedicated to the conduction of the Angra 3 project design and engineering as well as special large engineering projects, e.g., the interim spent fuel storage installations. This Superintendence can also provide support to the Plants in several specialized technical disciplines.

The recent Incentive Retirement Program has reduced substantially the available engineering and technical support personnel, which will probably lead to the need of more use of specialized Contractors.

Another source of requirements for modifications is the regulatory body, which normally updates its regulations on the basis of new technological developments, experience feedback and new international practices.

Article 19 (6) Reporting of incidents significant to safety

Reporting requirements to CNEN during operations are established in regulation CNEN-NN-1.14 [6].

This standard establishes requirements for notification and classification of events and the format of the event reports. This standard is being revised considering technical information obtained from a technical cooperation with European Community - Spain, France, German and Hungary and material from USNRC and IAEA.

Different types of reports are identified, such as periodical reports and reports of abnormal events. Notifications of 1 or 4 hours are required for events that involve degradation of the plant safety conditions, or exposure to radiation of site personnel or the public to levels above the established limits. Required report events should be reported within 30 days. There are also requirements for special reports established in Technical Specifications.

Reports are classified in levels (1, 2, 3 and minor events), where reports classified as level 1 require reporting to the Regulator, level 2 are events considered of enough significance to be documented in detail and level 3 are operational deviations, documented in less detail than level 2 events, but nevertheless important for gathering of internal operational experience. Collected minor events, documented in a simplified way, are compiled in specific families and used to identify negative trends.

Statistics of reported incidents significant to safety for the past three years

In addition, with the purpose of dissemination of operational experience that may be of value for other nuclear power plants, the ELETRONUCLEAR reports on the order of 5 significant events per plant/year to WANO and INPO.

Eletronuclear made the following required reports to CNEN due NN 1.14 regulations:

- Angra 1 reported 7 events of safety significance in 2013, 7 in 2014 and 3 in 2015. One special report required by technical specification;
- Angra 2 reported 6 events of safety significance in 2013, 1 in 2014 and 3 in 2015.

Other operational event reports as well as operational deviations that do not classify as reportable in accordance to regulation CNEN NN – 1.14[6], are available for CNEN audit and review.

Overview of the established reporting criteria and reporting procedures for incidents significant to safety and other events such as near misses and accidents

The national standard CNEN-NN-1.14[6] establishes criteria for notification and for event report.

The Operational Experience of the utility considers five types of events:

- Events required by the standard NN 1.14 (type 1);
- Events not classified as required by standard but the utility considers important or with potential risk for the safety (type 2);
- Events of an operational deviation (type 3);
- Near misses or quasi-events (type 4);
- Special Reports required by technical specifications.

There specific procedures to make the classification of the events and to establishes the investigation methodology (root cause analysis). There are also a procedure to deal with external operational experience.

Documentation and publication of reported events and incidents by both the licence holders and the regulatory body;

All operational events classified as above are recorded in events reports. The regulatory body perform an evaluation of all events classified as required (type 1) by the standard with a generation of a technical document with corrective actions when applicable.

When applicable, other types of operational event reports can be evaluated. The assessment of regulatory body are recorded in specific regulatory reports.

On an annual basis the regulatory body performs an audit to evaluate the application of the methodology and to verify efficiency, effectiveness, trends and lessons learned.

Policy for use of the INES scale

The International Nuclear Events Scale (INES) is used to classify the safety significance of the events in the event reports. Only INES events of level 0 have been reported to CNEN in the period from 2013 - 2015, related to Angra 1 and 2.

The classification of INES scale is required by CNEN-NN-1.14[6] regulation and performed by Eletronuclehar. CNEN perform the revision and when necessary, can require a revision and correction of the classification.

Regulatory review and control activities

The regulatory resident inspection receives all operational event reports and perform screening selecting ones to perform specific assessment. All the required operational event reports are evaluated.

CNEN performs annual audits on the operational experience process in Angra 1 and Angra 2 NPPs.

Angra 1 received an OSART Mission in 2012 and a follow-up Mission in 2014. An evaluation of the recommendations and suggestions were done and an assessment was done considering the corrective actions required by CNEN. The last OSART Mission in Angra 2 occurred in 2012.

Article 19 (7) Operational experience feedback

The operational experience feedback process in Brazil comprises two complementary systems: one performed by ELETRONUCLEAR, processing both in-house and external information, and one performed by CNEN.

At Eletronuclear the internal operational experience is collected and processed by specific groups inside the plants. Of the order of 80 to 120 reports of classes 1,2 and 3, per Plant, per year, were produced in the review period. Statistically, about 2 to 3% were reports class 1, 25 to 30% reports class 2 and of the order of 70% of reports class 3.The main contents of these reports are the identification, classification and description of the event, the identification of the direct and root causes, the causal factors, the consequences to safety and the recommended corrective actions.

Of these reports, between 1-7 per year/plant were formally reported to CNEN (see statistics for 2013-2015 in Article 19(6) above) following the requirements of CNEN-NN-1.14 [6].

The internal safety committee at each plant (CROU) review these reports before release and the most significant ones, basically the ones that are reported to CNEN, have to be evaluated also by the CAON, the committee that evaluates the safety of operation. A subcommittee of the CAON has the task of analyzing all produced reports and feedback to the CAON any specific or general deficiencies of individual reports or in the reporting procedure and the main insights derived from the analyzed reports.

As indicated in Article 19(6), ELETRONUCLEAR is committed to report of the order of 5 significant events /year/plant to the World Association of Nuclear Operators – WANO as well as to the Institute of Nuclear Operators – INPO. When pertinent, these reports are also supplied to VGB, the German Association of Plant Operators.

Beginning in 2007, the plants have started to collect minor events and near misses. Every year about 1000 minor events per Plant are collected. The collected events are classified in families and trended.

In both plants Angra 1 and Angra 2, the Low Level Events (LLEs) are the base of the pyramid and are recorded and appropriately evaluated to prevent adverse trends of plant events. LLEs result in immediately Work Orders Request to solve the adverse condition, or are quantitatively evaluated and when reaching 30 LLE during the previously 6 months with same WANO Root Cause Code besides comparable description are presented at a Daily Management Meeting when is determined the depth of event analysis to be performed (Operating Event Report, Significant Event Report) that will lead to Corrective Actions. LLEs are also being used to support the Human Performance Indicators.

Insights from evaluation of these trends are used to establish corrective actions, as for example the implementation of an extensive human performance improvement program, referred to in Article 12, Human Factors.

External experience is handled by an Operational Experience Analysis group, belonging to the Plants Support Engineering. This group investigates relevant incidents occurred in the Angra Plants and in similar nuclear installations in order to make recommendations.

Following recommendations from an IAEA PROSPER mission in 2007, the task of collecting, analyzing and disseminating External Operating Experience (EOE) within Eletronuclear, formerly done by the Engineering Support area, has been reorganized, with the goal of promoting more participation of the Plants in the process, improving the effectiveness of the process.

EOE Committees were established at each unit with participants from the plants Support Engineering and Nuclear Safety divisions. These committees evaluate the collected EOE, the main sources being WANO and INPO Significant Event Reports, IAEA Incident Reporting System, VGB, EPRI, and reactor designer pertinent information. Furthermore, they issue and follow up recommendations implementation.

The External Operating Events (EOE), coming from WANO/INPO/VGB/IAEA, are analyzed and, if applicable to the station, an evaluation in plants processes is done and procedures can be improved. In all cases the experience is spread among the organization. The EOEs related to outages are informed to the employees before the following plant outage.

For both plants, if a corrective action demands a revision of documentation this is made so. In practical terms, when a document is revised due to OE, this document must have the letters OE on the left side of the page, and a mark to signalize the revision made, and by procedure it cannot be removed without the approval of the Plant Operational Review Committee (PORC).

In Angra 1, the Reactor Vessel Head was changed preventively, based on a Davis Besse SOER. It was also used a lot of information which arose from Westinghouse Technical Bulletin and Nuclear Safety Advisory Letter to refer to other design modifications. Operational procedures are modified (when needed) upon OE recommendations such as the procedure to go from Hot Shut Down to Power (e.g. reactivity control - SOER).

In Angra 2, during the construction phase, several major improvements have been implemented based on the experience of the German plants, such as, replacement of the PZR valve station to allow discharge of water, use of the low pressure safety injection to provide back pressure to the high pressure safety injection, upgrading of the reactor limitation system, among others. Further modifications based on the same experience have been /are being implemented after beginning of plant operation, such as additional pressurizer valves for Primary Feed and Bleed, interconnection of emergency Diesels (large and small sets of emergency Diesels). Furthermore, several new or modified procedures have been implemented as result of international experience evaluation.

Sections B5 and D of the National Report show that the Eletronuclear Response Plan to Fukushima also mentions good examples of the company initiatives originated by external operating experiences.

To avoid the risk of insularity, due to the geographical location of the Brazilian plants, far away from the main nuclear centers, ELETRONUCLEAR has had from the beginning a policy of strong involvement with the nuclear industry. Technical exchange visits, technical review missions, observer or expert missions, from other nuclear power plants or organizations to Angra and from Angra personnel to other nuclear power plants, when conducted periodically, provide a valuable source of information on other plant experiences.

The invited Peer Review missions performed by WANO or the IAEA, as they aim to identify departure from industry best practices concerning safety and reliability in plant operation. ELETRONUCLEAR adhered to these review programs from their inception, and since 2004 has established policy of performing of a complete internal (self-assessment) and external evaluation at 3-year cycles, alternating IAEA OSART and WANO Peer Reviews.

An IAEA Operational Safety Review Follow-up Team visited the Angra 1 NPP from 17 to 21 February 2014. At the request of the Government of Brazil, an IAEA Operational Safety Review Team (OSART) of intenational experts visited Angra 1 Nuclear Power Plant (NPP) from 20 August to 6 September 2012. The purpose of the mission was to review operating practices in the areas of Management Organization and Administration; Operations; Maintenance; Technical support; Radiation Protection; Operating Experience; Chemistry and Accident Management. In addition, an exchange of technical experience and knowledge took place between the experts and their plant counterparts on how the common goal of excellence in operational safety could be further pursued.

Table 7 provides a list of such international review and technical support missions to Angra for the 2013 – 2015 review period.

Table 7 – International Technical and Review Missions to ELETRONUCLEAR power plants and head office between 2013 – 2015

No	Date	Organization	Location	Type of mission
1	December, 2012	IAEA	A2	OSART Follow up
2	October, 2013	WANO PC	Corporate	Corporate Peer Review Kick-off Meeting
3	October, 2013	WANO PC	A1/A2	Pre Visit WANO Peer Review A1 e A2
4	November, 2013	IAEA	SO.T/A1/A2	Pre SALTO Mission
5	January, 2014	WANO PC	A1/A2	WANO Peer Review
6	February, 2014	WANO PC	Corporate	Corporate Peer Review Pre-Visit
7	February, 2014	IAEA	A1	OSART Follow-up
8	October, 2014	WANO PC	Corporate	Corporate Peer Review
9	November, 2014	WANO PC	Corporate	Corporate Peer Review Exit Meeting
10	August, 2015	INPO	A1/A2	TSM on System Health Indicators
11	November, 2015	WANO	A1/A2	TSM on Lifting and Rigging

A1/A2/A3: Angra 1 / Angra 2/Angra3 NPP
EPRI: Electric Power Research Institute
IAEA: International Atomic Energy Agency (Vienna, Austria)
INPO: Institute of Nuclear Power Operations (Atlanta, USA)
OSART: Operational Safety Analysis Review Team
PROSPER: Peer Review of the Operational Safety Performance Experience Review
TECDOC: IAEA Technical Document
TSM: Technical Support Mission
WANO: Word Association of Nuclear Operators (PC – Paris Center, France)

Another important mechanism of transfer of experience is the participation in review or technical support missions to other nuclear power plants. ELETRONUCLEAR has had, since a long time, a strong participation in this type of missions.

Table 8 presents a list of international technical missions with participation of Angra personnel to other plants during the 2013 – 2015 period.

Table 8 – Technical Missions of ELETRONUCLEAR Personnel to other countries between 2013 – 2015

No	Date	Leading Organization	Type of mission / Area	Location	Country
1	January, 2013	WANO PC	Admission Training	WANO Head Office	France
2	February, 2013	WANO PC	Peer Review – Fire Protection	Ringhals NPP	Sweden
3	April, 2013	WANO PC	TSM – Configuration Management	Sellafeld NPP	England
4	April, 2013	IAEA	SALTO License renewal and life extension	Paks NPP	Hungary
5	June, 2013	IAEA	OSART Follow-up – Radiological Protection	Seabrook NPP	USA
6	August, 2013	WANO PC	Admission	WANO Head Office	France
7	August, 2013	WANO PC	Pre Start-up Peer Review – Simulator Training	TECNATOM Facilities	Spain
8	September, 2013	WANO PC	Peer Review – Support Engineering	Grohnde NPP	Germany
9	September, 2013	WANO PC	WIO Meeting	WANO Head Office	France
10	September, 2013	WANO PC	Peer Review – System Engineering	Trillo NPP	Spain
11	October, 2013	WANO PC	Peer Review – Operations	Bohunice NPP	Slovenia
12	October, 2013	WANO PC	Peer Review – Organization & Administration	Gundremmingen NPP	Germany
13	October, 2013	WANO PC	Peer Review – Operations	Goesgen NPP	Sweden
14	October, 2013	WANO PC	TSM – Maintenance	Dampierre NPP	France
15	November, 2013	WANO PC	Peer Review – Organization & Administration	Blayais NPP	France
16	November, 2013	WANO PC	Peer Review – Radiological Protection	Tihange NPP	Belgium
17	March, 2014	WANO PC	WIO Meeting	WANO Head Office	France
18	May, 2014	WANO PC	Peer Review – Chemistry	Cofrentes NPP	Spain
19	May, 2014	WANO PC	TSM – Outage Management	Fangchengang NPP	China
20	June, 2014	WANO PC	Peer Review – Support Engineering	Vandellos NPP	Spain
21	June, 2014	WANO PC	Corporate Peer Review	RWE	Germany
22	September, 2014	WANO PC	Peer Review – Organization & Administration	Vandellos NPP	Spain
23	September, 2014	WANO PC	WIO Meeting	WANO Head Office	France
24	October, 2014	WANO PC	Peer Review – Organization & Administration	Krsko NPP	Slovenia
25	October, 2014	IAEA	OSART – Operations	Paks NPP	Hungary
26	October, 2014	IAEA	OSART – Operations	Flamanville NPP	France

IAEA: International Atomic Energy Agency
INPO: Institute of Nuclear Operations, USA
SCART: Safety Culture Assessment Review Team
WANO: World Association of Nuclear Operators (AC: Atlanta Center / PC: Paris Center)
TSM: Technical Support Mission
WIO: WANO Interface Officer

From the regulatory point of view, from 2013 to 2015, CNEN/CGRC audited the licensee internal and external operational experience assessment system to evaluate its adequacy and found no non-compliance.

All Significant Events Reported by the licensee goes through a preliminary evaluation by the resident inspectors to check for any inconsistencies and for the adequacy of the applicable recommendations. A final analysis of the event is carried out by the headquarters divisions.

CNEN is a member of the IAEA-IRS technical cooperation program exchanging experience with other participant countries. Also CNEN has a bilateral technical cooperation agreement with German GRS to exchange experience in the areas of operational events, PSA and Ageing programs. In the period there was a meeting per year with GRS personnel.

Article 19 (8) Management of spent fuel and radioactive waste on the site

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 concrete and conditioned in 1 m3 liners. Compressible solid wastes may be conditioned in 200-liter drums and non compressible wastes in special boxes. Gaseous wastes are 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 wastes are being stored on site in an initial storage facility (Central Storage Facility).

A permanent long-term program for reduction of production of new waste and reduction of existing waste in Angra 1 is in place.

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 wastes are collected in storage tanks for further monitoring and adequate treatment or discharge to the environment. The concentrate resulting from the liquid waste treatment is immobilized in bitumen by means of an extruder-evaporator and the dry concentrate is conditioned in 200-liter drums. Spent resins and filter elements are also immobilized in bitumen and conditioned in 200-liter drums. Compactable solid wastes are conditioned in 200-liter drums. Gaseous wastes are 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 150 m 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 initial storage facility referred above.

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 initial storage facility. Additionally, there are also procedures established for clearance of radioactive waste.

According to the Brazilian legislation [19] CNEN is responsible for the final disposal of all radioactive waste generated in the country.

Since no final radioactive wastes repository is available to date, the generated low and intermediate level wastes of Angra 1 are being stored in the already mentioned on-site Central Initial Storage Facility located at the Angra Power Plants site.

This facility is composed of three units, called Storage Facility 1, Storage Facility 2 and Storage Facility 3. Additionally, there is a Steam Generators Storage Facility for storage of the two original Angra 1 steam generators, replaced in 2009, of the original Angra 1 reactor vessel head, replaced in 2013, of one Angra 1 waste evaporator and sixty six metallic boxes containing non compressible waste produced during the replacement of the old steam generators. All the referred Storage Facilities are presently in operation.

As required by the Regulator, before final disposal, the isotope content and concentrations in the individual radwaste drums has to be known. For this purpose a special building, to be equipped with equipment for remote handling and scanning of the drums, has been built and is ready for equipment installation.

In Angra 2, all the up to now produced waste drums are stored in a compartment of the Reactor Auxiliary Building, inside the Plant, specifically designed for this purpose. These drums will be transferred along the time to the Central Initial Storage Facility. The disposal system mentioned is the Initial Deposit Radioactive Solids Wastes - KPE, which is located inside the Reactor Auxiliary Building - UKA. This Radwaste Deposit has a capacity to store 1644 drums of medium and low activity.

The current inventory of waste stored at Angra site is presented in the Tables 9 and 10 below:

Table 9 - Waste Stored at Angra Site – Angra 1 NPP

Type of Waste	Nr. of Packages	Location
Concentrate	3033	Storage Facility 1/ Storage Facility 2 / Storage Facility3
Primary Resins	781	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Filters	530	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Non-Compressible	991	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Compressible	779	Storage Facility 1 / Storage Facility 2 / Storage Facility 3
Secondary Resins	828	Storage Facility 1
TOTAL	**7276**	

Table 10 - Waste Stored at Angra Site – Angra 2 NPP

Type of Waste	No. of Packages	Location
Filters	15	In Plant Storage (UKA building)
Concentrate	274	In Plant Storage (UKA building)
Primary Resins	140	In Plant Storage (UKA building)
Compressible	307	In Plant Storage (UKA building)
TOTAL	**736**	

With respect to spent fuel storage, the Angra 1 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 Angra 1 spent fuel pool, located in the Angra 1 Fuel Building, has two regions: Region 1, composed of normal cells, with 252 fuel cells, and Region 2, composed of high density storage racks, with 1000 fuel cells**.**

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 original enrichment.

Considering realistic assumptions the storage capacity of the Angra1 and Angra 2 Plants spent fuel pools will be exhausted by mid-2021. ELETRONUCLEAR has initially adopted the construction of the Spent Fuel Complementary Storage Unit of CNAAA – UFC, wet type and in 2013 submitted to CNEN the Site Report. Finally, in November 27th, 2014 CNEN issued the Site Approval. However, in 2015 the ETN after submitting the application for Construction License of UFC, and as a result of a strategic decision of the company, decided to postpone the implementation of the UFC, opting to to build a Dry Type Spent Fuel Complementary Storage Unit of CNAAA, now called UAS.

The company strategy to provide additional spent fuel storage capacity follows two approaches: acquisition of casks for dry storage for up to 5 years of Plants operation in the short term and completion of the spent fuel wet storage project, presently in the final design stage, for the long term.

The inventory of spent fuel and the occupation of the respective Spent Fuel Pools at Angra site are presented in Table 10 below:

Table 11 – Spent Fuel Storage at Angra Units (Dec 2015**)**

Angra 1 NPP		**Angra 2 NPP**	
Spent Fuel Stored	**Occupation (%)**	**Spent Fuel Stored**	**Occupation (%)**
914	73	656	60, 5

Conclusions on Article 19

All activities by CNEN and ELETRONUCLEAR related to Plants operation have always had the goal of ensuring Plant safety, reliability and search for continuous improvement.

Expectations for the operating Plants are good for near future. The replacement of Angra 1 steam generators, as well as the several upgrades made resulted in substantial performance improvement for this Plant. Implementation of the new Angra 1 Technical Specifications should allow better operator performance.

In the case of Angra 2 the plant effort to identify secondary side major equipment malfunction root causes and the countermeasures taken, were successful, as demonstrated by a Plant availability factor larger than 85% in the last 10 years, as shown in Table 2, of Article 6.

A considerable effort was spent in this review period, in enhancing the Plants response to beyond design events through the implementation of SAMGs, and all reported measures derived from lessons learned from the Fukushima accident (see section D).

The situation of storage capacity for the low and medium level Angra 1 waste up to conclusion of the final repository (planned for 2025), reported in previous National Reports, has been solved by means of several actions, including super-compaction of existing waste drums and construction of additional waste storage facilities.

The present critical items to ensure the long term operation of the Plants are: the life extension program being developed for Angra 1(Angra1 original lifetime expires in 2024) and the provision of additional interim spent fuel storage space for both.

The safety record for both plants has remained good with almost faultless safety system performance as demonstrated by the plants safety indicators and by the low number and low safety importance of the reported safety related events.

This has been also confirmed by the outcomes of the recent Angra 1 OSART follow up as well as the Angra 1 and 2 WANO peer review, both in 2014, and the subsequent Angra 1 and 2 WPR follow up in 2016.

D. Status of Activities Related to Fukushima Accident

As soon as it was identified the magnitude of the accident occurred in March, 11th 2011 at the Fukushima Daiichi Nuclear Power Station in Japan, the Board of Directors of Eletronuclear decided in March, 16th 2011 to constitute a Technical Committee, coordinated by the Presidency counting on senior staff members of all company's Directorates, with attributions to follow-up the accident evolution and measures taken to control it, to follow-up the recommendations from international organisms related to nuclear, environmental, industrial, radiological safety and security as a consequence of the accident, and also to help the Executive Board on nuclear safety related matters as a result of the event follow-up.

In April, 19th 2011, Eletronuclear responded to the World Association of Nuclear Operators Significant Operating Experience Report (WANO SOER 2011-2) issued in March 2011, including the results of the recommended verifications regarding the plants Angra 1 and Angra 2 NPPs capability to face beyond design basis accidents, with emphasis on station black out, flooding and fire hazards.

On May 13, 2011, CNEN issued a document number 082/11-CGRC/CNEN formally requiring Eletronuclear to develop a preliminary safety assessment report, including a specific set of technical aspects taking in account the Fukushima accident. These included:

1. Identify the major design differences between Fukushima and Angra Units;
2. Identify possible external initiating events (extreme) and the internal potential cause a common mode failure;
3. Control of concentrations of hydrogen in the containment;
4. Ensuring electricity supply emergency power;
5. Fulfillment of the requirements of station blackout;
6. Service water system, cooling chain;
7. Procedures for severe accidents;
8. Access to buildings and controlled area of the reactor after an severe accident;
9. Development of Probabilistic Safety Analysis Level 1, 1 and 2;
10. Performance of "stress tests";
11. Emergency planning.

Eletronuclear provided to CNEN a technical report, Preliminary Assessment Report of the Accident at the Fukushima Daiichi Central, in August 2011, with a preliminary evaluation of the above listed topics.

Along the second half of 2011 the ETN Technical Committee referred above developed an Action Plan, under request from the Board, with planned initiatives to be developed to respond to the Fukushima event. This Plan, named Eletronuclear Response Plan, was approved by the Executive Board of the company in November 2011 and shortly thereafter, submitted to CNEN.

The preparation of the Plan was based on the Preliminary Assessment Report referred above, and the results of preliminary evaluations developed by the nuclear industry worldwide, focused on three main Areas of Evaluation: Protection against Risk Events, Reactor and Fuel Pool Cooling Capacity, and Mitigation of Radiological Consequences, as shown in Figure 8.

The original version of the Plan had 56 initiatives, comprising studies and projects, originally planned to be developed in the period 2011 to 2016.

The main objectives for each of the Areas of Evaluation is summarized in Figure 8, namely: protection of safety structures/systems and components against extreme beyond design external events, provide alternative means of core and fuel pool cooling under beyond design conditions and protection of the containment integrity/limitation of consequences in case of beyond design accidents.

An Extraordinary National Report of Brazil, following the Guidance for National Reports specially issued by the officers of the Convention on Nuclear Safety was prepared and presented to the Extraordinary Meeting in Vienna in August 2012. More details about actions immediately taken by both CNEN and Eletronuclear due to the event can be found there.

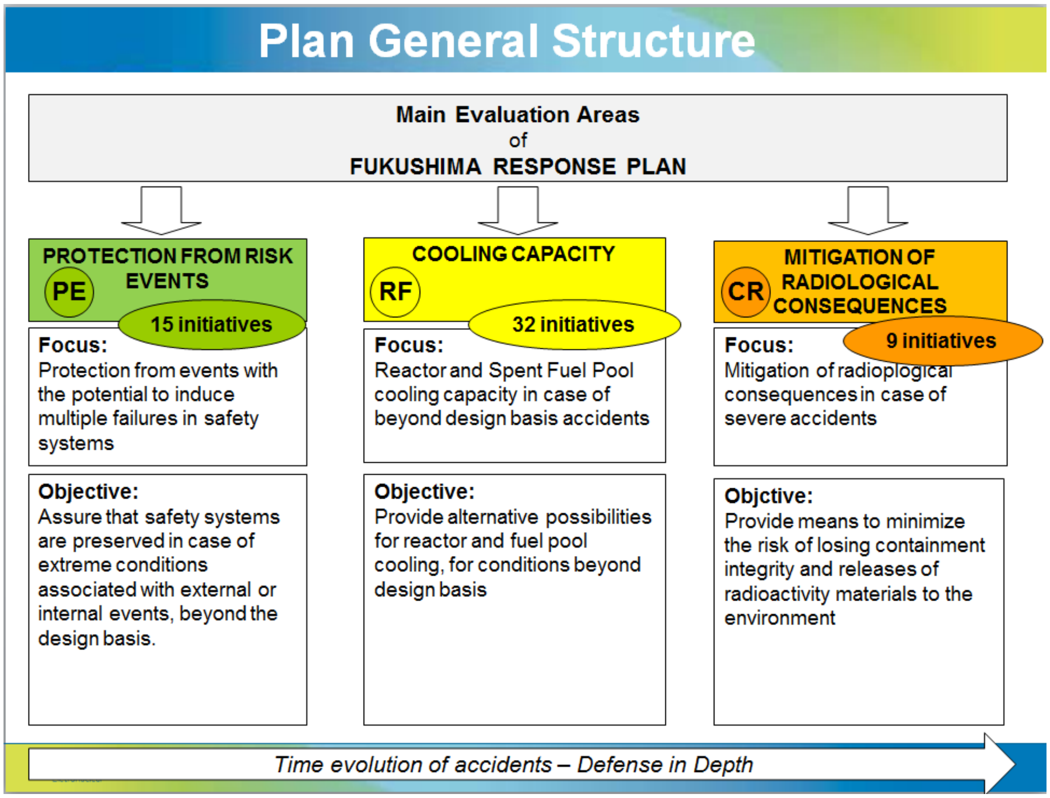

Fig 12. – ELETRONUCLEAR Fukushima Action Plan Structure

Some of these initiatives were already in progress, as part of Eletronuclear's continuous safety improvement programs. Studies and projects listed in the plan are aimed at the Angra Nuclear Site in general and for units Angra 1 and Angra 2 in particular, where the results for Angra 2 will be directly incorporated into the design of Angra 3, where applicable.

In parallel, the so called "stress tests", following WENRA and FORO guidelines for coping with prolonged Station Black Out and loss of Ultimate Heat Sink, were developed for Angra 1 and Angra 2, being completed by end of March, 2012. The results were evaluated by CNEN and presented to the Iberoamerican Forum of Nuclear and Radiological Regulatory Bodies (FORO) in June 2012, where a peer review of the country reports was made among the participants.

The results of the "Stress Test" Evaluation Report for the CNAAA plants was the base for the first revision of the Plan, with reorientation of priorities in order to accelerate initiatives that could provide important gains in safety margins in the short and medium term.

Furthermore, along the development of the work it was identified that some initiatives were redundant, some were not feasible for different reasons, and some had better alternative solutions. Nevertheless, the above stated objectives of the plan were maintained.

D.1 Area of evaluation: Protection Event Risk (Status in December 2015)

In the "stress tests' assessment report the specific Angra site external events have been assessed and a preliminary evaluation of the existing margins in case of beyond design occurrences was performed.

Later contracts with universities, and specialized technical organizations have produced detailed margin evaluations with the following results:

- External flooding: detailed study completed in November of 2013. The design flooding level of the Angra 1 and Angra 2 Plants can withstand the heaviest rain in 70.000 years, with simultaneous blockage of all the site drainage channels (landslide) and concurrent with the maximum tide. The study indicated that there is no need of special measures against extreme flooding, except for some specific points where the flooding barriers are either damaged or have been removed. Work on these points have been or are underway.

- Landslides: detailed study completed in November 2013. The Angra site is on the coast surrounded by nearby mountains and therefore subjected to possible landslides. Accordingly the surrounding slopes have been stabilized, provided with superficial and deep drainage channels and slope movement is continuously monitored. The study evaluated the existing protection measures, updated the geologic and geotechnical mapping around the site and performed the analysis of an extreme case where one of the full slopes slides down on to the site.

The results of this extreme case is that some site facilities (e.g. the switchyard) might be affected but the Plants would not be reached. The study further recommended reinforcement of some barriers, implementation of additional slope monitoring instrumentation. These recommendations are being implemented.

- Earthquakes: Brazil is a low seismicity country. The design Safe Shutdown Earthquake horizontal peak ground acceleration (PGA) value for the site was established at 0.1g, at the outcropping rock. The assessment of the existing margins against earthquake have been done a) by walkdown evaluation by international expert with large experience in seismic analysis and b) performance of a seismic PSA.

The walkdown evaluations results indicated that the Angra 1 Plant should resist to earthquakes with PGA between 0.2 g and 0.3g, and for Angra 2, PGAs betwen 0.25g and 0.35g, substantially higher than the design SSE.

A full seismic PSA, performed for Angra 2, and completed in December of 2015, indicated that the Angra 2 Plant could resist to an earthquake with a PGA of up to 0.4g, confirming the previous walkdown estimation (see also Article 14, Angra 2 PSA results). The Angra 1 seismic PSA has not been started yet, but similar results are expected.

- Sea movements: the Angra site is located in a small bay (Itaorna bay) inside a large bay (Angra dos Reis bay) protected by a large amount of islands from open sea hazards.
Tsunamis are not included in the Plants external events design bases nor in the subsequent reevaluations of the site external events (see also Article 17(1) and 17(3)). No tsunamis have ever been reported to reach the Brazilian coast, and the distance from tectonic plaque borders, size of continental shelf and other possible causes would result in minor effects at the site, so no assessment of tsunami consequences was done.

Studies completed in October of 2014, have been performed to reevaluate the maximum wave heights to reach the Itaorna Bay considering extreme external events, in this case hurricanes. Hurricanes reaching the Brazilian coast are very rare; only one has been reported up to now reaching the coast in the southern part of Brazil. Calculations considering extreme climatic events, associated to the worst wind direction and highest intensity as well as maximum sea level have resulted in wave heights between 4,8 and 5,7 m, for a recurrence time of 10.000 years. These wave heights are higher than the design waves (4,4 m) considered for the dimensioning of the wave breaker that protect the Plants, endangering its stability and eventually exposing the Plants.

Verification of the behavior of the wave breaker to these additional loads is underway, and in case of need it will be reinforced.

- Tornados: tornados were not considered in the external event design bases for the Angra Plants, because of its very low probability of occurrence in the 10-7 per year range. Studies for evaluation of a tornado impact to the Plants structures was performed and a list of Structures, Systems and Components(SSC) potentially exposed to the effects of a tornado with indication of need for protection or not, was prepared. In a few cases additional protection is needed, but no jeopardizing of the plants safe shutdown was identified.

D.2 Area of evaluation: Cooling Capacity (Status in December 2015)

In this Area of Evaluation conditions are evaluated to provide means of cooling of the reactor and of the fuel pool in beyond design conditions, that include the total loss of AC supply and the loss of the Main Heat Sink (blockage of Plant water intakes).

The importance of the loss of the Main Heat Sink (or Ultimate Heat Sink) and of the external power supply for the Angra site is confirmed by the results of the External Events PSA performed for Angra 2, where the dominant external events were "loss of Ultimate Heat Sink (UHS)", due to intake water blockage from organic material, and from the combination of "Loss Of Offsite Power (LOOP) and of UHS", caused by strong wind and organic material (see also Article 14(1), PSA results for Angra 2).

The main insights for alternative Reactor and Fuel Pool cooling in case of prolonged loss of power and/or loss of Ultimate Heat Sink (UHS) were provided by the results of the "Stress Test" Evaluation Report, already referenced. In this report strategies to counteract the different accident situations were developed, considering the use of mobile equipment for recovery of the cooling capacity.

Based on the Stress Tests results mobile equipment to provide additional means to supply power and cooling capacity, for the core and the fuel pools in different beyond design scenarios, were identified, specified and purchased, comprising different sizes of Diesel Generators, Diesel driven pumps, compressors and associated connection fixtures.

Design modification processes have been developed for the defined strategies, for the short and medium term in case of loss of all AC power and/or UHS, as follows:

Short term (1 to 3 hours): recharging of batteries and Steam Generator feed.

- Mobile equipment : one 250 KVA DG and 2 Diesel Driven pumps per Plant;
- Countermeasure: Bleed and Feed through the secondary side.

Medium term (1 to 2 days): in case of available UHS:

- Countermeasure: repowering one RHR cooling train;
- Mobile equipment: 3 large DG, 600 KVA each for Angra 1; 2 large DG, of 600 KVA each for Angra 2.

Medium term (1 to 2 days): in case UHS is unavailable

- Countermeasure: continue Secondary B&F and replenish source of water for SG cooling (tank/pool)
- Mobile equipment: 2 submergible Diesel powered pumps

Status of equipment and related procedures:

- Equipment on site, stored in location that is not affected by the external events that would affect the site, housed in a light tent-like structure. Place

for storage of spare parts and maintenance shop available;
- Maintenance procedures ready; operation procedures in draft;
- Maintenance, transport and operation team available;
- One Emergency Plan exercise planned for October 2016, with transportation and simulation of use of mobile equipment.

There were also prioritized the projects related to the water supply for CNAAA, including the installation of new water supply lines to the Water Pre-Treatment Plant (EPTA), presently close to conclusion.

In addition to the existing firefighting water reservoir (6000 m3) , located at a height of 110 m (not seismic) a new water reservoir of 4000 m3 meeting seismic requirements to be located at a height able to provide means of feeding the steam generators in a totally passive way, is in phase of design completion.

Another project prioritized according to the results of the "Stress Test" Evaluation Report was to provide alternative means of cooling the Diesel Groups in Angra 1, in case of loss of service water system, by means of sea water injection with a mobile Diesel powered pump. The equipment, the connection and the procedure are available.

Still considering means for cooling the reactor, in the last Angra 2 outage, the installation of additional valves in the Pressurizer valve station with dedicated power supply and I&C to allow Primary System's B&F in beyond design basis conditions.

Still in the last Angra 2 outage, the interconnection of the two Emergency Diesel sets was completed.

As alternative means of cooling the pools in "Station Black Out" scenarios for Angra 1 and Angra 2, the simplest option of replenishing the content lost by evaporation with water from the firefighting system was chosen. Procedures and connections for this purpose were provided.

D.3 Area of evaluation: Limitation of Radiological Consequences (Status in December 2015)

This area comprises measures designed to prevent or limit releases of radioactive materials into the environment in case of severe accidents, which are characterized by melting of the reactor core. The focus of the studies and projects in this area is maintaining the integrity of the containment steel shell that isolates the radioactive materials released from the damaged reactor core from the environment.

The main initiatives in this area and the respective status are presented below.

Passive Catalytic Recombiners for H2 control under core melt conditions were installed in the containments of both Plants in the last respective outages.

SAMGs adaptation/development, verification and validation and initial training was completed for both Plants (see also Article 19(4)). SAMGs provide orientation to the operators in actions to control or mitigate severe accidents.

As for the containment venting, technical discussions with Westinghouse on the installation in Angra 1 are still ongoing. For Angra 2 the “wet” option provided by AREVA was discussed in depth and an agreement for its installation was reached. Unfortunately the process did not progress because of shortage of budget.

With regard to initiatives related to the improvement of the Emergency Plan (EP), the use of SAMGs and of mobile equipment have been incorporated in the Site Emergency Plan Manual and associated procedures.

Upgrades concerning EP organizational aspects and realism of exercises have also been realized.

Upgrades of the Emergency Centers were essentially related with communications and layout. Substantial upgrade is still needed for the emergency centers external to the Plants to meet post Fukushima standards.

The projects of construction of peers for evacuation by sea by smaller boats was abandoned after verification that evacuation using large Navy barges, that did not need peers, were more effective(see also Article 17).

D.4 General Considerations

In two evaluation areas most directly related to the specific characteristics of each project, Cooling Capacity and Limitation of Radiological Consequences, Eletronuclear is developing studies and projects with the participation of the companies responsible for the original designs of Angra 1 and Angra 2, with the support of international institutions supporting business operators of nuclear power plants, such as INPO – Institute of nuclear Power Plant Operators, EPRI – Research Institute of Electric Power, both in the United States, and WANO – World Association of Operators of Plants nuclear.

The performance of the Stress Tests for Angra 1 and Angra 2 is also included as initiatives of the Eletronuclear Response Plan, and the time schedule for their completion takes into account two steps. The first step consists in the development of the required evaluations, considering only engineering judgment, and the second step comprises the performance of detailed calculations using computer codes. The first step was concluded only for Angra 2 by December 2011. The second step was completed in March 2012 and the results included in the CNAAA Stress Test Report

(Relatório de Avaliação de Resistência das Unidades da CNAAA para as Condições do Acidente de Fukushima – "Stress Test" – DT-006/12, de 29/03/2012), forwarded to CNEN in April 2012.

These results were evaluated by CNEN and presented to the Iberoamerican Forum of Nuclear and Radiological Regulatory Bodies (FORO) in a meeting held in Buenos Aires, in June 2012, when regulators from Argentina, Brazil, Spain and Mexico presented the National Report prepared by each country, as well as their cross related peer reviews, that were discussed and agreed by all participating countries.

As a consequence of the assessments performed, recommendations have been identified and are expected to be implemented on a three-step time frame: short, medium and long term, the latest reaching the year 2018. The follow-up technical meeting was accomplished in 2014 in Mexico for the short and medium term recommendations, and, finally, another meeting of the FORO in 2017 in Madrid, for the long term recommendations.

REFERENCES

[1] Convention on Nuclear Safety - Legal Series No. 16 - International Atomic Energy Agency - Vienna - 1994.

[2] Guidelines Regarding National Reports under the Convention on Nuclear Safety – INFCIRC/572.Rev5 (16 January 2015).

[3] Licensing of Nuclear Installations - CNEN-NE-1.04 - December 2002.

[4] Siting of Nuclear Power Plants - Resolution CNEN 09/69.

[5] Licensing of Nuclear Reactor Operator - CNEN-NN-1.01 – April 2014.

[6] Operational Reporting for Nuclear Power Plants - CNEN-NN-1.14 – January 2002.

[7] Operational Safety in Nuclear Power Plants - CNEN-NE-1.26 - October 1997.

[8] Safety Policy of CNEN – Directive n.295 of 23 December 1996.

[9] Quality Assurance Policy of CNEN – Directive n.296 of 23 December 1996.

[10] Health Requirements for Nuclear Reactor Operators - CNEN-NE-1.06 - 1980

[11] Certification of Qualification of Radiation Protection Supervisors - CNEN-NN-7.01 - October 1997.

[12] Quality Assurance for Safety in Nuclear Power Plants and Other installations - CNEN-NN-1.16 – April 2000.

[13] Basic Radiation Protection Directives - CNEN-NN-3.01 – March 2014.

[14] General Norm for Planning of Response to Emergency Situations – SIPRON – NG–02 - 1996

[15] Directive for the Preparation of Emergency Plans related to the Unit 1 of Almirante Alvaro Alberto Nuclear Power Plant – SIPRON Directiva Angra – 1997.

[16] General Norm for Establishing Public Information Campaigns about Emergency Situations – SIPRON - NG-05 – 1997.

[17] Maintenance of Nuclear Power Plants - CNEN-NE-1.21 - August 1991.

[18] In-service Inspection of Nuclear Power Plants - CNEN-NE-1.25 - September 1996.

[19] Law 10.308 of 2001.11.20 – Rules for the site selection, construction, operation, licensing and control, financing, civil liability and guaranties related to the storage of radioactive wastes.

Annex I

I.– EXISTING INSTALLATIONS

I.1. Angra 1

Thermal power	1876 MWth
Gross electric power	640 MWe
Net Electric power	610 MWe
Type of reactor	PWR
Number of loops	2
Number of turbines	1 (1High Pressure/2Low pressure)
Containment	Dry cylindrical steel shell and external concrete building.
Fuel assemblies	121
Main supplier	Westinghouse El. Co.
Architect Engineer	Gibbs & Hill / Promon Engenharia
Civil Contractor	Construtora Norberto Odebrecht
Mechanical Erection	Empresa Brasileira de Engenharia
Construction start date	March 1972
Core load	20 September 1981
First criticality	13 March 1982
Grid connection	1 April 1982
Commercial operation	1 January 1985

I.2. Angra 2

Thermal Power	3765 MWth
Gross electric power	1370 MWe
Net electric power	1300 MWe
Type of reactor	PWR
Number of loops	4
Number of turbines	1 (1High Pressure/3Low pressure)
Containment	Dry spherical steel shell and external concrete building.
Fuel assemblies	193
Main supplier	Siemens KWU
Architect Engineer	ELETRONUCLEAR/Siemens KWU
Civil Contractor	Construtora Norberto Odebrecht
Mechanical Erection	Unamon

Construction start date	1975
Core load	30 March 2000
First Criticality	14 July 2000
Grid connection	21 July 2000
Commercial operation	January 2001

I.3. Angra 3

Thermal Power	3765 MWth
Gross electric power	1400 MWe
Net electric power	1370 MWe
Type of reactor	PWR
Number of loops	4
Number of turbines	1 (1High Pressure/3Low pressure)
Containment	Dry spherical steel shell and external concrete building.
Fuel assemblies	193

Main supplier	Areva
Architect Engineer	ELETRONUCLEAR
Civil Contractor	Construtora Andrade Gutierres
Mechanical Erection	na TBD

Construction start date	1978
Construction restart date	1 July 2010
Core load	(2022) TBD
First Criticality	(2022) TBD
Grid connection	(2022) TBD
Commercial operation	(2022) TBD

ANNEX II

RELEVANT CONVENTIONS, LAWS AND REGULATIONS

II.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.

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management – Signature 11.10.1997. Entry into force 16.04.2006.

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

II.2. Relevant National Laws

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

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

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

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

Law Nº 12.731 of 21/11/2012 that reorganize the Brazilian Nuclear Protection System (SIPRON).

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

Law 7781/89 dated 1989.06.27 - Reorganizes the nuclear sector.

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

Decree 2210 dated 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 Program (COPRON).

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

Decree 3719 dated1999.09.21 – Regulates the Law 9.605 and establishes the penalties for environmental crimes.

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

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

Law 10.308 dated 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 wastes.

Decree 1.019 dated 2005.11.14 – Promulgates the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Federal Law 140 dated 2011.12.08 - Set standards to sections III, VI and VII of art. 23 of the Brazil's Constitution, associated with protection of outstanding natural landscapes, protection of the environment, control of pollution in any of its forms, and preservation of biodiversity. The law assigns roles to the multitude environmental agencies in the country at the Federal, Estate, and Municipal levels, as well as guidelines to pursue cooperation among these agencies.

II.3. CNEN Regulations

NN 1.01 - Licenciamento de operadores de reatores nucleares - Resol. CNEN 170/14 - ***(Licensing of nuclear reactor operators)*** April 2014***.***

NE 1.04 - Licenciamento de instalações nucleares - Resol. CNEN 15/02 - ***(Licensing of nuclear installations)*** December 2002***.***
NE 1.06 - Requisitos de saúde para operadores de reatores nucleares - Resol. CNEN 03/80 - ***(Health requirements for nuclear reactor operators)*** June 1980***.***

NN 1.14 - Relatórios de operação de usinas nucleoelétricas – Resol. CNEN 16/01 ***(Operation reports for nuclear power plants)*** January 2002***.***

NE 1.16 - Garantia de qualidade para a segurança de usinas nucleoelétricas e outras instalações - Resol. 17/00 - ***(Quality assurance for safety of nuclear power plants and other installations)*** April 2000***.***

NN 1.17 - Qualificação de pessoal e certificação para ensaios não destrutivos em itens de instalações nucleares – Resol. CNEN 118/11 - ***(Qualification and certification of personnel for non-destructive tests in nuclear power plants components)*** December 2011***.***

NE 1.18 - Conservação preventiva em usinas nucleoelétricas – Resol. CNEN 09/85 - ***(Housekeeping in nuclear power plants)*** September 1985***.***

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 calculation programs for the analysis of loss of coolant accidents in pressurized water reactors)*** November 1985***.***

NE 1.20 - Aceitação de sistemas de resfriamento de emergência do núcleo de reatores a água leve – Resol. CNEN 12/85 - ***(Acceptance criteria for emergency core cooling system for light water reactors)*** November 1985***.***

NE 1.21 - Manutenção de usinas nucleoelétricas - – Resol. CNEN 03/91 - ***(Maintenance of nuclear power plants)*** August 1991***.***

NE 1.22 - Programas de meteorologia de apoio de usinas nucleoelétricas – Ordinance CNEN DEx-1 04/89 - ***(Meteorological program in support of nuclear power plants)*** August 1989***.***

NE 1.25 - Inspeção em serviço de usinas nucleoelétricas – Resol. CNEN 13/96 - ***(In service inspection of nuclear power plants)*** September 1996***.***

NE 1.26 - Segurança na operação de usinas nucleoelétricas – Resol. CNEN 04/97 - ***(Operational Safety in nuclear power plants)*** October 1997***.***

NE 1.28 - Qualificação e atuação de órgãos de supervisão técnica independente em usinas nucleoelétricas e outras instalações - Resol. CNEN-CD Nº.15/99 de

16/09/1999 ***- (Qualification and actuation of independent technical supervisory agencies in nuclear power plants and other installations)*** September 1999***.***

NE 2.01 - Proteção física de unidades operacionais da área nuclear - Resol. CNEN 110/11 - ***(Physical Protection in operational units of the nuclear area)*** September 2011***.***

NN 2.02 – Controle de Materiais Nucleares – Resol. CNEN 11/99 – ***(Controlo f Nuclear Materials)*** September 1999.

NE 2.03 - Proteção contra incêndio em usinas nucleoelétricas - Resol. CNEN 13/99 - ***(Fire protection in nuclear power plants)*** September 1999***.***

NN 3.01 - Diretrizes básicas de Proteção Radiológica - Resol. CNEN 164/14 - ***(Radiation protection directives)*** March 2014***.***

NE 3.02 - Serviços de proteção radiológica – Resol. 10/88 - ***(Radiation protection services)*** August 1988***.***

NE 5.01 - Transportes de materiais radioativos - Resol. CNEN13/88 - ***(Transport of radioactive materials)*** August 1988***.***

NE 5.02 - Transporte, recebimento, armazenamento e manuseio de elementos combustíveis de usinas nucleoelétricas – Resol. CNEN 08/03 - ***(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 – Ordinance CNEN DEx1 02/89 ***(Transport, receiving, storage and handling of items in nuclear power plants)*** February 1989***.***

NE 7.01 - Certificação da qualificação de supervisores de radioproteção - Resol. CNEN 194/16 – ***(Certification of the qualification of radiation protection supervisors)*** June 2016***.***

NN 8.01 Gerência de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação (Resolução 167/14) **(Low and Intermediate Radioactive Waste Management)** – April 2014.

NN 8.02 Licenciamento de Depósitos de Rejeitos Radioativos de Baixo e Médio Níveis de Radiação (Resolução 168/14)- **(Licensee of Low and Intermediate Level Radioactive Waste Deposits**) - April 2014.

NN 9.01 – Descomissionamento de Usinas Nucleoelétricas – Resol. CNEN 133/12 – ***(Decommissioning of Nuclear Power Plants)*** – November 2012.

II.4. IBAMA 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).

IBAMA Normative Instruction n º 184/08– (*Establishes within this Agency, the procedures for federal environmental permits)* – (17/07/2008).

IBAMA Normative Instruction n º 184/08**– (*Establishes within this Agency, the procedures for federal environmental permits)* – (**17/07/2008**).**

IBAMA Normative Instruction n º 05/2012 **– (*Eestablishes transitional procedure for environmental authorization for the transport of dangerous goods activity*) - (09/05/2012).**

IBAMA Normative Instruction n º 01/2016 **– (*Establishes the criteria for the licensing of radioactive facilities)* - (01/02/2016).**

II.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 Coordination Commission for the Protection of the Brazilian Nuclear Program).*** Port. SAE 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 01/96.

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 01/96.

NG-04 - Norma Geral para situações de emergência nas unidades de transporte - ***(General norm for emergency situations in the transport units).*** Resol. SAE/COPRON 01/96.

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 campaigns about emergency situations).*** Port. SAE 150 of 11.12.1997.

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 27 of 27.03.1997.

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

NG-08 - Norma Geral sobre o planejamento e a execução da proteção ao conhecimento sigiloso no âmbito do SIPRON ***(General norm for the planning and execution of the protection of the classified knowledge within SIPRON).*** Port. SAE 145 of 07.12.1998.

NI-01 – Norma Interna que dispõe sobre a instalação e o funcionamento do Centro Nacional para o Gerenciamento de uma Emergência Nuclear (***Internal Norm on the installation and operation of the National Center for the Management of a Nuclear Emergency*)**. Port. SAE 001 of 05.21.1997.

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). GSIPR Nº 34 of 24 /08/ 2012.

Comitê de Planejamento de Resposta a Situações de Emergência Nuclear no Município de Angra dos Reis – COPREN/AR ***(Committee for Nuclear Emergency Response Planning in the city of Angra dos Reis)*** – Port. nº8 – GSIPR of 24/03/ 2011**.**

Comitê de Planejamento de Resposta a Situações de Emergência Nuclear no Município de Resende – COPREN/RES ***(Committee for Nuclear Emergency Response Planning in the city of Resende)*** – Port.nº 40 – CH/GSIPR, of 25/06/ 2012.

Comitê de Articulação nas Áreas de Segurança e Logística do Sistema de Proteção ao Programa Nuclear Brasileiro – CASLON ***(Coordination Commitee for the Safey and Suport Areas of the System for Protection of the Brazilian Nuclear Program) –*** Port. nº31 GSIPR, of 26 /03/ 2012.

Annex III

RESEARCH REACTORS

III.1 - The Research Reactor IPR-R1 TRIGA Mark I of Nuclear Technology Development Center (CDTN)

General information:

Details on TRIGA research reactor technical characteristics and general operation experience at CDTN can be found in the IAEA Research Reactor Data base http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details	TRIGA - MARK I
Country	Brazil
Facility Name	IPR-R1
Status	OPERATIONAL
Owner	Nuclear Technology Development Center CDTN , Belo Horizonte
Operator	Nuclear Technology Development Center CDTN , Belo Horizonte
Administrator:	MARETTTI, Fausto Jr, head of reactor operational group
Address	Rua Professor Mario Werneck S\N,
Telephone	+553130693309, +553130693405
Fax	+5531306932253
E-Mail	fmj@cdtn.br
Web Address	www.cdtn.br
Licensing	Brazilian Nuclear Energy Commission
Construction Date	1958/01/01
Criticality Date	1960/11/06
Safeguards	IAEA/ABACC

Technical Data

Reactor Type	TRIGA Mark I
Thermal Power, Steady (kW)	100
Max Flux SS, Thermal (n/cm2-s)	4.3 E+12
Max Flux SS, Fast (n/cm2-s)	1.5E+12
Thermal Power, Pulsed (MW)	0.00
Moderator	H2O, ZrH
Coolant	light water
Natural Convection Cooling	yes

Cool Velocity In Core	4CM/S
Forced Cooling at 300 KW	
Reflector	Graphite
Reflector Number of Sides	annular
Control Rods Material	B4C
Control Rods number	3

Experimental Facilities

Vertical Channels	1
Vertical Max Flux (n/cm2-s)	5.8 E+7
Vertical Use neutron radiography	Extractor
In-core Irradiation Channels	4+2+1
In-Core Max Flux (n/cm2-s)	4.3E12
Reflector Irradiation Channels	40-80 pos.

Fuel data

Enrichment	LEU 20% U-ZrH
Origin of Fissile Material	USA
Dimensions of Rods (mm)	37.3 DIA, 723.9 L
Cladding Material	SS
Cladding Thickness (mm)	0.51
Fuel Material	UZRH
Fuel Loading per Element	(g U-235) 56
Burnup on Discharge, max (%)	25
Burnup Average (%)	5
Last Spent Fuel Shipment, Year	1999
Last Spent Fuel Shipment, Rods	219
Final destination	USA
Last Receipt Year	1986
Last Receipt Element	86
Spent Fuel Storage Capacity	600
Fuel Fabricator	GENERAL ATOMICS, USA
Fuel, present status, core	56
spent fuel storage	0
fresh fuel storage	3
total at location	4

Reactor Utilization

Hours per Day	8
Days per Week	1
Weeks per Year	40

MW Days per Year	1
Materials/fuel test experiments	NO
Isotope Production	NO
Neutron Scattering	NO
Neutron Radiography	YES
Activation Analysis	YES
Number of samples irradiated/year	1700

Teaching:	
Number of students/year	2
Training NPP operators:	yes
Number of operators/year	10
Since 2013, operates at	4.5MW

Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report (originally provided by the reactor manufacturer, updated in 2013), Emergency Procedures, Operating Procedures, Fire Protection Plan, Security Plan and Quality Assurance Plan.

Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In the period from 2013 to 2015, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

Ad. Article 11: Financial and human resources

Financial and human resources available:

Annual Cost	100,000 US$
Total Staff	4
No. of Operators	4

Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- Quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC 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.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[5] and their medical qualification[10].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2013 – 2015, CNEN has issued a total of 6 licenses for Research Reactor IPR-R1 TRIGA Mark I, 2 new operator licenses (2 SRO) and 4 renewals (2 RO and 2 SRO).

Ad. Article 13: Quality assurance

The Nuclear Technology Development Center (CDTN) has established its quality assurance programs for IPR-R1 TRIGA Mark I Research Reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 10 of the Safety Analysis Report of IPR-R1 TRIGA Mark I Research Reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal and external audits and inspections.

Ad. 14: Assessment and verification of safety

The in-service inspection plan is implemented as part of the QA/QC program and a periodic safety verification are performed through internal inspections and audits. Safety related modification are reviewed by the internal Reactor Safety Committee. Major reconstruction and renewal was performed in 1995 related to control system of the IPR-R1. The IPR-R1 instrumentation upgrade also contemplates the International Atomic Energy Agency (IAEA) recommendations, for safe research reactors operation included in IAEA-TECDOC-1066 - *Specifications of Requirements for Upgrades Using Digital Instrumentation and Control Systems,* Safety Guide No. NS-G-1.3 - *Instrumentation and Control Systems Important to Safety in Nuclear Power Plants,* ANSI Guide ANSI/ANS 15.15-1978, “Criteria for the Reactor Safety Systems of Research Reactors” and the IAEA Safety Series 35-S1.

In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation protection service of CDTN. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year. The CGRC annually audits the IPEN’s Radiation Protection Program implementation.

Ad. 16: Emergency preparedness

Emergency plans for TRIGA reactor are specified in the Safety Analysis Report according to an appropriate IAEA format.

Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation, march 2013. The procedures are subject to internal and external verification and approval. The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- radiological reactor accidents:
- rupture of the coating of a fuel element
- loss of reactor shielding (primary water),
- release of radioactivity in the controlled area,
- release of radioactivity outside controlled area,
- non-radiological accidents:
- fire in the reactor building,
- sabotage and not-authorized access,

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office.

The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided.

Since when the Emergency Plan was implemented, the reactor has operated without incident record that has caused any material or physical damage.

The emergency classes are:

- Non Usual Event;
- Alert;
- Area Emergency.

CNEN is a member of the IAEA-IRSRR technical cooperation program exchanging experience with other participant countries related events in research reactors.

III.2 - The Research Reactor IPEN/IEA-R1 Pool Reactor of Institute for Energy and Nuclear Research (IPEN)

General information

Details on IEA-R1research reactor technical characteristics and general operation experience at IPEN can be found in the IAEA Research Reactor Data base http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details	IEA-R1 - POOL
Country	Brazil

Facility Name	IEA-R1
Status	OPERATIONAL – since 2013 – operates at 4,5 MW
Owner	Institute for Energy and Nuclear Research (IPEN), São Paulo
Operator	Institute for Energy and Nuclear Research (IPEN), São Paulo
Administrator:	Walter Ricci Filho head of reactor operational group
Address	Av Lineu Prestes 2241, CID Universitária, São Paulo - SP
Telephone	+551131338820
Fax	+5511338815
E-Mail	wricci@ipen.br
Web Address	www.ipen.br
Licensing	Brazilian Nuclear Energy Commission
Construction Date	1956/01/11
Criticality Date	1957/09/16
Safeguards	IAEA/ABACC

Technical Data

Reactor Type	POOL
Thermal Power, Steady (kW)	5000
Max Flux SS, Thermal (n/cm2-s)	4.6 E+13
Max Flux SS, Fast (n/cm2-s)	1.3E+14
Thermal Power, Pulsed (MW)	0.00
Moderator	GRAPHITE, BE,
Coolant	light water
Cool Velocity in Core	0,8 M /S
Natural Convection Cooling	yes≤200kw
Forced Cooling	≥200kw
Reflector	graphite
Reflector Number of Sides	annular
Control Rods Material	IN,AG and CD
Control Rods number	4

Experimental Facilities

Horizontal Channels	12
Horizontal Max Flux (n/cm2-s)	7.0 E+08
Horizontal Use	Neutron Scattering, nêutron radiography, NCT
Vertical Channels	1
Vertical Max Flux (n/cm2-s)	2.0 E+11
Vertical Use	pneumatic system

Irradiation Facilities

In-core Irradiation Channels	BE IRRAD.
In-Core Max Flux	1.17E14 n/cm2-s
Reflector Max Flux	1.17E14 n/cm2-s

Fuel data

Enrichment Uranium	LEU 19,9% (U3O8-AL and U3SI-AL)
Origin of Fissile Material	BRAZIL
Equilibrium Core Size	72
Dimensions of Rods (mm)	37.3 DIA, 723.9 L
Cladding Material	SS
Cladding Thickness (mm)	0.51
Fuel Material	UZRH
Last Spent Fuel Shipment,	Year 2007
Last Spent Fuel Shipment,	Rods 219
Final destination	USA
Spent Fuel Storage Capacity	600
Fuel Fabricator	GENERAL ATOMICS, USA
Fuel, present status,	core 56
spent fuel storage	24 LEU
fuel storage capacity	108
total occupied	27

Reactor Utilization

Hours per Day	24
Days per Week	3
Weeks per Year	42
MW Days per Year	525
Materials/fuel test experiments	YES - 2
Isotope Production	YES - 20000 GBq/year
Neutron Scattering -	600h
Neutron Radiography YES -	600h
Activation Analysis YES -	800h

Number of samples irradiated

Activation analysis -	800
Geochronology -	140

Teaching:

Number of students/year 64
Training Operators/Experiments 8

Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report (originally provided by the reactor manufacturer, updated following IAEA standard format in 2013), Emergency Procedures and Operating Procedures.

Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety experience Committee.

In the period from 2013 to 2015, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

Ad. Article 11: Financial and human resources

Financial and human resources available:

- Annual Cost 60,000 US$
- Total Staff 17
- No. of Operators 17
- Safety improvements financed within the yearly budget (00,000 US$).
- Financial provisions for decommissioning are not provided.

Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC 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.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[5] and their medical qualification[10].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2013 – 2015, CNEN has issued a total of 3 licenses for Research Reactor IPEN/IEA-R1, 3 new operator licenses (RO).

Ad. Article 13: Quality assurance

The Institute for Energy and Nuclear Research (IPEN) has established its quality assurance programs for the IEA-R1 Research Reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 18 of the Safety Analysis Report of IEA-R1 Research Reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. Major reconstruction and renewal was performed in 1995. The conversion of IEA-R1 Reactor from HEU to LEU has started in late 1988 with the introduction of the first Brazilian made fuel element of U3O8-Al dispersion type with 1.9 gU/cm3. The strategy was to substitute gradually the HEU fuel to LEU fuel. Having a heterogeneous core (HEU and LEU), the design decision was made to have identical geometry (plate thickness, width and pitch between plates) for both fuel assemblies, and to have the same quantity of 235U in the fuel plates (10 g /fuel plate; 180 g /fuel assembly) and this process was finished in 1997.

In 1995, the Instituto de Pesquisas Energeticas e Nucleares (IPEN/CNEN-SP) took the decision to modernize and upgrade the power of the IEA-R1 reactor from 2 to 5 MW. In the upgrading of the IEA-R1 Research Reactor, the core was completely converted from HEU to LEU. Its size was changed from 30 to 25 fuel elements in order to optimize the neutron flux. Also, the uranium content of the fuel plate was increased to 2.3 gU/cm3. Neutronic, thermalhydraulic and fuel performance analyses of the IEA-R1 core for 5 MW showed that all criteria are within the limits and margins established. To accomplish safety requirements, a set of actions was performed following the recommendations of the IAEA Safety Series 35 applied to research reactors. Such actions consisted in the modernization of old systems, design of new ones, safety evaluations and licensing and elaboration of experimental/operational routines to be submitted and approved by the Safety Review Committee after then the documentation was submitted to CGRC to regulatory approve.

The spent fuel was shipped from the location for permanent storing in the USA in 1998. The in-service inspection plan is implemented as part of the QA/QC program and a periodic safety verification are performed through internal inspections and audits. Safety related modification are reviewed by the internal Reactor Safety Committee.

Others implementations:

- New water treatment and purification system- 2004/2005;
- Replacement of reactor control and safety rods- 2004/2005;
- New primary heat exchanger-2006/2007;
- Installation of a new rabbit system for short irradiations in the reactor core-2007;
- Replacement of several radiation monitor and detectors-2006/2007;
- Pneumatic system to transfer reactor irradiated targets to processing area-2007;
- Replacement of heat exchange. Studies regarding ageing program were conducted according to IAEA procedures described in the TR 338 (2001)

and Technical document 792 (1995). Replacement of All auxiliary instrumentation racks at the reactor control room. - 2007;

- Installing a voltage stabilizer for protection of the control console and auxiliary systems – 2008;
- Installing monitoring and recording images system. As provided for Physical Protection Plan and the Safety Analysis Report – 2008;
- Installation inside reactor core the first fuel element with fixed instrumentation for collecting thermal parameters inside and outside cladding, allowing continuous online surveillance during operation. This activity was carried out with cooperation of the Nuclear Engineering department and considerable effort from Nuclear Metallurgy staff – 2010;
- Upgrading of electronic racks settled at the Control Room, as well as the initial operation of a meteorological tower that provide the Emergency Planning staff with accurate real time data regarding atmospheric conditions – 2011;
- Exchange of the secondary circuit pumps (2). Carried out the Reactor pool floor adjustment to the standards of radiation protection (epoxy floor)/reform of the engine room (basement), Repair of the emergency stairs and signaling of fire, exchanging of the cooling tower due to loss of heat exchange efficiency to 5 MW and exchanges of guy wires and tensioning of the ventilation and exhaust system chimneys due to corrosion – 2012;
- Modernization of the main gate of the Research Reactor Center to better personal control, emergencies and physical protection – 2013;
- Structural and electrical modernization of the diesel generators building – 2013;
- Improvement to the electrical discharges ground for reactor building – 2014;
- Exchange the pipe primary cooling circuit – 2014.

In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation Protection Service of the IPEN. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year. The CGRC annually audits the IPEN’s Radiation Protection Program implementation.

Ad. 16: Emergency preparedness

Emergency plans for IEA-R1 reactor were developed based on Regulatory Guide 2.6 - *Emergency Planning for Research and Test Reactors*, *Revision 1, March 1983, USNRC, USA* and ANSI/ANS-15.16-1982 - *Emergency Planning for Research Reactors, American Nuclear Society, E.U.A*. Appropriate procedures were prepared in the form of special written documents for practical use in emergency situation, March 2013. The procedures are subject to internal and external verification and approval.

The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities.

The emergency classes are:

- Non Usual Event;
- Alert;
- Area Emergency.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office. The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided. Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.3 - The Research Reactor IPEN/MB-01 Pool Reactor of Institute for Energy and Nuclear Research (IPEN)

General information

Details on IPEN/MB-01 research reactor technical characteristics and general operation experience at IPEN can be found in the IAEA Research Reactor Database http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details IPEN/MB-01

Country	Brazil
Facility Name	IPEN-MB-01
Status	OPERATIONAL
Owner	Institute for Energy and Nuclear Research (IPEN), São Paulo
Operator	Institute for Energy and Nuclear Research (IPEN), São Paulo
Administrator	Ultra Bitelli, ULYSSES, head of reactor operational group

Address	Av. Lineu Prestes 2242,
Telephone	+551131339423
Fax	+551131339423
E-Mail	ubitellij@ipen.br
Web Address	www.ipen.br
Licensing	Brazilian Nuclear Energy Commission
Construction Date	1984/11/01
Criticality Date	1988/11/09
Safeguards	IAEA/ABACC

Technical Data

Reactor Type	POOL
Thermal Power, Steady (kW)	00.100
Max Flux SS, Thermal (n/cm2-s)	1.0 E+9
Max Flux SS, Steady (n/cm2-s)	6.0 E+9
Thermal Power, Pulsed (MW)	0.00
Moderator	Deionized Water
Natural Convection Cooling	yes
Reflector	H_2O
Control Rods Material	AG, IN, CD, BC
Safety and Control Rods number	48 pins

Fuel data

Stainless stell fuel pins	
Fuels pellets	680 UO_2
Pins diameter	9.8 mm
Pins length	1.194 mm
Active length	546 mm filled LEU 4.35% UO_2 Pellets
Reactor Utilization	
Hours per Day	3
Days per Week	4
Weeks per Year	44
MW Days per Year	0
Materials/fuel test experiments	yes, 150
Isotope Production	NO
Neutron Scattering	NO
Neutron Radiography	NO
Activation Analysis	NO
Number of samples irradiated/year	00

Teaching:

Number of students/year	22
Training NPP operators:	NO
Number of operators/year	7

Ad. Article 10: Priority to safety

The IPEN/MB-01 research reactor (critical assembly) was designed based on BNL-5083l-I - *Design Guide for Category I Reactors - Critical Facilities, BRYNDA, W.J; & POWELL, R.W*. Brookhaven National Laboratory, 1978, and has followed the recommendation of Safety Series nº 35 da Agência Internacional de Energia Atômica – IAEA.

The following elements of nuclear safety are implemented: inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report, updated following IAEA standard format in 1991), Emergency Procedures and Operating Procedures. Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In the period from 2013 to 2015, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

Ad. Article 11: Financial and human resources

Financial and human resources available:

Annual Cost	00,000 US$
Total Staff	12
No. of Operators	7

Ad. Article 12: Human factor

Reactor operators are trained in according to Trainning and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC 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.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[5] and their medical qualification[10].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2013 – 2015, CNEN has issued a total of 21 licenses for Research Reactor IPEN/MB-01, 11 new operator licenses (2 RO and 9 SRO) and 10 renewals (3 RO and 7 SRO).

Ad. Article 13: Quality assurance

The Institute for Energy and Nuclear Research (IPEN) has established its quality assurance programs for IPEN/MB-01 research reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the Safety Analysis Report of IPEN/MB-01 research reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. The in-service inspection plan is implemented as part of the QA/QC program.

In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation protection service of IPEN/MB-01. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year.

Ad. 16: Emergency preparedness

Emergency plans for IEA-R1 reactor are specified in the Safety Analysis Report according to an appropriate IAEA format.

Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation, Nov 2013. The procedures are subject to internal and external verification and approval.

The procedures include reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- radiological reactor accidents:
- Fall of objects or tools in the tank Moderator outside the reactor core,
- Violation of the limits of Technical specifications for radioactive effluents,
- Electric Power loss of the external network and internal loss of electrical power,
- loss of reactor shielding (primary water),
- release of radioactivity in the controlled area,
- release of radioactivity outside controlled area,

- ATWS Accident Transients without SCRAM,
- non-radiological accidents:
- fire in the reactor building,
- Precipitation intense rainfall,
- Storms and strong winds.
- earthquake,
- sabotage and not-authorized access.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office. The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided. Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.4 - The Research Reactor IEN-R1 ARGONAUTA of Institute of Nuclear Engineering (IEN)

General information

Details on IEN-R1 ARGONAUTA research reactor technical characteristics and general operation experience at IEN can be found in the IAEA Research Reactor Database http://www.iaea.org/worldatom/rrdb/.

Research Reactor Details ARGONAUTA

Country	Brazil
Facility Name	IEN
Status	OPERATIONAL
Owner	Institute of Nuclear Engineering - IEN, Rio de Janeiro
Operator	Institute of Nuclear Engineering - IEN, Rio de Janeiro
Administrator:	RENKE, Carlos Alberto Curi, head of reactor operational group
Address	Rua Helio de Almeida 75, Ilha do Fundão, C.P.
Telephone	+552121733909
Fax	+5531306932253
E-Mail	renke@ien.gov.br
Web Address	www.ienmgov.br
Licensing	Brazilian Nuclear Energy Commission
Construction Date	1963/07/07
Criticality Date	1965/02/20
Safeguards	IAEA/ABACC

Technical Data

Reactor Type	ARGONAUTA
Thermal Power, Steady (kW)	0.200
Max Flux SS, Thermal (n/cm2-s)	4.4 E+09
Max Flux SS, Fast (n/cm2-s)	8.9E+09
Thermal Power, Pulsed (MW)	0.001
Moderator	H2O
Coolant	light water
Natural Convection Cooling	yes
Cool Velocity in Core	0.0113 M/S
Reflector graphite	6
Reflector Number of Sides	annular
Control Rods Material	CD
Control Rods number	3

Experimental Facilities

Horizontal Channels	15
Horizontal Max Flux (n/cm2-s)	2.5 E+05
Horizontal Use	Irradiations, Spectrometry, Neutron radiography and neutron tomography
Vertical Channels	5
Vertical Use	Exponential measurements
In-core Max Flux (n/cm2-s)	4.4 E+09
Reflector Irradiation Facilities	1

Fuel data

Enrichment Min	% 19.90 U3O8-AL
Enrichment Max	% 19.90 U3O8-AL
Origin of Fissile Material	USA
Dimensions of Rods (mm)	37.3 DIA, 723.9 L
Cladding Material	Aluminum
Cladding Thickness (mm)	0.51
Fuel Material	UZRH
Fuel Loading per Element (g U-235)	56
Burnup on Discharge, max (%)	25
Burnup Average (%)	5
Fuel Fabricator	GENERAL ATOMICS, USA
Fuel, present status, core	56
spent fuel storage	8LEU
fresh fuel storage	38
total at location	94

Reactor Utilization

Hours per Day	8
Days per Week	5
Weeks per Year	43
MW Days per Year	0
Materials/fuel test experiments	NO
Isotope Production	YES
Neutron Scattering	YES
Neutron Radiography	YES
Activation Analysis	YES
Number of samples irradiated/year	
Teaching:	YES
Number of students/year	
Training NPP operators:	NO
Number of operators/year	10

Ad. Article 10: Priority to safety

The following elements of nuclear safety are implemented: Inherently safe reactor design, technical specifications and limitations based on safety analysis, organization and staffing, training of personnel, quality assurance system, regular inspections and maintenance, inspections, promotion of safety culture, international inspections (safeguards).

The basic safety documents are: Safety Analysis Report (originally provided by the reactor manufacturer, updated following IAEA standard format in 1991), Emergency Procedures and Operating Procedures. Reactor safety is implemented and controlled by the internal Reactor Safety Committee consisting of members of the Institute management. All actions, experiments, plans and documents related to reactor safety must be reviewed and approved by the Safety Committee.

In the period from 2013 to 2015, no abnormal events recorded, no abnormal radioactive releases recorded and no radiological accidents recorded.

Ad. Article 11: Financial and human resources

Financial and human resources available:

Annual Cost	US$50,000
Total Staff	12
No. of Operators	3

Ad. Article 12: Human factor

Reactor operators are trained in according to Training and Retraining Program established by Operating Organization and approved by CGRC. Human errors basically are prevented by:

- Organization and system of personal responsibilities,
- quality assurance program,
- Verification and control.

Strong emphasis is put on personal qualification and responsibilities. The operation staff are carefully selected and trained. The CNEN/CGRC 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.

In the specific case of reactor operators, see Article 19 of this Seventh Report, CNEN has established regulations related to their authorization[5] and their medical qualification[10].

The Reactors Operators Licensing Board has the purpose to verify compliance with the standard CNEN-NN-1:01, Licensing of nuclear reactor operators, and CNEN-NE-1.06, *Health requirements for nuclear reactors operators*, evaluate and audit the training program and re-training of reactor operators and verify the ability of operators through written tests, practical-oral test and performs the test in the research reactor itself. It is responsible for all technical activities to support the issue of an Operator Reactor License.

In the period 2013 – 2015, CNEN has issued a total of 2 licenses for Research Reactor IEN-R1 ARGONAUTA, 2 renewals (1 RO and 1 SRO).

Ad. Article 13: Quality assurance

The Institute of Nuclear Engineering (IEN) has established its quality assurance programs for IEN-R1 ARGONAUTA research reactor, in accordance with the mentioned requirements in Article 13 of this Seventh National Report and assessed by CGRC. Quality assurance is implemented as part of the Quality Assurance Program. The head of the reactor operation department is responsible for its implementation. The corresponding procedures were developed and are currently in place. The programs provide for the control of activities which influence the quality of items and services important to safety as: design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, commissioning, operation, maintenance, repair and training. The quality assurance programs are described in Chapter 17 of the Safety Analysis Report of IEN-R1 research reactor.

Appropriate internal QA and QC documentation is applied. QA activities in reactor operation are subject to internal (QA manager team) and external (Brazilian Nuclear Energy Commission) audits and inspections.

Ad. 14: Assessment and verification of safety

The reactor is regularly maintained. Major reconstruction and renewal was performed in 1991. The in-service inspection plan is implemented as part of the QA/QC program.

Periodic safety evaluations are performed. In sense of regulatory activities the CGRC periodically audits in the following areas: radiation protection, conduction of operation, reactor operators retraining, fire protection, emergency preparedness.

Ad. 15: Radiation protection

Radiation protection is implemented and performed by the Radiation protection service of the IEN. Internal, national and international regulations and recommendations are respected. The maximum dose for a reactor operation staff member is 20 mSv per year.

Ad. 16: Emergency preparedness

Emergency plans for ARGONAUTA reactor are specified in the Safety Analysis Report according to an appropriate IAEA format. Appropriate procedures are prepared in the form of special written documents for practical use in emergency situation, April 2013. The procedures are subject to internal and external verification and approval.

The procedures include: reactor status data, identification of emergency situation, description of the actions, alarming, reporting, informing and responsibilities for the following internal and external emergency events:

- radiological reactor accidents;
- loss of reactor shielding (primary water);
- release of radioactivity in the controlled area;

- release of radioactivity outside controlled area;
- non-radiological accidents;
- fire in the reactor building;
- precipitation intense rainfall;
- storms and strong winds
- earthquake,
- sabotage and not-authorized access.

The procedures are part of the operation documentation permanently available in the control room, in the office of the reactor center and in the physical protection office.

The reactor operation staff, the radiological protection staff and the physical protection staff are trained in using the procedures. Periodic retraining is provided.

Since when the Emergency Plan was implemented the reactor has operated without incident record that has caused any material or physical damage.

III.5 - Research Reactor – RMB - Brazilian Multipurpose Reactor of Research and Development Directory – DPD/CNEN

General information

RMB main function are radioisotope production for medical and industrial applications, fuel and materials irradiation testing, neutron beam laboratory, educations and training.

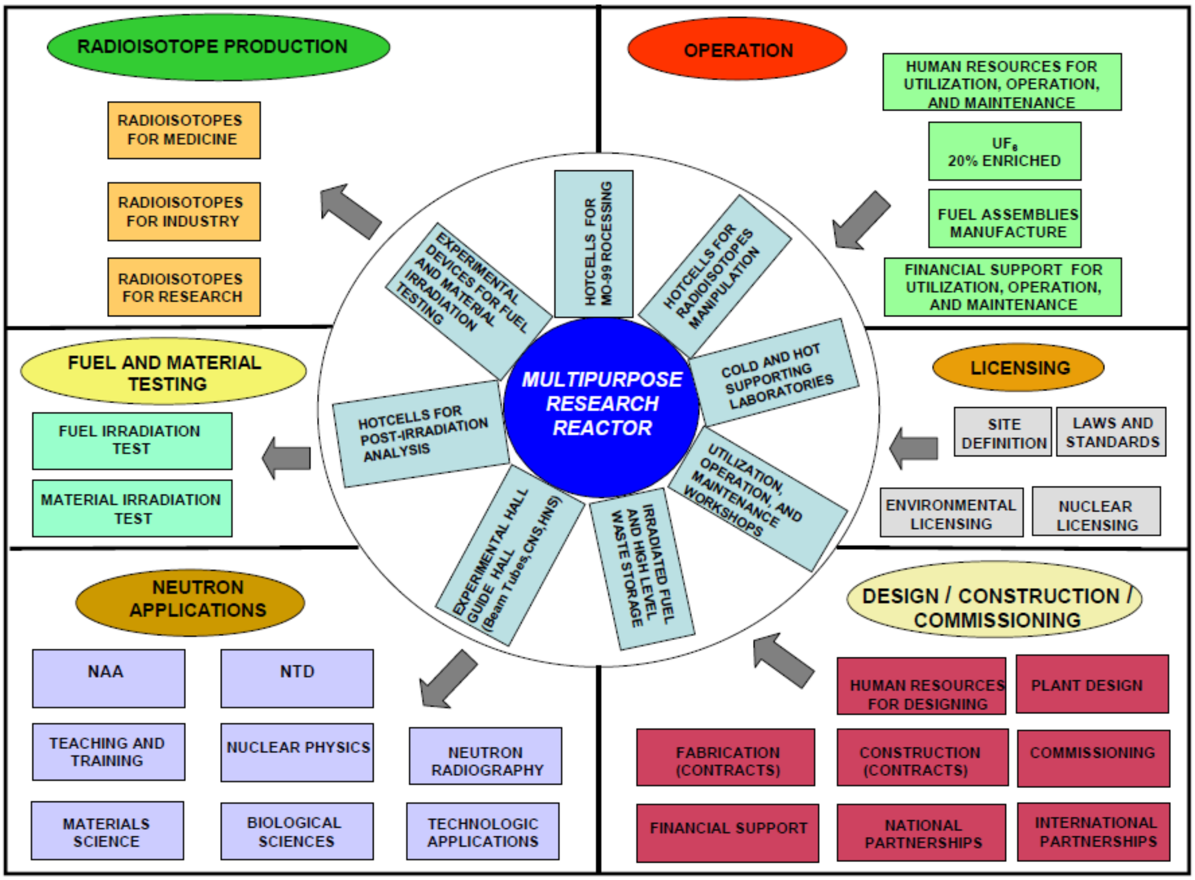

Fig.13 – RMB Project Scope

The RMB project managed by the Research and Development Directorate of the Brazilian Nuclear Energy Commission (DPD-CNEN) and the scope and conceptual design, licensing process management, and commissioning verification will performed by the Research Institutes of CNEN: IPEN, CDTN, IEN and CRCN.

The conceptual design and detailed project:

- CNEN – CNEA (Argentina) Cooperation Agreement on Reactor Design of RMB and RA-10 based on INVAP / Opal design
- Preliminary and detailed design, manufacturing, construction, assembling and their management will be carried out by national and international companies.
- Project technically supported by Brazilian Academy;
- Project Cost estimation of US$ 500 million;

- Open pool multipurpose research reactor with a primary cooling system through the core;
- The reactor core will be compact, using MTR fuel assembly type, with planar plates, U_3Si_2–Al dispersion fuel with 4,8 g U / c m^3 density and 19,9 % U^{235} enrichment.
- The reactor core will be cooled and moderated by light water, using light water, beryllium and heavy water as reflectors.
- Neutron flux (thermal and fast) higher than $2x10^{14}$ n / cm^2.s.

Core Design:

- Thermal Power: 30 MW;
- Fuel Assemblies: LEU – MTR;
- Core configuration: 5 x 5 grid with 23 FAs and 2 incore irradiation positions core irradiation positions ;
- Control Rods: 6 Hf plates (3 per Guide Box);
- Core Cooling: 3100 m3/h upward direction.

The RMB will a new Nuclear Research and Production Centre that will be built in a Sorocaba city about 100 kilometers from Sao Paulo city, in the southeast part of Brazil.

Ad. Article 13: Quality assurance

The Directorate for Research and Development of the Brazilian Nuclear Energy Commission (DPD-CNEN) has established its quality assurance programs for RMB project, in accordance with the mentioned requirements in Article 13 and assessed by CGRC. The corresponding procedures have been developed and are in use. The program provide for the control of activities which influence the quality of items and services important to safety and is applied to Site Selection, Implementation (Design, Manufacture, Construction) and Commissioning. The Preliminary and Final Safety Analysis Reports will have specific Chapter dedicated to Quality assurance.

Ad Article 17 – Siting

Ad Article 17(1)

The Directorate for Research and Development (DPD – CNEN) to comply with regulatory framework for site approval, presented in Article 17(1), has considered the important elements of site study and characterization as described in following IAEA Safety Standards NS-R-3, NS-R-4 (Chapter 5 - Site Evaluation), Safety Series nº 35-G1 - *Safety Assessment of Research Reactor and Preparation of the Safety Analysis Report* and NSG.3.1- 3.6.

The Site Safety Analysis Report was submitted to CGRC, in 2013, for regulatory evaluation and site approval.

The evaluation of all site related factors affecting the safety of the nuclear installations was started in 2012. Also in 2012, a contract was signed, with a Brazilian company with tradition in environmental studies, to perform environmental and site studies. The report was finished by middle 2013, allowing the starting of environmental and nuclear licensing processes, with presentation of site and local reports, requirements for first license. They were also the basis for the three public hearings, done in October 2013. Site topography was already surveyed; geological sampling completed, and a meteorological tower was installed and it is operational since 2012.

This 7th National Report was prepared by a Working Group composed by representatives from the following organizations:

Comissão Nacional de Energia Nuclear (CNEN)

Eletrobrás Termonuclear S. A (ELETRONUCLEAR)

Central Organization for the Protection of the Brazilian Nuclear Program (SIPRON)

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA)

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CNEN
Comissão Nacional
de Energia Nuclear

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