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Chapter 4. GENERAL SAFETY CONSIDERATIONS

4.1. Article 10. Priority to safety

4.1.1 At CNEN

CNEN has issued a safety policy[11] and quality assurance statements[12] in December 1996, which is based on the concept of Safety Culture. In November 2000, a working group was constituted to coordinate the implementation of this policy in the General Coordination for Licensing and Control. To date, the following activities have been performed or are under way: planning meeting with coordinators and supervisors; preliminary proposal of goals and activities, identification of existing procedures and instructions, preparation of a proposal with diagnosis, priority actions and implementation strategy for the next 3 to 4 years.

CNEN has established in its regulatory standards requirements to the applicants or licence holders based on safety principles, defense-in-depth and ALARA concepts, quality assurance control and human resources management. According to regulation CNEN-NE-1.26 [10] 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.

4.1.2. At ELETRONUCLEAR

ELETRONUCLEAR is a company resulting from the merger of the nuclear portion of the electric utility FURNAS and the nuclear engineering company NUCLEN, both with more than 20 years of experience in their field of activities. Both companies had policies aiming at giving priority to nuclear safety. The current organization structure of ELETRONUCLEAR is presented in Figure 9.

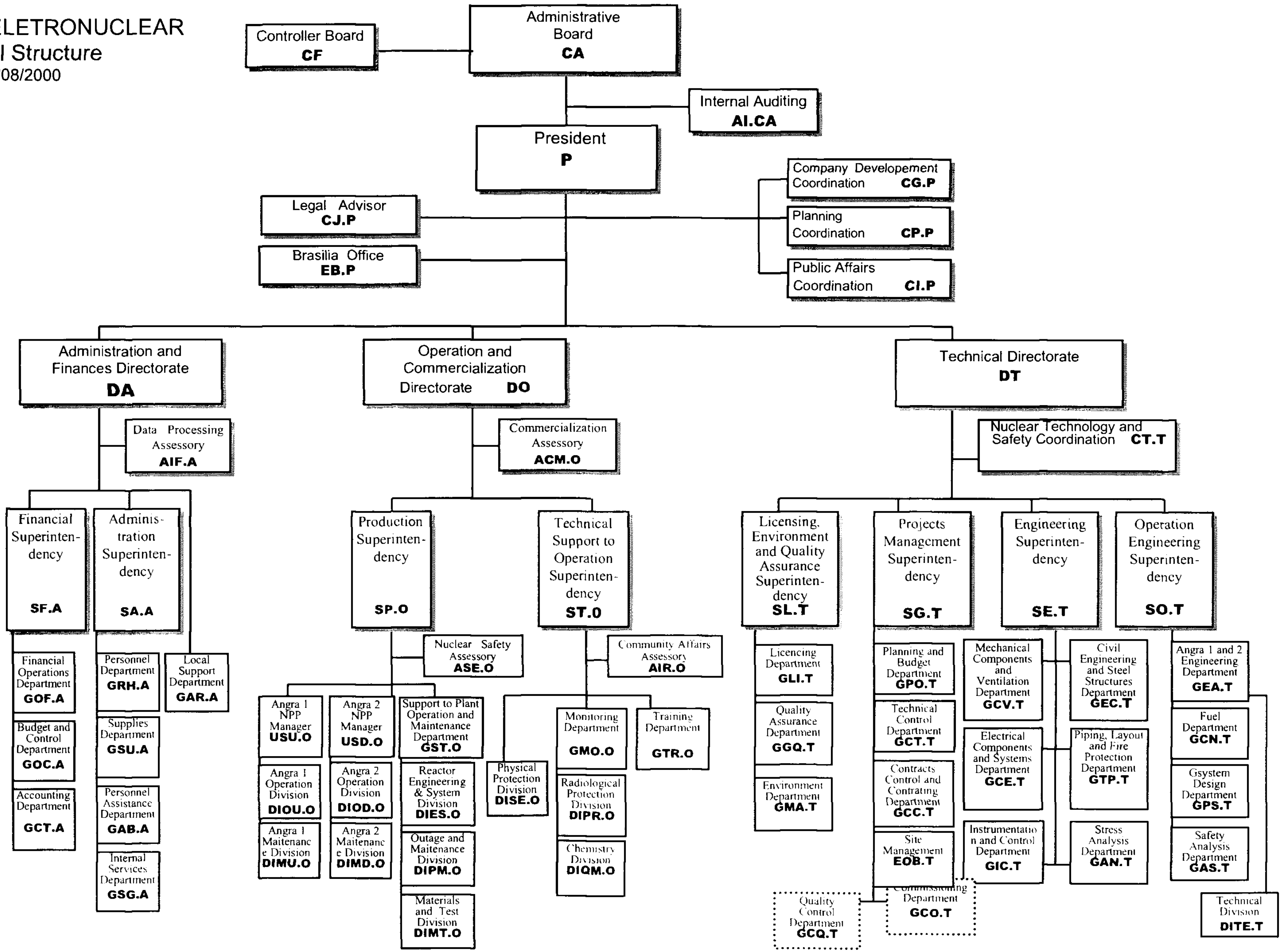


Fig.9- ELETRONUCLEAR
General Structure
Rev.: 01/08/2000

At the time of the merger, one of the first acts of the new company ELETRONUCLEAR was the approval by the Board of Directors of a document establishing formally the company priority to safety. As mentioned in section 3.3, the safety policy statement establishes that "Safety is the priority and precedes production and economics. Safety shall never be jeopardized by any other reason."

To ensure that this policy is being implemented, ELETRONUCLEAR has established a Committee for Nuclear Operation Analysis (CAON), with the responsibility to review activities related to nuclear safety. By its own initiative ELETRONUCLEAR has been engaged since beginning of 1999, in a programme of "self assessment" of the safety culture of the company, with the support of the IAEA, following the guidelines of the IAEA documents, Safety Series No. 75, INSAG-4, "Safety Culture", Safety Report Series No. 11, "Developing Safety Culture in Nuclear Activities". The goal of this activity is to determine the existing level of safety culture of the new company, identify any weaknesses and develop and implement a plan for improvement.

Following the line of the merged companies, from the beginning a strong Quality Assurance unit (SL.T) was established at ELETRONUCLEAR, with the level of Superintendency, which monitors all design, construction and operation activities and coordinates /supervises the plants nuclear and environmental licensing (see Eletronuclear Organization Chart, Fig. 9)

4.2. Article 11. Financial and human resources

4.2.1. Financial resources

As a governmental enterprise, ELETRONUCLEAR has its financial situation subjected to the holding company ELETROBRAS, which controls all federal electric utilities in Brazil. Its basic source of revenue comes from the selling of electricity, originally the energy from Angra1(626 Mw of net capacity) and beginning in September of 2000, of Angra 1 plus Angra 2 (1901 Mw of net installed capacity) through a long term energy supply contract ending in 2014, at a guaranteed minimum tariff, which today is of 57.91R$/Mwhr (~24 US$/Mwhr). This long-term contract was the mechanism utilized to protect nuclear generation from the unforeseeable situations that might occur with the ongoing liberalization of the Brazilian electricity market.

Adequate funds for operation and maintenance of Angra 1 and Angra 2 plants are made available through the annual budget, which includes the plants upgrading programme. For the sake of illustration the ELETRONUCLEAR budget for the year 2000 was of about 305 million US dollars, split as follows:

Primary Costs	In million US$
Personnel (salaries + benefits)	75
Other costs (subcontractors, insurance, office rent, equipment, consumables, etc.)	55
TOTAL	**135**
Investment	In million US$

Angra 1 (O&M, fuel and upgradings)	40
Angra 2 (completion of construction, Commissioning, trial operation)	126
Angra 3 (engineering)	2
Infrastructure	2
TOTAL	**170**

Feasibility studies for restart of Angra 3 project estimated total investments for plant completion about US$ 1.7 billion, US$ 1.1 billion for supplies and services in the Brazilian scope and US$ 0.6 billion for the import scope. The import scope is connected with the Supply and Service Contracts, transferred from SIEMENS A.G. to FRAMATOME A.N.P. Financing possibilities for the Brazilian scope are under evaluation in connection with the definition of the contractual arrangement with main suppliers to support the project.

In spite of the current privatization of the electric sector, now under way in Brazil, ELETRONUCLEAR will remain part of ELETROBRAS due to the constitutional provisions mentioned in item 1.1.

The provision of funds for decommissioning activities is to be obtained from ratepayers, and is included in the tariff structure, during the same period of depreciation of the plant (5%/year). For Angra 1, presently a reference decommissioning cost of 111 million dollars is estimated, corresponding to about 10% of the construction cost.

4.2.2. Human resources

Adequate human resources are available for ELETRONUCLEAR from its own personnel or from contractors. Currently ELETRONUCLEAR has a total of 1902 persons on its permanent staff and a few long-term contractors which supply additional personnel. At present there are 457 subcontracted persons working for ELETRONUCLEAR. Of the 1902 ELETRONUCLEAR employees 697 (37%) have a university degree, 937 (49%) are technicians and the remainder 264 are administrative personnel. Of the 1902 employees two hundred and fifty (250) are new employees hired in 2001 by ELETRONUCLEAR to fill in different positions in the organization, to compensate for the personnel to be retired in the coming next two years.

A project was organized in 2001 called "Determination of the Technological Know-how of ELETRONUCLEAR", which aims at identifying, in a formalized way, the know-how which exists in the company. Once this is done, the gaps will be identified and actions to fill these gaps will be proposed. In particular, loss of knowledge due to personnel attrition has to be considered. This is a pilot project with the broader aim of introducing Knowledge Management as a systematic activity in the company, in order to preserve the essential knowledge necessary for the safe and efficient construction and operation of its nuclear installations.

Activities related to qualification, training and retraining of plant personnel are performed by the Training and Simulator Department of ELETRONUCLEAR, which reports to the Operational Support Superintendent. Three facilities are available for training at the residential village close to the plant: a general training center, a training simulator for Angra 2, and a maintenance training center.

Angra 1 has no plant simulator. The installation of a full scope simulator for Angra 1 is scheduled to be completed in 2004. The specification for that simulator is ready and the international bidding is foreseen for the second semester of 2001.

Meanwhile, operators for Angra 1 are trained in simulators of similar plants in the USA (Ginna Simulator), Spain (Tecnatom Simulator) and, more recently in Slovenia (Krsko Simulator). Simulator training load is of 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 licence), a Shift Foreman (also a SRO), a Reactor Operator (who must hold a Reactor Operator – RO licence) 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 entire Angra 1 staff are established in Chapter 13 of the FSAR. Implementation and updating of these requirements are subject of CNEN audits of the licensee training and retraining programme and examination of new operators to comply with the regulations NE1.01 [8] and NE-1.06 [13].

In particular, the Plant Manager, the Deputy Plant Manager, the head of Operation Department, the head of Technical Support and the head of the Safety Team are currently licensed SROs or have previously held a SRO licence. The Radiation Protection Supervisor holds a special licence issued by CNEN, according to regulation CNEN-NE-3.03[14].

A full scope simulator for Angra 2 is available for training. Since the beginning of 1985 practical training of Brazilian specialists is being conducted. Instructors from ELETRONUCLEAR have also ministered classroom and practical training for operators, managers and licensing specialists from Germany, Spain, Argentina and Switzerland. The first group of control room operators was licensed in the beginning of 2000. Qualification training of additional Angra 2 operators is currently being performed.

Specialized training is also provided to the different groups of plant personnel. Maintenance technicians follow a qualification programme corresponding 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.

Technical visits and reviews of ELETRONUCLEAR training programme 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) have provided valuable contribution to the identification and implementation of good practices 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 programme 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[6] and their medical qualification[9]. CNEN conducts written and practical examinations for Reactor Operators and Senior Reactor Operators before issuing each individual authorization.

During the year 2000, for Angra 1 power plant, 27 Senior Reactor Operators (SRO) and 6 Reactor Operators (OR) licenses have been renewed and 3 SRO and 1 RO new licenses have been granted. For Angra 2, in the same period, 10 new SRO and 12 RO licenses have been issued.

Radiation Protection Supervisors certification is done in accordance with regulation CNEN – NN 3.03 "Certification of the Radiation Protection Supervisor Qualification"[14]. With the beginning of Angra 2 commissioning tests, Radiation Protection Supervisors had to be trained for their qualification also in this unit. In 1999, 4 Radiation Protection Supervisors were qualified from Angra 1 to Angra 2 and a new one was approved for actions in the two plants. In August 2000, ELETRONUCLEAR submitted the nomination of 4 technicians as candidates to the CNEN licence. These candidates are presently being submitted to the training programme provided by ELETRONUCLEAR in order to fulfill the requirements for the CNEN qualification examination.

4.2.2.1. Technical capability of ELETRONUCLEAR in the design and construction areas

The Brazilian-German Agreement of 1975 provides for the transfer of the technology necessary to the activities of design, equipment manufacture, construction and operation of NPPs to Brazilian companies involved in the nuclear programme. For Angra 2, the German counterpart assumed technical responsibility for the jointly built plant.

For this purpose, several contracts were signed, of which the foremost is the Technical Information Contract, with NUCLEN (now ELETRONUCLEAR) which provides for the necessary technology transfer. In the scope of this Contract, the following was accomplished (in round numbers):

- On-the-job training of Brazilian personnel in Germany: 250 engineers (550 man-years);
- German assignees in Brazil: 150 engineers, along 20 years;
- Documents transferred: 70.000.

In addition, 22 technology transfer contracts were signed with foreign traditional firms by different private Brazilian component suppliers. This assured a solid and continuous local technological basis for the design, construction and operation of Angra 2 and for support of Angra 1 operation.

After completion of the Angra 2 plant, SIEMENS supply and service contracts, now transferred to FRAMATOME ANP, are still in force. As foreseen in the service contract, FRAMATOME continues to provide services for post-completion activities and to support operation and maintenance areas in the first Angra 2 operation cycle. Post-completion activities include mainly updating of design documentation and data-banks, design modifications following commissioning experience and elaboration of technical reports to meet additional licensing requirements. The Supply Contract in this phase has been applied mainly for re-supply of spare and wear parts used during commissioning and supply of equipment and material for the design modifications planned for the first operation cycle.

4.3. Article 12. Human factors

Angra 1 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, and still before commencement of operations, a critical review of 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 for monitoring critical safety functions. 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.

Later on, human factors were considered in a much broader sense and several management initiatives were undertaken in this area, such as a programme for team-work training and a Human Performance Enhancement System (HPES). Training related to Safety Culture aspects was also undertaken using IAEA guidelines.

CNEN also established in the Regulation NE-1.26 [10] requirements for the periodic safety review which considers human factor as an important area of review. For Angra 1, at the opportunity (December, 2004) CNEN will review and assess the situation in areas of I&C and man-machine interface.

For the Angra 2 plant, CNEN has required during the licensing process that an additional chapter 18 to be included in the FSAR, addressing the Human Factor Engineering (HFE). The content and format of this new chapter was based on the guidance framework of chapter 18 of the Standard Review Plan (NUREG 800 - 1996 Revision), which defined the nine areas of human factor review (NUREG 711) by an HFE management group. The licensee has made a comprehensive review of the operational experience of German plants, Angra-1 and other plants (specially theTMI-2 accident). It has been also established the HFE Committee as part of the organizational structure, with the main responsibility to review the internal and external operational experience according to the nine areas of human factors and to approve any proposed man-machine interface modifications during the plant operational lifetime. HFE analyses of accident sequences and associated operator actuation times are being performed for the existing Angra 2 main control room panel. The purpose of these analyses is to identify man-machine interface problems and to propose improvements in the control room. As example of the improvements of the man-machine interface that have been introduced in the original design, it may be mentioned the computer system to monitor the Critical Safety Functions(CSF). A functional requirement analysis is described in chapter 18 of the FSAR concerning the definition of plant safety functions carried out by the automated actions of the reactor limitation and protection systems, and the definition of Critical Safety Functions (CSF).

ELETRONUCLEAR elaborated Chapter 18, Human Factors Engineering (HFE), according to the philosophy recommended by NUREG-711. Consequently the HFE Programme now being implemented has the purpose of assuring that, from the beginning of Angra 2 commercial operation on, the plant operational events will be evaluated following procedures which take due account of human factor aspects.

Still in the premises of the behavioural science, as already mentioned in item 4.1, ELETRONUCLEAR was engaged along 1999 and 2000, in a pioneering experience of self-evaluation of its safety culture. The overall result was satisfactory, but the assessment showed considerable margin for improvement. Presently, an action plan was developed with the purpose of improving the company safety culture relative to the weak points resulting from the self-assessment phase. After an action plan application period of about 2 years a repetition of the self-evaluation step is planned, for evaluation of the implemented measures and for eventual correction of direction. The work of the above programme in safety culture has been continuously supported by technical assistance from the IAEA.

4.4. Article 13. Quality assurance

The requirement for a quality assurance programme in any nuclear installation project in Brazil is established in the licensing regulation[6]. Specific requirements for the programmes are established in a specific regulation, Quality Assurance for Nuclear Power Plants, CNEN-NE-1.16[15] which is based in the IAEA code of practice 50-C-QA Rev.1 - Quality Assurance for Nuclear Power Plants, but with the introduction of the concept of an Independent Technical Supervisory Organization (Organização de Supervisão Técnica Independente - OSTI)[16].

Former FURNAS and now ELETRONUCLEAR have established their quality assurance programmes according to these requirements. The corresponding procedures have been developed and are in use. The programme provides for the control of the activities influencing the quality of items and services important to safety. These activities include design, design modifications, procurement, fabrication, handling, shipping, storage, erection, installation, inspection, testing, operation, maintenance, repair and training. The quality assurance programmes are described in Chapter 17 of the FSAR.

The Licensing, Environment Management and Quality Assurance

Superintendence (SL.T), reporting to the Technical Directorate, is responsible for the establishment and supervision of ELETRONUCLEAR Quality System. The Committee for Nuclear Operation Analysis (CAON) is a collective body under the coordination of the Production Superintendent (SP.O) whose purpose is to examine, follow-up and analyze issues concerning Angra 1 and 2 operational safety and to make recommendations to improve safety. Plant Operation Review Committees (CROUs) are collective bodies under the respective unit manager (USU.O for Angra 1 and USD.O for Angra2) with the responsibility to review and analyze, on a closer basis, questions related to operating nuclear power plants units.

The ELETRONUCLEAR Quality Assurance Department (GGQ.T) is responsible for performing internal and external audits in order to verify compliance with all aspects of the quality assurance programme. All audits are performed in accordance with written procedures. In case of internal audits, persons involved with the activities being audited have no involvement in the selection of the audit team. Audit reports are distributed to, and formally reviewed by organizations responsible for the area being audited and also by the CAON. In the three year period 1998-2000, 94 external audits and 65 internal audits have been conducted.

Audits and inspections by CNEN verify that quality assurance requirements are being implemented and that the quality assurance has been effective as a management tool to ensure safety. During the same period of 1998-2000, CNEN conducted 17 audits or regulatory inspections in Angra 1 and 47 in Angra 2. The high number of audits/inspections in Angra 2 reflects the increased supervision during the commissioning activities during that period.

4.5. Article 14. Assessment and verification of safety

A comprehensive safety assessment is a requirement established by the licensing regulation in Brazil[6].

For the Angra 1 and Angra 2 plants, both a Preliminary Safety Analysis Report (PSAR) and a Final safety Analysis Report (FSAR) were prepared. The FSARs followed the requirements of US NRC Regulatory Guide 1.70 - Standard Format and Contents for Safety Analysis Report of LWRs. These reports were reviewed and assessed by CNEN, and extensive use was made of the US NRC - Standard Review Plan (NUREG - 800).

For the Angra 2 NPP, the licensing process was started in accordance to the German licensing procedure. Such process foresaw a series of partial approvals, by each, a large amount of the actual design and licensing data being 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 USNRC 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 USNRC 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 already 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.

In parallel with the paper version, the FSAR has also been issued, in a user-friendly format, as a "hypertext" CD-ROM, envisaging better handling and consultation .

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 referred conservative approach is the Angra 2 large break LOCA Analysis. With basis on the extensive Large Break LOCA research and development in recent years and evolution of the regulatory requirements, ELETRONUCLEAR has submitted to the Brazilian regulatory body a LB-LOCA analysis performed with the latest analysis tools and methodology, that is, use of a “best estimate code” of the RELAP5 MOD2 family, coupled with uncertainty evaluation. This analysis is being evaluated by CNEN through an independent calculation performed with the support of a contract with the University of Pisa.

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 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”. The event tree/fault tree logic (i.e. accident sequence) quantification was performed by fault tree linking using the SAPHIRE 6.67 code. The model represents accident and transient initiating events starting from power operation and continuing for a 24 hours mission time. Component reliability analysis was performed using a generic industry data base updated with plant-specific data using Bayesian procedures for most of the modeled systems. Dependent (i.e. common cause) failure analysis was performed using Multiple Greek Letter method. Human reliability analysis was performed using the ASEP and HCR models for the cognitive portion of human errors and THERP methodology for the executive portion of human errors.

Several important findings, leading to upgrading of plant hardware and operational procedures, arose from this second PSA study, of which some highlights are described below :

1) The configuration at Angra 1 has a single instrument air line going into containment. An important weakness identified in the PSA was the failure to open the containment solenoid-activated-air-operated isolation valve (previously closed due to a S-signal) . Based on the PSA results a handwheel was installed in this containment isolation valve to allow the operator to open this valve locally, if it fails to open from the control room, in order to reestablish instrument air to the containment to increase the reliability of the Reactor Coolant System depressurization and cooldown functions.

2) Also identified as a weakness was the potential for a Reactor Coolant Pump (RCP) seal LOCA due to a loss of RCP seal cooling under loss of Service Water System, Component Cooling System or loss of off-site power. To minimize the potential for RCP seal LOCA the following actions were taken: a) the line-ups of the Service Water System and Component Cooling Water System were modified; b) a recommendation was issued to perform the electrical alignment of the small flow positive displacement charging pump (used for seal injection flow) based on the train of Service Water and Component Cooling Water which are in service during the event; c) a spare electrical motor was bought for the Service Water System pumps to improve the availability of the system;.

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 10E-5 per reactor.year.

As a further application, the Angra 1 level 1 PSA is being used to support the development of the Maintenance Rule in agreement with the NUMARC 93-01 Revision 2. Also a plant configuration control based on the risk rate (CDF) and the weekly cumulative risk (CDP) is being used for on-line maintenance planning.

ELETRONUCLEAR is planning to start a Angra 1 level 2 PSA this year. Fire analysis and shutdown risk analysis will be planned for the near future, after the level 2 PSA is finished.

In the case of Angra 2 the probabilistic insight comes from a major level 3 German PSA study performed for the 1300 MWe German PWR family, having as reference the Biblis B NPP- the German Risk Study (DRS), Phases A and B. A preliminary evaluation of the Angra 2 core melt frequency as well as gathering of information for Accident Management countermeasures development has been done, taking the DRS study as a basis, and adapting its models for the main design differences between Biblis B and Angra 2.

ELETRONUCLEAR plans to conduct a specific level 1 PSA also for Angra 2, to be initiated in the near future and concluded at most within four years.

4.6. Article 15. Radiation protection

Radiation protection requirements and dose limits are established in Brazil in the regulation for radiation protection[17]. These require 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 Health Physics Programme at each installation. Plant design is assessed at the time of the licensing review and by evaluating the dose records during normal operation.

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

The annual dose limits to workers are 50 mSv for effective dose equivalent and 500 mSv for dose equivalent for individual organs and tissues, except in the case of the eye lens whose limit is 150 mSv. For women of reproductive capacity the doses are limited to 10 mSv in any quarter of year and, if they should become pregnant, the limit is reduced to 1mSv for the entire gestation period. These limits are in accordance with CNEN regulations, with applicable labor legislation which has endorsed CNEN limits, and with the international Convention n. 115 of the International Labor Organization (ILO) to which Brazil is a Party.

The actual personnel radiation doses at Angra Nuclear Power Plants are much lower than the established limits. The dose distribution for workers at the Angra site demonstrates an adequate radiological protection programme, with almost all averaged annual accumulated individual doses below 5 mSv and no one with radiation dose above the annual administrative dose limit (20 mSv). The annual collective dose for the last 3 years has usually been lower than 1,30 Man.Sv and 0,20 Man.Sv, respectively during a year with and without outage. Actual dose distribution for the year 2000 is presented in Figure 10. The collective dose variation along the years is shown in Figure 11.

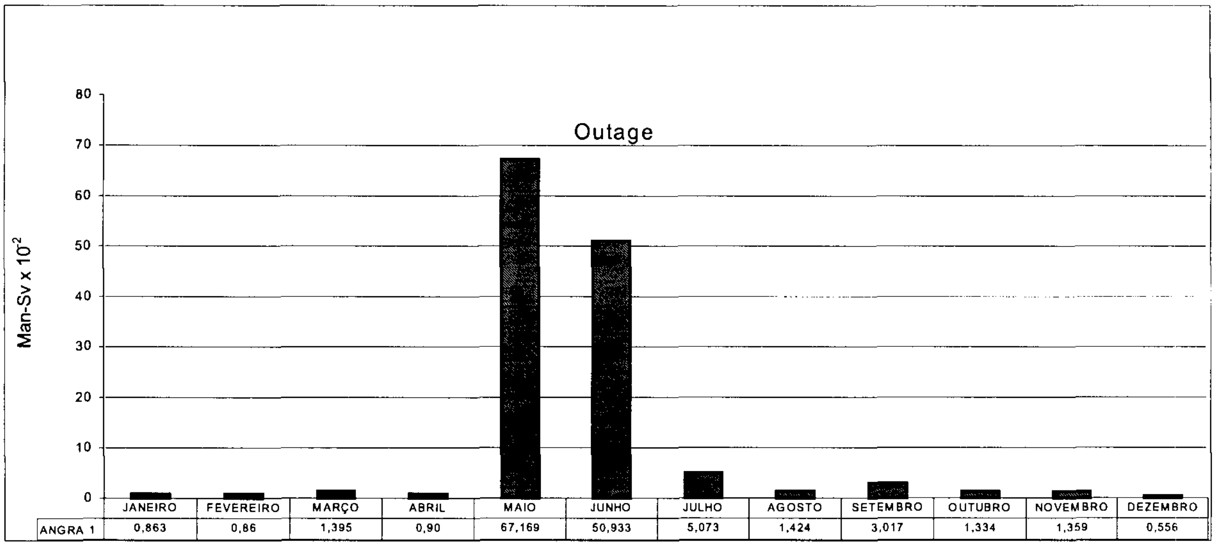
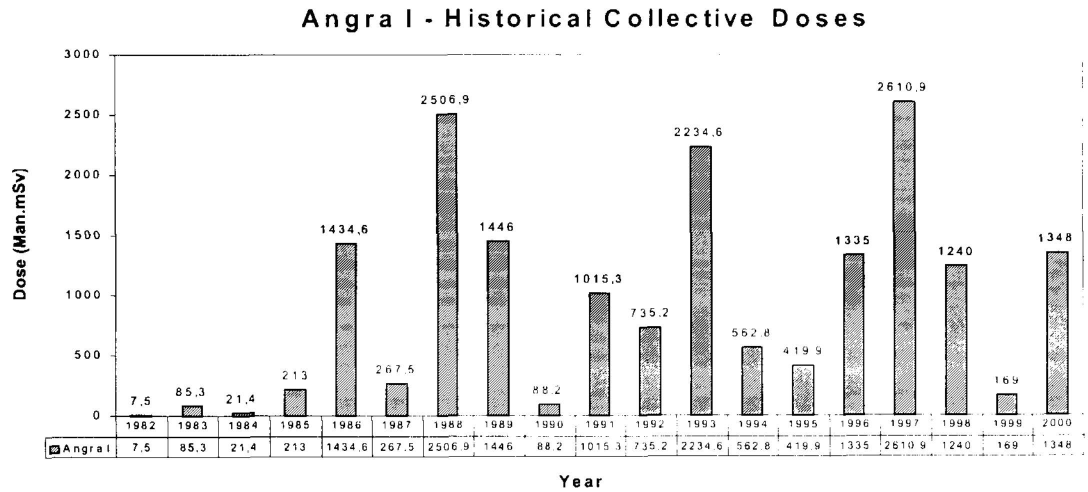


Fig. 10 – Occupational dose distribution at Angra 1 during 2000.

Fig. 11 - Collective Doses at Angra 1

Release of radioactive material to the environment is controlled by



administrative procedures and kept below CNEN established limits, in accordance with administrative procedures. Additionally, the amount of radioactive waste and the radioactive effluents discharged to the environment also follow the ALARA principle.

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

According to the CNEN regulation[5], an Effluents Releasing and Wastes

Report is issued every semester, documenting the liquid, gaseous and aerosol effluents – batch number, present radionuclides and concentration, waste quantity and type sent to the repository and the meteorological data in the period. Also, the effective equivalent dose for the critical individual is presented. In the period of 1998-2000, this dose reached the average 7×10^{-4} mSv, which is much lower than the 1 mSv value established in regulation CNEN-NE-3.01[17].

IBAMA also monitors the impact of the plants on the environment through a system of inspection in which the State Foundation for Environment Engineering (FEEMA) and the Prefecture of Angra dos Reis also participate.

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

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

Typical results of the monitoring programme is presented in Figure 12, for two areas: Impact area (27measuring points within 5 km radius from the plant) and Control area (15 measuring points beyond 5 km). The lines give the annual average values, and the bars the maximum and minimum values. The average values for the impact and Control areas are statistically equivalent, indicating the absence of radiological impact from the power plants.

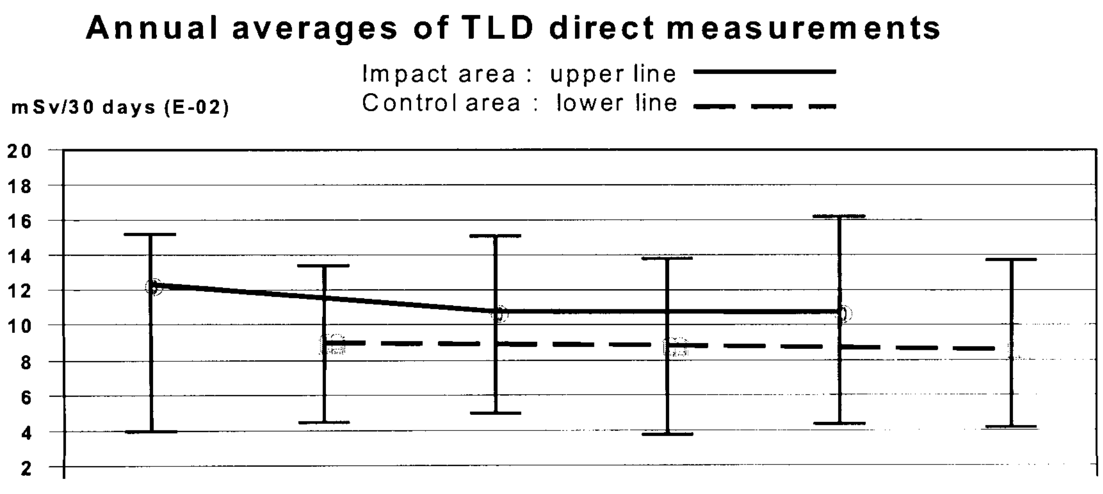


Fig. 12 – Environmental Monitoring Programme Results for 2000

4.7. Article 16. Emergency preparedness

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

The Emergency Planning Zone (EPZ) encompasses the area within a circle with radius of 15 km centered at the nuclear power plants. This EPZ is further subdivided in 5 smaller zones with borders at approximately 1.5 , 3, 5, 10 and 15 km from the power plants.

4.7.1. On Site Emergency Preparedness

The On-site Emergency Plan covers the area of property of ELETRONUCLEAR, and comprises the first zone (up to ~1,5 km from the power Plants). For these area, the planning as well as all actions and protection countermeasures for control and mitigation of the consequences of a nuclear accident are of 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.

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

The On-site Emergency Plan involves several levels of activation, from single alert status, through 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, which notifies the Plant Manager, as Emergency Group coordinator, which alerts the coordinators of the other Emergency Groups, the Site Superintendent and the Authorities (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, ensures the prompt actuation of the Emergency Groups.

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

4.7.2. Off Site Emergency Preparedness

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

SIPRON was established by Law n. 1809 of 7 October 1980. The Decree n. 2210 of 22 April 1997 has defined the Secretary for Strategic Affairs (SAE), directly linked to the Presidency of the Republic, as the Central Organization of SIPRON. More recently, a Governmental restructuring has designated the Ministry of Science and Technology (MCT) as the Central Organization for SIPRON, which now stays under the responsibility of a Special Advisor to the Minister as a part of the Coordination of Technical and Scientific Programmes of MCT (see Figure 4).

The decree also establishes a Coordination Commission (COPRON) composed of representatives of the agencies involved. Besides ELETRONUCLEAR, as the operator, and CNEN, as the nuclear regulatory body, other agencies are involved as support organizations of SIPRON, such as the municipal civil defense, the state civil defense, the Angra Municipality, the IBAMA, the National Road Department (DNER), the National Army, Navy and Air Force, and the Ministries of Health, Foreign Relations, Justice, Finance, Planning and Budget, Transportation and Communications (see Figure 13).

Within SIPRON, the Central Organization issued a General Norm for Emergency Response Planning (SIPRON- NG-02)[18] and has prepared specific guidelines for Angra site emergency planning (Diretriz Angra 1 and Diretriz Angra 2)[19], consolidating all requirements of related national laws and regulations and stating the responsibilities of each of the involved organizations. Additional norms related to emergency centers, communications, intelligence and information to the public were also issued by the Central Organization.

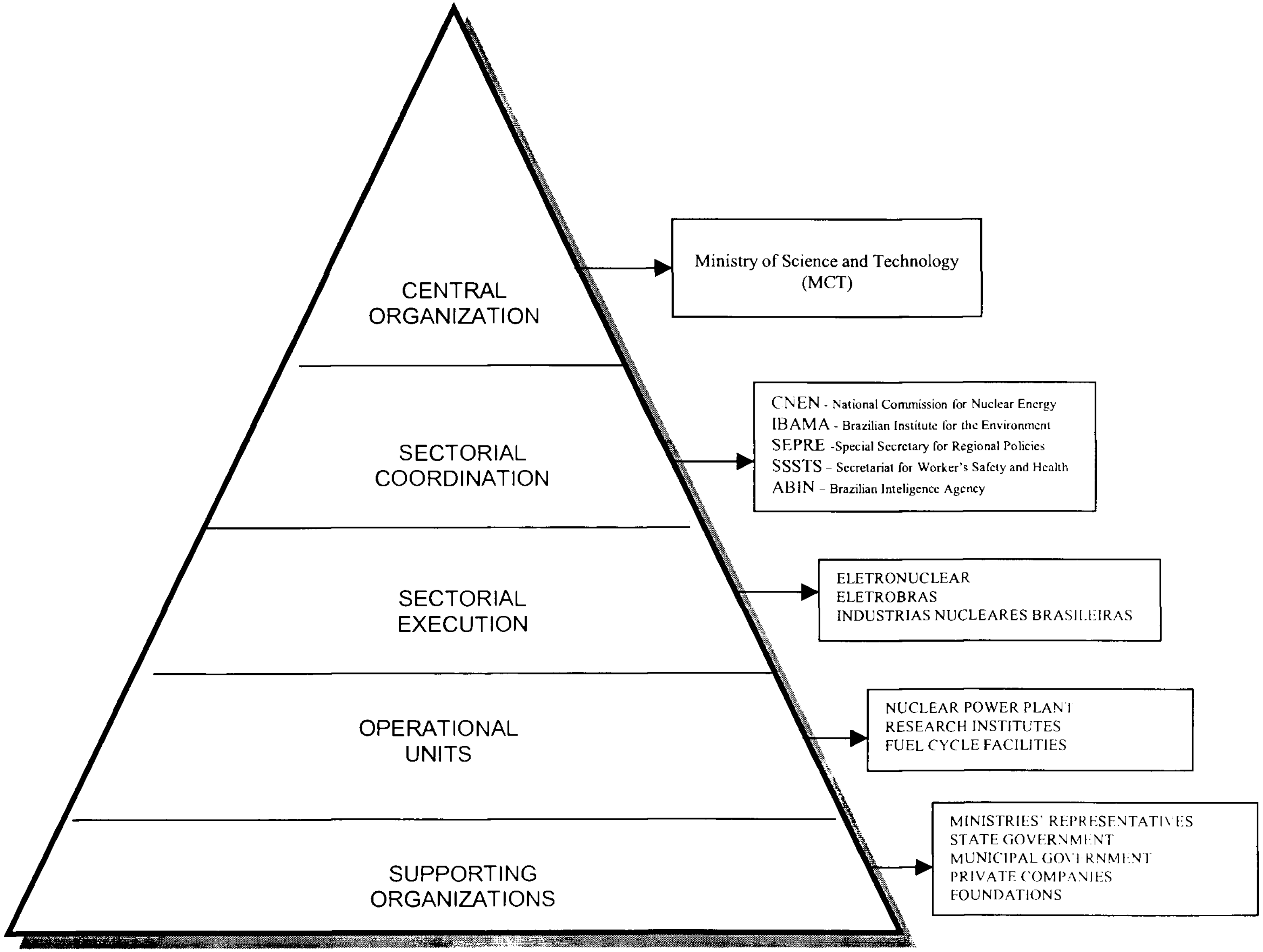
The approach to emergency preparedness is based in a “municipalization” of the response action to an emergency situation, utilizing mainly the resources available at the Municipality. The State and Federal Governments complement the local resources as necessary. In this way, SIPRON works at the operational level with the Municipal Government, and the State Government, and at the political level, through the Federal Government which provides the necessary material and financial resources.

At the plant level, a comprehensive Emergency Plan has been established and is periodically tested. The plan involves several levels of activation, from single alert status, through area emergency, to a general emergency. Dedicated facilities at the plant site have been designated and the equipment for emergencies has been greatly upgraded.

At the off-site level, a National Center for Management of Nuclear Emergency Situation (CNAGEN) has been created in Brasilia in the MCT. A State Center for Management of Nuclear Emergency Situations (CESTGEN) has been established in Rio de Janeiro. A Center for Coordination and Control of Nuclear Emergency Situation (CCCEN) and a Center for Information in Nuclear Emergency (CIEN) have been established in the city of Angra dos Reis. This centers' activities during an emergency have been established in the revised Rio de Janeiro State Plan for External Emergency, approved by the state governor by Decree 26586 of 21 June 2000.

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

Fig. 13 SIPRON STRUCTURE



In 1996, after a review of the existing plans and comparing with information obtained during the observation of an emergency exercise in the United States by a SIPRON working group, substantial changes were introduced in the emergency response approach. After these modifications were introduced, in 1997, the Central Organization of SIPRON coordinated two partial exercises and a full scale emergency exercise. The general emergency exercise established 20 objectives to be demonstrated and evaluated to verify and validate the adopted systematic approach. The exercise was observed by international experts from the IAEA and Argentina, who prepared a report [20] that concludes that the exercise achieved most of its objectives.

Since then, the Central Organization 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. Therefore, a full scale exercise was performed in 1999, and partial exercises were conducted in 1998 and 2000. Another full scale exercise is schedule for November, 2001, under the coordination of MCT, including the activation of several shelters and the simulated evacuation of part of the population in the Emergency Planning Zone (EPZ).

During the partial exercise on August 31, 2000, a new expanded siren system initiated its operation. This system is composed by 8 siren towers (the double of the old system) and has the capability to transmit both sound and voice messages. The system was tested during the exercise and demonstrate its adequacy to cover the whole Emergency Planning Zones of 3 and 5 km radius (EPZ-3 and –5).

Regarding information to the public, SIPRON norm NG-05[21] 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 last campaign in 2000 combined information on both on-site and off-site emergency plans, including the population living in the 15-km area around the plant. This campaign included 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 defense, state fire brigade, ELETRONUCLEAR volunteers, and CNEN and ELETRONUCLEAR technical and public information personnel. 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.

A training course on emergency preparedness and response was created in 2000 by the State Civil Defence of Rio de Janeiro in co-operation with CNEN and ELETRONUCLEAR. The course was primarily designed to civil defence personnel at the local and state levels.

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.