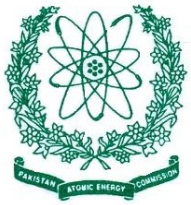
THE ISLAMIC REPUBLIC OF PAKISTAN

FOURTH NATIONAL REPORT

FOR THE

CONVENTION ON NUCLEAR SAFETY



Prepared on behalf of

The Government of Pakistan

by the

Pakistan Nuclear Regulatory Authority

in collaboration with the

Pakistan Atomic Energy Commission

S e p t e m b e r 2 0 0 7

Pakistan Nuclear Regulatory Authority

P. O. Box. 1912. Islamabad, Pakistan

ABSTRACT

The Pakistan Nuclear Regulatory Authority submits this Fourth National Report of Pakistan for peer review at the Fourth Review Meeting of the Convention on Nuclear Safety at the International Atomic Energy Agency in April 2008. This report covers the safety of commercial nuclear power plants. The report presents the appropriate steps taken by the Government of Pakistan to meet the main objective of the Convention — to achieve and maintain a high level of nuclear safety worldwide by enhancing national measures and international cooperation. It also describes how Pakistan meets the obligations of each article established by the Convention — specifically by the articles that address the safety of existing nuclear installations, the legislative and regulatory framework, the regulatory body, responsibility of the licensee, priority to safety, financial and human resources, human factors, quality assurance, assessment and verification of safety, radiation protection, emergency preparedness, siting, design, construction and operation.

TABLE OF CONTENTS

1. Introduction

1.1 General

Pakistan signed the Convention on Nuclear Safety (CNS) on 20 September 1994 and ratified it on 30 September 1997. The Government of the Islamic Republic of Pakistan is taking appropriate measures to install and operate nuclear power plants for generation of electricity. Highest priority is accorded to safety in nuclear installations.

In order to fulfill the obligation under Article 5 of the Convention on Nuclear Safety (CNS), on behalf of the Government of Pakistan (GoP) Pakistan Nuclear Regulatory Authority (PNRA) has prepared the Fourth National Report of the Islamic Republic of Pakistan in collaboration with Pakistan Atomic Energy Commission (PAEC).

The Fourth National Report (FNR) is an updated version of the Third National Report (TNR). It can be used as a stand alone document. The FNR begins with an introduction in article 1. The article 2 covers the progress made after the Third National Report and the special reporting required in the Summary Report[1] and in the areas identified by the rapporteur of the country group. This is followed by a brief description of the future challenges in article 3. The FNR then continues with Articles 4 to 19, and includes annexes to provide more detailed information. This part of the report generally follows the articles of the Convention on Nuclear Safety and the guidance[2] provided by the CNS Secretariat. Each section on the articles of the Convention begins with the text of the article. It is followed by the description of regulatory requirements that are put in place to meet the obligations of the article, appropriate steps taken by the nuclear installations to fulfill these requirements and the verification by the regulatory body.

An attempt has been made to provide the information identified in the synopsis guidance[3] based on IAEA safety requirements and guidelines. Moreover, consideration has been given to follow the recommendations made in the Report[4] of the President of the TRM.

Based on the information presented in the FNR, it is concluded that the Government of the Islamic Republic of Pakistan is committed to make all possible efforts in achieving and maintaining a high level of safety and has met its obligations under the Convention on Nuclear Safety.

1.2 National Policy Pertaining to Nuclear Installations

Planning Commission of GoP has prepared a working draft of Vision 2030[5] which envisages a developed, industrialized, just and prosperous Pakistan through rapid and sustainable development in a resource constrained economy by developing knowledge inputs. This can be achieved, among other things, by educating the population and introduction of technology. Energy is a multiplier of human effort; therefore abundant safe, secure, sustainable and affordable energy would be needed to fuel the growth. Concurrently, the issues of environment degradation and global warming have also to be addressed.

In view of the above, an Energy Security Plan (2005 to 2030) has been prepared which envisages utilization of all types of energy resources and enhancement of the role of nuclear power generation in the next few decades. Under this plan, the nuclear generation capacity is to be increased to 8,800 MWe by 2030.

[1] Third Review Meeting of the Contracting Parties 11-22 April 2005-CNS-RM-2005/08 FINAL
[2] INFCIRC/572/Rev.2 and CNS 2005 RM NATREP/DD Rev.02 December 2006
[3] CNS-Compiled-Synopsis-Final; 18 May 2006
[4] CNS-RM-2005/09 FINAL
[5] for details please visit www.planningcommission.gov.pk

The GoP is fully cognizant of its responsibilities regarding preservation and improvement of the quality of the environment. Organizations at various levels of the government have been established, under legislation and statutes, to regulate salient sources of environmental degradation and to carry out research on climatic changes due to global warming, etc.

PNRA is the competent authority for regulating nuclear safety and radiation protection aspects of nuclear installations. PAEC undertakes promotional activities in the use and application of nuclear energy including research, development, education, etc., on behalf of Government of Pakistan. PAEC owns and operates all nuclear installations in Pakistan. National Electric Power Regulatory Authority (NEPRA) determines tariffs and ensures fair competition in the electricity market.

Pakistan is the fifteenth country in the world that installed nuclear power plants for the generation of electricity. It has more than 35 years of nuclear power plant operating experience. The safety record of the operation of nuclear power plants has been satisfactory as concluded from the findings of the domestic regulatory reviews and inspections, and as corroborated by international peer reviews.

1.3 Ongoing National Program Related to the Nuclear Installations

The national program related to nuclear installations is being pursued for the last four decades. The national nuclear program is focused on:

- **a.** continued safe operation of nuclear installations
- **b.** construction of new nuclear installations to meet energy requirements
- **c.** strengthening and capacity building of institutions of PNRA and PAEC

Karachi Nuclear Power Plant Unit 1 (KANUPP or K-1) has completed its design life of thirty years. Most of the design modifications and upgrades required for relicensing have now been implemented. In support of its application for relicensing, K-1 carried out a periodic safety review and updated its Final Safety Analysis Report (FSAR). The latter was submitted to PNRA in March 2007. The regulatory review is expected to be completed by September 2007.

C-1 has been operating safely and four refueling outages have been carried out so far. During these outages, in-service inspections, scheduled maintenance, design modifications and periodic tests were performed in addition to refueling. PNRA has kept the plant under continuous regulatory surveillance. Some safety significant events that took place at K-1 and C-1 were reported to IRS.

The Site Evaluation Report (SER) and the Preliminary Safety Analysis Report (PSAR) for C-2 were submitted to PNRA. On completion of safety review of these reports, the site was registered and construction licence for C-2 was issued. Construction work and manufacturing of equipment is progressing satisfactorily.

GoP has approved projects of PAEC for evaluation of additional sites for installing new nuclear power plants and for upgrading design institutions. PAEC has taken steps to improve its infrastructure relating to nuclear installations at the corporate level. The prime responsibility for safety of the installation rests with the management of nuclear installations.

Pakistan is developing an infrastructure for manufacturing of components of nuclear installations. Heavy Mechanical Complex–3 (HMC–3) is a project of State Engineering Corporation. It can produce thick walled pressure vessels, process equipment, precision mechanical components, heavy steel structures, etc. HMC-3 is ISO 9001:2000 certified for "Design & Manufacturing of Engineering Products for Medium & Heavy Industries". It

has U & U2 stamps of ASME[6]. It is registered with the Federal Safety and Pressure Vessel Board of Pakistan. PNRA has also licensed HMC-3 to manufacture ASME Boiler & Pressure Vessel code Section III class 2 and 3 tanks, vessels and heat exchangers.

PNRA has been continuously improving its regulatory infrastructure. The Center for Nuclear Safety was established in 2005 as the technical support organization. Recruitment in CNS is now complete and the required competencies are now being developed. The human resource development in PNRA gained impetus with the establishment of the School of Nuclear and Radiation Safety (SNRS). In addition, projects have been approved by GoP to carry out country-wide radiation environmental surveillance, to establish dosimetry and calibration laboratories, etc. PNRA has expanded its programs related to public and other stakeholders' participation and international cooperation.

The regulatory framework was further enlarged and several new national regulations were issued. The regional directorates of PNRA were further strengthened to carry out inspection and enforcement activities at nuclear installations.

[6] American Society of Mechanical Engineers

2. Progress made after the Third National Report and Special Reporting

In the following sections the progress made after the Third National Report, measures taken in areas identified as a result of peer review during the Third Review Meeting and Special Reporting as required in the Summary Report[7] are described.

2.1 Progress made after the Third National Report

Progress made after the Third National Report in significant areas is presented below.

2.1.1 Regulatory Framework

Following national regulations related to nuclear installations were officially notified in the Gazette of Pakistan:

- **a.** Regulations on Licensing Fee by PNRA – PAK/900 (Rev 0)
- **b.** Regulations on Radiation Protection – PAK/904 (Rev. 0)
- **c.** Regulations on Safety of Nuclear Power Plants – Operation–PAK/913 (Rev. 1)
- **d.** Regulations on Radioactive Waste Management – PAK/915
- **e.** Regulations for Safe Transport of Radioactive Material – PAK/916

Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – PAK/907 (Rev.0) and Regulations on the Safety of Nuclear Power Plants – Site Evaluation PAK/910 (Rev.1) have been finalized and will be officially notified after the approval of the Authority. Regulations on Management of a Nuclear or Radiological Emergency – PAK/914 (Rev. 0) are in review stage.

National regulations, which establish processes for taking different enforcement actions are being drafted and address cancellation and suspension of license, mechanisms for dispute resolution and award of penalties.

2.1.2 Organization of PNRA

Slight changes in the organization of PNRA were made due to the establishment of the Centre of Nuclear Safety, School of Nuclear and Radiation Safety, etc. An Advisory Committee for Improving Utility–Regulatory Interface (ACIURI) was constituted in July 2005. Functions of ACIURI include giving recommendations on the PNRA regulations while maintaining a national tolerable level of risk and standard of safety, giving recommendations on the acceptability of impairments in the plants resulting from difficulties being faced by the utility and nuclear power plant suppliers and giving advice to facilitate smooth implementation of future nuclear energy generation programs.

PNRA carried out a self assessment of its performance in collaboration with the Lahore University of Management Sciences. Moreover, PNRA prepared a report for public on its performance from 2001 to 2005. A report for 2006 has also been published.

2.1.3 K-1 Relicensing

The second relicensing outage (RLO-II) of K-1 began in December 2005 to carry out the remaining safety upgrades. Major planned jobs have been completed. PNRA allowed restart of the plant in June 2006 and the plant was allowed to operate up to 90 MWe in October 2006. The revised and updated FSAR submitted to PNRA in February 2007 is being reviewed by PNRA and a decision on relicensing is expected by September 2007. The modifications and activities carried out during RLO-II are described in Article 19. Abnormal Transient Operating Guidelines have been revised on the basis of analysis performed during updating of KFSAR and due to addition of new components and systems. Two new guidelines have been added. Site seismology was re-investigated

[7] Third Review Meeting of the Contracting Parties 11-22 April 2005-CNS-RM-2005/08 FINAL

and the ‘g’ value was revised from 0.1 g to 0.2 g. The tsunami hazard at K-1 was assessed and it was determined that the plant is not threatened by tsunamis.

2.1.4 C-1 Operation

Operating licence was granted to C-1 in October 2004. The plant is operating satisfactorily since then and underwent refueling outages 3 and 4 (RFO-3 and RFO-4). At the end of each refueling outage, the licensee submitted a safety case for operation of the plant in the next cycle along with the documents specified in PAK/913. PNRA reviewed the safety case and allowed continuation of operation. Alarm Response Procedures are being developed to overcome human errors related to alarms and are expected to be completed by August 2008.

2.1.5 C-2 Construction

Licensing of C-2 is progressing satisfactorily. The Site Evaluation Report was approved by PNRA and site was registered. Preliminary Safety Analysis Report, Overall Quality Assurance Program and design PSA Report were reviewed and approved by PNRA and Construction Licence was issued. The design basis and beyond design basis accidents were considered at the design stage and modifications and improvements were made in the design. See Article 18 for details.

Construction at site and manufacture of equipment in China and Pakistan is progressing satisfactorily. The licensee and main contractor are carrying out quality assurance audits. Inspections are being carried out by PNRA at the site and at equipment manufacturing facilities.

A separate Safety and Licensing Division is established which is responsible for addressing all safety related issues. It has taken steps to cultivate safety culture right from the construction stage through trainings in the areas of Self Assessment, Corrective Action Program and Safety Performance Indicators. A Configuration Management Plan has been prepared and is being implemented in C-2. In addition, it is ensured that updated documents are available to C-2 personnel.

Probabilistic safety assessment was performed to balance the C-2 design. Analysis for several severe accidents sequences has been carried out and measures have been taken to reduce the probability of a severe accident and to mitigate its consequences. Decommissioning aspects have been considered in the design to facilitate dismantling. The design of the main control room has been improved with respect to human factors by using operating experience feedback from C-1.

2.1.6 Problems in procuring safety related items and services

Installation of a Loose Part Monitoring System (LPMS) was made a C-1 licence condition. The situation was reviewed at the completion of each refueling outage. As the LPMS could not be installed before the end of RFO-4, C-1 requested for a waiver till RFO-5 and took the following measures to ensure that no foreign material or loose parts are present within the reactor coolant system:

- **a.** all fuel assemblies to be loaded were visually inspected
- **b.** scope of visual inspection of reactor internals was extended to 100% to reduce the possibility of any loose parts in the next operation cycle
- **c.** inspection and vacuum cleaning of reactor pressure vessel performed before putting back the lower internals
- **d.** inspection of lower core plate was performed before fuel loading
- **e.** strict implementation of foreign material exclusion program

Consequently, PNRA allowed re-start with the condition to install LPMS by RFO-5.

2.1.7 Strengthening and Capacity Building of Institutions

Pakistan took steps for strengthening and capacity building of institutions responsible for nuclear safety, design, human resource development, etc. In this regard, Government of Pakistan approved several projects to be financed from the public sector development program. These included institutes of PAEC such as PIEAS[8], CHASCENT[9], KINPOE[10], Directorate of Nuclear Power Engineering, Pakistan Institute of Nuclear Science and Technology, etc. In addition, capacities of institutes responsible for manufacturing and quality control are also being enhanced.

Capacity building of PNRA that started a few years ago continued and the Centre for Nuclear Safety and School of Nuclear and Radiation Safety were established and financed from the public sector development program. In addition, projects have been approved to set up infrastructure for country-wide environmental surveillance, dosimetry services and calibration laboratories, etc.

2.1.8 Severe Accident Management Guidelines

K-1 completed a study of severe accident scenarios including containment behavior, metal water reaction and hydrogen generation. Severe accident management guidelines will be developed.

C-1 started work on symptom based EOP. The expertise so developed will be used later to prepare severe accident management guidelines (SAMG) for handling severe accidents. Data and information needed to carry out the task is being collected. Work started in February 2007 and will be completed in 30 months.

C-2 committed to prepare severe accident management guidelines. C-2 personnel are being trained on SAMG development.

2.1.9 Enforcement Program of PNRA

PNRA has, under its internal management system, established PNRA Enforcement Program. However, national regulations which establish processes for taking different enforcement actions including cancellation and suspension of licence, mechanisms for dispute resolution and award of penalties, etc., are under review.

2.1.10 Emergency Preparedness

After the earthquake of 8 October 2005, there was a realization that the emergency preparedness programs should be improved to handle emergencies due to natural and man-made calamities. Legislation for the establishment of National Disaster Management Commission (NDMC) and National Disaster Management Authority (NDMA) was enacted. The Commission provides policy guidelines and oversees the work of the NDMA. The NDMA coordinates with the relevant federal and provincial departments such as district governments, army, civil defence, etc., to implement the plans and disseminate information up to the district level. These organizations have been established at the federal level and it is expected that similar authorities will be established at provincial and district level. In addition, data on organizations involved in activities which have the potential to create man-made calamities have been collected to develop the hazard map of Pakistan. Emergency preparedness programs of such organizations will be integrated in the overall national, provincial and district level plans.

PNRA has increased its interaction with governmental organizations and ensures their participation in its regulatory activities. Representatives from NDMA, federal ministries and other concerned organizations were invited to observe the fourth integrated exercise of C-1. This practice would be continued and further expanded.

[8] Pakistan Institute of Engineering and Applied Sciences
[9] CHASNUPP Centre of Nuclear Training
[10] KANUPP Institute of Nuclear Power Engineering

2.1.11 Radioactive Waste Management

In July 2005, Regulations on Radioactive Waste Management PAK/915 were issued. These regulations set requirements for all aspects of radioactive waste management, including collection, segregation, characterization, classification, treatment, conditioning, storage, and disposal, where the waste arises from the operation and decommissioning of nuclear installations and the cleanup of contaminated sites.

PAEC allocated adequate resources for the safe management of radioactive waste in the country and to deal with decommissioning activities of the plants. Draft National Policy on Radioactive Waste Management was prepared which ensures safe and secure management of radioactive waste. It has been reproduced in Article 19.

2.2 Special Reporting

The President of the TRM prepared a Summary Report[11]. It summarized the discussions based on the national reports and presentations during the peer review process. In the observations and conclusions, several areas were identified for special reporting. The following sections present the status and progress made by Pakistan in these areas.

2.2.1 International Peer Review

Pakistan has followed a policy of transparency, openness, continuous learning and improvement and sharing of its experience with others. Several missions have visited nuclear installations and PNRA offices for peer reviews.

A RaSIA[12] mission visited PNRA in 2005. A full scope IRRS[13] mission was invited to review the PNRA performance in August 2007. The mission has now been scheduled to visit PNRA in early 2008. In addition, PNRA presents its performance on selected subjects in the annual meetings of NERS[14]. PNRA has presented its national reports before the review meetings of the Convention on Nuclear Safety for peer review.

PNRA invited a peer review mission from the National Nuclear Safety Administration (NNSA) China to review the organization and functions of Centre for Nuclear Safety which is the technical support organization of PNRA.

Similarly, several peer review missions from WANO[15] and IAEA visited the power plants.

2.2.2 Quality Management Systems within Regulatory Bodies

PNRA took initiatives to establish and document its quality management system in accordance with the requirements of internationally acceptable standards and quality management systems of other regulators. A bottom-up approach is being adopted for the development of PNRA QMS. Accordingly, management processes are being described in the form of programs, procedures and plans. The next step would be to integrate these processes into a documented QMS manual which would also include policy statement of PNRA on quality. Gap analysis of quality management system is in progress and a checklist was prepared to analyze gaps in the core functions of PNRA.

2.2.3 Methodologies for Analyzing Human Factor Events

Root cause analysis is performed for analyzing events caused by human errors. At K-1, database of all events is maintained under the Corrective Action Program. Human performance issues are coded and trended. Separate investigations are initiated for events showing adverse trends to determine the causes. Focused self-assessments were carried out to ensure that human performance issues are appropriately addressed.

[11] CNS-RM-2005/08 FINAL
[12] Radiation Safety Infrastructure Appraisal
[13] Integrated Regulatory Review Service
[14] Network of regulators of countries with small nuclear programs
[15] World Association of Nuclear Operators

At C-1, Alarm Response Procedures are being developed and are expected to be completed by August 2008 to overcome human errors related to alarms.

In Probabilistic Safety Assessment reports, human error probabilities are calculated for the errors, which are due to procedural lapses or operator errors through Human Reliability Analysis (HRA). These inputs are fed into simulator training to minimize human error. In case of C-2, HRA was performed in PSA to assess contribution towards initiating events. Based on this analysis, improvements have been suggested in the design and will be considered while writing procedures.

2.2.4 Notification of Nuclear Emergencies to Neighbouring Countries

Nuclear installations in Pakistan are located far from the international boundaries. Therefore, rather low possibility of trans-boundary effects exists in the case of a nuclear accident. Pakistan has signed the Convention on “Early Notification of a Nuclear Accident” and the Convention on “Assistance in the Case of a Nuclear Accident or Radiological Emergency”. In case of a nuclear incident in Pakistan or abroad, appropriate actions will be taken as required under the Conventions and under any bilateral agreement that exist between Pakistan and neighbouring countries.

2.2.5 High Collective Doses

During relicensing K-1 carried out several safety-related upgrades. ALARA[16] practices were followed during these activities and the doses received were always less than the estimated. Moreover, radiation exposure to all the radiation workers never exceeded the limits and in most cases were only a fraction of the limits. Similarly, the collective doses at C-1 show an increase during the refueling outages which is usual for a pressurized water reactor (PWR).

2.2.6 Risk-Informed Decision Making

One of the pre-requisite for risk-informed decision making is an accurate PSA. At present K-1 PSA can be used for risk-informed decision making. Allowable outage times for components of safety systems are specified in the OPP[17] of K-1. These had to be revised because of addition of new systems and increase in redundancy. These outage times were determined from PSA. Other than these changes, all other regulatory decisions were made deterministically.

2.2.7 Knowledge Management in PNRA

PNRA is assisting IAEA[18] in integrating existing nuclear data and information bases in the form of easily accessible Nuclear Knowledge Portals under the RAS/9/028 Asian Nuclear Safety Network. A CD-ROM containing structure of the NSK Portal along with relevant knowledge was prepared and shared with Member States to be used as a starting point for the development of their own Nuclear Safety Knowledge portals.

At the national level, PNRA initially developed an intranet website, accessible to the officers and staff of PNRA. This website covers main knowledge areas in which PNRA is working and whose knowledge is necessary for the staff of PNRA for proper accomplishment of their tasks. This arrangement will be used as a base line for development of Knowledge Management Portal of PNRA based on the international standards and professional expertise. The faculty of SNRS includes senior retired engineers who used to work in PAEC. They provide guidance and mentoring to the students of the School.

[16] As Low As Reasonably Achievable
[17] Operating Policies and Principles
[18] International Atomic Energy Agency

2.3 Progress on the Conclusions of the Peer Review on TNR of Pakistan

During the Third Review Meeting, the Country Group Rapporteur identified areas where Pakistan planned to improve safety and would be discussed at the Fourth Review Meeting. Actions taken in these areas are presented below.

2.3.1 Continuous Improvements in Nuclear Competence

PNRA initiated a multi-faceted program to develop and improve nuclear competence for its engineers, scientists and other professionals. The Human Resource Directorate and the School of Nuclear and Radiation Safety conducted orientation courses which were mandatory for new inductees. Qualifying some of the higher level courses is a requisite for promotion to higher posts. In addition, specialized courses were arranged on newly acquired software.

PNRA established contacts with several national universities where PNRA officers attended short courses. Selected courses offered by the Pakistan Institute of Management were attended by PNRA officers. PNRA and PAEC shared their training programs (including workshops, symposium, etc.) and officers from both organizations participated in these activities.

Building and improving competency remained the mainstay of the technical cooperation program with IAEA. PNRA made arrangements with the regulatory body of China to get PNRA officers trained at their technical support organization and their regional offices located at the nuclear installation sites. All Directorates have an informal program of mentoring and on-the-job training of officers. PNRA also sends its officers for training courses in national institutes like, PIEAS, CHASCENT, KINPOE, PWI[19], NCNDT[20], etc.

2.3.2 Assessment of Adequacy of KANUPP Upgrading

KFSAR revision-2 included the update of the design descriptions and accident analysis sections. Design description part had been updated by taking into account the design changes, modifications and updates carried out in the plant during relicensing. Dual accident analysis was also updated using latest computer codes and accident analysis tools. The effects of improvements in LOCA[21] handling and emergency core cooling system were analyzed in the revisions of accident analysis section of KFSAR-R2 and results show that all the modifications and upgrades fulfill their desired functions.

The national regulations are based on IAEA standards and formed the bases for review of KFSAR. Verification of compliance with national regulations will imply adequacy of the upgrades at K-1 and conformance with IAEA standards. The safety review of KFSAR is expected to be completed by September 2007.

2.3.3 Application of National Regulations Based on IAEA Safety Standards Nuclear Power Plant Licensing

The applicability of national regulations to C-2 which are based on IAEA requirements was verified through the review of C-2 SER and PSAR. PNRA experienced no significant difficulty in applying the national regulations to the licensing process. In addition, through an IAEA TC project, fifteen chapters of the C-2 PSAR were reviewed against the IAEA requirement documents and safety guides. The issues identified by the IAEA experts were mostly resolved during discussions with the designers. Some of the issues were taken up by PNRA and included in the regulatory safety review. These were also resolved in review meetings through commitments made by the owner/designers**.**

Pakistan's experience shows that IAEA safety standards and the national regulations provide a reasonable basis for nuclear power plant licensing.

[19] Pakistan Welding Institute
[20] National Center for Non-Destructive Testing
[21] Loss of Coolant Accident

2.3.4 Progress on Management of Safety and Safety Culture

It was reported in the Third National Report (TNR) that an inspection was planned in the end of 2004 for observing the safety culture at nuclear installations. PNRA conducted a safety culture inspection at K-1 in December 2004 and another in June 2007. At C-1 an inspection of safety culture was performed in June 2005.

The information and data on safety culture originated primarily from the notes and reports of resident and PNRA HQ inspectors observed during plant tours, review of documents, interviews with plant personnel, record of compliance with regulatory requirements and licence conditions including station policies and procedures, etc. It was supplemented by the review of events and near misses reports, post event inspections and licensees' self assessments.

In its safety culture inspections, PNRA verified that the licensee is placing special emphasis on safety in operation and is establishing and implementing policies that give safety matters the highest priority. It was determined that the attitude of management and individuals is generally positive and there is a desire to improve. Their strengths lie in realization of the issues involved and making efforts to resolve these. Individuals are motivated, culture of openness and transparency exists, and no-blame-culture is practiced. It was concluded that the safety culture in nuclear installations is generally satisfactory. Recommendations made in these inspections are being implemented by the licensees and followed up by PNRA.

2.3.5 Enhancement of International Cooperation

PNRA believes that the regulatory efficiency and effectiveness can be increased through international cooperation. It has an extensive program in the area of international cooperation which has been further expanded in the last three years.

The main focus is on cooperation with IAEA and with other nuclear regulatory bodies. The TC Project PAK/9/028 is being implemented smoothly while PAK/9/029 has been completed. One new project PAK/9/030 has been awarded to PNRA. PNRA is participating in several Regional Asia projects notable being RAS/9/043, RAS/9/045 to 050. In addition, PNRA is participating in IAEA activities related to Knowledge Management, Advisory Group on Nuclear Security (AdSec), Standard Review Committees[22], Commission on Safety Standards (CSS), Safety Analysis Report Review Plan (SARRP), etc. Several expert missions visited PNRA and PNRA officials availed scientific visits under the auspices of IAEA programs. PNRA is actively participating in the Extra Budgetary Program on Seismic Safety and the CASAT-Software Centre. PNRA made financial contributions to both the programs and its personnel are working at IAEA HQ on CASAT.

PNRA improved bilateral relations with National Nuclear Safety Administration (NNSA) of China, US Nuclear Regulatory Commission, Center for Nuclear Safety (CENS), etc. PNRA hosted the eighth annual meeting of NERS in 2005. During this meeting, PNRA was entrusted to develop and operate the e-secretariat[23] of NERS which PNRA is operating since then. PNRA also established contacts with STUK[24], Research Institute of Nuclear Power Operation (RINPO), Korean Institute of Nuclear Safety (KINS) and Nuclear Power Plant Research Institute (VUJE) of Slovakia.

PNRA was assisted by NNSA in the review of the C-2 PSAR and in carrying out QA inspections at manufacturing sites in Pakistan and China. NNSA is also providing training opportunities to PNRA staff at the Nuclear Safety Center and at the Qinshan site.

[22] These include Nuclear Safety Standards Committee (NUSSC), Radiation Safety Standards Committee (RASSC), and Transport Safety Standards Committee (TRANSSC).
[23] Please see the website **www.ners.info** for more information.
[24] the nuclear regulatory authority of Finland

2.3.6 Technical Support Organization of PNRA

Centre for Nuclear Safety (CNS) was established in June 2005 as the technical support organization to strengthen and improve the regulatory capabilities of PNRA. The main functions of CNS are to improve the capability of PNRA in performing review and assessment of regulatory documents submitted by the applicants/licensees and to perform audit calculations and R&D.

Recruitment in CNS is now complete and the required competencies are being developed. The CNS officers are participating in various programs for competency building at national universities, nuclear installations, IAEA and nuclear regulatory bodies abroad.

Since its establishment CNS has acquired several computer codes which are intended to be used for audit calculations. Some of these are Risk Spectrum, ANSYS, FLUENT, SAP, PIPESTRESS, WRC, Taproot and UNIGRAPHICS.

2.3.7 Development of capability in PSA

PNRA has been striving to develop the capability to review the PSA submitted to it by its licensees and has increased its efforts in this direction. So far PNRA has performed regulatory reviews of three reports submitted by the licensees (K-1, C-1 and C-2). PSA level 1 were submitted by K-1 and C-1, whereas C-2 submitted a design PSA. PNRA has acquired the software “Risk Spectrum” and has developed capability for using it. Several workshops were conducted in the area of PSA with the assistance of IAEA and other organizations. PNRA personnel were sent abroad for training and were attached with K-1 and C-1 PSA teams for on-the-job training.

3. Future Challenges

The future challenges faced by Pakistan are mainly linked to providing food, shelter, clothing, education and employment to a very large and growing population. The degradation of environment and its adverse effects on the health of the public, irrigation and drinking water, etc. are to be considered while deciding on the means of generating energy, especially the electrical energy. Nuclear is an option which can provide abundant, safe, secure, sustainable and affordable energy and can fuel the growth of the economy. Pakistan faces problems due to the discriminatory restrictions with regards to access to nuclear power technology and nuclear power plants. Despite the significance attached to nuclear safety at international level, Pakistan has been facing problems in procurement of safety related equipment even when recommended by IAEA. The prime challenge is to get equitable access to nuclear technology for peaceful uses and install nuclear power plants to meet the future energy needs.

The next challenge would be to further improve the existing capability to design, construct and operate the nuclear power plants safely and economically. This would depend upon a sound safety culture, broad base of scientific and engineering knowledge, indigenous capabilities for manufacturing nuclear power plants components, an effective and efficient regulatory body, manpower with the necessary academic qualifications and nuclear competency, etc. The national grid needs to be further improved, its stability increased and reactive power reduced. These challenges are to be met earnestly and without delay.

Other challenges are related to installation of new nuclear power plants of GEN[25] III as the present plants are now expected to remain in operation for the next sixty (or may be eighty) years. The idea of global nuclear safety regime is taking roots and it may not be possible to operate GEN II plants after a few decades from now. International cooperation is essential for success in this area and Convention on Nuclear Safety can be used to meet the aforementioned challenges. This forum can be used for removal of restrictions on sharing of knowledge related to nuclear technology and the trade of nuclear installations and their components. It can be a forum for improving international cooperation for the development of comprehensive nuclear safety standards and for providing guidance and assistance in meeting these standards with due regard to sovereignty of nations.

[25] Generation III

Article 4 – Implementing Measures

> *"Each Contracting Party shall take, within the framework of its national law, the legislation, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention".*

4. Implementing Measures

This report presents legislative, regulatory and administrative measures and steps that Pakistan has taken, within the framework of its national law, which are necessary for the fulfillment of its obligations under this Convention. These measures have been described earlier in the first, second and the third national reports. The main legislative instruments have been enacted and essential national regulations are in place. An approach of continuous and gradual fulfillment of the safety obligations is adopted by Pakistan and priority is given to the most safety significant issues.

Pakistan has, therefore, met the obligations of Article 4 of the Convention.

Article 5 – Reporting

> *"Each Contracting Party shall submit for review, prior to each meeting related to in Article 20, a report on the measures it has taken to implement each of the obligations of this Convention".*

5. Reporting

After signing the Convention on Nuclear Safety, the first, second and the third national reports were submitted and were reviewed by the contracting parties in the review meetings. This is the fourth national report by Pakistan in compliance with Article 5 of the Convention.

Pakistan has, therefore, met the obligations of Article 5 of the Convention.

Article 6 – Existing Nuclear Installations

> *"Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact."*

6. Existing Nuclear Installations

Pakistan took appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention on Nuclear Safety became effective was reviewed as early as possible. These steps were described in the previous reports.

Pakistan has reported on its existing nuclear installations, as defined in Article 2 of the Convention, to the CNS Secretariat. Existing nuclear installations are listed in Annex – I. The list includes the under construction Chashma Nuclear Power Project Unit–2 (C-2).

6.1 Karachi Nuclear Power Plant

Karachi Nuclear Power Plant (K-1) completed its thirty (30) years design operating life in 2002 and is the only pressurized heavy water reactor in the world that is undergoing life extension and relicensing. National regulations[26] PAK/909 allow renewal of licences of nuclear installations for operation beyond design life.

So far K-1 has fulfilled most of the relicensing requirements identified by PNRA. These include the installation of a screen around the active drainage sumps, third emergency diesel generator, a system capable of adding heavy or light water to the primary heat transport system, a medium pressure forced light water injection system, provision of redundant and diverse valves in the IJW[27] system, improvement in control room habitability, automation of emergency feed water system to the secondary side of steam generators, anchoring racks of DC battery banks, new delayed neutron monitoring system for failed fuel detection, etc. In addition, feeder pipe thinning inspection, condition assessment of steam generators and fuel channels, removal of booster rods, etc., were carried out. Several loops of ageing I & C were replaced including the regulating computers. Besides above-mentioned safety upgrades, maintenance and overhauling of a large number of plant equipments (pumps, motors, valves, heat exchangers, piping, etc.) was carried out as part of the Aging Management Program.

The submission of required safety documentations to PNRA by K-1 continued till March 2007. PNRA is reviewing these documentations to verify compliance with national regulations. A decision on relicensing of K-1 is expected in the last quarter of 2007. Meanwhile, based on the safety reviews and inspections carried out so far and the implementation of the required upgrades, K-1 has been allowed to operate up to 90 MWe. Few significant design parameters of K-1 are presented in Annex – II.

[26] Complete list of national regulations is presented in Annex V and complete text of officially notified regulations is available on PNRA web site (www.pnra.org)
[27] Injection Water System - similar to emergency core cooling system in other reactor designs.

6.2 Chashma Nuclear Power Plant Unit–1

Chashma Nuclear Power Plant Unit – 1 (C-1) was connected to the grid in June 2000 and began full power commercial operation in September 2000. The plant has been operating according to approved technical specifications. The operating licence (OL) was issued in October 2004.

Some significant design parameters of C-1 are given in Annex – III and summary of the last two refueling outages is provided in Annex – IV.

6.3 Chashma Nuclear Power Project Unit – 2

Chashma Nuclear Power Project Unit – 2 (C-2) is presently under construction. It will be a two loop PWR type reactor with gross output of 325 MWe. This will be an improved version of C-1 with similar design. Several modifications have been incorporated in the design to improve safety based upon C-1 operating experience and PSA studies. Three new systems have been included in C-2 design to mitigate the consequences of severe accidents.

A review of C-2 Preliminary Safety Analysis Report (PSAR) was performed by PNRA. C-2 PSAR was also reviewed by fifteen expert missions of IAEA as part of an IAEA Technical Cooperation Project. One follow-up mission also conducted. On the basis of the safety review, it was concluded that the plant design was in conformance with the national nuclear regulations. The construction licence was issued in March 2006.

Continuous inspection of construction is being carried out by resident inspectors of PNRA to ensure compliance with PSAR. Furthermore, control points have been selected by PNRA for inspection during manufacturing of safety related equipment to verify that the quality of equipment is according to applicable codes and standards.

Pakistan has, therefore, met the obligations of Article 6 of the Convention.

Article 7 – Legislative and Regulatory Framework

> *"1.Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.*
>
> *2.The legislative and regulatory framework shall provide for:*
>
> *(i) the establishment of applicable national safety requirements and regulations;*
>
> *(ii) a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a license;*
>
> *(iii) a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and terms of licenses;*
>
> *(iv) the enforcement of applicable regulations and of the terms of licenses, including suspension, modification or revocation."*

7. Legislative and Regulatory Framework

Pakistan has established a framework to regulate nuclear installations. This framework establishes, under the Ordinance, national regulations and safety requirements. A system of licensing of nuclear installations is established that prohibits their operation without a licence. Compliance with licence conditions is ascertained by regulatory inspections and assessments and enforced with suspension, modification or revocation of licences.

7.1 Regulatory Framework

The highest level document in the framework is the Pakistan Nuclear Regulatory Authority Ordinance 2001. The next tier is mandatory national regulations based on internationally acceptable requirements. Below these are non-mandatory guides which describe methods acceptable to PNRA to meet the requirements of regulations. Other methods can be adopted provided it can be demonstrated to the Authority that the proposed method achieve the same level of safety and quality. At the bottom are the standards referred to in the guides, internationally used industrial standards or industrial standards of the exporting countries.

7.2 Pakistan Nuclear Regulatory Authority Ordinance 2001

The Ordinance provides the statutory basis for the Authority. It defines the functions and responsibilities of PNRA, mechanism for determining civil liability, penalties that can be imposed in case of violations, sources of funds of the Authority, procedure for transition to newly established Authority, continuity of regulatory infrastructure and decisions, etc. No amendments have been made in the Ordinance since its promulgation.

The Ordinance empowers PNRA, in addition, to:

- **a.** make regulations, not inconsistent with the Ordinance and rules, for carrying out the purposes of the Ordinance under which the applicable safety requirements are established
- **b.** prohibit a person to establish nuclear installations in Pakistan unless licensed
- **c.** inspect all nuclear installations, nuclear substances or radioactive materials to ensure that regulations are properly followed
- **d.** cancel or suspend a licence if a person is found to have contravened any of the provisions of the Ordinance, regulations, or has failed to comply with the conditions of a licence
- **e.** enter into treaty with national and international organizations.

The Ordinance provides for a procedure for review of, and appeal against, regulatory decisions without compromising safety. The appeal against such decisions is heard by a tribunal. It is constituted when an appeal is filed.

7.3 National Regulations

Pursuant to PNRA Ordinance, PNRA is empowered to issue regulations. The procedure for issuing regulations is comprised of the following steps:

- **a.** preparation and review of the first draft of the regulations within PNRA
- **b.** seeking comments of licensees of nuclear installations
- **c.** incorporation of their comments as far as possible
- **d.** submission of updated draft to the Authority for approval
- **e.** formal official notification (publication in the Gazette of Pakistan)

List of national regulations which have been officially notified so far, or which are in the draft form or are under consideration is presented in Annex – V.

In October 2001, national regulations PAK/909 [28] were issued. These regulations establish a system of licensing for the nuclear installations comprising site registration, construction licence, fuel load permit, operation licence and licence beyond design life. It also required the licensee to allow inspections by PNRA during all the phases of plant life. These regulations also prescribe the applicable nuclear safety standards for siting, design, operation and quality assurance.

The national regulations PAK/911[29] were officially notified In January 2002,. These regulations establish requirements for the safe design of nuclear installations and are based on IAEA nuclear safety standard NS-R-1. In these regulations, emphasis is placed on rigorous application of defence in depth, management of design, proven engineering practices, consideration of severe accidents at the design stage, etc.

In September 2003, national regulations PAK/912[30] were issued, establishing requirements for the quality assurance during all phases of plant life. It provides for the establishment of QA programs, training and qualification of personnel, control of documents and records, performance of activities, procurement of items and services, self-assessments and audits, etc.

The national regulations PAK/913[31] were officially notified In December 2004,. These regulations establish requirements related to safe operation of nuclear installations. These include licensee's management elements; QA, emergency preparedness, fire safety, physical protection, feedback of operating experience, qualification and training of personnel, etc. In addition, several criteria have been laid down in Annexes; such as criteria for heads of nuclear installations, station health physicist, operating personnel licences, PWR refueling, and fracture toughness requirements to protect reactor pressure vessel (RPV) against pressurized thermal shock events.

In July 2005, regulations on Radioactive Waste Management PAK/915[32] were issued. These regulations set requirements for all aspects of management of radioactive waste arising from operation and decommissioning of nuclear installations and clean up of contaminated sites that include collection, segregation, characterization, classification, treatment, conditioning, storage, and disposal.

[28] Regulation on Licensing of Nuclear Installation (s) in Pakistan
[29] Regulations on Safety of Nuclear Power Plants-Design
[30] Regulations on Safety of Nuclear Power Plants-Quality Assurance
[31] Regulations on Safety of Nuclear Power Plants-Operation
[32] Regulations on Radioactive Waste Management

The national regulations on radiation protection PAK/904[33] were issued in October 2004. These are also applicable to nuclear installations and specify annual dose limits for radiation workers and the public.

In April 2007, the regulations PAK/916[34] were officially notified. These regulations set requirements for transport of radioactive material by all modes on land, water and air in Pakistan. These regulations require that the IAEA Regulations for the Safe Transport of Radioactive Material, TS-R-1, 1996 edition (as amended 2003) shall be followed for the transport of radioactive material under PAK/916 within Pakistan.

The regulations PAK/900[35] were officially notified in May 2007. These specify the licence fee that PNRA can charge for issuance and renewal of various licences. It also gives the schedule for surcharges to be levied on late payments of licence fees.

Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – PAK/907 (Rev.0) and Regulations on the Safety of Nuclear Power Plants – Site Evaluation PAK/910 (Rev.1) have been finalized and will be officially notified after the approval of the Authority. Regulations on Management of a Nuclear or Radiological Emergency – PAK/914 (Rev. 0) are in review stage.

Under PNRA Ordinance enforcement actions can be taken in case of violations and non-compliances of the Ordinance, regulations and conditions of a licence. PNRA has, under its internal management system, established “PNRA Enforcement Program”. However, national regulations which establish processes for taking different enforcement actions are under review. These draft regulations address cancellation and suspension of licence, mechanisms for dispute resolution and award of penalties.

7.4 PNRA Guides

PNRA and its predecessors issued a number of guides. These guides were based on IAEA Nuclear Safety Standards issued in 1988. However, IAEA has issued a new series of safety guides which PNRA intends to adopt in future. In addition, PNRA is making efforts to issue guides in important areas to provide guidance. In areas where PNRA guides are unavailable, PNRA accepts, under provisions of PAK/909, the guidance from regulatory guides of USNRC or IAEA.

7.5 Industrial Standards

The USNRC regulatory guides specify internationally used industrial standards such as ASME, IEEE, etc. These standards can be used by the licensees. In addition, the industrial standards of the exporting countries such as RCC-M of France or GB of China can also be used. If necessary, international standards such as ISO, IEC, etc. can also be referred.

Pakistan has, therefore, met the obligations of Article 7 of the Convention.

[33] Regulations on Radiation Protection
[34] Regulations for the Safe Transport of radioactive Material – PAK/916
[35] Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority – PAK/900 Rev.0

Article 8 – Regulatory Body

"1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfill its assigned responsibilities.

2. Each Contracting Party shall take the appropriate steps to ensure an 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."

8. Regulatory Body[36]

Pakistan established PNRA which has been entrusted with the implementation of the regulatory framework. Necessary authority is vested in PNRA and is provided with human and financial resources to fulfill its assigned responsibilities.

8.1 Vision and Mission of PNRA

The vision of PNRA is to become a world class regulatory body with highly trained, competent and dedicated personnel working in unison with zeal to foster a positive safety culture in their licensees. It should regulate nuclear installations to protect the public, workers and the environment from the harmful effects of radiation in a manner that wins the confidence of all the stake holders such as the public, the Government and the licensees.

The mission of PNRA will be fulfilled by formulating and implementing effective regulations, building a relationship of trust with the licensees and maintaining transparency in its actions and decisions.

8.2 Legal Basis of PNRA

PNRA Ordinance provides the legal basis. It describes the constitution of the Authority, tenure and eligibility of its Chairman and the Members, interface with Government of Pakistan, etc. PNRA is the only regulatory authority responsible for regulating nuclear safety and radiation protection. Environmental Protection Agency regulates all aspects of environment protection except for radiological impact which is regulated by PNRA.

8.3 Organization of PNRA

The organizational set up of PNRA is continually under review and is revised as and when found necessary. As provided for in the Ordinance, PNRA comprises of a Chairman, two full-time and seven part-time members. The Federal Government appoints the Chairman and the Members. Chairman is the chief executive of the Authority and reports to the Federal Government on all matters related to nuclear safety and radiation protection. Annex – VI shows the organizational structure of PNRA.

PNRA is organized on the basis of executive and corporate wings; headed by Executive Member and the Corporate Member respectively. The executive wing is responsible for core functions of the Authority, whereas the corporate wing is responsible to drive the Authority as an organization. The Secretary of the Authority, the Advisory Committees and the Director-General of the Chairman Secretariat reports directly to Chairman. The latter assists Chairman in planning of future activities of PNRA.

There are two Directors-General under the Executive Member; namely D-G (Technical) and D-G (Inspection & Enforcement). The former looks after the three Technical Directorates, whereas the latter looks after the three regional directorates. The Corporate

[36] For details please visit PNRA website www.pnra.org

Member has under him the Establishment Section and the corporate wing.
D-G (Corporate) looks after the activities of the corporate wing which comprises of six Directorates. The Directorates of Administration and Finance report to both members and perform their assigned functions for both wings. The main functions of some of the Directorates are given below:

Directorate of Nuclear Safety (NSD) – NSD is responsible for matters related to the safety of nuclear installations. It establishes and maintains regulatory framework for nuclear safety. Licensing of nuclear installations including approval of modifications, periodic safety reviews and relicensing are also in the domain of this Directorate.

Directorate of Radiation Safety (RSD) - RSD is responsible for regulation and supervision of matters related to radiation protection. It ensures that harmful effects of radiation on human health and the environment arising from licensed activities are As Low As Reasonably Achievable (ALARA). RSD operates the National Radiation Emergency Coordination Centre (NRECC). It is the national and international focal point for notifying nuclear or radiological emergencies.

Directorate of Transport and Waste Safety (WSD) - WSD is responsible for regulating matters related to radioactive waste management, safe transport of radioactive materials, safety and security of radioactive sources and decommissioning of nuclear installations. It establishes and maintains regulatory framework in these areas and ensures compliance with regulatory requirements through joint regulatory inspections with regional directorates.

Regional Nuclear Safety Directorates (RNSD) – The regional directorates are responsible for inspections and enforcement within their areas of jurisdiction and monitor activities at the plant affecting safety. RNSD conducts routine and special regulatory inspections to provide a high level of assurance that all activities performed at the installations during all stages of licensing process and all phases of the life cycle of a nuclear installation are executed according to regulations and conditions of licence. The areas covered by inspection programs are radiation protection, operations, maintenance, testing and surveillance, quality assurance, emergency preparedness, industrial safety, fire protection, etc.

Directorate of Human Resource Development (HRD) – HRD is responsible for developing and improving competency of PNRA personnel. Its functions are divided into three main categories; a systematic assessment of future manpower requirements of various directorates, recruitment of manpower and organizing professional trainings and retraining courses for competency development and improvement.

Directorate of Information Services (ISD) – ISD maintains computer networks, PNRA library, conducts media campaigns for public education and awareness, issuance of press releases on important matters and interaction with the media.

Directorate of International Coordination (ICD) – ICD interacts with IAEA and other international bodies for visits/trainings/workshops. ICD also facilitates security clearance/visa of foreign experts and departure formalities for PNRA officials while proceeding on visits or training abroad.

Directorate of Regulatory Affairs (RAD) – RAD is responsible for preparing annual performance reports for submission to the GoP and for the general public. It coordinates with the government, autonomous and semi-autonomous organizations having a stake in PNRA activities. It performs self assessment of regulatory effectiveness and develops performance indicators and programs for improving performance. It is also responsible for development of quality policy, quality management manual and lower tier procedures. Issuance of national regulations is also one of its responsibilities.

Center for Nuclear Safety (CNS) – Under a project approved by the GoP, PNRA

established CNS within the corporate wing as its technical support organization. It was established with the main objective of strengthening and enhancing the existing regulatory capabilities. CNS is acquiring nuclear safety and radiation protection related software and is developing competence for their use and application. This will be helpful in the review and assessment of the documents submitted along with the application for licences for nuclear installations in future.

School of Nuclear and Radiation Safety (SNRS) – GoP approved a project for establishing the School of Nuclear and Radiation Safety to develop regulatory-specific competencies, knowledge, skills and abilities of technical officers through indigenous training programs in order to improve effectiveness and efficiency of the organization.

Advisory Committees – Three advisory committees have been established, namely, Advisory Committee on Research and Development (ACRD), Advisory Committee on Draft International Safety Standards (ACISS) and Advisory Committee for Improving Utility – Regulatory Interface (ACIURI). The committees are autonomous in their working and present their recommendations to Chairman PNRA.

The ACRD is responsible to identify research topics in the fields of nuclear energy, applications of ionizing radiation and management of radioactive waste and to bring together national research institutes in the country to collaborate on these research topics. ACISS reviews the IAEA draft documents with the objective to see if the IAEA standards are applicable to the developing countries specially Pakistan. This review is done independently from the review done by PNRA Technical Directorates. ACISS also advise PNRA on actions needed to adopt and implement these standards.

ACIURI was constituted in July 2005. The members of the committee represent all the stakeholders (public, GoP, universities, PAEC and PNRA) concerned with nuclear safety issues. Functions of ACIURI include giving recommendations on the PNRA regulations while maintaining a national tolerable level of risk and standard of safety, giving recommendations on the acceptability of impairments in the plants resulting from difficulties being faced by the utility and nuclear power plant suppliers and giving advice to facilitate smooth implementation of future nuclear energy generation programs.

8.4 Offences and the Corresponding Penalties

Violation of any provision of the Ordinance or of rules and regulations made under the Ordinance is a criminal offence and is punishable by fine up to one million rupees or seven years imprisonment or both.

8.5 Human Resources

Prior to the establishment of PNRA, Directorate of Nuclear Safety and Radiation Protection (DNSRP) was the de facto nuclear regulatory body. It was a part of PAEC and depended heavily on other departments of PAEC. After the promulgation of the PNRA Ordinance, DNSRP was absorbed in PNRA and links with PAEC ceased. PNRA faced shortage of technical manpower and support. A program for recruitment and training of manpower was started in 2002. As of June 2007, there were 207 professionals in PNRA (please see Annex – VII). New inductees have to qualify basic orientation courses before absorption in the PNRA. Training opportunities are arranged with the assistance of IAEA and other nuclear regulatory bodies. Agreements and memoranda of understanding have been signed with several national universities and institutes for training PNRA staff and for R&D in nuclear safety.

The manpower requirements of each Directorate are assessed regularly and manpower distribution is made according to the workload of the Directorate and nature of its activities. Special teams comprising professionals drawn from all Directorates are formed in the case of tasks such as review of SER, PSAR, etc.

8.6 Financial Resources

Funds provided to PNRA consist of grants from the federal government, income from the licence fees, international assistance, etc. These funds are adequate to meet the current financial requirements of PNRA. PNRA is financially independent of the organizations it is regulating.

8.7 Separation between Regulatory and Promotional Functions

No function or responsibility assigned by the Ordinance to PNRA is related with the promotion of nuclear energy, and none of its functions and responsibilities conflict with its responsibility for regulating nuclear safety and radiation protection. PAEC or any other organization, responsible for promotion or utilization of nuclear energy or ionizing radiation, does not have any regulatory function. Moreover, Chairman PNRA reports to the Prime Minister of Pakistan who is the head of the Government. This feature, among others, ensures the independence of PNRA.

8.8 Monitoring and Evaluation

PNRA has a self assessment program for monitoring and evaluating its performance on the basis of twelve indicators. These indicators are shown in Annex – VIII. An annual report describing the performance of PNRA, judged against the twelve indicators, is submitted to the Government. PNRA prepared a report for public on its performance from 2001 to 2005. A report for 2006 has also been published. Performance reports will be published annually.

In 2006-07, PNRA conducted a self assessment of its performance in collaboration with the Lahore University of Management Sciences (LUMS). An International Regulatory Review Team (IRRT) conducted a review of the performance of PNRA in December 2003. Later a RaSIA mission visited PNRA in 2005. As a follow up to the IRRT and RaSIA missions, PNRA invited a full scope IRRS. This review will now be conducted in early 2008.

8.9 Cooperation with National/International Organizations

PNRA cooperates with other government bodies to carry out its regulatory activities effectively and efficiently. This enables the stakeholders to play their roles in improving nuclear and radiation safety in the country.

PNRA is cooperating with international organizations. PNRA is participating in IAEA TC program and projects PAK/9/028 and PAK/9/030 are progressing satisfactorily. PNRA is participating in RAS/9/043, RAS/9/045 to 050. In addition, PNRA participated in IAEA activities related to Knowledge Management, CASAT – Software Center, Advisory Group on Nuclear Security (AdSec), Commission on Safety Standards (CSS) and Safety Standards Committees[37], Extra Budgetary Program on Seismic Safety, Safety Analysis Report Review Plan (SARRP), etc. Several expert missions visited PNRA and PNRA officials availed scientific visits under the auspices of IAEA programs.

PNRA promoted bilateral relations with National Nuclear Safety Administration (NNSA) of China, US Nuclear Regulatory Commission (USNRC), Center for Nuclear Safety (CENS), etc. PNRA hosted the eighth annual meeting of NERS. During this meeting, PNRA was entrusted to develop and operate the e-secretariat[38] of NERS which PNRA is operating since then. PNRA also established contacts with STUK[39], Research Institute of Nuclear Power Operation (RINPO), Korean Institute of Nuclear Safety (KINS) and Nuclear Power Plant Research Institute (VUJE) of Slovakia.

Pakistan has, therefore, met the obligations of Article 8 of the Convention.

[37] NUSSC, RASSC and TRANSSC.
[38] Please see the website **www.ners.info** for more information.
[39] the regulatory authority of Finland

Article 9 – Responsibility of the Licence Holder

> *"Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility."*

9. Responsibility of the Licence Holder

Pakistan has ensured that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence. Appropriate steps are taken to ensure that the licence holder fulfills this responsibility.

9.1 Statutory Requirements

PAEC is the owner and operator of the nuclear installations. It functions under the Pakistan Atomic Energy Ordinance 1965. This Ordinance requires that the Commission shall do all acts and things, including research work, necessary for the promotion of peaceful uses of atomic energy in the fields of agriculture, medicine and industry and for the execution of development projects including nuclear installations and generation of electric power.

The national regulation PAK/909 states that the licensee is directly responsible for the safety of the nuclear installation. It is also mentioned in PAK/911 that the licensee has the overall responsibility for safety. Similarly, according to the PAK/912, the licensee shall retain the responsibility for the effectiveness of the quality assurance program. PAK/913 also states that the licensee shall have the responsibility for safe operation of nuclear power plant.

The licensee shall retain prime responsibility for safety but it may delegate authority to the plant management for operation of the plant. In such cases, the licensee shall provide necessary resources and support to the plant management and ensure that the plant is operated in accordance with regulatory requirements.

9.2 Responsibilities of PAEC

The responsibilities of PAEC Headquarters and nuclear installations are described below.

9.2.1 PAEC Headquarters

According to the licence of the nuclear installations, issued by PNRA, PAEC is the licensee on record for the nuclear installations in Pakistan. However, PAEC has delegated its responsibilities related to the safe operation of the plant to the respective Directors-General[40] of the plants. PAEC is providing necessary financial and material resources as well as qualified and trained manpower for the nuclear installations to meet the requirements for:

- **a.** safe and continued operation of nuclear installations during the operating life
- **b.** safety upgrades/modifications needed for safe operation
- **c.** safe design, construction and operation of new nuclear installations

PAEC has established safety and quality infrastructure at the corporate and nuclear installation levels. At the corporate level, the Directorate of Nuclear Power Safety (DNPS) and Directorate of Quality Assurance (DQA) are established to advise the corporate management on safety and quality issues. At the nuclear installation level, Divisions having required authority and independence are in place, which are responsible for nuclear safety, licensing and quality assurance control of safety related

[40] Previously nuclear installations were headed by General Managers

activities. In addition, safety committees advise the Directors-General on safety and quality related issues.

Improving and strengthening the design and engineering capacity and competence to provide support to nuclear installations in engineering design has, among other benefits, a positive effect on enhancement of safety in nuclear installations. Accordingly, PAEC has established several new Directorates, affecting nuclear installation safety; notable among these are Directorate of Nuclear Power Engineering (NPE), Directorate of Nuclear Power Engineering Structures (NPES), Directorate of Nuclear Power Engineering Plants (NPEP) and Directorate of Nuclear Power Engineering Reactor (NPER). An abridged version of PAEC organizational chart is shown in Annex – IX.

9.2.2 Karachi Nuclear Power Plant (K-1)

At K-1, a KANUPP Safety Committee (KSC) exists at the plant level which meets regularly to discuss safety issues and gives recommendations to the Director-General, if required. All senior managers are member of the committee. The committee is chaired by DPM (E)[41]. A Nuclear Safety and Licensing Division (NSLD) also functions under the DPM (E). This Division interfaces with PNRA and provides oversight of safety matters within the plant.

9.2.3 Chashma Nuclear Power Plant Unit -1 (C-1)

The mission of C-1 is to generate electricity in a demonstrably safe, reliable and cost effective manner over the long term, for the benefit of our society and stake holders, as well as to consolidate the basis for development of the nuclear power program in Pakistan. The vision of C-1 is to establish a modern, effective and efficient management system within the organization, to enhance the total standard of management so that the safety and economic performance of the plant is in the top quartile in the world nuclear power industry by the year 2010. C-1 is earnestly working to achieve its mission and vision.

A high level safety committee, namely Operational Safety Review Committee (OSRC) is constituted which is headed by Director-General C-1. Other members include the Deputy Director-General, Deputy Plant Managers and the Managers. This committee, among other things, reviews and assesses changes in approved technical specifications, procedures, equipment, systems, tests or experiments, new safety issues, violations of approved technical specifications, reportable events, deficiencies in design or operation that may affect safety, radiological emergency response plan, etc.

The Engineering Department of C-1 is responsible for the review of plant status, deficiencies or events and follow-up actions on day to day basis. This Department interfaces with the regulatory authority. Engineering Department also coordinates working of Operational Safety Analysis Group (OSAG) which is composed of members from engineering, safety analysis, health physics, ISI, QA, etc. The Group reports to Manager Technical. This group analyzes the operational activities to verify that the activities are being conducted correctly, safely and in accordance with plant procedures. The group carries out detailed studies to recommend revision of procedures, equipment modification, maintenance, operational improvement and other means for ensuring plant safety.

CHASCENT coordinates analysis of events, determines their root causes, executes operating experience feedback program for lessons learnt and identifies corresponding actions. It is performing PSA and its applications to evaluate performance and to study proposed modifications, test intervals and operating practices.

[41] Deputy Plant Manager (Engineering)

9.2.4 Chashma Nuclear Power Project Unit -2 (C-2)

C-2 is in the construction phase. A Safety and Licensing Division has been established in C-2 which is responsible for addressing safety related issues. This Division is also responsible for implementing Configuration Management Plan in C-2. A Quality Assurance Division ensures quality through the implementation of the Quality Assurance Program. The Reactor Core Analysis Division ensures safe and optimum design for core performance and assessment of any design modifications related to core and fuel. This group also coordinates with other establishments of PAEC in performing its tasks. Design Coordination Division reviews basic and detailed design in coordination with other design establishments of PAEC. The review performed by the Design Coordination Division is independent of the review performed by the designer.

The licensee abides by the provisions of the Ordinance, rules and regulations made under the Ordinance, licence conditions and directives of PNRA issued from time to time. The licence holder submits the required safety reports and documentation as laid down in the regulations or required by PNRA in support of safety case. In addition, the licence holder agrees to regulatory inspections, during all phases of the plant life, which are carried out by PNRA to verify that the requirements of the regulations and conditions of the licence are met.

PAEC interacts with PNRA both at the corporate level and at the nuclear installation level. At the corporate level interaction is through Chairman and Members of PAEC to their corresponding counterparts in PNRA. The interaction between the regulatory body and the nuclear installations is through the technical directorates and regional directorates.

Pakistan has, therefore, met the obligations of Article 9 of the Convention.

Article 10 – Priority to Safety

"Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety."

10. Priority to Safety

Pakistan has taken appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations have established policies that give due priority to nuclear safety.

10.1 Regulatory Requirements

National regulations PAK/909 require that 'safety first' shall be the guiding principle in the siting, design, construction, commissioning, operation and decommissioning of nuclear installations. Regulations require that special emphasis be placed on safety in operation. The operator is to establish an effective organizational structure for making and implementing policies for nuclear safety and quality, allocating adequate resources, enforcing fitness for duty requirements, etc.

National regulations PAK/913 further require that a policy on safety shall be developed by the licensee and applied by all site personnel. This policy shall give the utmost priority to the safety at the installation, overriding if necessary the demands of production and project schedules. The policy should include a commitment to excellent performance in all the activities important to safety and shall encourage an inquisitive attitude. All activities that may affect safety and which can be planned in advance shall be conducted in accordance with established procedures and shall be performed by suitably qualified and experienced individuals. Furthermore, regulations require that regular reviews of the operational safety of the plant are conducted, with the aim to ensure that an appropriate safety consciousness and safety culture prevails, the provisions set forth for enhancing safety are observed, documentation is up to date and there are no indications of overconfidence or complacency. The recently issued IAEA guides on safety management system provide guidance on how to meet these requirements. These guides can be utilized by licensees to meet the requirements of national regulations.

10.2 Priority to Safety in Nuclear Installations

The licensees of nuclear installation (this includes designers, constructors, operators, suppliers, etc. working on behalf of the licensee) in Pakistan are committed to giving due priority to nuclear safety. This commitment is reflected in their 'Safety Policies'. Significant steps were taken by PAEC to improve safety culture in nuclear installations. The process of improvement appears to be sustainable, continuous and the trend is quite favorable.

The design and operation of nuclear installations is in conformity with the national regulations and adherence to safety principles such as defence in depth, ALARA, single failure criterion, etc., is closely observed. All activities that may affect safety are performed by suitably qualified and experienced staff.

PAEC further enhances safety culture and improves quality consciousness in its personnel by:

- **a.** having a qualification and training program focusing on establishing and enhancing safety and quality culture within the organization, developing understanding of safety and quality and their importance in achieving operational and economic goals of nuclear power plants
- **b.** establishing a system of checks and balances through a proper QA assessment system based on techniques of self assessment, independent checks and verifications, QA inspections, audits and surveillance, non-conformance control,

peer reviews, management reviews, etc.

c. encouraging plant personnel to report safety concerns and taking appropriate and timely corrective actions and providing feedback to plant personnel; and

d. fostering a 'no-blame culture'

Operational safety is further improved by event reporting system, corrective action program, establishing a system of reporting near misses and operational experience feedback (within plant, other plants operating in the country, plants operating worldwide through IRS, WANO and other reporting systems). In addition, PAEC has an active collaboration with IAEA and with organizations such as WANO and COG. This has greatly helped in increasing know how in the area of safety through exchange of personnel and information. Several peer reviews have been carried out in nuclear installations and a number of plant personnel have participated in similar peer reviews at nuclear installations elsewhere. Through such activities, familiarity with good practices was developed, which helped to improve safety at nuclear installations in Pakistan.

10.2.1 Priority to Safety at KANUPP

At K-1, a station instruction entitled "Station Goals and Objectives" establishes overriding priority to safety. In addition, station instructions for Corrective Action Program (CAP), Self Assessment Program (SAP), and Safety Performance Indicators (SPI) have also been issued and implemented.

A comprehensive system for event reporting is established under the CAP. Collected information is screened and an in-depth analysis and trending of events is carried out, where needed. The corrective actions are implemented and tracked.

Under the SAP, it is mandatory that at least four seminars should be held annually with a view to increase employees' understanding of diagnostic programs and safety culture. The self assessment of the "Effectiveness of Operational Experience Programs" has been carried out. A focused self-assessment for the soft issues generated through Corrective Action Program (CAP) is also in-progress. Furthermore, yearly and five yearly self assessment audits are part of self assessment program. K-1 conducted a self assessment of its performance in 2005 and again in 2007.

10.2.2 Priority to Safety at CHASNUPP-1

The safety policy of C-1 has been prepared and approved. It is displayed prominently at the plant entrance so that all plant personnel become familiar with it. Director-General holds daily work plan meetings to discuss safety issues and their resolution. Safety and quality takes precedence on production.

10.2.3 Priority to Safety at CHASNUPP-2

Safety and quality are the most important considerations in the design and construction of C-2. Design of the plant is in accordance with the applicable national regulations and other standards specified by PNRA. Compliance to these regulations and standards has been verified through reviews by PNRA and international experts under an IAEA project. In addition to the deterministic safety analysis, probabilistic safety assessment has also been performed for the design of C-2. Analysis for several severe accident scenarios has been carried out and various measures have been taken to reduce the probability of a severe accident in C-2 and to mitigate its effects. Decommissioning aspects have been considered in the design to facilitate decommissioning and dismantling

A separate Safety and Licensing Division (SLD) is established which is responsible for addressing all safety related issues. Various steps have been taken by SLD regarding implementation of safety culture right from the construction stage. Short trainings on safety culture were arranged by availing expertise in PAEC in the areas of Self Assessment, Corrective Action Program (CAP) and Safety Performance Indicators. The

CAP program has been initiated for collecting information on unusual events.

A Configuration Management Plan has been prepared and is being implemented in C-2. At the present stage of the project, it is being ensured that updated and corrected documents are readily available to C-2 personnel.

10.3 Verification of Safety by PNRA

PNRA verifies that the licensees are according due priority to safety in activities related to nuclear safety, radiation protection, quality management, etc. PNRA promotes safety culture in nuclear installations by placing it on the agenda of the licensee at the highest organizational level. The licensee assigns priorities to safety issues that are commensurate with the importance given by the regulatory body to that issue. Thus, PNRA stimulates the development of a safety culture by providing positive reinforcement. This is done by encouraging good safety practices and by recognizing initiatives of licensees.

So far PNRA has performed three inspections specific to safety culture at the nuclear installations. First safety culture inspection was carried out by PNRA at K-1 in December 2004. A special inspection for observing safety culture at C-1 was performed in July 2005. Another safety culture inspection of K-1 was carried out in June 2007.

In safety culture inspections, PNRA relies primarily on the notes and reports of inspectors collected during plant tours, reviews of documentation, and interviews with plant personnel, etc. It is supplemented through reviews of event and near misses reports, post event inspections and licensees' self assessments.

Consequent to these inspections, it was concluded that the safety culture in nuclear installations is satisfactory. However there exists room for improvement. The recommendations made after these inspections are being implemented by the licensees and are followed up by PNRA.

Pakistan has, therefore, met the obligations of Article 10 of the Convention.

Article 11 – Financial and Human Resources

> *"1. Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.*
>
> *2. Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life."*

11. Financial and Human Resources

Pakistan has taken appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life and sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities at each nuclear installation, throughout its life.

11.1 National Requirements for Financial Resources

The licensee is required to ensure that adequate resources, services and facilities are provided for the safety of the nuclear installation throughout its life.

11.2 Financial Resources at Nuclear Installations

Nuclear installations are national assets. The Government of Pakistan ensures that PAEC is provided with adequate resources to ensure safety of nuclear installations throughout their life. National Electrical Power Regulatory Authority (NEPRA) is the electricity tariff determining body. While fixing the unit (kilowatt-hour) price to be paid by the distribution companies to PAEC, it takes into consideration the specific issues related to nuclear installations such as refueling outages, decommissioning costs, storage and disposal of spent fuel and radioactive waste, periodic safety reviews and upgrades, etc.

Nuclear installations have never felt shortage of financial resources for supporting safety upgrades. However, difficulties have been experienced in acquiring necessary items and services due to restrictive policies of supplier countries.

11.3 National Requirements for Human Resources

National regulations PAK/913 require that the nuclear installations are staffed with competent managers and qualified personnel having proper awareness of the technical and administrative requirements for safety. The regulations specify the academic qualifications, experience of nuclear and other installations, training requirements, examination procedures, retraining requirements, etc. The regulations also specify the validity of the license, conditions to be satisfied for renewal, conditions for revoking or cancellation of license.

11.4 Human Resources, Training and Retraining at Nuclear Installations

At the national level, PAEC has established a number of institutions for the development of human resources. The Pakistan Institute of Engineering and Applied Sciences (PIEAS) at Islamabad awards post graduate degrees in several disciplines including nuclear and systems engineering. KANUPP Institute of Nuclear Power Engineering (KINPOE) at Karachi and Computer Training Center (CTC) at Islamabad are conducting post graduate level degree courses. In-Plant Training Center (IPTC) at K-1 is mainly training operating personnel for licensing examinations, whereas CHASNUPP Center of Nuclear Training (CHASCENT) at C-1 provide training to plant personnel according to plant requirements including training in radiation protection and industrial safety.

Specialized training courses are offered through National Centre for Non-Destructive Testing (NCNDT) and Pakistan Welding Institute (PWI) in the fields of quality control and welding technology respectively. PAEC has a large pool of specialists working in fields

such as design and engineering, reactor physics, thermal hydraulics, computers and controls, engineering services, accident analysis, probabilistic safety assessment, etc., who can support the design and engineering activities in nuclear installations. Support from the designers, vendors/suppliers is also available under various agreements to supplement the PAEC expertise especially in case of C-1 and C-2.

PNRA and PAEC organized symposia, workshops, training courses, etc., in collaboration with IAEA in the areas related to nuclear safety. The scientists and engineers of PNRA and PAEC received training in the area of nuclear safety in other countries through the support of IAEA.

Service conditions offered by PAEC are considered to be comparatively better than those of other government organizations. Fresh engineers, scientists and technicians are inducted every year so that the age profile of the organization remains balanced. Training and retraining are provided to operation and maintenance crews of the plants. PAEC employs engineers and scientists possessing high academic qualifications such as Masters of Science in relevant disciplines or other post graduate training courses. Many engineers and scientists have received comprehensive training in relevant fields both in Pakistan and abroad. The plant technicians possess three years' diploma after their Secondary School Certificate examination from various institutes of the country or have B.Sc. degrees from recognized universities. They are given one year Post Diploma Training (PDT) at CHASCENT.

The plant organization is such that all the managerial and supervisory positions are held by graduate engineers with a minimum of 6 to 10 years experience in respective fields at a power plant. The shift supervisor and shift engineers are required to be graduate engineers holding shift supervisor and shift engineers license respectively.

Qualification and training of operating personnel follow the regulatory requirements of PAK/913 and training program of the plant. PNRA conducts oral and operating examination for award of licences to operating personnel. Main Control Room (MCR) engineers of C-1 have to undergo mandatory training on a Full Scope Training Simulator (FSTS) for shift personnel licence. The licensed operation engineers are retrained on FSTS twice every year. The licensed personnel are re-examined internally every year. The field operators also undergo two months retraining every year.

While considering issuance of Fuel Load Permit or allowing commissioning, the availability of appropriate manpower is verified by PNRA. MCR operators including the shift supervisors are required to obtain licences from PNRA prior to first fuel loading. The shift complement is also verified by PNRA resident inspectors during operation. Therefore, the nuclear installations maintain a sufficient number of qualified and skilled manpower in all areas necessary for safe operation.

In view of the GoP plans to increase the nuclear power generation capacity to 8800 MWe by 2030, PAEC is planning to enhance the capacity and quality of its training institutes such as PIEAS, KINPOE, CHASCENT, etc. Projects to be funded from Public Sector Development Program have been approved by the GoP for this purpose.

11.5 Resources for Decommissioning and Waste Management

PAEC has allocated adequate resources for the safe management of radioactive waste in the country and to deal with decommissioning activities of the plants. National Policy on Radioactive Waste Management has been drafted which also ensures the provision of funds for the safe and secure management of radioactive waste in the country.

Pakistan has, therefore, met the obligations of Article 11 of the Convention.

Article 12 – Human Factors

> *"Each contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation."*

12. Human Factors

Pakistan has taken appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation. PNRA and PAEC recognize that human performance plays an important role in ensuring the safety of a nuclear installation during all phases, i.e. siting, design, construction, commissioning, operation and decommissioning. Accordingly, PNRA has set regulatory requirements for establishing management systems and procedures for human factors to ensure safe operation. Subsequently, PAEC has established management systems and procedures for analyzing events involving human factors and to improve human performance for ensuring safe operation.

12.1 Regulatory Requirements

National regulations Pak/911 impose several requirements regarding human factors at the design stage. The design is required to be ‘’operator friendly’’ aiming at limiting the effects of human errors. Systematic consideration of human factors and the human-machine interface must be included in design process at an early stage and should continue throughout the entire process, in order to ensure an appropriate and clear distinction of functions between operating personnel and the automatic systems.

The aim of the design is to promote the success of operator actions with due regard to the time available for action, the physical environment to be expected and the psychological demands to be made on the operator. The need for intervention by the operator on a short time scale must be kept to a minimum. The necessity for such intervention is only acceptable provided it can be demonstrated that the operator has sufficient time to make a decision and to act. In addition, the information necessary for the operator to make the decision to act is simple and unambiguous and that following an event the physical environment in the control room or in the supplementary control room and on the access route to that supplementary control room is acceptable.

Human factors’ effects are also considered in PAK/913 while establishing the criteria for appointment of Director-General, station health physicist and operating personnel. PAK/913 requires that the licensee shall define the qualifications and experiences necessary for personnel performing duties that may affect safety. Suitably qualified personnel shall be selected and given the necessary training and instruction to enable them to perform their duties correctly for different operational states of the plant and in the event of an accident, in accordance with the appropriate procedures.

A high level of health and fitness is required for the personnel of nuclear installations. Accordingly, PAK/913 requires that all personnel of the licensee whose duties may affect safety shall be medically examined on appointment and at subsequent intervals as required to ensure their fitness for the duties and responsibilities assigned to them. Psychological examination is also required for licensed control room operating personnel. PAK/904 elaborates details of medical examination required for medical fitness of radiation workers.

12.2 Steps Taken by PAEC to Ensure Consideration of Human Factors

K-1 has made several design improvements to enhance human performance. These include:

a. work environment in various areas made more comfortable

b. man-machine interface made more operator-friendly by installing computer displays and convenient set point changing facilities in control room.

c. Work Control Office relieves the control room operator from log writing and enables the operator to pay more attention on safety related activities.

d. few annunciation windows were either specially marked or re-arranged in groups for operator ease.

e. Emergency Control Centre is designed considering human performance.

Furthermore, a facility has been installed in the Emergency Feed Water room to remotely monitor the plant status. Integrated and concise information under all modes of plant operation is provided through the Critical Parameter Display System (CPDS) and Safety Parameter Display System (SPDS). CPDS displays real time values of pressure, temperature and other critical parameters with reference to operating plant status. The system also monitors status of parameters with reference to core cooling.

SPDS provides the status of eight safety significant functions in the control room. These functions are:

a. Primary Heat Transport System Integrity

b. PHT System Heavy Water Inventory

c. Reactor Core Cooling

d. Reactor Power & Criticality

e. Secondary Core Cooling

f. Containment Integrity

g. Radiological Emission

h. MH system inventory

Currently state of two of the above functions (Reactor Power and Radiological Emission) can be determined from the SPDS and the operator can take corrective action when so required to bring and maintain the plant in safe state. Both these facilities will eventually be installed in the Emergency Control Centre, which is being constructed.

ATOG (Abnormal Transient Operating Guidelines) have been revised on the basis of analysis performed during updating of KANUPP Final Safety Analysis Report.

The design of the main control room (MCR) at C-1 is based on a comprehensive and systematic task analysis and follows good human factors practices. It is compatible with human psychological and physical characteristics and enables the required tasks to be performed reliably and efficiently. In order to overcome human errors related to alarms, Alarm Response Procedures (ARP) are being developed.

The design of the Main Control Room of C-2 has been improved with respect to human factors by using operating experience feedback from C-1. On the basis of MCR functional analysis, operator tasks and operation area during normal operation, anticipated operational occurrences and accident conditions are specified. C-2 design includes Human System Interface (HSI)[42] devices suited to various operator tasks, especially necessary monitoring and control means for the operator to perform emergency operations efficiently. It is ensured that sufficient information associated with individual plant systems and equipment is available to operators to confirm that necessary safety actions can be initiated in a timely manner.

[42] Also known as Man Machine Interface

At C-1, Event-based Emergency Operating Procedures were provided by the vendor and the Symptom-based Emergency Operating Procedures (SEOP) are being developed. C-2 has committed to prepare SEOP. A plan has been chalked out for preparation of severe accident management guidelines (SAMG). C-2 personnel are being trained on SEOP and SAMG development.

All activities at nuclear installations are carried out in accordance with written, approved, regularly reviewed and revised procedures. The licensee ensures that technical content of the instructions is correct, and that the design and presentation of instructions enables users to follow them accurately and reliably. This reduces the chances of human error. The procedures and instructions are subject to a process of verification and validation to ensure that they accurately represent operational requirements and are compatible with the design of plant and equipment. Suitable arrangements are provided to implement these procedures and instructions. PNRA verifies this during regulatory inspections.

Nuclear installations have performed and submitted the PSA reports at different stages of the plant life to analyze the human factor events and their importance. Through Human Reliability Analysis (HRA) human error probabilities are calculated for the errors, which are on the basis of procedural lapses or operator errors. These inputs are fed into simulator training to minimize the human error. In case of C-2, HRA was performed in PSA report to assess contribution towards initiating events. Based on this analysis, improvements have been suggested in the design and will be considered while writing procedures.

Root cause analysis is performed for analyzing events caused by human errors. At K-1, database of all events, whether significant, low level or near misses is maintained under the CAP. It also has the responsibility to facilitate investigations, root cause analysis and apparent cause analysis of events requiring follow-up and the implementation of the corrective actions. In 2006, a program was started for trending of events and issues based on different types of events (e.g. house keeping events, industrial safety events, equipment failure events, etc.) and the causes of events (e.g. design deficiencies, training deficiencies, document deficiencies, etc.). Human performance issues are coded and trended. Separate investigations are initiated for events showing adverse trends to determine the causes of adverse trends. Meetings were held with plant management to discuss safety significant issues. Focused self-assessments are carried out to ensure that human performance issues are satisfactorily resolved.

12.3 Verification of Human Factors Considerations by PNRA

PNRA verifies that the human factors are considered throughout the life of a nuclear installation. Inspectors check work conditions such as lighting, labeling, environmental and habitability issues, house keeping, fitness for duty, etc. Inspectors witness simulator exercises to confirm that the design adequately accommodates all necessary operator actions. Compliance to procedures is also checked during inspections. While reviewing PSA, it is verified that human factors have been adequately considered. Human performance is an aspect considered in safety culture inspections. While analyzing un-usual occurrence reports, role of human factors in initiating and progression of the event is determined.

Pakistan has, therefore, met the obligations of Article 12 of the Convention.

Article 13 – Quality Assurance

> *"Each contracting party shall take the appropriate steps to ensure that quality assurance program are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation."*

13. Quality Assurance

Pakistan has taken appropriate steps to ensure that quality assurance programs are established and implemented with a view to providing confidence that specified requirements for activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

13.1 Regulatory Requirements

The national regulations PAK/909 stipulates requirements for the submission of quality assurance programs (QAP) at the time of applying for construction licence and then again at the time of applying for first fuel load permit. The national regulations PAK/912 describe the requirements for establishing and implementing QAP for all phases of nuclear power plants. It specifies the quality assurance requirements for activities performed during siting, design, construction, equipment manufacturing, installation, etc. The QAP applies to all items and services important to safety. PAK/912 is based on IAEA safety standards series No. 50-C/SG-Q (1996). Contractors are also required to develop and submit their own QAP according to the requirements of PAK/912.

IAEA has revised its standards related to quality assurance to management systems for facilities and activities. PNRA is reviewing the new standards for updating its regulations. The licensees would accordingly be required to transform their QA system into an overall management system.

13.2 Quality Assurance Activities at Nuclear Installations

PAEC has established its QAP at nuclear power plants to achieve its safety objectives. QAP includes organizational structure with defined responsibilities and functions, documented programs, established goals/objectives and prescribed procedures for performance evaluation.

13.2.1 Quality Assurance at Corporate Level

A Directorate of Quality Assurance (DQA) has been established at corporate level in the PAEC HQ to coordinate QA activities in various PAEC establishments, to have corporate oversight on QA matters, to advise the plant and the corporate management on quality issues and to recommend actions for improvements.

13.2.2 Quality Assurance at Nuclear Installations

QAP for operation phase have been established at C-1 and K-1 to ensure quality in their safety related activities. K-1 updated its operational QAP to address specific issues related to operation beyond design life. The QAP of C-2 at present addresses design and construction phases, whereas for commissioning and operation phase a separate QAP will be prepared. These nuclear installations have established Quality Assurance Divisions (QAD) staffed with appropriately qualified personnel reporting directly to the highest level of the plant management. These have been entrusted with the necessary authority to ensure the implementation of QAP through inspections and audits. Among other things QAD has the authority to stop any work not meeting the QA requirements.

Assessment of QAP is carried out through self and independent assessments. This is done by performing internal and external audits, peer reviews, technical reviews, etc. The purpose of such assessments is to highlight the strengths and weaknesses of the

management systems and to identify areas for improvement.

At K-1, Quality Assurance Division (QAD) conducts QA audits of Operation, Engineering Support, Chemistry Control, Health Physics, Maintenance, Procurement, Material Management and Training. All field activities related to areas mentioned in QA manual are routinely inspected. The work undertaken by the work groups is reviewed from QA point of view before it is started. The work is observed during the execution and reviewed again after the completion to verify that QA requirements are fulfilled. QA verification of important plant documents such as operation and maintenance procedures, station instructions, change approvals, etc., is also carried out. The non-conformance control system identifies non-conformances and necessary corrective measures.

The QAD ensures that the work groups clearly understand management expectations to establish and maintain quality culture at K-1.Training and retraining of QA personnel including auditors is a continuous activity at K-1 to maintain and enhance their qualifications and skills.

The QAP of C-1 is based on national regulations PAK/912 and encompasses all items and activities important to safety and availability of the plant. The Quality Assurance and Assessment Division (QAAD) is staffed with adequately qualified manpower and reports directly to the highest level of plant management, i.e., Director General C-1. In all its activities, QAAD emphasizes safety and quality culture.

Through planned QA surveillance and audit programs, the QAAD ensures compliance with the established requirements and implementation of QAP. Planned as well as general surveillances are carried out in all plant areas such as nuclear island, main control room, turbine building, electrical building, diesel generator building, radioactive waste storage building, access control areas, warehouses, workshops, laboratories, etc. Internal and external audits are performed according to the audit plans and procedures and the reports are followed up.

QAAD also performs inspections during fuel manufacturing and transportation, and controls the activities of contractors involved in in-service inspection (ISI) and refueling activities through audit and surveillance. QAAD provides support to plant management during management reviews and assessments. Procedures related to safety and quality undergo a thorough QA review and are signed by QAAD.

In case of C-2, the applicant established and implemented a separate QAP for the siting phase and preparation of Site Evaluation Report. C-2 also established an “Overall Quality Assurance Program (OQAP) for Design, Procurement, Construction and Commissioning of Chashma Unit-2” in accordance with PAK/912. The OQAP was reviewed and approved by PNRA. The OQAP includes a written quality policy statement providing management policy, commitments, priorities and expectations regarding safety and quality of the project.

C-2 has a Quality Assurance Department which assists the Director General on QA matters and is also responsible for its maintenance and implementation. The OQAP covers all activities related to design, construction and commissioning including management, work and assessment. Non-conformances are dealt with according to the severity and safety implications. Disposition actions are approved at different levels of the overall QA and regulatory system, depending upon the severity and implications.

The QAP of project contractors and sub-contractors are required to be in line with the OQAP. C-2 performs QA audits of its contractors and sub-contractors to verify compliance with the OQAP. The QA system of manufacturers of equipment is also audited by C-2 to ensure compliance with its OQAP. Coordination meetings between PNRA, C-2 and main contractor are held annually to facilitate resolution of issues and for better interface between them.

13.3 Quality Assurance Activities of HMC-3

Heavy Mechanical Complex-3 (HMC-3) Taxila is one of the largest projects in the heavy engineering sector of Pakistan. PNRA has issued a licence to HMC-3 to manufacture safety class mechanical equipment for nuclear power plants. HMC-3 has an independent QA department responsible for the maintenance and implementation of Quality Assurance Manual (QAM). The QAM is in line with national regulations PAK/912 and requirements of ASME Boiler and Pressure Vessel Code. The QAM has been reviewed and approved by PNRA for licensing. The QAM covers all activities related to manufacturing such as forging, bending, welding, brazing, heat treatment, testing and examination including non destructive testing, pressure testing, etc.

The manufacturing activities are performed according to quality plans which describe the processes, testing, examination, reviews and checks in sequential order. Processes are required to be qualified according to the requirements of applicable codes and standards, and the standards of the client. Mock-ups are also prepared to qualify the processes. Manpower involved in manufacturing and testing is qualified based on the requirements of relevant regulations, codes and standards.

13.4 Regulatory Surveillance of QA Activities

PNRA periodically performs regulatory surveillance of overall QA activities of its licensees. During routine and non-routine inspection activities, surveillance of relevant aspects of QAP/QAM is observed. Comprehensive vertical slice inspections of specific areas of QA are performed as and when required.

The inspections at the sites of nuclear power plants are controlled and carried out by the Regional Directorates of PNRA, while the inspections at the manufacturing facilities are controlled by PNRA Headquarter. In addition to the inspections of the licensee's QA activities, PNRA also performs QA inspections of the contractors and sub-contractors of the licensee. During these inspections, PNRA verifies compliance with the requirements of national regulations and the licence conditions.

13.5 PNRA Quality Management System

In order to continuously improve its effectiveness, PNRA has taken initiatives to establish and document its quality management system (QMS) in accordance with the requirements and recommendations of internationally acceptable standards and guidelines. Such standards include IAEA TECDOC-1090, ISO 9001-2000, etc., and quality management and quality assurance systems of other regulators.

A bottom-up approach is being adopted for the development of PNRA QMS. Accordingly, management processes are being described in the form of programs, procedures and plans. The next step would be to integrate these processes into a documented QMS manual which would also include policy statement of PNRA on quality.

Management system of PNRA is generally in line with the requirements of the IAEA safety standard GS-R-3[43]. A self assessment of existing management system based on current IRRS guidelines (Module VIII) is being carried out to identify strengths and weaknesses of the system.

Pakistan has, therefore, met the obligations of Article 13 of the Convention.

[43] The Management System for Facilities and Activities, IAEA Safety Standard

Article 14 –Assessment and Verification of Safety

> *"Each contracting party shall take the appropriate steps to ensure that:*
> *(i) comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of the operating experience and significant new safety information, and reviewed under the authority of the regulatory body;*
> *(ii) verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions."*

14. Assessment and Verification of Safety

Pakistan has taken appropriate steps to ensure that comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments are documented and subsequently updated in the light of operating experience and new safety information. Such assessments are reviewed by PNRA. Verification by analysis, surveillance, testing and inspection is carried out to ensure that physical state and the operation of a nuclear installation continue to be in accordance with its design and operational limits and conditions.

14.1 Regulatory Requirements

Assessment and verification is required for site evaluation, preliminary and final safety analyses of the design, and then after every ten years during operation in the form of periodic safety reviews. Assessment requirements for operation beyond design life have been addressed in PAK/909. In addition, PAK/909 links safety assessment and verification with other national regulations.

The regulations PAK/911 relate to safety aspects of the design of nuclear installations. National regulations PAK/910, PAK/913 and PAK/915 describe other regulatory requirements for nuclear installations. National regulations PAK/910 establish requirements for site evaluation and determination of site characteristics to be used as design parameters and assessment of the effects of plant operation on site. The national regulations PAK/911 address assessment and verification of safety including the following:

a. "A comprehensive safety assessment shall be carried out to confirm that the design meets the safety requirements set out at the beginning of the design process.

b. The safety assessment shall be part of the design process, with iteration between the design and confirmatory analytical activities, and increasing in the scope and level of detail as the design program progresses.

c. The basis for safety assessment shall be the data derived from the safety analysis, previous operational experience, results of supporting research and proven engineering practice."

National regulations PAK/913 specify requirements that are applicable during operation. The regulations also include the assessment and verification requirements during operation phase, in particular the assessment and verification of design modifications, events and incidents, operational aspects and periodic safety reviews.

As national regulations of Pakistan are largely based on IAEA safety standards, these completely encompass the requirements of the Convention. Consequently, through the implementation of these regulations, Pakistan will fulfill obligations of the Convention.

14.2 Assessment and Verification of Safety by Nuclear Installations

The safety of the plant is continuously assessed and verified during all phases of the plant life. This includes:

- **a.** Self assessments including management reviews
- **b.** Reviews of plant safety performance by plant safety committee, quality assurance division, engineering department, health physics division and relevant operation and maintenance departments
- **c.** Quality Assurance and Quality Control Inspections and Verifications
- **d.** QA audits
- **e.** Independent reviews and assessments (peer reviews, OSART mission, IPSART mission, etc.)

In addition, nuclear installations have established effective systems for:

- **a.** recording deficiencies identified during the assessment and verification activities
- **b.** planning and implementing corrective and preventive actions
- **c.** monitoring these actions to assess their effectiveness
- **d.** initiating and controlling the work
- **e.** maintaining records for authorization and control of temporary changes to the equipment, procedures, etc.

All these systems take into account the requirements of applicable regulations, codes, standards and international practices.

In-service inspection programs based on the requirements established in the technical specifications and in the ASME Code Section XI are implemented to assess and verify the condition of plant structures, systems and components important to safety.

14.2.1 Assessment and Verification of Safety at KANUPP

Safety of K-1is being assessed and verified through periodic safety reviews, ageing management, in-service inspections, surveillance, operation and maintenance, and quality assurance. K-1 is in the final stage of relicensing. A number of modifications were made during the relicensing process. Before implementation, these modifications were thoroughly reviewed and assessed by K-1and by PNRA in case these were safety related.

KANUPP Final Safety Analysis Report revision-2 includes the update of the design descriptions and accident analysis sections. Design description part has been updated by taking into account the design changes, modifications and updates carried out in the plant during relicensing.

The effects of improvements in LOCA handling and emergency core cooling system were analyzed in the revisions of accident analysis section of KFSAR-R2 and results show that all the modifications and upgrades fulfill their desired functions and intent.

Dual accident analysis was also updated using latest computer codes and accident analysis tools. The major scenarios include “loss of coolant accident with loss of emergency coolant injection system” and “loss of reactivity control coincident with loss of protection”. Review of KFSAR by PNRA may be completed by September 2007.

Aging Management Work plan, based on the recommendations of IAEA expert missions, is in progress. Accordingly, degradation monitoring plans for three more systems have been developed. Condition of fueling machines, civil structures, dousing spray water system, etc., were assessed and reports issued. Feeder pipes inspections continued.

None of these require removal within 3 EFPY[44]. Several tubes of the condenser were replaced. Based on performance assessment, time-delay relays and medium-voltage circuit breakers were replaced with new ones.

Condition assessment of steam generators (SG) was carried out. No significant degradation or effect of flow accelerated corrosion could be found except for the on-going pitting, wastage and denting in tubes on its secondary side. The vendors have been asked through COG[45] to submit a proposal for sludge lancing of SG, to assess the aforementioned degradation. Follow up actions subsequent to fuel channel integrity assessment (FCIA) carried out in 2003, to monitor and increase database on reactor fuel channels and to assess their condition are in progress. Next FCIA including core assessment will be carried out around 2012 with Canadian assistance.

A detailed probabilistic safety assessment (PSA) was performed by K-1 and all significant recommendations have been implemented. Some of these recommendations include improvement in reliability of emergency boiler feed water, installing a third diesel generator for providing redundancy on running failures of the existing two diesel generators, increasing the charging tank capacity, etc. PSA-1 was completed in 2001 and is kept living by incorporating the modifications in the model. Fire PSA is expected to be completed under the guidance of IAEA experts.

14.2.2 Assessment and Verification of Safety at C-1

C-1 performs assessment and verification of safety under its Quality Assurance Program for Operation. The support from the designer and vendor is also sought when required. The plant has an Operational Safety Review Committee which performs review and assessment of the safety evaluation, modifications, events reports, plant operations, etc.

Independent assessments are carried out in the form of audits, surveillance and peer reviews. Audits and surveillance are conducted according to approved audit and surveillance plans. Reactive surveillance and audits are also conducted, if needed. Peer reviews are conducted by organizations such as IAEA and WANO. An IAEA OSART Mission visited C-1 in January 2004 and its follow-up mission came in January 2006. WANO peer review of C-1 was carried out in March 2006. A Pre-IPSART mission is scheduled in November 2007 to review the PSA report of the plant.

14.2.3 Assessment and Verification of Safety at C-2

In accordance with the PAK/909, C-2 submitted the Site Evaluation Report (SER) in June 2004 along with the application for site registration. Subsequently, C-2 submitted the Preliminary Safety Analysis Report (PSAR) in May 2005, Overall Quality Assurance Program (OQAP), Design PSA and Severe Accident Analysis Report in August 2005 required for Construction Licence.

Regarding verification of safety, the design of C-2 was assessed at various levels. The designer performed detailed assessment at the first level and it was verified again by the engineers who were not directly involved in the design. At the second level the design was independently verified by C-2. Modifications in the design followed the same course for approval as for the original design. The safety analysis of the preliminary design was reviewed and approved by the regulatory authority. International experts also reviewed the safety analysis of the preliminary design under an IAEA TC project.

14.2.4 Performance Indicators Program of Nuclear Installations

The nuclear power plants (K-1 and C-1) have established their performance indicators programs to monitor the performance trends and take actions appropriate for performance improvement.

[44] Effective full power year
[45] CANDU Owners Group

K-1 has developed safety performance indicators (SPI) to monitor operational safety. The first two phases of the project have been completed while the final phase is expected to be completed by the end of 2007.

C-1 has adopted WANO performance indicators program consisting of collecting, trending, exchanging, and disseminating performance data in ten key areas. The indicators include unit capability factor, unplanned capability loss factor, unplanned automatic scrams per 7000 hours, forced loss rate, grid related loss factor, safety system performance (safety injection system, auxiliary feed water system and emergency diesel generators), fuel reliability indicator, chemistry performance indicator, collective radiation exposure and industrial safety accident rate (plant personnel and contractor). Safety performance indicators are being developed by C-1 based on national/international experience.

14.3 Regulatory Review Process

National regulations PAK/909 describe the licensing process for nuclear installations and retain the previous practice of three stage licensing, namely Site Registration, issuance of Construction Licence and Operating Licence. In addition, there is an intermediate stage of Fuel Load Permit when the nuclear installation has to obtain permission for loading fuel into the core. Documents required to be submitted during these licensing stages and applicable nuclear safety standards are listed in these regulations.

According to these regulations, PNRA performs safety review and assessment of the Site Evaluation Report, Preliminary Safety Analysis Report (PSAR), Final Safety Analysis Report (FSAR), Commissioning Program, Periodic Safety Review (PSR) Report, PSA Report, etc., during various licensing stages.

The safety reviews are performed mainly by PNRA staff. However, in specific areas the services of consultants are also availed. Safety reviews are carried out according to review plans which in case of SER, PSAR and FSAR are based upon Standard Review Plan (NUREG 0800) of USNRC. In case of PSA, the review plan is based on IAEA Safety Series No. 50-P-4. In the area of severe accidents, PNRA is evolving review plans with the assistance of IAEA.

On completion of the safety review, PNRA issues a Safety Evaluation Report. For instance, after the safety review of a PSAR, a PSAR Safety Evaluation Report (PSER) is issued describing the review details including review of data, main queries and their resolutions, evaluation basis, acceptance basis, findings and conclusion of the review.

The objective of PSR is a systematic re-assessment of the safety of nuclear installation at an interval of 10 years to deal with the cumulative effects of ageing, modifications, operation and technical developments, aimed at ensuring high level of safety. The scope of PSR is similar to the contents of NS-G-2.10.

Any change in the plant or its operations that may have an effect on the licensing basis requires PNRA approval prior to implementation. In this regard a formal request for approving the change is submitted which needs approval by PNRA before implementation. Accordingly, PNRA reviews and approves the modifications in operational limits and conditions of structures, systems and components important to safety, design, surveillance requirements, management structure, etc. The modifications are reviewed to assess the implications of modifications on plant safety and to ensure that safety margin provided in the original design is not reduced.

Applicants and licensees have been asked to submit PSA reports along with PSAR, FSAR and PSR report at the construction licence, fuel load permit and licence revalidation stages, respectively.

14.4 Verification of Safety by PNRA

Verification of safety of nuclear installations is through review, analysis and inspections. PNRA performs safety review of the design and verifies the design implementation through regulatory inspections. Based on these assessments “Fuel Load Permit” is issued. The assessment of safety continues during approach to criticality and power ascension.

The inspection programs are focused on ensuring that plant construction, equipment manufacturing, installation and commissioning is in conformity with design intent, and operation is within the approved limits and conditions. Special inspections are performed considering the safety significance of a particular activity. PNRA has also included safety culture within its regulatory framework and has inspected safety culture of K-1 and C-1.

All activities of C-1 and K-1 related to safe operation and maintenance of the plant, including engineering support, health physics, emergency preparedness, quality assurance, etc., are inspected by the regulatory inspectors under an approved inspection program to verify compliance with the regulatory requirements. Detailed inspection plans are chalked out and the inspections are conducted accordingly. Depending upon the situation and feedback from review and assessment and trend of the safety performance of the nuclear installation, additional inspections are performed.

14.5 Assessment of Performance Using Indicators

Assessment and enhancement of performance is one of the activities of PNRA. A performance indicators program has been initiated comprising of direct and indirect indicators. The direct indicators related to nuclear installations are number of licensing of operating personnel, number of event reports or unusual occurrence reports reviewed in the reporting year, number of unusual events rated on INES[46], total number of planned or scheduled inspections actually conducted. The indirect indicators are number of scrams, availability of safety systems, fuel integrity, reactor coolant system integrity, collective radiation exposure and significant events. PNRA plans to integrate the performance indicators program with the inspection program of the Authority.

14.6 Safety Reviews and Assessments through External Organizations

At C-1 a pre-OSART Mission was conducted by IAEA in February1999. Most of the recommendations of the mission were implemented to the satisfaction of IAEA and PNRA. A full-scope IAEA OSART Mission was conducted in January 2004. OSART Follow-up Mission was conducted in January 2006. WANO Peer Review was also completed in March 2006. For K-1, independent reviews and assessments were carried out by WANO and IAEA.

The reviews showed that critical components and equipments were in good health. Good operational safety procedures and practices were being followed and inherent conservatism existed in design and safety. Most of the recommendations made by the review missions have been implemented.

Pakistan has, therefore, met the obligations of Article 14 of the Convention.

[46] International Nuclear Event Scale

Article 15 - Radiation Protection

> *"Each Contracting Party shall take the appropriate steps to ensure that in all operational steps the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed the prescribed national dose limits."*

15. Radiation Protection

Pakistan has taken appropriate steps to ensure that in all operations the radiation exposure to the workers and the public caused by a nuclear installation is kept as low as reasonably achievable and that no individual is exposed to radiation doses which exceed the prescribed dose limits.

15.1 Regulatory Requirements

PNRA is responsible for controlling, regulating and supervising all matters related to radiation protection. PAK/909 requires submission of a radiation protection program as one of the pre-requisites for issuance of operating licence. PAK/913 requires that the licensee shall establish and implement a radiation protection program to ensure that, in all operational states, doses due to exposure to ionizing radiation in the plant or due to any planned releases of radioactive material from the plant are kept below prescribed limits and are as low as reasonably achievable. This program shall meet the requirements of regulations on radiation protection and shall be approved by the Authority. The dose limits for radiation workers and public during normal operation are given in PAK/904 and are reproduced in Annex – X.

15.2 Radiation Protection at Nuclear Installations

In conformance with the regulatory requirements, the nuclear installations in Pakistan have developed policies and procedures, for the protection of workers, public and environment from the harmful effects of radiation. It is ensured that:

- **a.** all reasonably practicable steps are taken to ensure safe plant operation and to prevent accidents and risks to health at work and to minimize the consequences of any accident involving radiological consequences.
- **b.** no person shall receive doses of ionizing radiation in excess of the prescribed dose limits as a result of normal operation and the exposure of any person is kept as low as is reasonably achievable.

Continuous air sampling and ambient dose level monitoring are performed at the nuclear installations. Environmental samples of air, water, soil, vegetables, fruits, milk, meat etc., are collected at regular periods for analysis and estimation of radionuclide content. Due consideration is given to seasonal effects and the distance from the installation. On-Site and off-site environmental monitoring points are selected at different locations. Environmental TLD dosimetery is also performed to record the cumulative dose level on quarterly basis.

15.2.1 Radiation Protection at K-1

Radiation doses of plant workers are kept below the regulatory dose limits. Exposure is controlled with the help of job planning, job briefing, frequent radiation surveys, radioactive contamination control, and regular training. Internal radiation dose is controlled by providing suitable respiratory protection equipment, reducing the airborne contamination level and bioassay sampling. Administrative internal uptake limits have been defined, which are followed strictly.

An environmental monitoring program is in place that includes regular radiation dose rate monitoring at different locations at plant periphery and in different areas of Karachi, by

placing TLD and high volume air sampling system away from the plant. Environmental samples from the vicinity of plant are collected and analyzed. Recorded radiation doses to the public are a small fraction of the limiting values.

Following are the steps taken to keep the radiation exposure of the radiation workers as low as reasonably achievable:

- **a.** Job planning by health physics personnel and supervisors of the working groups before starting the job. ALARA techniques are adopted, depending upon the job and area requirements.
- **b.** Workers involved in radiation related jobs are briefed about the radiological conditions in the job area.
- **c.** A Health Physics Coordinator is nominated for radiation intensive jobs with the prime responsibility to take part in each activity right from planning to execution.

Radiation exposure to the public is kept as low as reasonably achievable by controlling the release of radioactive effluents from the plant. This is done by on-line monitoring of the releases, removing the Tritium contents from boiler room air, filtration of gaseous effluent before releasing to the environment, decay and dilution of liquid effluent before its release, collection, processing and safe storage of solid radioactive waste, etc. As a result, the gaseous and liquid effluent released from the plant is well below the Derived Release Limits for K-1.

Annual collective dose during 2004, 2005 and 2006 at K-1 was 1.59 man-Sv, 1.43 man-Sv and 4.48 man-Sv respectively. Average individual dose for these years was 1.86 mSv, 1.61 mSv and 4.24 mSv respectively. The graphical representation of these doses is shown in Annex – XI A.

Gaseous radioactive effluents released during 2004, 2005 and 2006 were ~ 64 TBq, ~75 TBq and 100 TBq respectively. On the average gaseous releases remained less than 1% of annual release limits.

The liquid effluents released to sea during 2004, 2005 and 2006 contained 15 TBq, 34 TBq and 38 TBq of Tritium respectively. Generally, these were of the order of 0.15% of annual release limit for Tritium. Gross beta-gamma radioactivity released to sea was ~ 39 GBq, 31 GBq and 7.7 GBq respectively. These releases were less than 2.5% of annual release limit for gross beta-gamma radioactivity. The effluent releases of K-1 are shown graphically in Annex – XII.

15.2.2 Radiation Protection at C-1

In order to implement the radiation protection program, C-1 has established the necessary organizational set up headed by Manager, Safety & Health Physics Division. Under the Manager (SHPD) there are station health physicists responsible for implementing the radiation protection program[47] for handling and monitoring radioactive materials, including source and byproduct materials. This program conforms to national regulations and includes the following:

- **a.** Working procedures for implementing the radiation protection program.
- **b.** Survey of all incoming and outgoing shipments that may contain radioactive material.
- **c.** Investigation and documentation of any radiological incident to minimize the potential for recurrence and for reporting these incidents to PNRA in accordance with the regulations.
- **d.** Periodic surveys of radiation, contamination and airborne activity.

[47] Radiation Protection Program is called Health Physics Program at C-1

e. Record keeping of occupational radiation exposures and reporting to the PNRA.

f. Provision of personnel and other radiation monitoring equipments and their periodic calibration.

g. Establishment of access control points to separate potentially contaminated areas from uncontaminated areas and survey of tools and equipments before removal from a controlled area.

h. Issuance of radiation work permits (RWP) in accordance with the station radiation control procedures.

i. Bioassay program including whole body counting and / or a urinalysis sampling to measure the uptake of radioactive material,

j. An environmental radiological monitoring program to measure any effect of the installation on surrounding environment.

Annual collective dose during 2004, 2005 and 2006 was 575 man-mSv, 423 man-mSv and 22 man-mSv respectively. Average individual dose for these years remained 0.42 mSv, 0.27 mSv and 0.03 mSv respectively. The graphical representation of these doses is shown in Annex – XI B.

At C-1, all liquid and gaseous effluents are monitored before release to the environment. Liquid effluents are released from C-1 into the discharge canal, which falls into the Indus River. Gaseous effluents released during 2004, 2005 and 2006 were 98 TBq, 2 TBq and 10 TBq respectively. On the average these releases remained less than 1.2% of release limit. Liquid effluent releases for the years 2004, 2005 and 2006 were 0.76 GBq, 4 TBq and 2 TBq respectively. These releases were less than 0.1% of annual release limit. C-1 effluent releases are shown graphically in Annex – XII.

15.3 Verification of Implementation of Radiation Protection Program

Performance of the nuclear installations is continuously monitored to verify compliance with radiation protection requirements. In this regard, PNRA reviews the reports submitted by the licensees, conducts periodic inspections of the plant and the work practices and monitors the radioactive releases from nuclear installations and verify the reports submitted to PNRA.

During inspections, the effectiveness of the monitoring program is verified by checking the sampling and analysis techniques, calibration of instruments, etc. PNRA may cross check the results through independent verification by employing other establishments.

At nuclear installations the doses to radiation workers remain well below the radiation dose limits. The average dose received by an individual remains less than a fraction of the annual dose limit. The ALARA philosophy is applied in safety significant activities. It has been experienced that the actual dose received is much less than that anticipated. For instance, the doses received during removal of booster rods at K-1 and those during refueling outages at C-1 were less than estimated.

Similarly, in the entire operating history of nuclear installations in Pakistan the gaseous and liquid effluent releases have been well below (only a few percent) the derived release limits. The licensees report the ambient dose levels at nuclear installations to PNRA on quarterly and annual basis. PNRA has observed that the ambient dose levels at the boundary of K-1 and C-1 are generally close to the level of natural background. These levels are far below the world average background dose of 274 nGy/hr. The ambient dose levels at K-1 and C-1 are summarized in Annex – XIII.

Pakistan has, therefore, met the obligations of Article 15 of the Convention.

Article 16 - Emergency Preparedness

"1. Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.

2. Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.

3. Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency."

16. Emergency Preparedness

Pakistan has taken appropriate steps to ensure that there are on-site and off-site emergency plans for nuclear installations that are routinely tested and cover the activities to be carried out in the event of an emergency. For new nuclear installations, such plans are prepared and reviewed before the commencement of operation. In addition, appropriate steps have been taken to ensure that the surrounding population is provided with appropriate information for emergency planning and response.

16.1 Regulatory Requirements

PNRA Ordinance requires that the Authority shall ensure, coordinate and enforce preparation of emergency plans for action to be taken following foreseeable types of nuclear incidents that might affect the public. Such plans shall include arrangements for reporting and communication, coordination between the stakeholders, training of personnel and the provision of necessary facilities and instrumentation.

The national regulations PAK/909 set the requirement for preparing an emergency preparedness plan prior to introduction of nuclear material in the system. PAK/913 requires the licensee to establish appropriate emergency arrangements from the time the nuclear fuel is brought to the site and to put in place emergency preparedness plans before the commencement of operation. Emergency preparedness plans are required to cover the capability of managing accidents, mitigating their consequences if these do occur, protecting the site personnel, public and the environment. These plans are to be submitted to PNRA for approval and adhered to in the event of an emergency.

PNRA prepared “Regulations on Management of a Nuclear or Radiological Emergency - PAK/914” to ensure a timely, managed, controlled, coordinated and effective response at the installation, in the immediate vicinity and in the region affected by the nuclear or radiological emergency. Implementation of these regulations will help to minimize the radiological consequences to public, property and the environment arising from such an emergency. In case of severe emergencies, the response at national level and international liaison is also covered by these regulations. These regulations are still being reviewed by various stakeholders.

16.2 Emergency Plans of Licensees

The operating nuclear installations (K-1 and C-1) have taken appropriate measures to

ensure that there are on-site and off-site emergency plans. These emergency plans describe the on-site and off-site response organizational setups, classification of emergencies, assessment and declaration of emergencies, emergency facilities, on-site and off-site notification systems, emergency planning zones, intervention and derived intervention levels, environmental dose measurement and assessment facilities, application of protective measures, recovery operations and termination of emergency, public information, records and reports pertaining to exercises and drills, etc. The effectiveness of emergency plan is demonstrated in a comprehensive exercise before the commencement of operation of the nuclear installation. The frequency of the exercises is given in Annex – XIV and the exercises performed at K-1, C-1 and NRECC from January 2004 to June 2007 are shown in Annex–XV. The exercises are designed in a manner that all aspects of the emergency plan are tested. In the integrated exercises, participation of as many concerned organizations as possible is ensured. The plans are updated in the light of experience gained from the exercises and drills, to conform to changing regulatory requirements and changes in the local government organizational structure.

Emergency plans give brief details of plant systems, demography and regional climatology. The operating organization, on-site emergency response organization and off-site emergency organization are described in the emergency plans covering the role of each responsible person during an emergency situation. Emergency facilities like emergency control center, auxiliary emergency control center, communication facilities, radiation monitoring system, post accident monitoring system, medical facilities, decontamination facilities, etc., are described in the emergency plans.

In order to ensure an appropriate response, emergencies are classified according to the severity of an event or accident. Emergencies have been categorized into four classes in increasing order of severity as standby emergency, plant emergency, site emergency and general emergency. The details of the initiating conditions and actions to be taken during these emergencies are defined in the emergency plans. The initial assessment of the accidents and determination of associated emergency class is at the discretion of shift supervisor (SS) on duty. The initiating conditions are used for this purpose and the procedure for assessment and declaration of emergency class is followed. After the situation is under control and the plant is brought to a safer mode, SS terminates the emergency with the authorization of Site Emergency Director (SED). Implementation of protective measures during emergency situation is described in the emergency plans. The plans are implemented according to emergency implementing procedures.

A program is being developed to educate the public with the help of local Government about emergency preparedness. The public will be educated through electronic and print media. Written material is developed for distribution to the public. This literature covers following aspects:

- **a.** Brief Introduction to plant and its safety aspects.
- **b.** Basic concept that nuclear energy is pollution free.
- **c.** Need of emergency planning and preparedness.
- **d.** Public protective actions and their implementation.
- **e.** Public response during emergency.

Emergency preparedness plan for C-2 was submitted to PNRA as part of PSAR for review. The licensee will submit a revised version of the plan along with the FSAR. If the plan is accepted, then prior to issuance of fuel load permit by PNRA, C-2 will carry out a comprehensive drill to demonstrate the implementability of the plan.

16.3 Verification of Emergency Plans by PNRA

PNRA verifies the emergency plans of the licensee through observance of periodic emergency drills and exercises conducted by the licensee in fulfillment of regulatory requirements. About two months prior to the conduct of exercise, the licensee prepares and submit emergency exercise scenario for review and evaluation to PNRA. A team comprising observers from PNRA HQ and Regional Directorates witnesses the integrated exercises, whereas PNRA resident inspectors and facility observers witness the emergency drills. On the basis of the results of drills and exercises a report is prepared describing the actions to be taken for improvement of emergency plans and procedures for implementation of the plans. In order to verify the accuracy and continuous availability of emergency contacts, PNRA conducts Communication Test Exercises (COMTEX) on regular basis.

16.4 National Radiation Emergency Coordination Centre

National Radiation Emergency Coordination Center (NRECC) is established at PNRA Headquarters for coordination of response to nuclear accidents or radiological emergencies happening domestically or abroad. It also functions as the secretarial arm to Chairman PNRA, who is the National Competent Authority (NCA) for an emergency Abroad (NCA-A) and Domestic (NCA-D). NRECC is the National Warning Point (NWP) of Pakistan for the Conventions on “Early Notification of a Nuclear Accident” and “Assistance in the Case of a Nuclear Accident or Radiological Emergency”. It is responsible for notifying to National Competent Authority (Abroad and Domestic) and IAEA about a nuclear accident or radiological emergency.

NRECC is provided with communication facilities. It is supported by a Mobile Radiological Monitoring Laboratory (MRML) and other radiological monitoring equipment and supplies. MRML is stationed at PNRA HQ and can be activated after receipt of emergency notification within 20 to 30 minutes for dispatch to the affected site. Periodic emergency exercises are conducted in order to test the readiness and proper operation of MRML, and for continuous training of response personnel. In order to ensure a timely response to nuclear or radiation emergency, PNRA intends to provide MRML to regional nuclear safety directorates. PNRA is procuring advance equipments for assessment of radiation or contamination levels at the scene and a high frequency communication system to link the base station with MRML if they are in areas where normal means of communications are not available.

During emergencies, PNRA makes available and maintains communications facilities, protective equipment, MRML and emergency response teams at the NRECC. Radiological monitoring is coordinated by NRECC in support of nuclear installations and off-site authorities. According to PNRA Ordinance, PNRA may call upon civil defence organization, police, armed forces or other law enforcing agencies to assist in the implementation of protective and safety measures during emergency situation. In this regard, PNRA is coordinating with these response and law enforcing agencies to familiarize them with their role during a nuclear accident or radiological emergency. After finalization of national disaster management plan, a national level emergency exercise will be conducted.

16.5 International Cooperation

Pakistan is participating in a number of international projects sponsored by the IAEA in the area of emergency planning and preparedness. Pakistan actively participates in IAEA ConvEx[48] exercises, which are conducted to test the accuracy, availability and accessibility of contact points, adequacy of response time and capability to exchange information through ENAC web site. These exercises, especially the large-scale ones

[48] Convention Exercises

like ConvEx3[49], helped in testing our planning and preparedness. IAEA has observed that in most cases the system worked as designed and intended. Corrective measures were introduced where the response was not according to the expectations.

IAEA has three contact point entries for Pakistan. These are Permanent Mission of Pakistan to the IAEA, NRECC of PNRA (designated as the National Warning Point for Pakistan) and the Pakistan Nuclear Regulatory Authority {as the National Competent Authority for Domestic Emergencies NCA (D) and for Emergency from Abroad NCA (A)}.

Bilateral agreements do not exist so far between Pakistan and other neighboring countries regarding emergency preparedness or trans-boundary effects of nuclear emergencies. However, as a State Party to the Convention on Early Notification of a Nuclear Accident and to the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Pakistan will exchange information or consider provision of assistance in case of a nuclear accident or radiological emergency according to the provisions of the Conventions.

Pakistan has, therefore, met the obligations of Article 16 of the Convention.

[49] A convention exercise carried out after every four years

Article 17 – Siting

> *"The Contracting Parties shall take the appropriate steps to ensure that appropriate procedures are established and implemented:*
> *(i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;*
> *(ii) for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;*
> *(iii) for re-evaluating as necessary all relevant factors referred to in subparagraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;*
> *(iv) for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation."*

17. Siting

Pakistan has taken appropriate steps to ensure that adequate procedures are established and implemented for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime and for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment. The continued safety acceptability of the nuclear installations has been ensured by re-evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime.

17.1 Regulatory Requirements

The regulatory requirements for licensing of nuclear installations are described in PAK/909. The national regulations entitled “Regulations on the Safety of Nuclear Power Plants – Site Evaluation (PAK/910 Rev. 0)” (not officially notified) establish the requirements for siting of nuclear installations. In addition, PAK/904, PAK/912, PAK/914 (draft) and Pak/915 concern some aspects of siting.

Regulations on Radiation Protection (PAK/904) require the licensee to determine all the significant exposure pathways, establish dose constraints on the release of radioactive substances to the environment and determine discharge limits on the basis of established dose constraints.

The Regulations on Safety of Nuclear Power Plants – Quality Assurance (PAK/912) require that a quality assurance program be established and approved before the commencement of site investigation activities.

In the light of regulations on Radioactive Waste Management (PAK/915), the licensee has to determine all the significant exposure pathways through which the discharged radio-nuclides can cause public exposure. The licensee has to estimate the dose constraints in relation to the discharges of radioactive substances to the environment and determine discharge limits on the basis of the estimated dose constraints.

The national regulations PAK/910 (Rev. 0) is based on the IAEA NUSS 50-C-S (1988). These are currently under revision and would now be based on IAEA safety requirements NS-R-3. These regulations encompass site related and site-plant interaction factors, relating to nuclear power plant operational states and accident conditions. These factors include those conditions which require emergency measures, and natural and human induced events external to the plant that are important to safety. These regulations are concerned mainly with severe events of low probability that relate to the siting of nuclear power plants and which need to be considered in designing a particular nuclear power plant. If events of lesser severity but higher probability make a

significant contribution to the overall risk, these should also be considered in the design of nuclear power plants.

The scope of the investigation for the site of a nuclear power plant covers the entire process of the site evaluation that is the selection, assessment, pre-operational and operational stages. The intention is to determine all site parameters that may have an effect on plant design and the impact of the plant operation on the population and the environment. Accordingly, site studies cover areas such as geography, geology, seismology, demography, etc. One important aspect of these regulations is the evaluation of the effects of accidental and routine releases to the environment so that appropriate emergency measures are planned.

The site characteristics are assessed on the basis of historical evidences, recorded data, site surveys, detailed investigations and detailed analysis in line with IAEA requirements and recommendations and based on international practices and proven engineering techniques. Generally, site specific data (recorded data) are used. If site specific data are not available, data are derived from historical information and / or data of similar site are used. The site is evaluated against natural hazards as well as man-made hazards (storage, transportation, etc.). These evaluations are used to establish design bases for nuclear installations.

Seismic activities, ground water, meteorological conditions are continuously monitored and monitoring instruments are installed at proposed sites. At the stage of Periodic Safety Review (PSR), demography and man-induced hazards are re-evaluated based on census data and industrial development including transportation, etc. In PSR, the data are updated and evaluated to verify if there is any change in the hazards previously determined. Development in methodology for determining the hazards is also considered during these evaluations. In case of any change in the hazards that may pose a threat greater than that previously determined, plant design would be studied for its adequacy and / or for any subsequent action.

National regulations PAK/909 require provision of “No Objection Certificates” from local, provincial and other federal agencies at the time of site registration to ensure that the plant conforms to national rules and regulations regarding environment protection, land and water use, etc.

17.2 Nuclear Installation Sites

The site of C-1 was discussed in the previous national reports. Site of K-1 was investigated as part of relicensing and reported in the updated FSAR. The Site Evaluation Report of C-2 was submitted to PNRA and after review the site was registered.

17.2.1 K-1 Site

The site for K-1 was selected in sixties. The ground acceleration due to design basis earthquake has been re-evaluated for K-1 site and the ‘g’ value has now been established as 0.2 g instead of the original design value of 0.1 g.

On the basis of the studies conducted by PAEC on seismic re-assessment, it has been concluded that there is no seismic source near K-1 and as such no hazard due to tsunami exists. No evidence of any effect was found at K-1 site due to tsunamigenic source near Sumatra, Indonesia in December 2004 because of the presence of bulge of Sri Lanka and Indian landmass. A study was carried out for assessment of tsunami hazard for K-1 site based on field evidences. It was concluded that maximum height of the wave resulting from tsunami, like the one that occurred near Pasni in 1945, would be from 0.6 to 1 meter. This will not pose any hazard, because K-1 is about 6.1 meter above mean sea level. In the worst case where intake structure is damaged or intake water system is severely choked by flooding due to storm, hurricane and / or tsunami, long

term post shut down cooling will be provided by the independent and seismically qualified emergency feed water system.

A seismic monitoring system has been installed at the site to help in estimating the severity of the seismic event and to enable the plant management to take necessary actions. As regards airplane crash, it is mentioned that the site has been declared as no fly zone.

17.2.2 Site Evaluation of C-2

C-2 is the second PWR in Pakistan located adjacent to C-1. Most of the site data and studies pertaining to C-1 have been utilized in the evaluation of C-2 site. As a requirement of national regulations PAK/909, C-2 submitted a detailed Site Evaluation Report (SER) which was reviewed by PNRA in the light of existing regulations and IAEA Safety Standard NS-R-3. The C-2 site was registered after fulfilling the requirements and the construction work began.

Site characteristics of C-2 such as geology and demography; nearby industrial and transport facilities, meteorology, hydrologic engineering, seismology and geotechnical engineering are the same as for C-1. Population data for C-2 SER were obtained from the records of 1998 census. In view of the increase in the population in the vicinity of C-1 due to plant related activities, field surveys were conducted in 2003 to determine the population growth within 5 km of the site and the population figures were updated accordingly. The nearest population centre is located at a distance of more than 1.3 times the Low Population Zone boundary.

Around the site, there is an exclusion area that has been determined on the basis of dose due to accidental releases. The plant management has the authority to control all activities within the exclusion area in case of an accident.

Meteorological data were obtained from the stations located at Chashma Site, Mianwali, Sargodha and Dera Ismail Khan. Since C-2 is adjacent to C-1, geology remains the same. Records of earthquakes in the region have been updated up to 2004. All recorded earthquakes are less than the maximum postulated earthquake considered in the design. Like C-1, ground acceleration due to Safe Shutdown Earthquake (SSE) for C-2 is 0.25 g.

A number of boreholes were drilled for geotechnical studies of C-2. The subsurface soil was found to be the same as that for C-1. Therefore, the geotechnical parameters of C-1 were adopted. Surface mapping of the top 6 meters did not indicate any stratigraphical offset. From these studies, it was concluded that the problem of on-site surface faulting does not exist.

In view of the fact that the soil at the site consists of a deep deposit of dense to very dense sands and alluvial deposits, with a high water table level, a detailed liquefaction analysis was performed both for the free-field and non free-field conditions. It was concluded that liquefaction will not occur in the free-field and non free-field conditions in case of SSE.

17.3 Verification by PNRA

The site verifications of C-1 and K-1 were performed at the time of their construction. The details were given in previous reports. In June 2004, C-2 submitted application for Site Registration for the construction of second unit at Chashma Site along with SER. The review of the SER was conducted in two phases and all issues related to site were resolved by providing additional information, analysis and tests.

An IAEA expert mission also conducted a review in March 2005. The mission concluded that there are no major safety issues related to the C-2 Site. C-2 completed all the necessary formalities in October 2005 and the site was registered in December 2005 for the construction of the plant.

17.4 Trans Boundary Effects

The nuclear installations in Pakistan are located away from international boundaries; therefore, a rather low possibility of trans-boundary effects exists in the case of a nuclear accident. Pakistan has signed the Convention on “Early Notification of a Nuclear Accident” and the Convention on “Assistance in the Case of a Nuclear Accident or Radiological Emergency”. In case of an accident, Pakistan will respond according to the obligations of these Conventions.

17.5 Monitoring at Sites

At K-1 and C-1 sites, all radioactive effluents at the point of release are monitored according to the environmental monitoring programs. These programs are under the regulatory surveillance of PNRA. Radioactivity monitoring instruments are installed (during site investigation, construction and operation stages) at both the sites and in nearby region to assess the ambient radiation level. A comprehensive program to determine ambient radiation level in air, water, soil and vegetation has been initiated throughout the country.

Pakistan has, therefore, met the obligations of Article 17 of the Convention.

Article 18 - Design and Construction

"Each Contracting Party shall take appropriate steps to ensure that:

(i) the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence-in-depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;

(ii) the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;

(iii) the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface."

18. Design and Construction

Pakistan has taken appropriate steps to ensure that the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence-in-depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur; and that the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis.

18.1 Regulatory Requirements

The regulations PAK/911 relate to the design and construction of nuclear installations. In addition, PAK/904, PAK/910, PAK/912, PAK/913 and PAK/915 are also concerned with design and construction. These regulations are based on the IAEA safety requirements. The obligations of Article 18 will be met through implementation of these regulations.

18.2 Defence-in-depth

The defence-in-depth in nuclear installations in Pakistan is same as that required in NS-R-1.

18.3 Design of Nuclear Installations

Nuclear installations are adequately designed and constructed for preventing, controlling and mitigating the consequences of anticipated operational occurrences, faulted conditions, design and beyond design basis accidents. As part of relicensing and plant life extension, improvements were made in the design of K-1. These include the installation of a screen around the active drainage sumps, third emergency diesel generator, a system capable of adding heavy or light water to the primary heat transport system, improvement in control room habitability, automation of emergency feed water system, anchoring racks of DC battery banks, new delayed neutron activity monitoring systems at north and south sides, etc.

The designs of C-1 and C-2 are comparable to other PWR operating elsewhere in the world and meet the current safety requirements. In the design of C-1, several measures are provided such as increased thickness of the base slab to retain corium for longer duration, large containment volume, increased capacity of pressurizer, relief and safety valves for rapid depressurization, etc.

In C-2, the design basis and beyond design basis accidents were considered in the design stage and following modifications and improvements were made in the design:

a. motor throttle valve in the pressurizer of reactor coolant system to depressurize the primary system and avoid high pressure core melt ejection and consequent

direct containment heating and containment failure at an early stage

b. cavity flooding system to avoid reactor pressure vessel failure and consequent ex-vessel corium-concrete interaction

c. passive auto-catalytic Hydrogen recombiners inside the containment to limit the volume of hydrogen and to avoid hydrogen explosion

d. SRH piping design pressure setting is raised to 900 psi (instead of 600 psi) to reduce the probability of interface LOCA, etc.

18.4 IAEA Review of C-2 Design

The PSAR of C-2 was reviewed by international experts from various Member States under an IAEA TC Project. Fifteen expert missions were conducted in addition to one follow-up mission. The experts made recommendations for the improvement of safety that are being incorporated in the design. Based on the results of this review, it can be concluded that the design as presented in the PSAR along with the commitments made during the review is in compliance with current international standards.

18.5 Construction of Nuclear Installations

The activities during construction of C-2 are described in the following section.

18.5.1 Construction Activities at Site

Construction of the containment building, nuclear auxiliary building, electrical building, fuel building and structures of balance of plant is progressing satisfactorily. Installation of containment steel liner is almost completed. However, concreting work is expected to be completed by early 2008. Equipment installation has started in the plant. Construction and installation are performed by qualified sub-contractors and their activities are being supervised by the main contractor. PNRA, licensee and main contractor are performing inspections to verify compliance with regulations and conditions of Construction Licence.

18.5.2 Manufacturing in Pakistan

Heavy Mechanical Complex – 3 (HMC-3) is a project of State Engineering Corporation that has been licensed by PNRA to manufacture ASME B&PV code Section III class 2 and 3 tanks, vessels and heat exchangers. HMC-3 is manufacturing class 3 tanks for C-2 project. These tanks are being inspected by the main contractor for C-2 as well as by the owner. PNRA is carrying out inspections to ensure compliance with safety requirements and performs annual inspection of HMC-3 to verify that the minimum capability and competence required for manufacturing safety class equipment is maintained. Manufacturing of the first batch of equipment ordered by the client has been completed and equipment has been handed over to the client. Manufacturing of the second batch of equipment is in progress.

18.5.3 Manufacturing in China

Except for few equipment manufactured in Pakistan, most of the equipment for C-2 will be manufactured in China. The manufacturers have been selected by the main contractor according to the procurement control requirements of its QAP. The QAP of main contractor has been developed on the basis of Overall Quality Assurance Program of C-2, which has been approved by PNRA. C-2 inspects and audits the manufacturers. PNRA has selected safety significant equipment for regulatory inspections, including QA inspections during manufacturing, testing and qualification of these equipments.

Man- machine aspects have been covered in article 12.

Pakistan has, therefore, met the obligations of Article 18 of the Convention.

Article 19 - Operation

"Each Contracting Party shall take the appropriate steps to ensure that:
(i) the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning program demonstrating that the installation, as constructed, is consistent with design and safety requirements;
(ii) operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;
(iii) operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;
(iv) procedures are established for responding to anticipated operational occurrences and to accidents;
(v) necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;
(vi) incidents significant to safety are reported in a timely manner by the holder of the relevant license to the regulatory body;
(vii) programs to collect and analyze operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;
(viii) the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal."

19. Operation

Pakistan has taken appropriate steps to meet the intent of Article 19 of the Convention. Authorization for initial operation is issued based on appropriate safety analysis, commissioning program and other documents demonstrating that the constructed plant is consistent with design and safety requirements. Operational limits and conditions are derived from safety analysis, commissioning tests and operational experience to identify safe boundary for operation and are updated as necessary. All activities are performed according to approved procedures. Engineering and technical support is available at the plant and from sister organizations. Designer and vendor support is also available for C-1. Operating experience feedback process is in place to collect and analyze operating experience and to take appropriate actions. Experience is also shared with IAEA IRS, INES, WANO, COG, etc.

19.1 Regulatory Requirements

The national regulations PAK/913 establish regulatory requirements for safety of nuclear installations during operation. These include requirements such as organization and staffing, quality assurance, emergency preparedness, fire safety, physical protection, operating experience feedback, qualification and training of personnel, commissioning program, plant operation, licensee event reporting system, notification of events to the regulatory authority, radiation protection and waste management, testing and surveillance program, criteria for appointment to safety significant posts, etc.

National regulations PAK/912 set the requirements for quality assurance during operation. The licensee is required to establish a comprehensive quality assurance system that covers safety related activities during operation.

According to PAK/909 a nuclear installation can only be operated after a licence is issued by PNRA. The issuance of licence is based upon an appropriate safety analysis and a commissioning program demonstrating that the installation, as constructed, is consistent with design and safety requirements. The dose limits for radiation workers and the public, are specified in PAK/904, to be followed during normal operation.

19.2 Initial Authorization to Operate

PNRA is licensing nuclear installations according to PAK/909. The licensing process has three stages. These are site registration, issuance of construction and issuance of operating licence. PAK/909 lists the documentation that is to be submitted for each stage. Permission to operate a nuclear installation is granted by PNRA in steps. First a commissioning program is reviewed and approved. This allows the licensee to start cold commissioning. If the safety review of FSAR is also satisfactory and other requirements of PAK/909 are fulfilled, the licensee is allowed to load fuel, perform low power tests, raise power and perform other tests as specified in the commissioning program. On satisfactory completion of the commissioning program, operation after attaining full power and submission of updated versions of FSAR and other documents, an operating licence is issued. In case of relicensing, PAK/909 prescribes a procedure for operation beyond design life. The required documentation for the purpose is an updated report of last periodic safety review, revised FSAR, PSA (level one plus), decommissioning program, etc. The operating licence is normally valid for a period of up to ten years subject to certain conditions.

The relicensing process of K-1 is expected to be completed by September 2007. Meanwhile, the plant has been allowed to operate at 90 MWe. The operation so far is satisfactory. The relicensing and plant life extension activities were proposed to be completed in two phases. The relicensing outage phase II (RLO-II), began in December 2005. Major planned jobs were completed during the outage. Following are few salient activities that were completed during RLO-II:

- **a.** New LOCA qualified moderator pump-motors and emergency core cooling re-circulation pump-motors installed
- **b.** Redundant and diverse valves provided in the emergency core cooling system
- **c.** Medium pressure injection system (FIJW) installed to cater to small LOCA.
- **d.** Fire prevention and control in cable galleries.
- **e.** Junction box sealed against steam ingress
- **f.** Annulus Gas System modified for protection against Leak Before Break
- **g.** Critical Parameters Display System installed
- **h.** Safety Parameters Display System partially installed with two functions – reactor power criticality and radiological emission.
- **i.** Containment pressurization test at the pressure expected during a critical break completed successfully.
- **j.** C&I loops replaced with state-of-the-art PLC based control loops
- **k.** LOCA handling capability outside boiler room improved
- **l.** Thermal Conductivity Detector analyzer installed for H2 detection at turbine generator floor and H2 addition station.
- **m.** Recommendations of Fuel Channel Integrity Assessment carried out in 2003 partially implemented in 2006 and rest will be carried out in 2009 shut down.
- **n.** Inspection of tendon gallery as per routine surveillance (grouting of the

anchorage box of the tendon and concrete gallery were found in extremely good condition).

o. Third emergency diesel generator installed and commissioned

p. Control room habitability improved by:

i. new air conditioning units installed for MCR ventilation

ii. MCR block masonry wall along which main steam lines are passing was strengthened with steel plates

The revised and updated FSAR submitted to PNRA is under review and a decision on relicensing is expected by September 2007. In the review of FSAR, K-1 is being assessed against national regulations based on IAEA safety standards. Therefore, compliance with national regulations implies conformance with IAEA standards.

Operating licence was granted to C-1 in October 2004. The plant is operating satisfactorily and has undergone four refueling outages and is currently in its fifth operating cycle. At the end of each refueling outage, the licensee submits a safety case for operation of the plant in the next cycle along with the documents specified in PAK/913. PNRA review the safety case and allows continuation of operation. The plant is preparing for first periodic safety review which is to be completed by 2010.

The C-2 is under construction and the project staff is participating in construction and installation as a preparatory activity for commissioning and operation. Commissioning will be performed by C-2 staff under the supervision of commissioning sub-contractor. Commissioning procedures will be developed by C-2.

19.3 Operational Limits and Conditions

The license for each nuclear installation contain technical specifications (operating policies and principles) that set operational limits and conditions derived from the safety analyses, tests, and operational experience. The operational limits and conditions define the safe envelope for operation. The OPP of K-1 is according to Canadian practices, whereas the technical specifications of C-1 are according to USNRC practices. These are revised as and when required if the safety analysis and national regulations are amended or design modifications are carried out. PNRA inspectors continuously verify that the installations are operated within the operational limits and the conditions specified in the technical specifications.

Due to safety improvements and upgrades carried out during RLO-1 and RLO-II, changes were made in the OPP in May 2006 related to newly installed systems. In addition, Allowable Outage Times (AOT) needed revision due to addition of new systems. Changes proposed by K-1 in the OPP were agreed to by the PNRA.

19.4 Operating Plant Procedures

All operation, maintenance, inspection and testing activities at nuclear installations are carried out in accordance with written, approved, reviewed and revised procedures.

K-1 prepared several new operating procedures for operating, maintaining and testing newly installed systems such as FIJW, third diesel generator, etc.

Whenever any degradation is found during surveillance periodic testing of equipment or system, a procedure is developed in C-1 for providing instructions to the operators to take immediate corrective action till the restoration. These instructions are in the form of operation instructions and are temporary until degraded equipment or system is restored. The revision and updating of operating plant procedures is a continuous process in C-1.

19.4.1 Procedures for Operation

Administrative procedures establish the methodology regarding development, validation, acceptance, modification and approval of operating procedures for normal operation and for abnormal and emergency conditions. These procedures are required to be developed before commissioning and are checked and validated for applicability and quality in terms of technical accuracy. This is to ensure their usability with installed equipment and control system during commissioning. Plant personnel engaged in operation are adequately trained and re-trained in the use of these procedures.

19.4.2 Procedures for Maintenance and Inspections

Maintenance, testing, surveillance and inspection programs are required to be put in place before the commencement of operation according to regulations PAK/913 and are updated, as needed. Surveillance and testing of systems and components important to safety is a part of plant technical specifications and all the inspections, surveillance and testing is performed according to plant approved procedures. These procedures are subject to revision within the time frame defined in each document.

19.4.3 Procedures for Modification Management

Approved procedures are also in place to manage and control modifications in the plants. Both permanent and temporary modifications are controlled through implementation of these procedures.

19.4.4 Emergency Operating Procedures

Pakistan is striving to change event-based Emergency Operating Procedures (EOP) at its nuclear installations to symptom-based. At C-1, Event-based Emergency Operating Procedures were provided by the vendor and the Symptom-based Emergency Operating Procedures (SEOP) are being developed.

At K-1, Abnormal Transient Operational Guidelines (ATOG) are available to guide the operational staff in handling abnormal events and accidents. Two new ATOG have been issued regarding "Pressure Tube Leak Before Break Detection" (prepared in the light of modifications made in the Annulus Gas System) and "Total Loss of Process Salt Water System / Standby Salt Water System During Plant Operation". ATOG regarding the LOCA handling has been revised because of the addition of FIJW system and redundant equipment in Injection Water (IJW) system.

19.5 Reporting of Emergencies and Events

Requirements for reporting emergency conditions and abnormal events to the regulatory body are specified in regulations PAK/913 and are reproduced in plant technical specifications and OPP. PAK/913 impose condition on plant for submitting preliminary reports at various time intervals starting from one hour to 8 hours after declaration of emergency. These reports are submitted through emergency notification system. If emergency notification system is inoperable, licensee shall make the required notifications through telephone service, some other dedicated system or any other method (fax / mail, etc). Detailed event report on a prescribed format has to be submitted by the licensee to the PNRA within 60 days of occurrence of the event. These reports are analyzed by the PNRA to identify any additional corrective action which needs to be taken by the licensee. Root Cause Analysis (RCA) is also required in the detailed event report. PNRA reviews it with the assistance of the Regional Directorates to ascertain its adequacy and to ensure that the likelihood of recurrence of similar events is minimized.

19.6 Engineering and Technical Support

Efforts are made at all installations to provide necessary engineering and technical support in all safety related fields. Installations have their own engineering departments for technical support, whereas engineering support is also available from other organizations within PAEC.

Engineering department of C-1 is responsible for collecting and analyzing the operating experience from within the installation and other installations (including non-nuclear installations) operating in the country and international experience feedback to identify necessary actions. Engineering support of vendor and designer is available for C-1 under lifetime support agreement. In addition, support from vendor country organizations for maintenance, in-service inspection, refueling operations, etc., are also available.

In case of K-1, vendor support has been non-existent but the situation improved to some extent in 1989, when K-1 joined COG & WANO. Technical help on safety matters is currently available from Canada in certain cases. The fuel channel integrity assessment was carried out in July 2003 using AECL equipment and the link to AECL through internet. Support for updating the K-1 FSAR was provided by Nuclear Safety Solutions of Canada.

19.7 Incident Reporting to INES and IRS

Safety significant reportable events occurring at nuclear installations are reported to INES. One event was reported to INES in 2006. Similarly, when events of safety significance and of interest to others in the nuclear industry, occurs in a nuclear installation it is reported to the Incident Reporting System (IRS). Four events have been reported to IRS since 2004.

19.8 Safety Performance Evaluation

K-1 has developed about ninety performance indicators to monitor operational safety which have been discussed earlier. K-1 is also contributing to WANO Performance Indicator Program since 1992. Regarding Operating Experience (OPEX) Feedback, a process exists for exchange of operational safety information by collecting, analyzing, and disseminating lessons learned from information arising from their own as well as other utilities including COG and WANO operating experience. K-1 interacts on-line with COG and WANO networks to exchange OPEX information. Methods of using operating experience are structured to provide applicable information. Relevant international OPEX is screened daily at K-1 and distributed to relevant personnel for follow up action.

A team of engineers is responsible to review messages from COG and WANO/INPO[50] OPEX. Messages retrieved through the nuclear networks or received in the form of reports are scrutinized. Screened material is sent to relevant personnel for review and to determine relevance with K-1. If the information is found applicable, it is incorporated through changes in procedures, systems or equipment, etc., in order to prevent recurrence of industry event at K-1. Specific queries are also raised by K-1 regarding its own problems where it is felt that COG or WANO could be of help. A number of changes in plant systems and procedures have been carried out on the basis of operating experiences. The nuclear networks have been of assistance in resolution of some of the K-1 technical problems. In the areas, where it has experience and expertise, K-1 responds to the queries raised by other NPP.

C-1 has international operating experience feedback through the IAEA, OSART, WANO, QNPC, SNERDI, RINPO, etc. on various safety related issues. In addition, C-1 has access to the IAEA Incident Reporting System (IRS) and INES. As a member of WANO, C-1 shares plant operating experiences with other members. The Operating Experience (OE) program is mainly based on WANO and INPO literature with adjustments according to the environment of C-1.

19.9 Radioactive Waste

Under PAK/915, licensee is required to keep the generation of both activity and volume of radioactive waste to the minimum practicable by suitable design, operation and

[50] Institute of Nuclear Power Operation

decommissioning of its facilities. To fulfill this requirement, the licensee is required to:

- **a.** avoid the use of unnecessary hazardous / toxic material
- **b.** use the minimum quantity of radioactive materials
- **c.** minimize the amount of waste by preventing unnecessary contamination of material
- **d.** maintain consistency with the management strategy and systems.

Waste generation is kept to a minimum by maintaining and controlling fluid chemistry, recycling of fluid, good operating practices, routine surveillance, etc. Strict requirements are defined in PAK/915 for processing of radioactive waste so that the resulting waste, packaged or unpackaged, can be safely stored and retrieved from the storage facility for disposal. Treatment and conditioning of radioactive waste is to be carried out in accordance with the waste acceptance criteria. Installations have developed their radioactive waste management programs and the waste is managed accordingly. Discharges to the environment and environmental monitoring are performed according to an established monitoring program.

The draft national policy on radioactive waste management is in the process of finalization.

19.10 Spent Fuel Storage

At K-1, irradiated fuel discharged from reactor is stored in the spent fuel storage located inside the service building. Spent fuel storage bay is designed to store spent fuel safely until it is removed for interim storage or final disposal. After 35 years of operational life, spent fuel storage bay is approaching its full capacity. Due to good chemistry in spent fuel storage bay and low oxidation rates, no aging seems to be visible on the structural material used in stacking the fuel bundle and the spent fuel under water appears to be in good condition. However, there are plans to transfer spent fuel from spent fuel storage bay to dry storage in order to create space for fuel bundles discharged during the extended life of K-1. In this regard, work has already been started for making the dry storage facility for K-1 spent fuel.

At C-1, spent fuel storage facility can meet storage requirements for 15 years and additional facility will be constructed at an appropriate time.

Pakistan has, therefore, met the obligations of Article 19 of the Convention.

Annex – I : Existing Nuclear Installations

	K-1[51]	C-1[52]	C-2[53]
Status	Operation	Operation	Construction
Location	Karachi, Sindh	Chashma, Punjab	Chashma, Punjab
Type	CANDU	PWR	PWR
Capacity (gross)	137 MWe	325 MWe	325 MWe
First fuel loading	July 1971	November 1999	September 2010 (expected) [54]
First criticality	August 1971	May 2000	April 2011 (expected)
Date of operation	December 1972	September 2000	2011 (expected)

[51] Karachi Nuclear Power Plant Unit 1
[52] Chashma Nuclear Power Plant Unit 1
[53] Chashma Nuclear Power Project Unit 2
[54] date of first concrete pour – 28 December 2005

Annex – II: K-1 Design Parameters

Net electrical output	125 MWe
Gross generator output	137 MWe
Reactor type	PHWR Heavy water cooled and moderated
Fuel	Natural UO_2
Containment building	4 feet and 5 inch thick concrete walled circular building capped with concrete dome of 19 inch thickness
Containment building diameter	115 feet
Containment building design pressure	28.28 psig
Total fission power	456.8 MWt
Fission heat to coolant	432.8 MWt
Number of fuel channels	208 (3.25” dia Zr-Nb heat treated pressure tube)
Number of fuel bundles per channels	11 – (19 pin fuel bundle)
Average/maximum axial flux	0.649
Average/maximum radial power	0.7374
Average fuel burn-up at discharge	6538 MWD/ton U
Calandria form	Horizontal vessel with integrated dump space
Calandria material	Type 304L-ASTM A 240 Austenitic Stainless Steel
Length of Calandria	16´ and 3˝
Number of absorber rods	04
Number of boilers	06
Number of refueling machines	02
Total coolant flow rate	15.15 million lb/hr
Primary coolant pumps	08
Pump type Flow	Centrifugal, vertical, 4670 igpm
Turbine type	Tandem compound
Heat sink	Sea water from Arabian Sea
No of Forced Injection Water (FIJW) system pumps	02
FIJW pump type	Centrifugal type
FIJW pump discharge head	900 feet
FIJW pump flow	360 igpm

Annex – III: C-1 Design Parameters

Gross electrical output	325 MWe
Net electrical output	300 MWe
Number of primary loops	2
Reactor type	PWR
Fuel	Enriched uranium
Containment building	1 meter thick pre-stressed concrete walled circular building capped with concrete dome
Containment building diameter	36 m (inner)
Design pressure of containment	0.26 MPa
Design Pressure of Coolant	17.16 MPa
Design Temperature of Coolant	350 ^{o}C
Coolant flow rate (Best Estimate)	16800 x 2 m^3/h
Fuel assemblies	121
Pressure vessel material	SA508 Class 3
Height of pressure vessel	10.366 m
Active core height	2.9 m
Coolant operating pressure	15.2 MPa
Control rod assemblies	37
Number of steam generators	2
Primary coolant pumps	2
Turbine type	Horizontal tandem machine

Annex – IV: Summary of Activities Performed during RFO at C-1 after TRM[55]

Activities	RFO-3	RFO-4
Total jobs planned	4014	3813
Total jobs completed	3865	3781
Maintenance jobs	3141	3187
ISI jobs	645	509
Modifications	17	25
Surveillance tests	176	176
Deferred jobs	149	32
Additional jobs completed which were identified during outage	600	800
Planned radiation collective doses & Max individual	500 man-mSv 10 mSV	500 man-mSv 10 mSV
Received radiation collective doses & Max individual	381 man-mSv 6.2 mSv	427 man-mSv 6.1 mSv
Outage duration (planned/actual)	49.8/47.6	57/76.6
Major problems faced	Earthquake of 7.8 at Richter scale intensity was felt	Spacer grid of one fuel assembly found slightly damaged; new core reload pattern was used

[55] Third Review Meeting of the Convention on Nuclear Safety

Annex – V: National Regulations

National Regulations – Officially Notified

Pakistan Nuclear Safety and Radiation Protection Regulations – 1990

Regulations on Licensing Fee by PNRA – PAK/900 Rev 0

Regulations on Radiation Protection – PAK/904 (Rev. 0)

Regulations for the Licensing of Radiation Facility (ies) other than Nuclear Installation(s) – PAK/908

Regulation for licensing of Nuclear Installation(s) in Pakistan – PAK/909 (Rev 0)

Regulations on the Safety of Nuclear Power Plant – Design – PAK/911 (Rev.1)

Regulations on the Safety of Nuclear Power Plants – Quality Assurance Pak/912 (Rev.1)

Regulations on the Safety of Nuclear Power Plants–Operation –PAK/913 (Rev.1)

Regulations on Radioactive Waste Management – PAK/915

Regulations for the Safe Transport of Radioactive Material – PAK/916

National Regulations – in the Draft Form

Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers–PAK/907 (Rev.0)

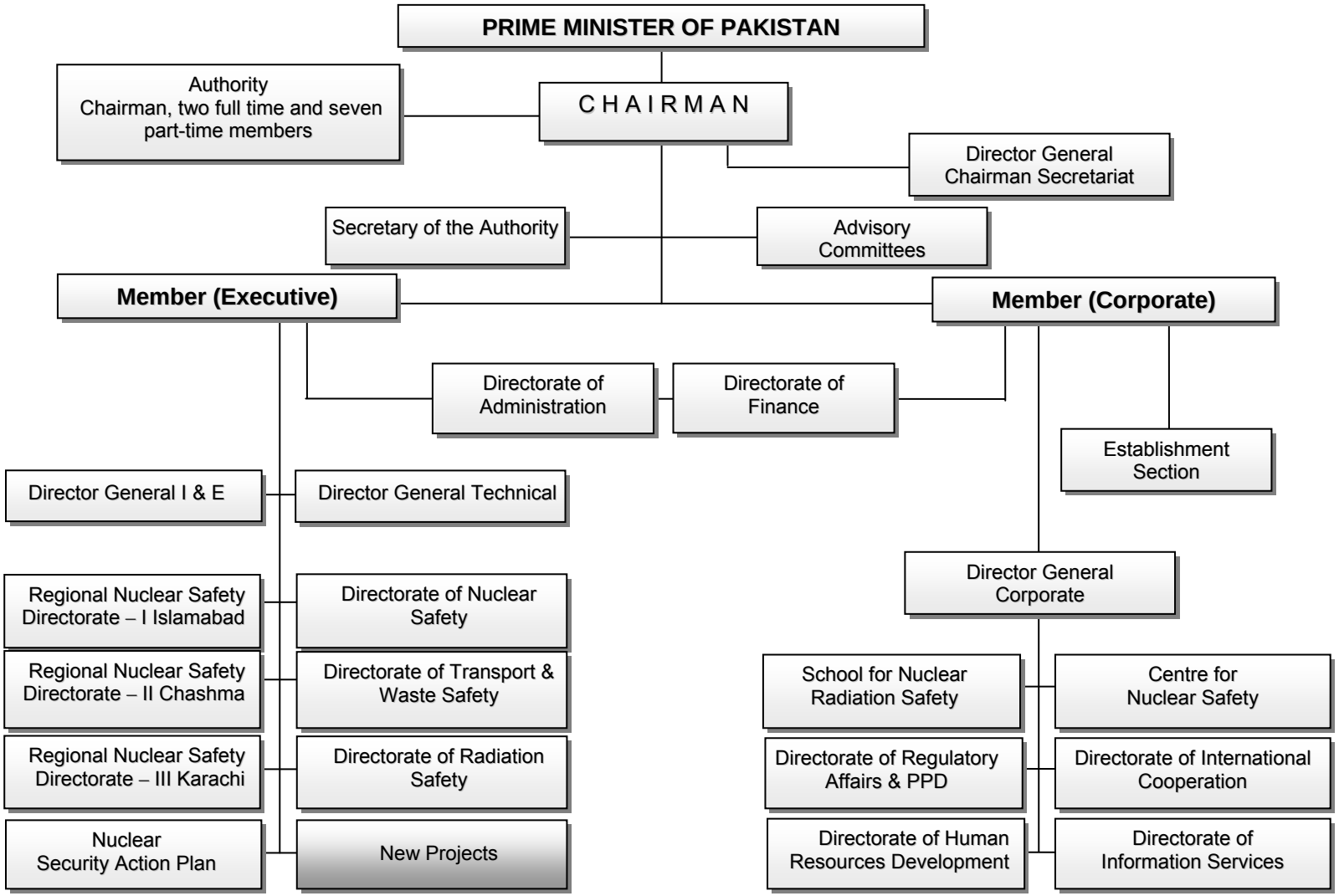
Regulations on the Safety of Nuclear Power Plants - Site Evaluation PAK/910 (Rev.1)

Regulations on Management of a Nuclear or Radiological Emergency - PAK/914 (Rev.0)

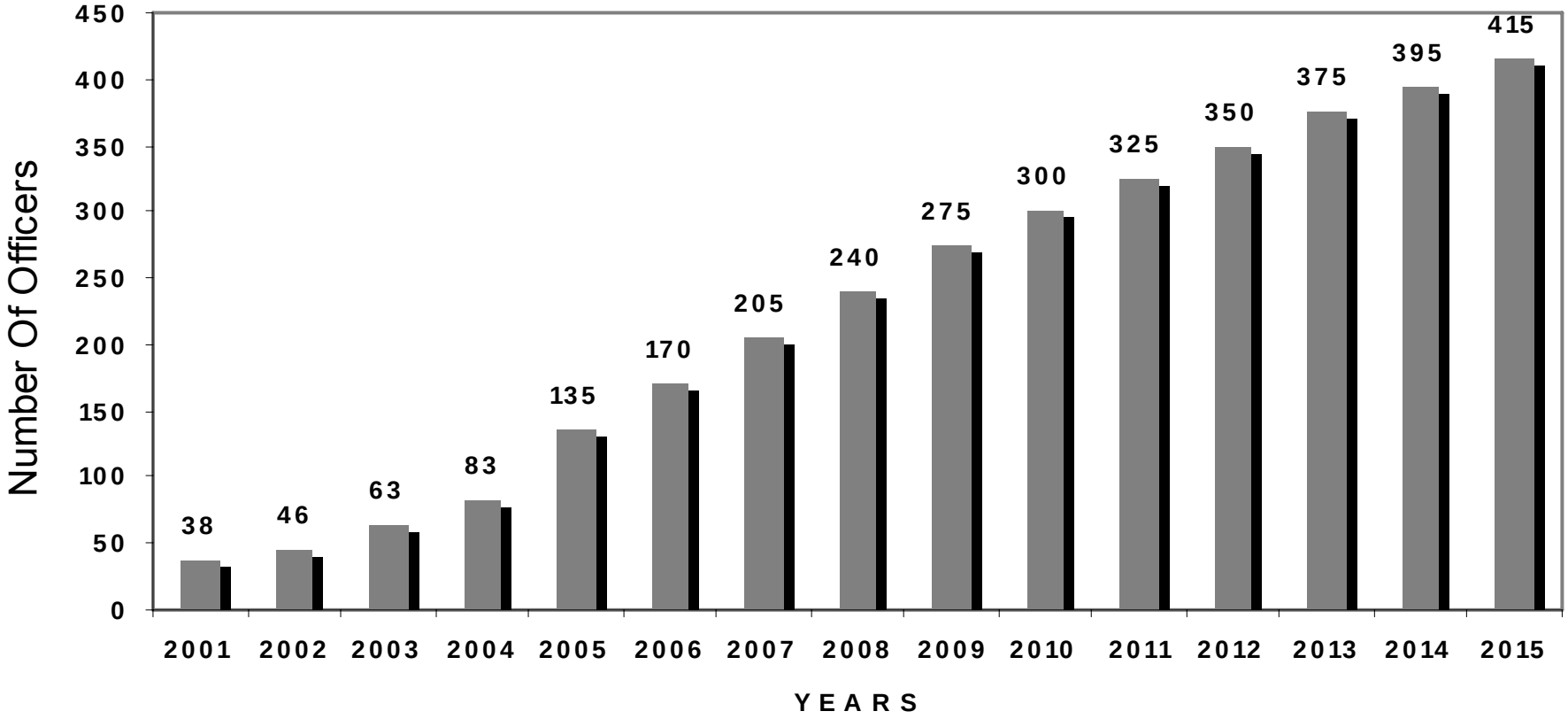
National Regulations – Under Consideration

Regulations on Decommissioning of Nuclear Installations – PAK/917

Annex – VI: Organizational Chart of Pakistan Nuclear Regulatory Authority



Annex – VII: Manpower at PNRA from 2001-2006 and projected requirement from 2007-2015



Annex – VIII: PNRA Performance Indicators

Indicator 1. Ensures acceptable level of safety being maintained by licensees

Indicator 2. Ensures regulations and procedures in position and understood by licensees

Indicator 3. Strives for continuous improvement of its performance

Indicator 4. Appropriate actions taken to prevent degradation of safety and to promote safety improvements

Indicator 5. Takes appropriate steps for human resource development and has competent and certified regulatory staff

Indicator 6. Ensures that adequate legal provisions exist for enforcement,, i.e., dealing with non-compliance or licence violations

Indicator 7. Performs its functions in a timely and cost-effective manner

Indicator 8. Ensures that a well-established quality management system exists

Indicator 9. Ensures that adequate resources are available for performing its functions and Technical Support Centre(s) available for specialist assistance when required

Indicator 10. Performs its functions in a manner that ensures the confidence of the operating organization

Indicator 11. Performs its functions in a manner that ensures the confidence of the general public

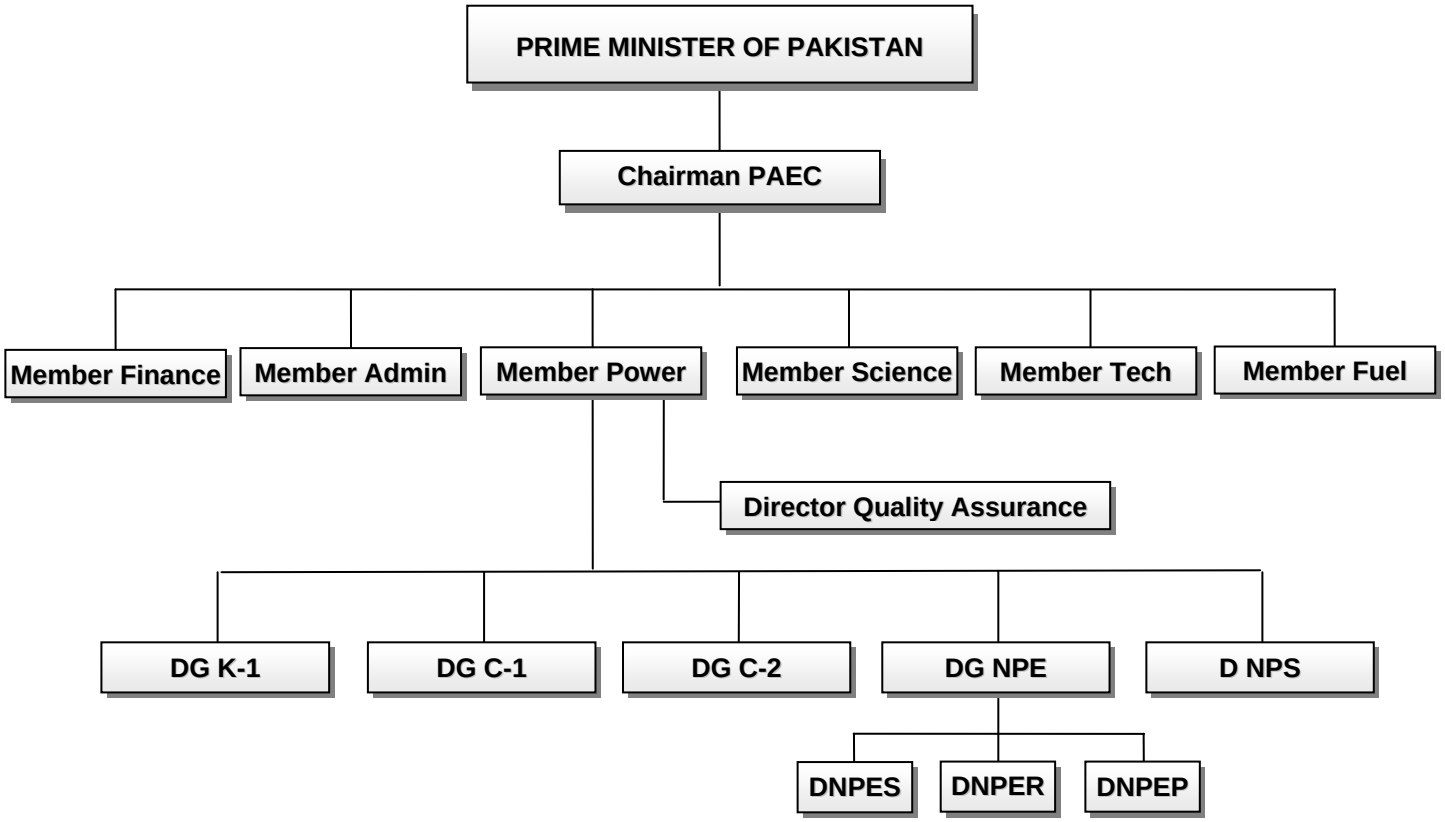
Indicator 12. Performs its functions in a manner that ensures the confidence of the government.

Grading Scale for Performance Indicators

Green	Satisfactory
White	Minimally acceptable
Yellow	Needs improvement
Red	Unsatisfactory

Annex – IX: Abridged Organizational Chart of Pakistan Atomic Energy Commission

As applicable to management of nuclear installations



Annex – X: Dose Limits for Exposures Incurred From Practices

ANNUAL DOSE LIMITS FOR RADIATION WORKERS

Organ or Tissue	Dose Quantity	Dose Limits (mSv)
Whole body	Effective dose	20*
Lens of the eye	Equivalent dose	150
Extremities (hands and feet) or Skin (average dose over 1 cm2 of the most highly irradiated area).	Equivalent dose	500

* In special circumstances, an effective dose of up to 50mSv in a single year provided that the average dose over five consecutive years does not exceed 20mSv/year.

ANNUAL DOSE LIMITS FOR APPRENTICES/STUDENTS

(16 TO 18 YEARS OF AGE)

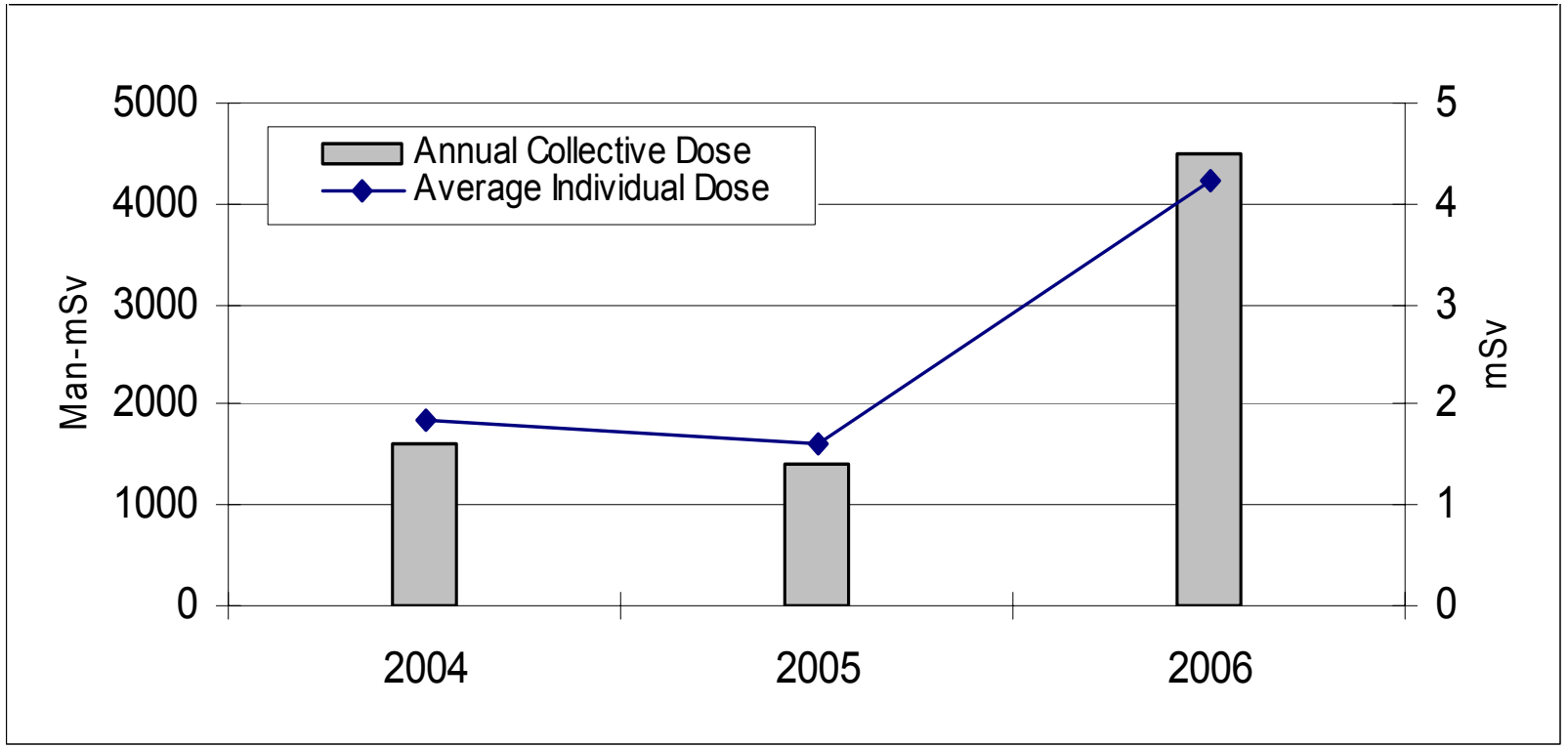
Organ or Tissue	Dose Quantity	Dose Limits (mSv)
Whole body	Effective dose	6
Lens of the eye	Equivalent dose	50
Extremities (hands and feet) or skin (average dose over 1 cm2 of the most highly irradiated area).	Equivalent dose	150

ANNUAL DOSE LIMITS FOR PUBLIC

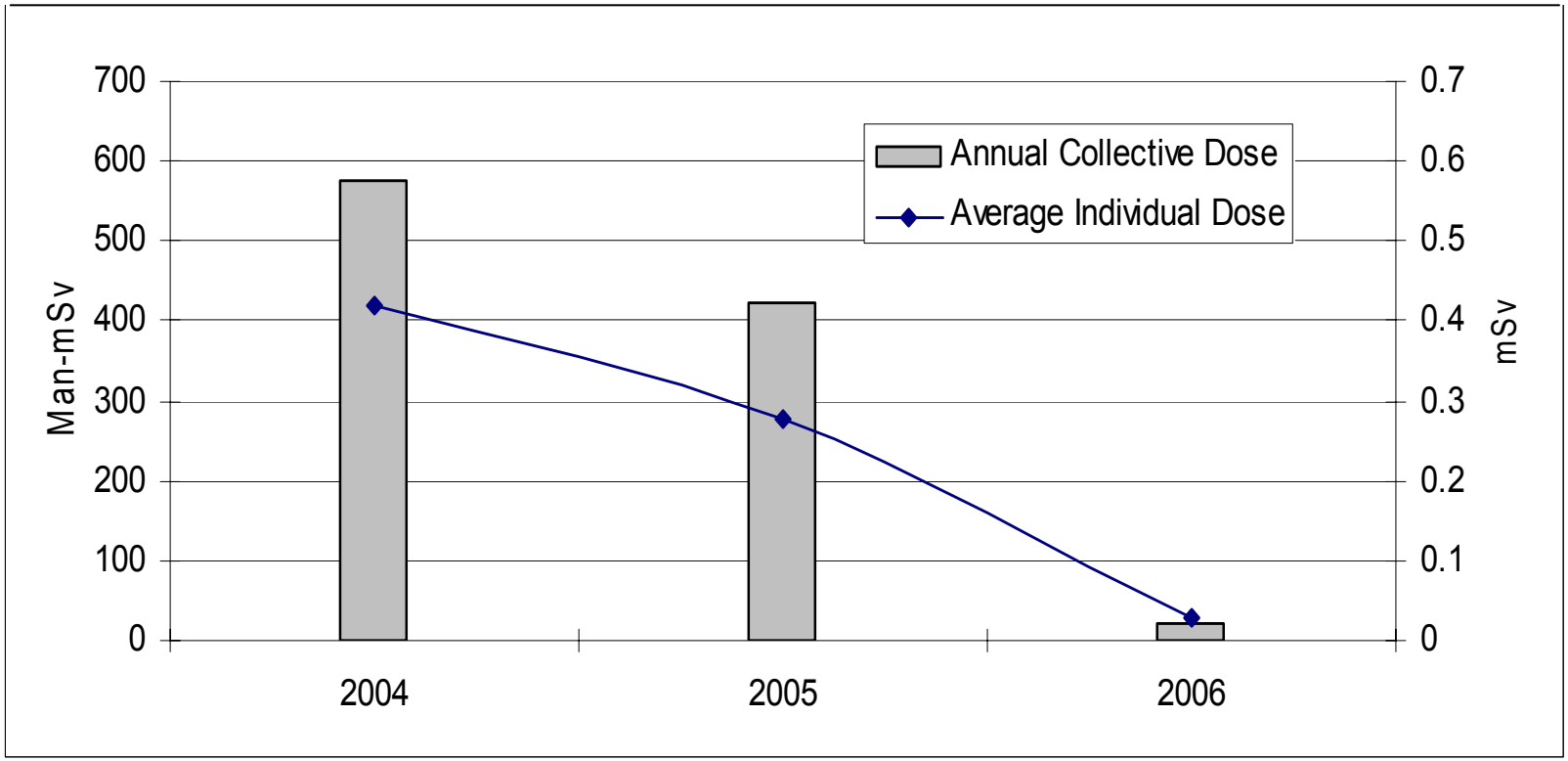
Organ or Tissue	Dose Quantity	Dose Limits (mSv)
Whole body	Effective dose	1*
Lens of the eye	Equivalent dose	15
Skin	Equivalent dose	50

* In special circumstances, an effective dose of up to 5mSv in a single year provided that the average dose over five consecutive years does not exceed 1mSv/year.

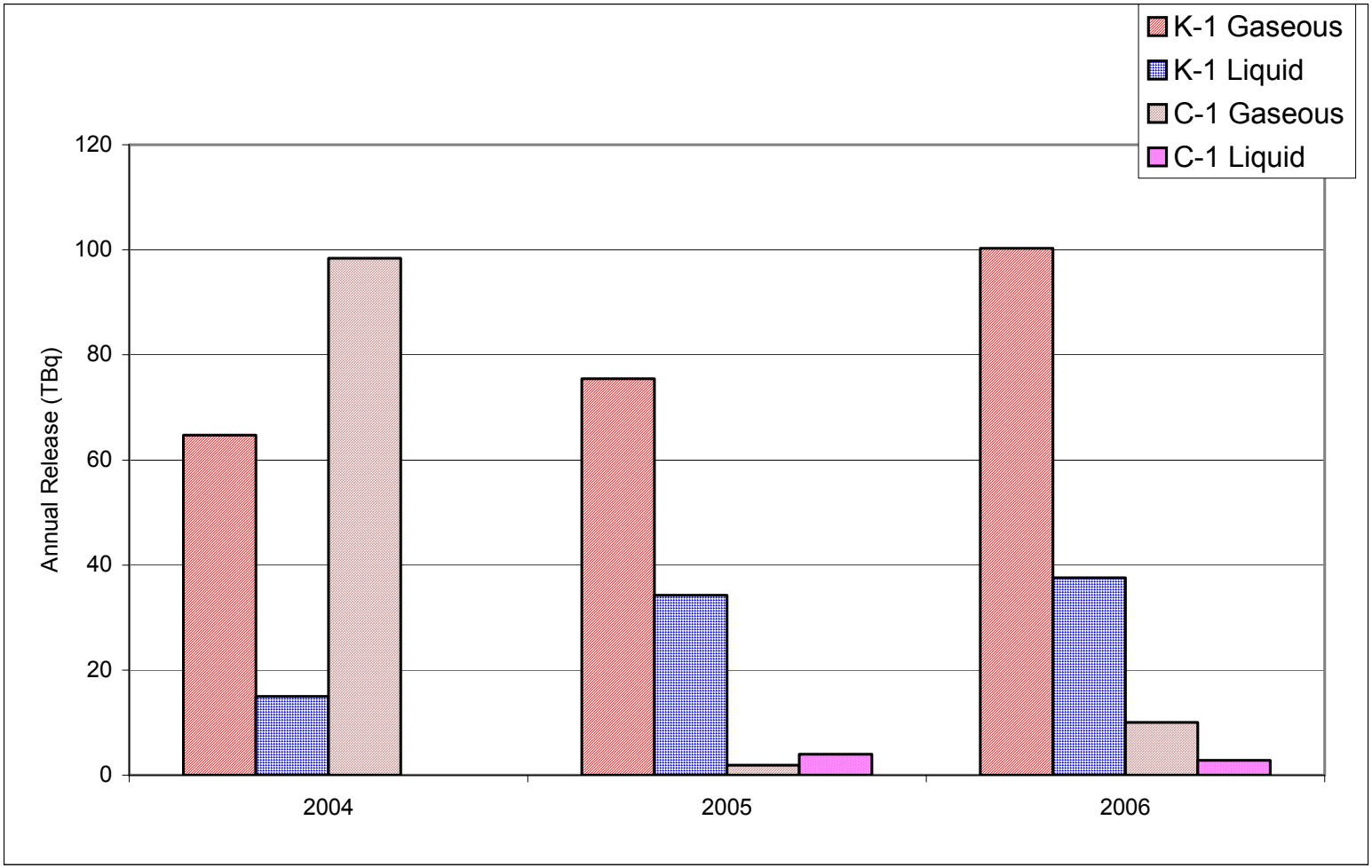
Annex – XI A: Occupational Exposures at K–1 from 2004 to 2006



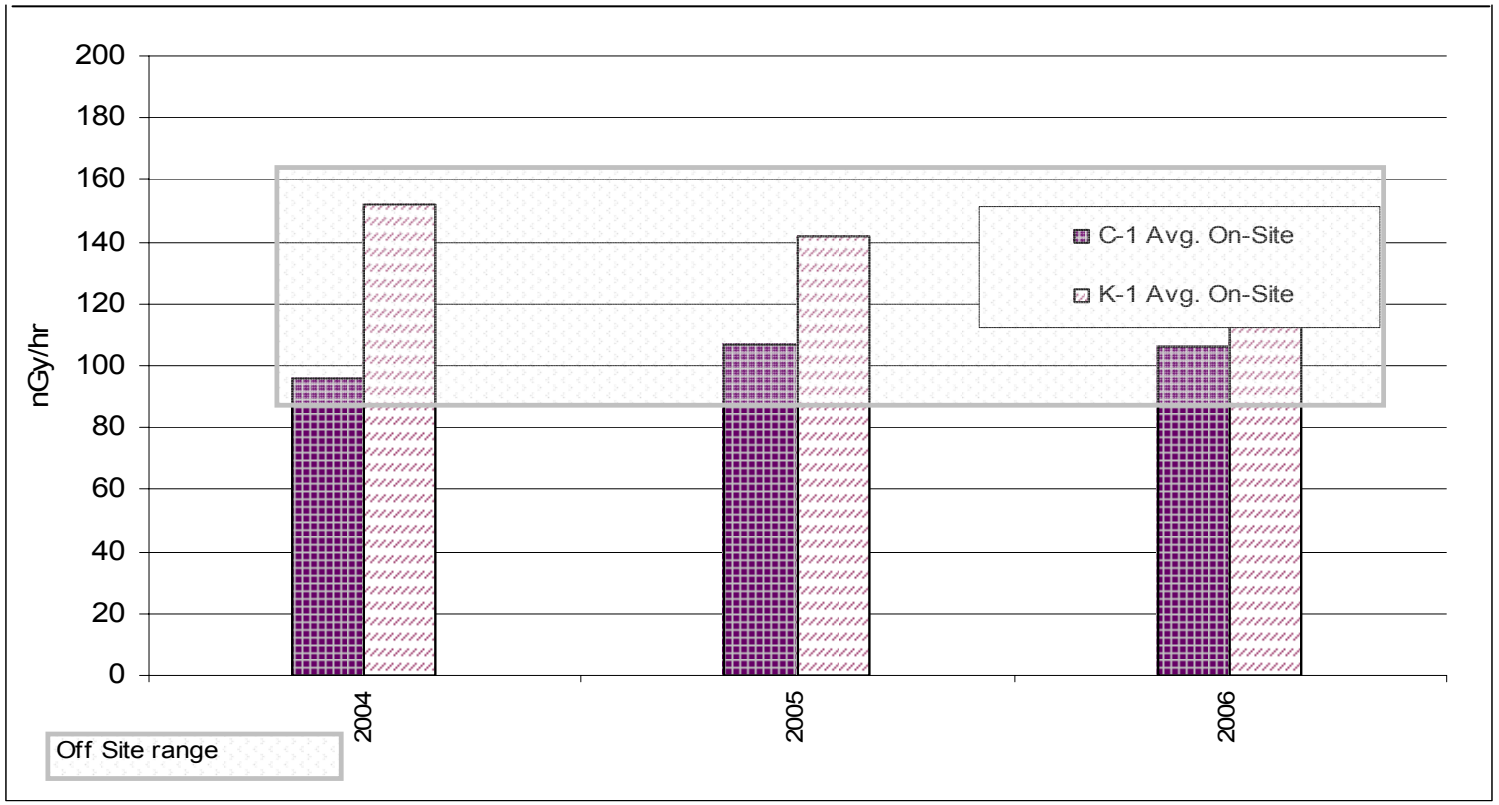
Annex – XI B: Occupational Exposures at C–1 from 2004 to 2006



Annex – XII: Effluent Releases from K-1 & C-1



Annex – XIII: Annual Average Ambient Dose Levels around Nuclear Installations (2004-06)



Annex – XIV: Frequency of Various Types of Drills/Exercises at K-1 & C-1

Sr.	Type of Drill/Exercise at K-1	Frequency
1	Radiological Emergency Exercise	Annually
2	Checking of all emergency equipments	Quarterly
3	Radiological Survey Drill	Quarterly
4	Air sampling drill (of the Assembly Areas)	8 weeks
5	Checking of healthiness of the installed VHF communication sets	2 weeks
6	Checking of Personnel decontamination facilities	Weekly
7	Mobile Radiation Monitoring Laboratory drill	Quarterly
8	Revision of list of telephone numbers and addresses of on-site and off-site emergency response personnel	Half Yearly
9	Class A Fire drill Class B Fire drill	Monthly Yearly
Sr.	**Type of Drill/Exercise at C-1**	**Frequency**
1	Communication drill	Quarterly
2	Off-site radiation monitoring drill	Annually
3	On-site radiation monitoring drill	Annually
4	Medical drill	Annually
5	Fire fighting drill	Twice a year
6	Partial Exercise (PE)	Once in every two years (but not in the year of FSIE)
7	Full Scale Integrated Exercise (FSIE)	Once in every two years (Year other than year of PE)
8	Personnel contamination control drill	Twice a year
9	Environmental dose assessment drill	Twice a year
10	Emergency class assessment drill	Once a year
11	Post accident sampling analyses drill	Once a year

Annex – XV: Emergency Exercises Performed at K-1, C-1 and NRECC

1. Emergency Exercises Performed at K-1

Sr. No.	Date of Exercise	Type of Exercise
1.	January 2004	Annual Radiological Emergency Exercise
2.	November 2004	Annual Radiological Emergency Exercise
3.	April 2006	Annual Radiological Emergency Exercise

2. Emergency Exercises Performed at C-1

Sr. No.	Date of Exercise	Type of Exercise
1.	January 2005	Integrated Emergency Exercise
2.	December 2005	Partial Emergency Exercise
3.	December 2006	Integrated Emergency Exercise

3. IAEA ConvEx Exercises

Sr. No.	Date of Exercise	Type of Exercise
1.	January 2004	ConvEx 1a
2.	February 2004	ConvEx 2c
3.	April 2004	ConvEx 2a
4.	July 2004	ConvEx 1a
5.	October 2004	ConvEx 2a
6.	January 2005	ConvEx 1a
7.	February 2005	ConvEx 2c
8.	April 2005	ConvEx 2a
9.	May 2005	ConvEx 3
10.	July 2005	ConvEx 1a
11.	August 2005	ConvEx 2b
12.	October 2005	ConvEx 2a
13.	May 2006	ConvEx 2b
14.	August 2006	ConvEx 2a
15.	November 2006	ConvEx 2C
16.	May 2007	ConvEx 2d
17.	June 2007	ConvEx 1b
18.	July 2007	ConvEx 1a