CONVENTION ON NUCLEAR SAFETY

Report by the Government of the

Islamic Republic of Pakistan

for the

Fifth Review Meeting, 2011

Prepared on behalf of

The Government of the Islamic Republic of Pakistan

by the

Pakistan Nuclear Regulatory Authority

in collaboration with the

Pakistan Atomic Energy Commission

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ABSTRACT

The Pakistan Nuclear Regulatory Authority submits this Fifth National Report of Pakistan for peer review at the Fifth Review Meeting of the Convention on Nuclear Safety at the International Atomic Energy Agency in April 2011. 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. This report covers the safety of civilian nuclear power plants. It 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, radioactive waste, emergency preparedness, siting, design, construction and operation.

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1. Introduction

1.1 General

The Convention on Nuclear Safety (CNS) was signed by Pakistan on 20th of September 1994 and subsequently ratified on 30th 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. As a matter of policy, highest priority is accorded to safety in nuclear installations.

The Fifth National Report (5NR) has been prepared by the Pakistan Nuclear Regulatory Authority (PNRA) in collaboration with Pakistan Atomic Energy Commission (PAEC) in fulfillment of Pakistan's obligations under the Convention on Nuclear Safety on behalf of the Government of Pakistan

The Fifth National Report (5NR) is an updated version of the Fourth National Report; however, it can be used as a stand-alone document. The 5NR begins with an introduction in Section 1. The Section 2 covers the progress made after the Fourth National Report, and the special reporting required in areas identified during the Fourth Review Meeting[1] along with areas identified in the document "Issues and Trends in Nuclear Safety" issued by the IAEA Secretariat. This is followed by a brief description of the future challenges in Section 3 and then continues with Articles 4 to 19. Annexures are included to provide more details. This part of the report generally follows the Articles of the Convention on Nuclear Safety and the guidance provided by the INFCIRC/572[2].

Each section on the articles of the Convention begins with the text of the article. It is followed by a 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.

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 Electrical Energy Market in Pakistan

Pakistan's present installed electricity generation capacity comes to 21,450 megawatts (MW). Major sources of electricity in the country are fossil fuel fired thermal power plants, owned largely by independent power producers (IPPs) and hydroelectric plants, which fall under the purview of the Water and Power Development Authority (WAPDA). Nuclear power, supplied by the PAEC, and renewable energy play a relatively smaller role in supply at present, as indicated in the following table.

Table 1.2-1: Pakistan's Electricity Generation Capacity

Generation Type	*Capacity*	*Share in Total Capacity*
Thermal (Fossil Fuels)	14,283 MW	66.59%
Hydroelectric	6,705 MW	31.26%
Nuclear	462 MW	2.15%
Total Installed Capacity	21,450 MW	

[1] Fourth Review Meeting of the Convention on Nuclear Safety- 14th to 25th April , 2008 held at Vienna, Austria CNS/RM/2008/ 6 FINAL

[2] Guidelines regarding National Reports – IAEA INFCIRC/572 Rev 3 (28th Sept 2009)

Pakistan's electricity needs were historically met by two power entities: WAPDA, serving most of the country, and the Karachi Electric Supply Corporation (KESC) serving the city of Karachi and its adjoining areas. Since the 1990s, the Government of Pakistan has been conducting an extensive privatisation program to improve the performance of the electricity sector. KESC has already been privatised. Recent reforms also led to the division of WAPDA's Power Wing to create three generation companies, the National Transmission and Dispatch Company (NTDC), and nine distribution companies.

Since October 2007, WAPDA's role has been restricted to water and hydropower development, while the Pakistan Electric Power Company (PEPCO) has been established and empowered for overall management of thermal power generation, transmission, distribution and billing. PEPCO thus oversees the distribution and generation companies as well as the NTDC. Tariffs are determined and fair competition in the electricity market ensured by the National Electric Power Regulatory Authority (NEPRA).

1.3 National Policy Pertaining to Nuclear Installations

Pakistan is the sixth most populous country in the world. Being a fossil fuel deficient nation, it has been experiencing an acute energy shortage of around 5,000 MW which adversely impacts the economy, business sector and the common man. Pakistan considers nuclear technology an important tool in socioeconomic development.The Government of Pakistan, in view of these considerations, has adopted an Energy Security Plan 2030[3] which envisions 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 MW by 2030. In fulfilment of the Energy Security plan, PAEC intends to construct more units and other sites have been identified for construction of NPPs and site evaluation studies have been initiated.

The Energy Security Plan 2030 envisages a developed, industrialized, just and prosperous Pakistan through rapid and sustainable development in a resource constrained economy. This can be achieved, among other things, by educating the population and introduction of technology. The issues of environment degradation and global warming have been given due consideration.

The Government of Pakistan 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 38 years of nuclear power plant operating experience. The safety record of the operation of nuclear power plants has been quite satisfactory as concluded from the findings of the national regulatory reviews and inspections. This has also been substantiated by international peer reviews.

1.4 Ongoing National Program Related to the Nuclear Installations

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

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[3] For details see http://www.planningcommission.gov.pk/energy.htm

a. Continued safe operation of nuclear installations
b. Construction of new nuclear installations to meet energy requirements
c. Strengthening and capacity building of regulatory infrastructure in the country.
d. Strengthening and capacity building of research and development in the country.

Karachi Nuclear Power Plant Unit 1 (K-1) completed its design life of thirty years in December 2002. After completion of most of the design modifications and upgrades required for relicensing, PNRA allowed operation of K-1 under a special license beyond design life in November 2003. The license was initially issued for one year and continued till 2007. In December 2007, K-1 was allowed to operate at 90 MWe. This license was issued for two years i.e. up to 2009, subject to fulfillment of licensing conditions. Upon fulfilment of the conditions, K-1 was allowed to operate at 98 MWe till December 31, 2010.

Chashma Nuclear Power Plant Unit-1 (C-1) has been operating safely and six refuelling operations have been carried out so far including two refuelling operations during the reporting period. During the refuelling outages, in-service inspections, scheduled maintenance, design modifications and periodic tests were performed in addition to refuelling. PNRA has kept the plant under continuous regulatory surveillance. C-1 is now in the process of conducting Periodic Safety Review (PSR) as per regulatory requirement for renewal of operating license after ten years of operation. PNRA is conducting review of PSR reports of C-1in accordance with a mutually agreed upon strategy. The whole activity of review and approval of PSR is expected to be completed by December 2010.

Some significant events that took place at K-1 and C-1 were reported to the international community through World Association of Nuclear Operators (WANO) and IAEA Incident Reporting System (IRS).

Chashma Nuclear Power Plant Unit-2 (C-2) Civil Construction, equipment manufacturing and installation has been completed. Commissioning Program (CP) was submitted to PNRA for review and approval. CP was reviewed according to the regulatory requirements and operating experience feedback from C-1. Approval of CP was granted upon fulfilment of regulatory requirements. The commissioning is now in progress. C-2 has now submitted Final Safety Analysis Report (FSAR) as part of regulatory submissions for Fuel Load Permit (FLP). Review of FSAR is in progress and it is expected to be completed by November 2010 subject to satisfactory response to the regulatory review queries by the licensee. Additional NPPs are being planned in Pakistan to meet the energy requirements.

Pakistan has developed infrastructure for manufacturing components of nuclear installations including safety class 2 and 3 and non-safety class components for NPPs. The equipment include tanks, thick walled vessels, process equipment, precision mechanical components, heavy steel structures, etc.. Facilities are now being upgraded to manufacture safety class-1 mechanical components.

Since its establishment in 2001, PNRA has been continuously improving its regulatory infrastructure. Centre for Nuclear Safety has enhanced its technical competency as technical support organization of PNRA to accomplish review and assessment of licensee submittals indigenously. The human resource development in PNRA continues to flourish in terms of increase in manpower and improvement in technical competencies through various basic and advanced level training courses through PNRA School of Nuclear and Radiation Safety (SNRS). In addition, various activities are being executed to carry out countrywide radiation environmental surveillance, and to establish dosimetry and calibration laboratories, under the Public Sector Development Program of the Government of Pakistan.

2. Progress after the Fourth National Report and Special Reporting

In the following sections the progress made after the Fourth National Report and measures taken in areas of interest identified during the Fourth Review Meeting are described.

2.1 Progress after the Fourth National Report

Progress made after the Fourth 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 for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – PAK/907 (Rev.0) – September 01, 2008
b. Regulations on the Safety of Nuclear Power Plants – Site Evaluation – PAK/910 (Rev.1) – September 01, 2008
c. Regulations on Management of a Nuclear or Radiological Emergency – PAK/914 (Rev.0) – September 01, 2008
d. Amendment in Regulations on the Safety of Nuclear Power Plants Operation – PAK/913 (Rev.1) – November 03, 2008.
e. Amendment in Regulations on Radioactive Waste Management – PAK/915 – March 04, 2010.

In addition, Regulations on Safety of Nuclear Research Reactor(s) Operation – (PAK/923); Regulations on Decommissioning of Facilities using Radioactive Material – (PAK/930); and PNRA Enforcement Regulations – PAK/950); are in the preparation phase, whereas, Regulations for Licensing of Nuclear Installation(s) in Pakistan – PAK/909 and Regulations on the Safety of Nuclear Power Plant – Design – PAK/911 are in the revision process.

2.1.2 Organization of PNRA and PAEC

The founding Chairman of PNRA retired after a meritorious service of eight years and new Chairman assumed the charge in 2009. The Advisory Committee for Improving Utility-Regulatory Interface (ACIURI) was re-constituted due to replacement of some of its members. However, there is no major change in the organizational structure of PNRA (Annexure-X) since the last report.

Chairman PAEC also got retired and the new Chairman took charge in April 2009. Organisational structure of PAEC remains the same as before and is shown in Annexure-XII.

2.1.3 K-1 Relicensing

Karachi Nuclear Power Plant Unit 1 (K-1) completed its design life of thirty years in December 2002. PNRA allowed operation of K-1 under a special license beyond design life in November 2003. The license was initially issued for one year and continued till 2007. After completion of major modifications and safety upgrades as required by PNRA and submission of updated Final Safety Analysis Report, PNRA awarded license to K-1 to operate (Beyond Design Life) at 90 MWe in December 2007. This license was initially issued for two years i.e. up to 2009, subject to fulfilment of licensing conditions. After 2009, upon fulfilment of the conditions, K-1 was allowed to operate at 98 MWe till December 31, 2010.

As part of its regulatory activities at K-1, PNRA conducted review of plant safety performance, design modifications, event reports, routine reports and other documents. The plant's follow-up of the licence conditions was specifically monitored to ensure that satisfactory actions were being taken by the licensee. PNRA's review and assessment did not identify any condition requiring issuance of a violation notice after relicensing beyond design life. The releases of radioactivity to the environment, as well as radiation doses received by the workers at K-1, remained well below the authorized/regulatory limits.

2.1.4 C-1 Operation

The plant is operating satisfactorily since the award of Operating Licence in October 2004 and has undergone two refuelling operations during the reporting period. At the end of each refuelling 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 plant operation.

Major review and assessment activities performed during the refuelling outages included corrective and preventive maintenance activities, in-service inspections, surveillance tests and modifications, etc. In addition, PNRA performed review and assessment of the plant performance, routine reports, event reports, modifications, and conformance to conditions of the Operating Licence. No major violation of the approved operating envelope was observed during the reporting period. The radioactive releases from C-1 to the environment and doses to workers remained well below the authorized/regulatory limits.

C-1 has started ten yearly Periodic Safety Review (PSR) since beginning of 2009. The PSR is largely based on the evaluations of fourteen safety factors pertaining to significant areas like plant design, condition of structures, systems and components, safety analyses (both deterministic and probabilistic), operating experience feedback, management and environment. All one hundred and ninety four (194) reports related to various Safety Factors have been submitted to PNRA. PNRA is conducting review of PSR reports. The review and approval process of PSR is expected to be completed by December 2010.

2.1.5 C-2 Construction, Installation and Commissioning

Licensing process of C-2 is progressing satisfactorily. Civil construction and installation of equipment has largely been completed. Commissioning Program (CP) was submitted to PNRA, and was approved in March 2009. It was ensured during the review that CP included all the tests necessary to demonstrate that the plant as installed meets the requirements of the Safety Analysis Report and satisfies the design intent. It was ensured that the tests were planned in a logical order in three stages; pre-operational tests; fuel loading and sub-critical tests; and initial criticality and power tests. After completion of each stage approval of PNRA would be required to proceed to the next stage on the basis of satisfactory completion report of the tests in each stage. Collection of baseline data for future safety reviews, validation of operating procedures with participation of future operating staff are other salient features of the commissioning program. CP has been approved and the commissioning is progressing satisfactorily. PNRA is monitoring the commissioning activities at site in accordance with the approved inspection program to verify compliance with national regulations and licence conditions. Commissioning stage-1 of C-2 is expected to complete by the end of year 2010.

Final Safety Analysis Report (FSAR) for C-2 is presently under review at PNRA. This also includes Level-1 PSA report, Severe Accident Analysis, Human Factor Engineering and certain design improvements as the commitment made during PSAR review. The review of FSAR is expected to be completed by the end of November 2010 after which decision on fuel load permit will be taken.

2.1.6 New Nuclear Power Plants

The Government of Pakistan, under its National Energy Security Plan, has tasked PAEC with increasing the country's nuclear electricity generation capacity from the current level of 425 MW to 8,800 MW by the year 2030. To meet this target, PAEC has prepared plans to install a number of new nuclear power plants at the existing sites of K-1 and C-1. In addition, new sites for NPP's have been identified and initial site studies have been started.

2.1.7 Problems in Acquiring Safety Related Items and Services

Installation of Loose Part Monitoring System (LPMS) was made a C-1 licence condition. The LPMS could not be installed before the end of RFO-5 due to international procurement constraints. So C-1 requested for a waiver and took appropriate administrative measures such as implementation of foreign material exclusion program during the RFOs and major maintenance/modification activities involving opening of reactor pressure boundary. The surveillance frequency of activity monitoring of reactor coolant system was increased to ensure that no foreign material or loose parts are present within the reactor coolant system which may affect the fuel integrity.

C-1 has now managed to install LPMS in RFO-6 with indigenous efforts.

2.1.8 Strengthening and Capacity Building of Institutions

In recent years, the Government of Pakistan has approved several projects under the Public Sector Development Programme for the strengthening and capacity building of institutions serving in the nuclear energy sector. The projects are aimed at building national capacities for nuclear safety, design, human resource development, manufacturing and quality control.

PNRA is among the institutions whose capacity has been built through this initiative, chiefly with the establishment and financing of the Centre for Nuclear Safety and School of Nuclear and Radiation Safety. In addition, projects have been approved to set up the infrastructure for countrywide environmental surveillance, including dosimetry services and calibration laboratories.

The Centre for Nuclear Safety completed the fourth year of its existence in 2010. In accordance with its plan, the Centre recruited 55 professional scientists and engineers, and imparted specialized trainings in various aspects of safety review, assessment and analysis. These professionals are now discharging their responsibilities in the review of C-2's final safety analysis report as well as the review and assessment of other submittals by the licensee.

2.1.9 Severe Accident Management Guidelines

K-1 has developed first draft of Severe Accident Management Guidelines (SAMGs).

C-1 is about to complete the development of Symptom based Emergency Operating Procedures (SEOPs) by the end of December 2010. Upon completion of SEOPs, C-1 will start work on development of SAMGs targeting 2013 as completion date.

C-2 has made a commitment for preparing Severe Accident Management Guidelines. Some C-2 personnel are receiving training in this area.

2.1.10 Enforcement Program of PNRA

PNRA, under the provisions of Ordinance of 2001 is empowered to regulate all matters related to nuclear safety and radiation protection during all stages of siting, design, construction, commissioning, operation and decommissioning of nuclear installations. In order to ensure that national regulations are being complied with, PNRA has developed an enforcement program which delineates certain enforcement actions such as the issuance of warnings, directives or orders to curtail activities, modification or cancellation of licenses or authorisations, etc. However, preparation of national regulations, which would establish detailed processes for taking enforcement actions including prosecution and penalization, mechanisms for dispute resolution, etc., are in final stage of approval within PNRA.

2.1.11 Emergency Preparedness

In order to ensure that the licensees can effectively handle emergencies and to mitigate the consequences of any untoward incident, the “Regulations on Management of Nuclear Accidents or Radiological Emergency (PAK/914)” were promulgated in 2008. These regulations formally establish the requirement of maintaining an adequate level of preparedness and response capability during a nuclear or radiological emergency.

Following the promulgation of PAK/914, K-1 has updated its off-site radiological emergency plan, KOFREP. The revised KOFREP plan was reviewed at PNRA and several changes were proposed which were incorporated and KOFREP was approved by PNRA.

C-1 is also conducting review of existing emergency plans in line with the provisions of the regulations.

In 2008 and 2009, C-1 and K-1 conducted exercises to evaluate their effectiveness regarding approved emergency plans. PNRA witnessed these exercises and issued recommendations for improvements in the emergency preparedness plans. The effectiveness of K-1 off-site plans in accordance with updated KOFREP was demonstrated in June 2010 during an exercise to fulfil relicensing requirement. Governmental organizations such as Provincial Disaster Management Authority (PDMA), City Government, District Health Authorities, Local Police, etc. were also involved in the exercise.

The National Radiation Emergency Coordination Centre (NRECC) routinely participates in international emergency exercises such as ConvEx[4] arranged by the IAEA during which the Centre's Emergency Response System is comprehensively tested for performance in a nuclear emergency with transboundary consequences. A number of brochures, pamphlets, booklets regarding nuclear and radiation emergencies have also been published for members of the response organizations.

Pakistan is a member of international “Convention on Assistance in Case of a Nuclear or Radiological Accident”. According to the provisions of this Convention, member states have to register their National Assistance Capabilities (NAC) with the IAEA RANET[5]. Pakistan's registration with RANET entitles Pakistan to call upon any necessary assistance through IAEA in case of a Nuclear or Radiological Accident.

2.1.12 Radioactive Waste Management

PAEC formally issued its policy on nuclear safety in 2009, although the safety objectives were being fulfilled even before this formal policy statement. According to this policy PAEC has committed itself to safe and secure management of radioactive waste generated from activities in its nuclear facilities. PAEC has also undertaken to ensure provision of adequate financial resources for decommissioning and waste management at nuclear installations by creating funds for decommissioning and waste management.

Work remained in progress in 2009 on “Draft National Policy on Control and Safe Management of Radioactive Waste”. The Draft Policy aims at establishing a national commitment to control and manage radioactive waste generated in the country in accordance with national legislation/regulations and international standards. According to this Draft Policy the Government of Pakistan will be committed to the management of radioactive waste in such a manner as to avoid imposing an undue burden on future generations; that is, the generation that produces the waste has to seek and apply safe, practicable and environmentally acceptable solutions for its long term management.

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[4] Convention Exercise (ConvEX)

[5] Response Assistant Network (RANET)

PNRA conducted numerous inspections of nuclear installations in different safety areas which included waste management also. The objective of waste management inspections was to verify compliance with the regulatory requirements set forth in the Regulations on Radioactive Waste Management – PAK/915.

2.2 Special Reporting

In response to a request at the Fourth Review Meeting of the Convention on Nuclear Safety (CNS) held in April 2008, a report[6] was prepared by the IAEA Secretariat which summarizes the major global trends and challenges that have impacted the nuclear community generally in recent times and trends in Nuclear Safety as identified during the IAEA Safety Review Services. The following sections present the status and progress made by Pakistan in these areas as applicable to its nuclear power program.

2.2.1 Regulatory Effectiveness and Independence

PNRA has been performing annual monitoring and evaluation of its regulatory activities since its inception. In addition to regular self-evaluation and performance reporting to the Government and the public, PNRA frequently invites international experts for peer reviews. This process contributes to continuous improvement of regulatory effectiveness and efficiency, and drives PNRA towards improved performance in all of its activities. PNRA regularly submits its annual report to the Government at the end of each calendar year. These submissions have improved transparency and enabled the Government to keep abreast of regulatory oversight of nuclear facilities in the country by PNRA.

As a regular practice, PNRA, stakeholders and the general public of Pakistan are engaged in the review process of national regulations. Draft regulations are placed on PNRA website[7] for feedback from the stakeholders before approval and gazette notification of these regulations. PNRA has also established liaison with other national regulators to exchange information regarding licensing process adopted by different regulatory authorities.

PNRA has prepared a comprehensive plan for the development, implementation, and assessment of its Management System. Work remained in progress on the development of this system and a draft Management System Manual was prepared in accordance with international practices. The implementation of management system will start in the end of 2010 after finalization.

Activities initiated under the PNRA Leadership Development Program continued during the reporting period. The leadership development framework of PNRA, consisting of 4Cs and 1P (Competence, Compassion, Credibility, Consistency and Passion), was widely appreciated at international forum of regulators. The experts were of the view that the model may serve as starting point for leadership development within regulatory bodies.

2.2.2 Continuous Improvement to Strengthen Nuclear Safety and to Avoid Complacency

As a forward-looking organization PNRA continuously strives for excellence and is committed to improve its regulatory performance. In accomplishment of its vision to become a world class regulatory body, PNRA has focused all its resources on enhancing its capacity and technical capabilities. The competency development of the regulatory staff has been on top priority of PNRA to strengthen professional capabilities of its staff through in-house professional trainings, courses in local training institutes, foreign regulatory bodies and technical organizations. It has arranged international workshops/fellowships in specialized fields, provided on-the-job training, and scientific visits to enhance the

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6 Issues and Trends in Nuclear Safety- A Report of the IAEA Secretariat to the Fifth Review Meeting on the Convention on Nuclear Safety (2009)

7 http://www.pnra.org

technical competence of staff for the regulation of nuclear power plants and radiation facilities in Pakistan.

PNRA has achieved many short term goals thereby ensuring continuous improvement in its performance. Some of the highlights are mobilization of the projects like Nuclear Dosimetry and Protection Level Calibration Laboratories and National Program for Environmental Radioactivity Surveillance, the finalization of the Management System Manual, self-assessment of its performance under the Self-Assessment Tool of the IAEA.

In striving to enhance safety in its nuclear installations PAEC has established safety and quality infrastructure at the corporate and nuclear installation levels and issued a Nuclear Safety Policy from which specific safety rules, procedures and other requirements are derived. As a policy, PAEC always aims to exceed the regulatory requirements. As a result, most of them are met with comfortable margins. 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. DNPS and DQA conduct safety inspections and the QA audits of the nuclear installations. The observations and recommendations resulting from these inspections and audits serve as additional and independent source of information for the senior management. At the nuclear installation level, Divisions with necessary authority and independence are in place, which are responsible for nuclear safety, licensing and quality assurance related activities. In addition, safety committees advise the management on safety and quality related issues.

Within the nuclear power industry, efforts are underway to enhance team capacities so as to cater to the needs of increased nuclear power generation capacity envisaged in the *National Energy Security Plan.* The PAEC is enhancing the capacity and quality of its key training institutes, such as Pakistan Institute of Engineering and Applied Sciences (PIEAS), Karachi Institute of Power Engineering (KINPOE), and Chashma Centre for Nuclear Training (CHASCENT). Projects to be funded from Public Sector Development Program have been approved by the Government for this purpose.

2.2.3 Managing Challenges in the Construction Quality of New NPPs

The proper management of the wide scope of activities to be planned and executed during construction period represents a major challenge for the utility, contractor, supplier, supporting organizations and regulatory body. In many NPP operating countries, construction of new NPPs has not been undertaken since long, and much of the workforce with NPP construction experience has retired.

Pakistan is among a few countries having the unique experience of management of construction of new nuclear power plants. The construction of C-2 started when construction experience of C-1 was still available. In addition, technological advancements in civil construction were also utilized. However, during construction, licensee confronted various challenges like coping with dewatering issue due to high water table, continuous monitoring of C-1 for any structure settlement due to dewatering, C-1 shutdown conditions for working on shared systems such as common switchyard, intake bay, etc. But despite all these issues, the project progressed according to the schedule while maintaining quality and safety standards. PNRA provided active regulatory oversight throughout the construction process particularly during the construction of safety structures. At all construction stages from excavation to final finish of concrete work, all activities were executed smoothly and no occasions of regulatory non-compliance arose to require actions like ‘work stop’. However, implementation of quality assurance program identified some non-conformances requiring ‘Re-work’ which were appropriately addressed by the licensee under intimation to PNRA. Close regulatory involvement served to facilitate the successful accomplishment of construction work.

2.2.4 Management of Safety and Safety Culture

The Government of Pakistan accords highest priority to nuclear safety. Regarding management of Safety at the Nuclear Installations, a formal Nuclear Safety Policy of the Pakistan Atomic Energy Commission was approved and adopted which emphasizes the commitment of PAEC to ensure excellence in all activities important to safety and to strive for improvements in safety related equipment and practices. PAEC has undertaken the responsibility to provide the financial, material and human resources required for the safe operation and safety upgrades of operating facilities and for the safe design of new facilities. It is quite pertinent to mention that PAEC has been fulfilling safety objectives even before this formal statement of policy on nuclear safety. Complete text of Nuclear Safety Policy of Pakistan Atomic Energy Commission is available at PAEC website; **http://www.paec.gov.pk**

The level of safety in plant operations is monitored in several ways. The information and data on safety culture originated primarily from the notes and reports produced by PNRA inspectors during plant tours, review of documents, interviews with plant personnel, records of compliance with regulatory requirements and licence conditions, station policies and procedures, etc. It was supplemented by the review of event and near miss reports, post event inspections and licensees' self assessments.

In safety culture inspections, PNRA verifies that the licensee places 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 for resolving them. Individuals are motivated, culture of openness and transparency exists, and no-blame environment prevails. Recommendations made in the inspections are being implemented by the licensees and followed up by PNRA. This has contributed in overall improvement of safety culture.

2.2.5 Openness and Transparency

Pakistan has followed a policy of transparency, openness, continuous learning and improvement and sharing its experience with others. The activities at the nuclear power plants are appropriately reported, and the reports are kept open to reviews at national and international level, by PAEC. This report itself and its review by the contracting parties to the CNS form the highest such forum.

Reports about the nuclear power plants (including event reports) submitted by PAEC to PNRA are in the public domain. Significant events are reported by PAEC to WANO, and through PNRA to the IRS.

PAEC invites international Review Missions to its nuclear power plants. The WANO Peer Review Program presently aims to review each nuclear power plant every 6 years, with another review between successive Peer Reviews, in the form of an IAEA OSART Mission, a WANO Follow-up Mission or an internal review mission from within the owner organization. Accordingly, two Review Missions have been received, at K-1 and C-2, since April 2007. A Follow-up Review of C-1, scheduled in December 2009, could not materialize so far. The missions, in general, are satisfied with the safety record of country's nuclear installations.

The operation of the nuclear power plants is also subject to routine reviews by PNRA, and by DNPS from the corporate level in PAEC itself.

Occasionally, the nuclear power plants organize visits for the press / media and brief them. Visits from various professional organizations and students, etc. are arranged on request. K-1 and C-1 issue a brief daily production report, monthly technical reports covering all aspects of their operation and maintenance, annual reports analyzing their safety performance, quarterly performance indicator reports to WANO, reports about events and their analysis (besides those reportable under PNRA regulations), reports about their significant outages, technical reports on specific topics. K-1 also sends a monthly report to COG. All these reports are available to PNRA also, besides being analyzed and reviewed by the Directorate of Nuclear Power Operations (DNPO) in the PAEC corporate office. PAEC issues an annual report which includes the significant aspects and achievements at the nuclear power plants as well. PAEC also maintains its own web-site.

PNRA has also established open communication, cooperation and linkages with national and international organizations for improvement in regulatory performance. PNRA keeps the general public informed about its activities through a frequently updated website and a regularly published annual report. Special activities and unusual events at radiation facilities are also reported through timely press releases. Because of this openness and transparency, the print and electronic media routinely approach PNRA with queries and provide adequate coverage to PNRA's public statements.

A full scope IRRS[8] mission was invited to review the PNRA performance in August 2007. It was postponed due to travel advice by the United Nations. The IRRS Mission is now planned for 2011.

A Review of PNRA Self Assessment Report was conducted in Vienna by the IAEA experts in October 2009, regarding preparation for the Integrated Regulatory Review Service to be conducted in 2011. IAEA appreciated the efforts and commitment of PNRA for initiating the self assessment process in a regulatory body. The PNRA approach to its self assessment was found to be progressive.

At the time of the PNRA self-assessment, the IAEA's methodology was still evolving and the 'Requirements for Management Systems' were just published. In parallel IAEA developed computer software "Self Assessment Tool" for conducting self assessment of regulatory activities prior to IRRS Mission (IRRSAT). As an outcome of the workshop, PNRA planned to review and compare its regulatory performance on national regulatory infrastructure for nuclear, radiation, transport and radioactive waste safety, and emergency preparedness against current IAEA standards and international best practices using the IRRSAT to identify areas for improvement prior to the IRRS mission.

In addition, PNRA presents its performance on selected subjects in the annual meetings of NERS[9]. PNRA has presented its national reports before the review meetings of the Convention on Nuclear Safety for peer review.

2.2.6 Sharing and learning from experience

National Regulation PAK/913 requires that operating experience at the plant be evaluated in a systematic way. The regulation stipulates in detail the measures to be taken for such an evaluation:

- Events with significant safety implications are to be investigated to establish their direct and root causes and appropriate corrective action is to be taken without undue delay;
- Information resulting from such evaluations and investigations is to be fed back to plant personnel;
- The plant management is to obtain and evaluate information on operating experience at other national and international organizations and plants to derive lessons for its own operations;

[8] International Regulatory Review Services (IRRS)

[9] Network of regulators of countries with small nuclear programs (NERS)

- Operating experience is to be carefully examined by designated competent individuals for any precursors of conditions adverse to safety, so that necessary corrective action can be taken before serious conditions arise;
- The plant is to maintain liaison, as appropriate, with organizations involved in its design (manufacturer, research organization, and designer) to feed back information on operating experience and to obtain advice, if necessary, in the event of equipment failure or an abnormal event;
- All plant personnel are to be required and encouraged to report all events as well as any "near misses" relevant to the safety of the plant; and
- Data on operating experience is to be collected and retained for use as input for the management of plant ageing, for the evaluation of residual plant life, and for probabilistic safety assessment and periodic safety review.

Both K-1 and C-1 have arrangements in place for complete compliance with this Regulation.

K-1 interacts online with CANDU Operators Group (COG), WANO and IAEA networks to Operating Experience (OPEX) exchange information. Methods of using OPEX information are structured to provide applicable information to concerned plant divisions/sections. Information received from external sources is screened for relevancy and applicability at K-1 by “Operational Experience Feedback” (OEF) section and disseminated to relevant divisions/sections for review and follow-up actions. Much emphasis is laid on implementation of recommendations of WANO Significant Operating Experience Reports (SOERs). K-1 also shares its own plant operating experience with COG (e.g., good practices) and WANO (e.g., event reports).

For better and effective utilization of OPEX information, special lectures on recent or significant OEF information are conducted for plant personnel at operation and maintenance training centres. Queries on various plant issues are raised on COG networks.

C-1 receives international operating experience feedback on various safety related issues from forums and institutions such as the IAEA Operational Safety Review Team (OSART), WANO, Qinshan Nuclear Power Company (QNPC), Shanghai Nuclear Engineering Research and Design Institute (SNERDI), and China Nuclear Power Operation Technology Corporation (CNPO). In addition, C-1 has access to the IAEA-IRS and International Nuclear and Radiological Event Scale (INES). As a member of WANO, C-1 also shares its own operating experience with other members. Its Operating Experience program is based mainly on the literature of WANO and Institute of Nuclear Power Operations (INPO), with some adjustments according to the specific environment of C-1.

The operating experience of C-1 has been utilized to improve the design of C-2, for example, through better designed reactor internals, installation of a loose parts monitoring system, and installation of additional cooling towers to be used during normal operation.

The operating experience with problems like management issues, unexpected degradation, design weaknesses, external hazards not considered earlier, etc., is shared through peer reviews conducted within and outside Pakistan under the auspices of forums like IAEA, WANO and COG.

PNRA verifies the licensee’s programs to collect and analyze operating experience through reviews of safety analysis reports and regulatory inspections.

2.2.7 Ageing workforce, knowledge transfer, training

Ageing of Nuclear workforce has been managed well in Pakistan as both the regulator and the licensee have invested heavily in this sector since the start of the nuclear power program. Training institutes such as PIEAS, KINPOE, and CHASCENT produce adequate number of trained professionals needed for the nuclear industry. These organizations have the capability of producing a larger number of professionals, if so needed. Both PAEC and PNRA provide financial assistance to the graduate students of Nuclear Engineering and Nuclear Systems Engineering. The professionals after joining PNRA undergo initial and advance level training courses in various regulatory disciplines at the PNRA School for Nuclear and Radiation Safety (SNRS).

At the time of its establishment, Pakistan Nuclear Regulatory Authority (PNRA) had 40 technical officers at its strength and was facing serious problems of ageing of its work force. To cope with immediate shortage of manpower, PNRA decided to induct new technical staff and to take the strength to 415 by 2015. Similarly, competency development of the regulatory staff has been a top priority of PNRA to strengthen professional capabilities of its staff through in-house professional trainings, courses in local training institutes, foreign regulatory bodies and technical organizations. It was observed that with the passage of time, employee skills set had become much localized and to offset this situation, PNRA now proactively encourages rotation and cross training of staff in different regulatory regimes. This approach provides personnel with additional experience, training and breadth of their regulatory perspective.

Several Knowledge Management projects are in place to retain the knowledge available in PNRA. Most of these projects have been launched under the umbrella of PNRA Leadership Development Program and the PNRA School of Nuclear and Radiation Safety.

2.2.8 Probabilistic Safety Assessment

National Regulations PAK/909 and PAK/911 require submission of Probabilistic Safety Assessment (PSA) for nuclear power plants in Pakistan at the design stage. Since the PSA was made regulatory requirement after the licensing of K-1 and C-1, both C-1 and K-1 were required to perform full power PSA.

K-1 performed full power PSA study which was reviewed by PNRA. As part of the review, an International PSA Review Team (IPSART) mission was conducted at K-1 in March 2001 to evaluate K-1 full power PSA. The experts expressed their satisfaction on the K-1 PSA. Later, PNRA licensing condition required K-1 to incorporate the updated modifications and safety improvements in full power internal event PSA and Fire PSA, to meet the regulatory requirement for target core damage frequency. After incorporating design improvements updated full power internal event PSA Level-1 and Fire PSA were performed in 2009. Subsequent regulatory review concluded that K-1 had satisfied the regulatory requirement on core damage frequency (CDF) in the full power internal event PSA.

C-1 submitted full power internal event PSA which was reviewed at PNRA. C-1 was required to perform human reliability analysis (HRA) by taking into account actual human actions involved in plant operation which had dominant failure probability. On the basis of review queries, the revised PSA report, incorporating plant specific data and HRA results was submitted and found acceptable by PNRA. Later, as part of the Periodic Safety Review, C-1 updated the PSA report on the basis of operating experience and additional analyses showing conservatism in actual analysis of some initiating events under safety factor 06 which are presently being reviewed by PNRA. C-1 also requested for the IAEA services of IPSART mission on PSA in December 2009 which was conducted in Vienna (for details see section 14.2.2).

C-2 performed full power PSA at design phase which was reviewed by PNRA at PSAR stage. It was agreed that C-2 will perform flood and fire hazard analysis at FSAR stage. C-2 has submitted PSA Level-1 plus report, which envelops full power internal event (flood). This report is part of submissions for fuel load permit and is presently under review by PNRA.

2.2.9 Ageing Management (AM) and Lifetime Extension

National Regulations PAK/909 require nuclear power plants to conduct periodic safety review after every ten years. Ageing Management is also an integral part of the PSR which requires the following:

- Operation within operating guidelines
- Inspection and monitoring consistent with applicable requirements
- Assessment of the observed degradation
- Repair or replacement of parts

K-1 started commercial operation in 1972 and completed its design life of 30 years in October, 2002. In spite of many challenges and restrictions imposed by the supplier countries, the plant was kept operating safely by embarking on a well-planned program initiated by the PAEC, based on self reliance, to overcome the problems due to lack of vendor's support. The Ageing Management Program (AMP) started in late 90’s for KANUPP. Ageing Management Plan consists of the following components:

- Active components – replacement (routine maintenance and surveillance)
- Passive equipment and structures – In Service Inspection (ISI) (to determine the extent of deterioration due to ageing)
- For certain other items such as cables, laboratory accelerated ageing tests (to determine residual life)

In K-1, Coolant channel material Zr-Nb2.5% (heat treated) was used instead of Zircaloy-4 which is used in many other CANDU plants. Zr-Nb2.5% exhibits better performance as compared to Zicaloy-4 regarding ageing effects. No unusual ageing effects beyond expectation were observed in K-1 coolant channel material. Monel 400 was used in Steam Generator (SG) tubes which showed better properties against corrosion. No apparent signs of deterioration were observed in the containment concrete and tendon gallery (including anchorage). The results of the laboratory tests indicate that cables can be used for another 15 years. However, systems in contact with sea water showed increased tendency of corrosion causing ageing. After carrying out necessary safety up-gradations and improvements, K-1 was relicensed to operate at 98 MWe till December 2010.

C-1 has completed ten years of operation and PSR of C-1 is presently underway for operating license renewal. Ageing management programs of both NPPs are similar.

2.3 Progress on the Conclusions of the Peer Review on Fourth National Report

During the Fourth Review Meeting, the Country Group Rapporteur identified challenges faced by Pakistan and certain areas where Pakistan planned to improve safety. Actions taken to overcome those challenges have already been described in Sections 2.1 and 2.2, whereas progress on the planned measures identified by the Rapporteur in some areas is given below:

2.3.1 Severe Accident Management Guidelines at K-1

Please refer to Section 2.1.9

2.3.2 Symptom-based Emergency Operating Procedures at C-1

Please refer to Section 2.1.9

2.3.3 Capacity Building at PNRA

PNRA’s human resource development program has shown remarkable positive results within a short period of time.

To develop the next generation of regulators, around 200 young technical staff have been recruited during 2002-10, through direct induction drives and fellowship schemes. Around 80% of the employees are below 35 years of age; hence the organization is younger looking and quite dynamic. The extensive and rigorous in-house and external trainings have enabled the technical staff to perform all regulatory activities independently, effectively, efficiently and cost effectively. Human resource development program has shown remarkable positive results within a short period of time, where a number of officers are working as experts in their relevant fields. Imparting and preserving nuclear knowledge has been on top priority of PNRA, therefore, right from its inception it has focused on the transfer of knowledge and skills of the experienced nuclear professionals to the younger generation. PNRA has adopted a two pronged strategy for the competency development of its staff that is through in-house training programs and trainings arranged at external organizations (for more detail, please see Article 11.6).

Centre for Nuclear Safety is the Technical Support Organization (TSO) which comprises fifty-five (55) professionals in various technical disciplines. The TSO is assisting PNRA technical directorates in the review and assessment of submittals from the licensees of nuclear power plants and research reactors. The TSO also regularly provides technical input during review of design modifications and inspection findings. In addition, the TSO has taken initiatives in research and development activities which will form the basis for regulatory decision making in specialized areas such as deterministic and probabilistic safety analyses, stress analysis, evaluation of NPP sites, radiological hazards assessment, and estimation of damages caused at NPP sites as a result of anticipated accidents at NPPs. All these activities help enhance regulatory effectiveness.

Various research activities remained in progress at PNRA during the reporting period. PNRA in collaboration with national academic and research institutions like Pakistan Institute of Engineering and Applied Sciences (PIEAS), Ghulam Ishaq Khan Institute (GIK) of Engineering, Pakistan Institute of Nuclear Science and Technology (PINSTECH) and National Centre for Non-Destructive Testing (NCNDT) has initiated research projects in the areas of nuclear and radiation safety. Moreover, PNRA maintains bilateral relationships with some international research institutions like Nuclear Safety Centre Beijing (NSC), China Nuclear Power Operation Technology Corporation (CNPO) and the IAEA for exchange of safety related information and research. Technical projects funded by the Government’s Public Sector Development Programme are also part of R&D activities.

Project on “Seismic Hazard Assessment in the vicinity of Chashma” has been completed in collaboration with Quaid-e-Azam University. Overview of Karachi’s Tectonics and Seismotectonic History of Earthquakes is in process.

2.3.4 Participation in International Peer Review Missions

PAEC personnel with relevant experience participate and contribute with their expertise in many international activities (Expert Missions, Technical Committee Meetings, Conferences, Peer Reviews etc.) organized by IAEA, WANO, COG, and other international bodies and professional organizations. Senior managements from K-1, PAEC and PNRA routinely participate in the IAEA Steering Committee for IAEA Technical Cooperation Projects for improving the safety of K-1. Experts from K-1 participated in topical meetings organized by COG to exchange experience on CANDU ageing, chemistry and fueling machine performance.

Six (06) experienced persons from K-1, C-1 and C-2 participated in WANO Peer Reviews of various nuclear power plants in South Korea, China and Canada since April 2007. These Peer Reviews contributed not only to the improvement in the target nuclear power stations but also provided a powerful and direct learning experience for the reviewers as well, helping them to improve their own plants.

PNRA also actively contributes in a number of IAEA activities in the areas of knowledge management, education and training, safety review, safety analysis, operational safety, physical security, and self assessment. Experts from PNRA were part of IRRS missions to Vietnam and Ukraine during the reporting period. PNRA also contributed actively in Expert Missions under various IAEA regular Technical Cooperation and extra-budgetary programs. Nine professionals from PNRA participated as experts and delivered lectures at 24 international events organized by the IAEA, including:

- Basic professional training courses in Nigeria, Bangladesh and Lithuania;
- A regional workshop for sharing experience in the application of knowledge management (KM) methods for competence building in nuclear safety in Dhaka, Bangladesh;
- A seminar on Systematic Training Needs Assessment, Dhaka, Bangladesh;
- Regional workshop on Self Assessment Process for the Continuous Improvement of Regulatory Bodies, Ukraine;
- The IAEA regional (Asia and the Pacific) seminar on "Facts of Nuclear Power and Consideration to Launch a Nuclear Power Programme", Chengdu, China;
- A seminar on "Management System for Nuclear Power Plants", Thailand.

In addition, PNRA participated as a member in the proceedings of various IAEA committees for the development of safety standards, such as the Nuclear Safety Standards Committee (NUSSC), Transport Safety Standards Committee (TRANSSC), Waste Safety Standards Committee (WASSC), Radiation Safety Standards Committee (RASSC), and the Committee on Safety Standards (CSS). The Authority has also been nominated as an observer in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

PNRA also reviewed and submitted its comments on various draft documents of the IAEA during the reporting period.

In the operational safety regime of IAEA, PNRA experts provided consultancy in the development of TECDOCs on event investigation; revision of the *IAEA-IRS Guidelines*; relating the findings of events reported in the IRS systems to the applicable Nuclear Safety Standards to recommend improvements in the Safety Standards; development of standards related to the construction of NPPs; and various IRS topical studies.

PNRA is contributing actively in the development of IAEA's Safety Analysis Report Review Program (SARRP), which is intended to guide member states in applying IAEA safety standards for systematic review of safety analysis reports. SARRP is a "living" tool which will be regularly updated with lessons learned from reviews, and PNRA has been engaged with it from the very beginning. During the reporting period, several PNRA experts contributed to chapters 4, 5, 6, 7, 8, 9, 10, 11, 12, 14 and 16 of Safety Analysis Report (SAR). Validation for SARRP is also being carried out at PNRA.

Among other notable interactions, PNRA contributed in the "International Symposium on Nuclear Security" in Vienna, and the "International Ministerial Conference on Nuclear Energy in the 21st Century" in Beijing, and chaired the first session of the "International Conference on Effective Nuclear Regulatory System – Further Enhancing Global Nuclear Safety and Security Regime" in Cape Town.

As mentioned earlier, PNRA is also a member of the Network of Regulators of Countries with Small Nuclear Programs (NERS), an international forum intended to facilitate communication between nuclear regulators and inspectors of member countries. PNRA participates in the activities of this forum which maintains and updates its website; **http://www.ners.info/**

2.3.5 Development of Integrated Management System at PNRA

PNRA has developed an Integrated Management System which provides a single framework for the arrangements and processes necessary to address the Authority's goals. The system is designed to serve as a tool for efficient discharge of regulatory responsibilities. By increasing the transparency of PNRA's internal mechanisms, it will also ensure continuous improvement and make for enhanced organizational efficiency and effectiveness.

The management system is generally in line with the requirements of the IAEA Safety Standard GS-R-3. At present it is being assessed further based on current *IRRS Guidelines* to identify strengths and weaknesses. Implementation is envisaged to be initiated within the current year and completed by the end of 2011.

In addition, an internal audit is being conducted to ensure that the targets and objectives of the different directorates are being met.

3. Future Challenges

The total installed electricity generation capacity of Pakistan is around 21,450 MW. The country is facing frequent load shedding mainly because of insufficient reliable electricity generation capacity, variation in monsoon, insufficient natural gas supply to power sector and circular debt of electricity industry. On the other hand, the peak demand of electricity has been projected to increase to at least 54,000 MW by 2020 and 107,000 MW by 2030. The energy sources are constrained as follows:

- Oil and gas resources are limited.
- Hydro potential is moderate, but associated with socio-political and project financing issues.
- Coal resources are abundant but of lignite quality, needing large-scale mining infrastructure.
- Renewable resources are beginning to be developed, but are not expected to meet large-scale base load needs.

Nuclear power is a viable option to meet the projected future base load electricity generation requirements. However the main challenge in its development is equitable access to the technology, as Pakistan is currently facing discriminatory embargoes by the international community.

The next challenge would be to further improve the existing capability to design, construct and operate nuclear power plants safely and economically. This would depend upon a sound safety culture, broad based scientific and engineering knowledge, indigenous capabilities for manufacturing nuclear power plants components, an effective and efficient regulatory body, manpower with necessary academic qualifications and nuclear competencies, etc. The national grid needs to be further improved in terms of strengthening its stability. These challenges are to be met earnestly.

For continued safe operation of existing NPPs, the country also needs to develop the capacity to assess and address the ageing of principal components of these installations. This requires resources and expertise within the utility and the regulatory body.

In view of considerable increase in nuclear energy production envisaged in the *National Energy Security Plan*, development of fuel fabrication facilities is envisioned, which would also require additional capabilities for safety assessment and licensing of such facilities.

Another area that will gain importance in the future is the safe disposal of radioactive waste. The concept, siting, licensing requirements and other key factors in establishing a medium term waste storage facility are being discussed by the operating organization and regulatory body.

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 fulfilment of its obligations under this Convention. These measures have been described in earlier four national reports. The main legislative instruments have been enacted and essential national regulations are in place. An approach of continuous and gradual fulfilment 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, four national reports were submitted and were reviewed by the contracting parties in the respective review meetings. This is the fifth 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 signed the Convention on Nuclear Safety before the establishment of independent Pakistan Nuclear Regulatory Authority. The regulatory and licensing matters were then looked after by Directorate of Nuclear Safety and Radiation Protection (DNSRP) of Pakistan Atomic Energy Commission. DNSRP conducted licensing process according to IAEA standards and other international practices. The de-facto regulatory body (DNSRP) 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. This along with the details of safety in existing nuclear installations has been reported in previous national Reports.

Pakistan has reported on its existing nuclear installations, as defined in Article 2 of the Convention, to the CNS Secretariat. The existing nuclear installations are listed in Annexure–I.

6.1 Karachi Nuclear Power Plant

Karachi Nuclear Power Plant (K-1) continued safe operation since its licensing beyond design life. In the previous report details of some of the relicensing requirements and their fulfilment by K-1 were described. After submission of required safety documentation by K-1, a thorough regulatory review was completed in 2007. After fulfilment of most of the relicensing requirements, PNRA granted operation license to K-1 for two years i.e. up to December 2009 with certain license conditions for further extension of operating license. These conditions required:

a. Availability of Emergency Control Centre
b. Sludge lancing of steam generators
c. Submission of PSA Level-1 report and Fire PSA report.
d. Installation of Post Accident Monitoring System
e. Installation of CPDS and SPDS system
f. Replacement of Oil Circuit Breakers with SF6 type circuit breakers
g. Fuel channel Integrity Assessment
h. Development of Emergency Operating Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs).
i. Decommissioning Plan.
j. Emergency Preparedness Plan
k. Diversity of Emergency Core Cooling System

After successful completion of some of the above activities, PNRA further extended the operating license (beyond design life) to December 2010 subject to fulfilment of certain conditions. Few significant design parameters of K-1 are presented in Annexure–II.

6.2 Chashma Nuclear Power Plant Unit–1

Chashma Nuclear Power Plant Unit – 1 (C-1) is operating satisfactorily since award of Operating License. The plant has undergone six refuelling outages. At the end of each refuelling 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 reviews the safety case and allows continuation of operation. Major review and assessment activities performed during a refuelling outage included corrective and preventive maintenance activities, in-service inspections, surveillance tests and implementation of modifications. The list of design modifications implemented during the reporting period is presented in Article 18.3. However, the most safety significant is the modification of Irradiation Surveillance Capsules (ISCs) and Supporting & Positioning Structure to address the effect of flow induced vibrations. The modification was conducted on the basis of results of in-service inspection of reactor internals during RFO-4. The ISI results showed some deterioration on the welds of supporting structures of surveillance capsule hangers as a result of flow induced vibrations during plant operation. The case was thoroughly reviewed by PNRA and operation was allowed until RFO-5 under enhanced surveillance during the fifth cycle and subject to implementation of design modification during next RFO. The licensee prepared the case for design modification in consultation with the designer which was then reviewed and approved by PNRA. The design modification was implemented during RFO-5. In addition, PNRA performed review and assessment of plant performance, routine reports, event reports, modifications, and conformance to conditions of the Operating Licence. No major violation of approved operating envelop was observed during the reporting period. Its radioactive releases to the environment and doses to workers remained well below the authorized/regulatory limits.

The operating license of C-1 will expire in December 2010 and as part of ten yearly license renewal requirements of National Regulations PAK/909, plant has to conduct Periodic Safety Review (PSR). Work on PSR was started in the beginning of 2009. The safety factors of PSR cover the areas like plant design, condition of Structures, Systems and Components (SSC), safety analyses (both deterministic and probabilistic), operating experience feedback, management and environmental impact assessment. List of all PSR safety factors is attached as Annexure -VII. For timely completion of the review of PSR by PNRA, approach of on-line review has been adopted in which the licensee would submit results of safety factors soon after completion without waiting for the deadlines. Both licensee and PNRA have designated coordinators for submission and online review of PSR safety reports. So far around 194 documents related to various Safety Factors have been submitted to PNRA for review and approval. The PSR review is expected to be completed by December 2010.

Some significant design parameters of C-1 are given in Annexure–III.

6.3 Chashma Nuclear Power Project Unit – 2

C-2 has completed civil construction, equipment manufacturing and installation phases. As part of licensing procedure, Commissioning Program (CP) of C-2 was submitted to PNRA for review and approval. PNRA had to ensure that CP included all the tests necessary to demonstrate that the plant as installed meets the requirements of the Safety Analysis Report and satisfies the design intent. The tests are to be conducted in a logical order in three stages. The stages include; pre-operational tests; fuel loading and sub-critical tests; and initial criticality and power tests. After completion of each stage, approval of PNRA would be required to proceed to the next stage on the basis of satisfactory completion report of the tests in the previous stage. Collection of baseline data for future safety reviews, validation of operating procedures with participation of future operating staff are other salient features of the commissioning program. After thorough review, CP was approved and Commissioning is progressing satisfactorily. PNRA is monitoring the commissioning activities at site in accordance with the approved inspection program to verify compliance with national regulations, licensee’s commitments and licence conditions. Commissioning Stage-1 (pre-operational tests) of C-2 is expected to be completed by the end of the year 2010, followed by fuel loading, initial criticality and power operation tests.

Final Safety Analysis Report (FSAR) is another important licensing submission. C-2 submitted FSAR in November 2009. C-2 FSAR also includes Level-1 PSA report, Severe Accident Analysis and certain design improvements as agreed during PSAR review. The regulatory review is aimed at verifying compliance with the commitments of the licensee as well as conformance to national regulations and standards that were agreed upon to be followed. PNRA has prepared FSAR review plan extending over a period of one year. The review plan stipulates four review phases and important milestones of regulatory review meetings with the licensee involving the personnel from the designer and main contractor. The regulatory review meetings are aimed at addressing the review queries and seeking commitment from the licensee for necessary improvements in plant safety. The FSAR review team is also interacting with the resident inspectors who are witnessing important commissioning tests. The review of FSAR is expected to be completed by the end of the year 2010. The conclusion of FSAR review and accomplishment of pre-operational commissioning tests will form the basis for regulatory decision for granting fuel load permit.

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, under the Ordinance, establishes 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[10]. 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 would 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, penalties that can be imposed in case of violations, sources of funds of the Authority, continuity of regulatory infrastructure and decisions, etc. No amendments have been made in the Ordinance since its promulgation.

The Ordinance empowers PNRA 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

[10] Ordinance No III of 2001 (see http://www.pnra.org/ legal_basis/PNRA-Ord-2001.pdf)

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 regulations are made to ensure nuclear safety and radiation protection in the country. These regulations are binding on the licensee. The procedure for issuing regulations comprises 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)

The regulations have been placed on the website **http://www.pnra.org** for easy access and information. List of gazette notified regulations is given in Annexure-IX

7.3.1 Regulations Published Since the Last Report

The National Regulations, PAK/909[11], PAK/911[12], PAK/912[13], PAK/913[14], PAK/915[15], PAK/916[16], PAK/900[17] regarding licensing procedure, design, quality assurance, operation, radioactive waste management, transport of radioactive material, and license fee for nuclear installations respectively were reported in the previous report. Three more regulations were issued during the reporting period and are briefly described below.

Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – (PAK/907) (Rev.0) were issued in September 2008. The regulations explain the licensing process for granting license to manufacturers of Nuclear Safety Class Equipment and Components. The regulations also require the licensee to submit quality plans, process flow diagrams (production technology) and manufacturing schedules so that control points for inspections may be selected.

Regulations on the Safety of Nuclear Installations – Site Evaluation (PAK/910) (Rev.-1) were issued in September 2008. These regulations encompass site related factors and site–installation interaction factors relating to plant operational states and accident conditions, including those which could lead to emergency situations, and natural and human induced events external to the installation that are important to safety. These regulations cover the entire process of site selection, evaluation and assessment, pre-operational and operational stages, etc.

Regulations on Management of a Nuclear or Radiological Emergency - (PAK/914) (Rev.0) were also issued in September 2008. These Regulations are largely based on IAEA Safety Standards, GS-R-2, “Preparedness and Response for a Nuclear or Radiological Emergency” and define goals of emergency response, emergency preparedness, responsibilities, response to emergency and actions to be taken in case of emergency.

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[11] Regulation on Licensing of Nuclear Installation(s) in Pakistan

[12] Regulations on Safety of Nuclear Power Plants-Design

[13] Regulations on Safety of Nuclear Power Plants-Quality Assurance

[14] Regulations on Safety of Nuclear Power Plants-Operation

[15] Regulations on Radioactive Waste Management

[16] Regulations for Safe Transport of Radioactive Material

[17] Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority

7.3.2 Revision of Regulations

National Regulations are revised periodically so that new research and experiences may be incorporated for the fulfilment of the prime objective of safety. In addition, previous implementation experience, comments from other national/international reviews and licensee's views are also important factors in such revisions. The regulations are reviewed after every 5 years and revised if necessary. Some regulations that underwent revision during the reporting period are;

i. An amendment in Clause 6(2) of Annexure III of PAK/913 was made and issued on 03 November 2008. According to the amendment, the requirement of experience for shift engineer to become eligible for shift supervisor license was relaxed from three to one year. The amendment was based on PNRA licensing experience and international practice in this regard.

ii. The license fee for nuclear installations has been increased through amendment in Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority – PAK/900 (Rev. 1) in view of country's economic factors.

iii. Amendment in regulations on Radioactive Waste Management, PAK/915 to include criteria for appointment of Radioactive Waste Management Officer (RWMO).

Regulations on the Safety of NPP Design - PAK/911, issued in 2003 and Regulation for Licensing of Nuclear Installations in Pakistan – PAK/909, issued in September 2001 are being revised on the basis of experience feedback during implementation. The process has been initiated and comments from the stakeholders are being sought.

7.3.3 Regulations Under Preparation

In order to further strengthen the regulatory framework and to discharge functions specified in PNRA Ordinance, following regulations are being prepared;

i. PNRA Enforcement Regulations – PAK/950.

ii. Regulations on the Safety of Nuclear Research Reactors Operation – PAK/923.

iii. Regulations on the Decommissioning of Facilities Using Radioactive Materials – PAK/930

7.4 Regulatory Guides and Industrial Standards

PNRA under the provisions of Regulations PAK/909 delineates that the guidance from regulatory guides of USNRC[18] or IAEA is acceptable. Since the USNRC regulatory guides specify internationally used industrial standards such as ASME, IEEE[19], etc., therefore, these standards can also be used by the licensees. In addition, the industrial standards of the exporting countries such as RCC-M[20] of France or GB of China can also be employed. If necessary, international standards such as ISO[21], IEC[22], etc. can also be referred to.

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

[18] United States Nuclear Regulatory Commission (USNRC)

[19] Institute of Electrical and Electronic Engineers

[20] French Pressure Vessel Code

[21] International Organization for Standardization (ISO)

[22] International Electrotechnical Commission (IEC)

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[23]

Government of Pakistan established Pakistan Nuclear Regulatory Authority (PNRA) under the Ordinance No. III of 2001 The Ordinance entrusted PNRA with the implementation of the regulatory framework. PNRA has been provided with necessary authority as well as human and financial resources to fulfil 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 its licensed facilities. 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 stakeholders 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 No. III of 2001 of Government of Pakistan provides the legal basis for an independent nuclear regulatory body. It describes the constitution of the Authority, tenure and eligibility of its Chairman and the Members, interface with Government of Pakistan, etc.

The Chairman is the chief executive officer of the Authority and is responsible for the day-to-day administration of the affairs of the Authority.

PNRA is the only regulatory authority in Pakistan responsible for regulating nuclear safety and radiation protection. Environmental Protection Agency regulates all aspects of environment protection except for those having radiological impact, which are regulated by PNRA.

8.3 Organization of PNRA

The organizational setup of PNRA is continually under review and is revised as and when found necessary. As provided for in the Ordinance, PNRA comprises 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. Annexure–X shows the organizational structure of PNRA.

PNRA is organized on the basis of executive and corporate wings; headed by Member (Executive) and the Member (Corporate) respectively. The executive wing is responsible

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

for core functions of the Authority, whereas, the corporate wing is responsible to drive the Authority as an organization and provides technical support to the executive wing as the Technical Support Organization (TSO). The Secretary of the Authority, the Advisory Committees and the Director of the Chairman Secretariat, report directly to the Chairman. The latter assists Chairman in planning future activities of PNRA.

There are two Directors General under the Member (Executive); namely DG (Technical) and DG (Inspection & Enforcement). The former looks after three Technical Directorates, whereas the latter looks after three regional directorates. The Member (Corporate) has under him the Establishment Section and the corporate wing. DG (Corporate) looks after the activities of the corporate wing which comprises 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, control of radioactive discharges to the environment, 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 (RNSDs) – The regional directorates are responsible for inspections and enforcement within their areas of jurisdiction and monitor activities at the plants 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 competencies 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.

HRD conducts Training Need Assessment (TNA) on the basis of IAEA four quadrant competency model given in TECDOC-1254[24]. This assessment has identified a number of training modules for junior, intermediate and senior regulatory staff which are being accomplished through indigenous training facilities as well as through international cooperation, mostly through IAEA.

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[24] IAEA TECDOC 1254 - Training the staff of the Regulatory Body for Nuclear Facilities (2001)

Directorate of Information Services (ISD) – ISD maintains computer networks, PNRA official website, PNRA internal network site, 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. International cooperation with other organizations such as NNSA, NSC, CNPO, USNRC, VUJE, etc. is also accomplished through ICD. In addition to other activities, ICD also facilitates security clearance/visa of foreign experts to PNRA 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 Government of Pakistan 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.

Centre for Nuclear Safety (PNRA's TSO) – The TSO scientists and engineers have been trained in different areas of regulatory aspects and nuclear power plant design and operation through in-house training programs as well as local and foreign trainings and workshops. During the reporting period, the TSO provided valuable technical support in different licensing activities pertaining to nuclear power plants C-1, C-2, K-1 and research reactors PARR-I[25] and PARR-II. Currently, Centre for Nuclear Safety is engaged in conducting the review and assessment of the C-2 Final Safety Analysis Report (FSAR).

School of Nuclear and Radiation Safety (SNRS) – SNRS is established in PNRA to develop regulatory-specific competencies, knowledge, skills and abilities of technical officers in nuclear and radiation safety through indigenous training programs in order to improve effectiveness and efficiency of the organization. SNRS conducts various courses, workshops, symposiums, etc., as and when needed to impart the cutting edge knowledge to staff members

Directorate of Policies and Procedures (PPD) – PPD is responsible for the preparation of guidelines/procedures for preparing all PNRA documents like regulations, regulatory guides, guidelines, policies, internal working procedures and establishment of framework of legal and guidance instruments (e.g. rules, regulations, orders, codes of practice, policies and guides) on which to base regulatory actions..

Advisory Committee

Advisory Committee for Improving Utility – Regulatory Interface (ACIURI) was initially established in 2005 and was reconstituted during the year 2009 due to retirement of some of its members. The members of the committee represent all the stakeholders (public, Government of Pakistan, 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 Human Resources

The existing workforce at PNRA stands at two hundred and fifteen (215) technical professionals and by 2015 the manpower strength has to be increased to four hundred

[25] Pakistan Research Reactor - I

and fifteen (415), through direct recruitments and fellowship schemes, to cater for expanding nuclear power generation capacity. During 2009, no recruitment was conducted at PNRA; the human resource remained at two hundred and fifteen (215) technical professionals as it was in 2008. However, ten (10) candidates were awarded fellowships for Masters Programs in nuclear and power engineering disciplines respectively at Pakistan Institute of Engineering and Applied Sciences (PIEAS) and KANUPP Institute of Nuclear Power Engineering (KINPOE). These fellows will join PNRA in 2011 after successful completion of studies.

The leadership development programme initiated at PNRA in collaboration with Lahore University of Management Sciences (LUMS) remained in progress during the reporting period.

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, SAR, etc.

8.5 Financial Resources

Funds provided to PNRA consist of grants from the federal government, income from the licence fees, and through PSDP[26] funded projects for capacity building. These funds are adequate enough to meet the current financial requirements of PNRA. PNRA is financially independent of the organizations it is regulating.

8.6 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.

8.7 Monitoring and Evaluation

Monitoring and Evaluation is an integral part of the management systems of the PNRA. The monitoring of the regulatory performance of the PNRA is based on 12 strategic performances. These indicators are shown in Annexure–XIII. The submission of annual report of the activities of PNRA to the Government of Pakistan and the general public is a regular feature of PNRA. This submission enables PNRA to keep the public, the Government and other stakeholders informed about its efforts for ensuring safety of the public, the workers and the environment from ionizing radiation. As part of its self assessment program, PNRA has conducted an internal audit of activities of all its directorates to identify areas for improvement in order to enhance regulatory effectiveness.

8.8 Cooperation with National/International Organizations

PNRA keeps liaison with other governmental organizations for maintaining nuclear and radiation safety in Pakistan. In March 2009, PNRA hosted the second liaison meeting of the major national regulators of different sectors for exchange of information. Representative of NEPRA, OGRA, PPRA and CAA participated in this meeting. The main objective of this meeting was to discuss the licensing processes of various regulatory bodies so as to identify national best practices and learn from the experiences of others.

[26] Public Sector Development Program

PNRA made efforts to fulfil Pakistan's international commitments and obligations arising from four Conventions, namely, the Convention on Nuclear Safety (CNS), Convention on Early Notification of a Nuclear Accident, Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency; and Convention on Physical Protection of Nuclear Materials.

Presently, PNRA is participating in various IAEA assisted Technical Cooperation (TC) and Regional Asia (RAS) Projects. Activities pertaining to these projects are in progress. Under the IAEA TC Projects PAK/9/028 and PAK/9/034, IAEA in collaboration with PNRA, arranged three workshops for PNRA in Vienna, two on self assessment of PNRA using self assessment tools (SAT) and one workshop on strengthening emergency planning, preparedness and response infrastructure. Besides IAEA experts, National Counterparts and Project Coordinators also delivered lectures during the workshops. Moreover, PNRA personnel under IAEA fellowship program contributed in the "Development of Safety Analysis Report Review Program (SARRP)". Under these projects, besides capacity building tasks, IAEA also provided equipment for the establishment of radiation protection environmental laboratories in PNRA.

PNRA also contributed actively in Expert Missions under various IAEA regular TC and extra-budgetary programs. In this regard, an officer from PNRA contributed in Integrated Regulatory Review Services (IRRS) mission to Vietnam as IAEA expert. Nine (9) professionals from PNRA participated as IAEA experts in twenty four (24) international events that were organized by IAEA and delivered lectures. Major activities include; Basic Professional Training Courses in Nigeria, Bangladesh and Lithuania; Regional Workshop for Sharing Experience in the Application of Knowledge Management (KM) Methods for Competence Building in Nuclear Safety, Dhaka, Bangladesh; Seminar on Systematic Training Needs Assessment, Dhaka, Bangladesh; Regional Workshop on Self Assessment Process for the Continuous Improvement of Regulatory Bodies, Ukraine; IAEA Regional Asia and Pacific Seminar on Facts of Nuclear Power and Consideration to Launch a Nuclear Power Programme at Chengdu, China; Seminar to Apply SNTA Methodology and Associated Software for Regulatory Bodies, Vienna and Management System for Nuclear Power Plants, Thailand.

Eight (8) IAEA experts including Ms Anita Nilson, Director Nuclear Security Division from the Agency visited PNRA and discussed matters pertaining to nuclear security and safety.

PNRA is a member of various IAEA committees such as Nuclear Safety Standards Committee (NUSSC), Transport Safety Standards Committee (TRANSSC), Waste Safety Standards Committee (WASSC), Radiation Safety Standards Committee (RASSC) and the Committee on Safety Standards (CSS). PNRA participated in the proceedings of these committees for the development of safety standards. In addition, PNRA is nominated as observer in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

PNRA contributed in International Symposium on Nuclear Security, Vienna, International Ministerial Conference on Nuclear Energy in the 21st Century, Beijing China and chaired first session of International Conference on Effective Nuclear Regulatory System; Further Enhancing Global Nuclear Safety and Security Regime, Cape Town, South Africa.

PNRA also reviewed various IAEA draft documents and the comments were sent to IAEA for discussions and inclusion in their final drafts.

PNRA has established strong bilateral relationships with National Nuclear Safety Administration (NNSA), Nuclear Power Operation Technology Corporation (CNPO) and Nuclear Safety Centre (NSC) of China. The bilateral agreements with these organizations provide a forum for free exchange of information on matters related to nuclear safety. These prestigious Chinese institutes are assisting PNRA in the review and assessment as well as inspections of Chashma nuclear power projects.

Besides Chinese organizations, PNRA has made bilateral agreements with VUJE, of Slovak Republic. VUJE is an engineering, design and research organization specializing in nuclear power plant technology, safety and environmental issues. It provides assistance in training of PNRA personnel in nuclear safety, specifically in safety review and inspection of pressurized water reactors components. PNRA is also interacting with United States Nuclear Regulatory Commission (USNRC) for institutional strengthening and capacity building in order to face the current challenges and issues related to nuclear safety.

Being a member of Network of Regulators of Countries with Small Nuclear Programs (NERS), PNRA participates in the activities of this forum. NERS is an international forum intended to facilitate communication between nuclear regulators and inspectors of countries with small nuclear programs. It maintains and updates its website (**http://www.ners.info**).

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

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 license. Appropriate steps are taken to ensure that the license holder fulfils this responsibility.

9.1 Regulatory Requirements

PAEC is the owner and operator of nuclear installations in Pakistan. It functions under the Pakistan Atomic Energy Commission Ordinance, 1965. According to this Ordinance 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.

National regulations that regulate various aspects of nuclear installations such as licensing, design, quality assurance and operation explicitly state that the license holder is responsible for the safety of nuclear installations. The national regulation for licensing, PAK/909, states that the licensee is directly responsible for the safety of the nuclear installation. The regulations on design, PAK/911 envisage that the licensee has the overall responsibility for safety. Similarly, according to the quality assurance regulations, PAK/912; it is a requirement that the licensee shall retain the responsibility for the effectiveness of the quality assurance program. Likewise, regulations on operation of nuclear installations, PAK/913; delineate that the licensee shall have the responsibility for safe operation.

It is stated in the authorizations that the licensee shall retain prime responsibility for safety but it may delegate authority to the respective management of nuclear installation for operation according to the applicable regulations. The management of the installation is also responsible for providing clear and adequate guidance to its contractors to ensure that safety is integrated into all the activities and any other objective such as production shall not have priority over the responsibility for safety. PAEC being the licensee of nuclear installations has overall responsibility for the fulfilment of safety requirements for its nuclear installations, and for providing necessary resources and support to the respective management for safe operation in accordance with regulatory requirements.

9.2 Responsibilities of PAEC

PAEC interacts with PNRA both at the corporate level and at the nuclear installation level. At the corporate level interaction is through Chairman, Members of PAEC and Directorate of Nuclear Power Safety with corresponding counterparts in PNRA. Detailed interaction on regulations is handled by Directorate of Nuclear Power Safety (DNPS) in the PAEC Corporate Office. The interaction between the regulatory body and the nuclear installations is through the technical directorates and regional directorates of PNRA.

Various directorates at corporate level are providing design and engineering support to nuclear installations. This indigenous capability in design and engineering has a positive impact on enhancing the operational safety of nuclear installations as well as in review and implementation of safety upgrades. PAEC cooperates in reviews and sharing of operating experience between its NPPs, and with relevant international bodies.

The licensee abides by the provisions of PNRA 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 organizational chart showing the corporate directorates is shown in Annexure–XII. 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 respective plant managements. PAEC is providing necessary financial and human resources 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

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. The committee among other things reviews safety related design modifications, changes in the operating policies and principles, new safety issues, reportable events, etc. Senior managers are member of the committee. The committee is chaired by Deputy Plant Manager (Engineering). A Nuclear Safety and Licensing Division (NSLD) also functions under the Director General, which interfaces with PNRA and DNPS, 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 the 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 raise the overall standard of management so that the safety and economic performance of the plant is in the top quartile in the world nuclear power industry. 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, In Service Inspection, 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. The Engineering Department is also coordinating the first comprehensive Periodic Safety Review (PSR). The PSR mainly encompasses the review of plant design, actual condition of Structures, Systems and Components (SSC), equipment qualification, ageing, deterministic safety analysis, probabilistic safety analysis, hazard analysis, safety performance, use of experience from other plants and research findings, organization and administration, procedures, human factors, emergency planning, radiological impact on the environment and global assessment, etc.

CHASCENT coordinates analysis of events, determines their root causes, executes operating experience feedback program for lessons learnt and identifies corresponding actions. It is also performing activities related to PSA and PSA applications.

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

The Safety and Licensing Division of C-2 is responsible for addressing safety related issues. This Division is also responsible for coordinating the safety reviews, review of commissioning program, implementing Configuration Management Plan during installation and commissioning. A Quality Assurance Division ensures quality through implementation of the Quality Assurance Program. It performs audit of the activities of designer, contractor and sub-contractors and performs QA surveillance at the site during installation and commissioning. 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 and design modifications 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.

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 PAK/913 requires that special emphasis is 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 requirements like fitness for duty, 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.

10.2 Nuclear Safety Policy of PAEC

Pakistan Atomic Energy Commission is the owner and operator of nuclear installations. Being a licensee, PAEC has overall responsibility for safety. PAEC has been fulfilling safety objectives without a formal nuclear safety policy. In 2009 PAEC formally announced a Nuclear Safety Policy from which specific safety rules, procedures and other requirements would be derived. The Policy states: "It is the policy of Pakistan Atomic Energy Commission (PAEC) that the general public is protected such that no individual bears significant additional risk to health and safety from the operation of a PAEC nuclear facility above the risks to which the members of the general population are normally exposed. PAEC is committed to taking appropriate steps so that occupational radiation exposure to personnel working in its nuclear facilities is maintained as low as reasonably achievable (ALARA). PAEC is also committed to achieving excellent performance in all activities important to safety and to striving for improvements in safety related equipment and practices. PAEC undertakes that necessary financial and material resources as well as qualified and trained manpower continue to be provided for safe operation and safety upgrades of operating facilities and for safe design of new facilities. PAEC is committed to ensuring that an acceptable level of nuclear safety is accorded the highest priority and is not compromised for any reason".

Complete text of Nuclear Safety Policy of Pakistan Atomic Energy Commission is available at PAEC website: **http://www.paec.gov.pk**

10.3 Priority to Safety in Nuclear Installations

The licensee(s) of nuclear installations in Pakistan are committed to give due priority to nuclear safety. 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 favourable.

The design and operation of nuclear installations are in conformity with the national regulations and to the safety principles such as defence in depth, ALARA, single failure criterion, etc. 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. Establishing and implementing qualification and training programs focusing on safety and quality culture within the organization and their importance in achieving operational and economic goals,
b. Establishing and implementing management systems based on techniques of self assessment, independent checks and verifications, QA inspections, audits and surveillance, non-conformance control, peer reviews, management reviews, etc.,
c. Fostering a no-blame culture and encouraging plant personnel to report safety concerns,
d. Taking appropriate and timely corrective actions and providing feedback to plant personnel.

Operational safety is further improved by a system of event reporting, corrective action program, equipment health monitoring, 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. Several peer reviews have been carried out at nuclear installations and a number of plant personnel have participated in similar peer reviews at nuclear installations elsewhere. Such activities have helped improve safety at nuclear installations in Pakistan.

10.3.1 Priority to Safety at K-1

At K-1, Station Vision, Mission, Goals and Objectives have been clearly outlined so that every plant personnel is well aware of his/her responsibility in ensuring safe and reliable operation of the plant. In addition, station instructions for Corrective Action Program (CAP), Self Assessment Program (SAP), and Safety Performance Indicators (SPI) have also been issued and implemented.

Event reporting has been made quite easy so that any worker of the plant can directly report an event to the CAP Group without any formalities. After evaluation and/or investigation, wherever required, necessary corrective measures are taken and feedback is provided to the reporting personnel. An in-house database of CAP has been developed and made easily accessible to all the plant personnel through Local Area Network (LAN).

Open training sessions / lectures are carried out on CAP and SAP to enhance awareness and acceptance of these programs amongst plant personnel. To further improve safety culture and event reporting attitudes, every year a shield is awarded to the Division having best reporting record and Certificates are awarded to one officer and one staff member for best safety suggestion.

Focused Self Assessment (FSA) is carried out monthly to assess the areas in which deficiencies in soft issues are highlighted by the CAP. Necessary actions are then developed and tracked to improve these areas.

10.3.2 Priority to Safety at C-1

The safety policy of C-1 has been prepared and approved. It states that the management of C-1 headed by Plant Manager bears full responsibility for the safety of the plant. The mission of C-1 management is to generate electricity in a demonstrably safe, reliable and cost effective manner over the long term for the benefit of the society and stake holders as well as to consolidate the basis for development of nuclear power industry in Pakistan. Vision, Mission, Goals and Objectives have been clearly outlined so that every plant personnel is well aware of his/her responsibility in ensuring safe and reliable operation of the plant. Safety policy is displayed prominently at the plant entrance so that all plant personnel become familiar with it. Plant Manager holds daily work plan meetings to discuss safety issues and ways of their resolution. Safety and quality takes precedence over production objectives.

Event reporting is encouraged and any worker of the plant can directly report events and near misses through a user friendly reporting system. After evaluation and/or investigation, wherever required, necessary corrective measures are taken and feedback is provided to the reporting personnel. An in-house database of event reports and corresponding corrective actions has been developed and made easily accessible to all the plant personnel through Local Area Network. C-1 has also developed safety performance indicators to monitor operational safety of the plant.

10.3.3 Priority to Safety at C-2

Safety and quality are the most important considerations in the design, construction, installation and commissioning of C-2. Compliance of design with national regulations and other standards has been verified through reviews by PNRA. In C-2 design, probabilistic safety assessment was performed in addition to the deterministic safety analysis. Furthermore, analyses for some severe accident scenarios have also been carried out. Various measures were taken in the design to reduce the probability of a severe accident in C-2 and to mitigate its effects. Some enhanced and passive safety features were also included in C-2 design for enhancing safety. Actions on certain commitments of the licensee were further verified by PNRA during review of commissioning program.

A separate Quality Assurance Division (QAD) was established in C-2 for verifying the implementation of QA requirements during design, construction, installation and commissioning. The QAD conducted audit of the contractors and subcontractors, performed QA surveillance, issued non-conformance notices in non-compliance situations and verified corrective actions accordingly.

Safety and Licensing Division (SLD) was also established in C-2 with the responsibility for addressing all safety related issues during design, construction, installation and commissioning stages. Various steps have been taken by SLD regarding implementation of safety culture right from the construction stage. Major steps taken include trainings on safety culture, development of Self Assessment Program, Corrective Action Program (CAP), Safety Performance Indicators Program and Configuration Management Program.

Adequate work control and modification procedures are in place to ensure that the objectives of commissioning tests remain valid in the performance of the commissioning program. Necessary steps have been taken to ensure that during all the stages from construction to commissioning and from commissioning to operation, the plant is adequately monitored and maintained. This is required to protect plant equipment, to support the testing phase and to maintain consistency with the Safety Analysis Report. Validation of operating procedures with the participation of future operating staff is an important element of the commissioning.

10.4 Verification of Safety by PNRA

PNRA verifies that the licensees accord due priority to safety in activities related to nuclear safety, radiation protection, quality management, emergency planning and preparedness, etc. PNRA promotes safety culture in nuclear installations by ensuring that it is on the agenda of the licensee(s) at the highest organizational level and then by including it in the inspection plans of nuclear installations. Further motivation is provided by apprising good safety practices and initiatives of the licensees.

PNRA has developed detailed inspection plans compatible with the licensee's plans to systematically cover areas of operation, maintenance, in-service inspection, and radiation protection, emergency planning and preparedness, etc. during daily, weekly, fortnightly, monthly and annual inspections. A reactive inspection in response to any event is also conducted depending upon the safety significance of the issue.

Special inspections, such as inspections specific to safety culture at the nuclear installations are also part of the inspection plans. 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, etc. In these inspections, it has been found that the safety culture in nuclear installations is quite satisfactory; however there exists room for improvement. The recommendations made after these inspections are taken seriously by the licensees and are followed up by PNRA.

The policy of priority to safety issues is closely followed by PNRA as top-down approach for handling nuclear safety related issues.

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 nuclear installations and sufficient number 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 lifetime.

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[27] (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 refuelling 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 safety equipment 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 requirements for academic qualifications, experience at nuclear and other installations, training and retraining, examination procedures, etc. The regulations also specify the requirements for qualification, training and experience required for issuance of license to operating personnel, validity, revalidation and conditions to be satisfied for renewal of the license, conditions for revoking or cancellation of license.

A Shift Engineer, having three years of experience, could get Shift Supervisor Licence by taking oral and practical operation examinations. The operating organization considered the eligibility criterion of three years' experience to be too stringent and proposed to relax the criterion. After due deliberations, appropriate review and assessment of this proposal at various levels, an amendment in national regulations was made to relax the requirement of experience from three years to one year.

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 imparts education at the post graduate level in several disciplines including

[27] For more information please visit http://www.nepra.org.pk

Nuclear Engineering and Systems Engineering. Karachi Institute of Power Engineering (KINPOE) at Karachi is also conducting post graduate level degree courses. In-Plant Training Center (IPTC) at K-1 trains mainly the operating personnel for licensing examinations. CHASNUPP Center of Nuclear Training (CHASCENT) at C-1 provides training to plant personnel according to plant requirements including training in radiation protection and industrial safety. CHASCENT also runs a one year post graduate training program (PGTP).

Specialized training courses are offered by National Centre for Non-Destructive Testing (NCNDT) and Pakistan Welding Institute (PWI) in the fields of non-destructive testing and welding technology respectively. PAEC has a sizeable 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., to support the design and engineering activities in nuclear installations. Support from the original plant designers and 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 organize 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 also through the support of IAEA.

Service conditions offered by PAEC to its employees are considered better than those in other government organizations. Fresh engineers, scientists and technicians are inducted every year so that the age profile of the organization remains balanced. Trainings and re-trainings are provided to operation and maintenance crews of the plants. PAEC employs engineers and scientists possessing high academic qualifications such as Master of Science in relevant disciplines or other post graduate degrees. 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 in the country or have B.Sc. degrees from recognized universities. They are given one year Post Diploma Training (PDT) at CHASCENT. KINPOE also conducts Post Diploma Training for technicians.

The organization of the power plants 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. The shift supervisors and shift engineers are required to be graduate engineers before obtaining necessary licenses.

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 receive retraining 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. It is ensured that the nuclear installations maintain a sufficient number of qualified and skilled manpower in all areas necessary for safe operation.

In view of the Government of Pakistan 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 Government for this purpose.

11.5 Resources for Decommissioning and Waste Management

PAEC has undertaken to establish ageing management programs at its nuclear power plants for maintaining the level of safety. PAEC is committed to carrying out decommissioning of its nuclear facilities in a safe manner when it becomes necessary. PAEC is also committed to safe and secure management of radioactive waste generated from activities in its nuclear facilities according to Draft National Policy on Radioactive Waste Management. PAEC has also undertaken to ensure provision of adequate financial resources for decommissioning and waste management at important nuclear facilities by creating funds for decommissioning and waste management.

Draft National Policy on Control and Safe Management of Radioactive Waste requires that the generator of radioactive waste shall be responsible for safe and secure management of radioactive waste and shall pay for its safe disposal.

11.6 Human Resources, Training and Retraining at PNRA

Ageing of nuclear workforce and loss of nuclear knowledge have become a global issue over the last decade. This has forced the International atomic Energy Agency to convene several conferences to emphasize the importance of the issue and establishment of sustainable training and education programs.

At the time of its establishment, Pakistan Nuclear Regulatory Authority (PNRA) had only 40 technical officers at its strength and there was a serious problem of ageing work force. To cope with the immediate shortage of manpower, PNRA decided to induct new technical staff taking the strength to 415 by 2015.

Competency development of the regulatory staff has been on top priority of PNRA. Therefore, right from its inception it has focused on the transfer of knowledge and skills of the experienced nuclear professionals to the younger generation who would take the place of ageing nuclear workforce. A number of steps were taken over the last few years to strengthen professional capabilities of PNRA staff. This included in-house professional trainings, courses in local training institutes, foreign regulatory bodies and technical organizations. PNRA arranged participation of its manpower in international workshops and fellowship programs in specialized fields, provided on-the-job training, and scientific visits to enhance the technical competencies for the regulation of nuclear power plants and radiation facilities in Pakistan.

11.6.1 Human Resource Development in PNRA

Initially, PNRA established an Education and Training unit with the responsibility for inducting new technical staff and to arrange training for them. Later, the unit was transformed into a full fledged Human Resource Development Directorate (HRD). PNRA adopted two pronged approach for recruitment of technical officers:

a. Fast track direct recruitment drive, and
b. Recruitment through fellowship scheme.

11.6.1.1 Fast Track Direct Recruitment

PNRA conducted several fast track direct recruitment drives in which fresh university graduates of engineering and science disciplines were selected. This process included advertisement of vacancies in the national press, reception/ assessment of applications, conduct of entrance tests/ interviews and final selection of the candidates.

11.6.1.2 Recruitment through Fellowship Scheme

There are a few prominent institutes in the country which conduct Masters level degree programs in Nuclear / Systems / Power Engineering and Medical Physics disciplines. It was considered essential that some candidates with nuclear background should also be inducted in PNRA. Therefore, PNRA signed a memorandum of understanding with Pakistan Institute of Engineering and Applied Sciences (PIEAS) for a fellowship scheme, under which it would sponsor engineering and science graduates for Masters Program. Such candidates undertake to join PNRA after successful completion of studies.

PNRA signed another agreement with Karachi Institute of Power Engineering (KINPOE) for a similar fellowship scheme for Masters Program in Nuclear Power Engineering where some candidates are sponsored by PNRA. They undertake to join PNRA after successful completion of postgraduate studies.

PNRA made another agreement with Chashma Centre for Nuclear Training (CHASCENT) for providing training to its personnel on power plant systems. In this case, engineers are selected from within PNRA.

PNRA has attached four (04) of its engineers with C-2 operation group for a period of four years. These engineers will receive plant operation training to obtain operation licence. After that they will work with C-2 operation group in MCR for at least one year before rejoining PNRA. These engineers will help PNRA in conducting the licensing examinations of plant operating personnel.

The total manpower strength of technical professionals at present is 220 as shown in Annexure-XI However, in view of the Government's plan for increasing nuclear power production from the current 425 MWe to 8800 MWe by the year 2030, regulatory responsibilities of PNRA are also expected to increase. Obviously, a considerable number of professionals are to be employed to increase the manpower strength to about 415 by 2015.

11.6.2 Methodology for Competency Development

Preserving nuclear knowledge has been a top priority of PNRA. Therefore, right from its inception PNRA has focused on the transfer of knowledge and skills of the experienced nuclear professionals to the younger generation who will replace the ageing nuclear workforce. PNRA adopted following processes for the competency development of its staff:

i. In-house training programs and
ii. Trainings arranged in external organizations.

PNRA initiated its first ever in-house professional training program in 2003 by adopting the syllabi of the IAEA basic professional training courses, since training material of these courses was easily available. The focus was on three areas, namely, nuclear safety, radiation protection and regulatory control.

To make the training more structured and meaningful, PNRA carried out Training Need Assessment (TNA) in 2003-04 on the basis of IAEA four quadrant competency model given in TECDOC-1254, in order to identify areas where its staff needs regulatory-specific trainings. The study identified a number of training modules for senior, intermediate and junior levels of staff.

The biggest challenge for PNRA was to arrange these training courses in a systematic and consistent manner for its staff. In this perspective, PNRA established a "School for Nuclear and Radiation Safety (SNRS)" with the objective to develop and maintain a sustainable training program.

11.6.2.1 In-house training program

Most of the officers recruited over the last few years were graduates from engineering universities and faculties of science, while a few had Master's degrees in nuclear engineering. Although, they possessed basic knowledge in engineering and science but they required continuous improvement and updates in their regulatory-specific knowledge.

PNRA prepared a specific career development program under which all employees are required to attend training courses at various phases of their service in PNRA. The in-house training program consists of following:

a. Classroom lectures
b. Workshops/ conferences
c. On-the-job trainings
d. Plant visits

PNRA School for Nuclear and Radiation Safety is responsible for providing in-house training. It arranges classroom lectures using senior regulatory staff as resource persons, conducts workshops, organizes conferences and arranges on-the-job trainings for technical staff at plant sites. In addition, short courses on current and emerging technologies and refresher training courses/ seminars are also arranged.

The SNRS faculty has gained enough teaching experience over the last 6 to 8 years, and is now capable of transferring knowledge at the international level. The School has generated a number of training manuals for these courses and possesses well equipped classrooms, computers and multimedia systems. Other facilities at the training centre include PWR simulator, physical models of plant equipment, radiation protection laboratory and various computer codes. The School can also assist the international community in enhancing the competency of those professionals who are expected to be engaged in nuclear regulatory activities.

11.6.2.2 Trainings Arranged at External Organizations

PNRA has arranged a number of training courses and training fellowship schemes at national and foreign institutes as detailed below.

a. Participation in training courses at PIEAS, KINPOE, CHASCENT, PWI, NCNDT, PIM[28], PSQCA[29]
b. Training in Pakistan through expert missions from IAEA, NSC[30], VUJE, etc.
c. Fellowships at IAEA and other countries through TC projects
d. Placement at China Nuclear Power Operation (CNPO) Ltd., NNSA[31] and NSC China

11.6.2.3 Summary of Human Resource Development

A total of 204 young technical staff was recruited during 2002-08; 169 through direct induction drives and 35 through fellowship scheme. Around 80% of the employees are below 35 years of age; hence the organization is younger looking and more dynamic.

The extensive and rigorous in-house and external trainings have enabled the technical staff to perform all regulatory activities independently, effectively, efficiently and in a cost effective manner. Human resource development program has shown remarkable positive results within a short period of time. A number of professionals are now working as experts in their relevant fields.

11.6.2.4 Research and Development

Research and development activities remained in progress at PNRA in collaboration with national academic and research institutions like Pakistan Institute of Engineering and Applied Sciences (PIEAS), Ghulam Ishaq Khan Institute (GIK) of Engineering and

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[28] Pakistan Institute of Management (PIM)

[29] Pakistan Standards and Quality Control Authority (PSQCA)

[30] Nuclear Safety Center (China)

[31] National Nuclear Safety Administration (China)

Pakistan Institute of Nuclear Science and Technology (PINSTECH) in the areas of nuclear and radiation safety. Moreover, PNRA maintains bilateral relationships with some international research institutions like Nuclear Safety Centre Beijing (NSC), China Nuclear Power Operation Technology Corporation (CNPO) and the IAEA for research and exchange of safety related information. The Government of Pakistan has allocated sufficient funds for a number of research projects undertaken by PNRA for further strengthening nuclear and radiation safety 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 require due consideration of human factors at the design stage. The design is required to be ''operator friendly'' aiming at minimizing human errors and their effects. Systematic consideration of human factors and the man-machine interface must be included in design process at an early stage and should continue throughout the entire process. This would ensure an appropriate and clear distinction between the functions of operating personnel and those of 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 when it can be demonstrated that the operator has sufficient time to make a decision and to act. The information necessary for the operator to make the decision to act should be simple and unambiguous. In addition, 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 should be acceptable.

Human factors effects are also considered in PAK/913 while establishing the criteria for appointment of Director General, Plant Manager, station health physicist and operating personnel. PAK/913 requires that the licensee would define the qualifications and experience necessary for personnel performing duties that may affect safety. Suitably qualified personnel are selected and given 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 their appointment and at subsequent intervals as required to ensure their fitness for duties and responsibilities assigned to them. Psychological examination is also required for licensed control room operating personnel. PAK/904 elaborates medical examination required for 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 has been made more comfortable.

b. Man-machine interface has been made more operator friendly by installing computer displays and convenient set point changing facilities in control room.
c. A Work Control Office has been established to relieve the control room operator from log writing, which has enabled the operator to pay more attention to safety related activities.
d. Few annunciation windows have been either specially marked or rearranged in groups for operator ease.
e. Emergency Control Centre was designed considering human performance.

Furthermore, a facility has been installed in MCR and the Emergency Control Centre to monitor the plant status in transient and accident conditions. 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 Emissions
h. MH System Inventory

Currently out of the above eight, five critical functions have been implemented fully. The critical function ‘PHT integrity’ has been implemented partially and will be fully implemented in the long shutdown of 2010. Similarly the remaining two functions ‘Reactor Core Cooling’ and ‘Secondary Cooling’ will be implemented during the long shutdown of 2010. This facility is available both in MCR and Emergency Control Centre so that the operator can monitor the plant status under accident and transient conditions more easily and can take corrective actions when required to bring the plant in safe state. Emergency Operating Procedures (EOPs) have been prepared to help operator in case of design basis accident. K-1 has also prepared first draft of Severe Accident Management Guidelines (SAMGs)

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 to facilitate the operators. 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. In MCR a number of alarms were lit undesirably such as pump low flow alarm when pump was not in service, thus causing undue burden on MCR operators. C-1 accordingly initiated an Undesired Alarm Reduction Program to reduce all such alarms by changing the alarm logic. For this a number of alarms were identified both in conventional and nuclear systems. The reduction of undesired alarms on conventional side system is completed whereas for nuclear systems about 40 such alarms are suppressed while work on remaining is in progress.

In C-2 Human Factor Engineering has been applied from the conceptual design phase to final detailed design. All elements of Human Factors were considered in the control room design in accordance with international practice. PSA was conducted at design stage and Human Reliability Analysis was performed for Human Factor Engineering (HFE). The design of the Main Control Room of C-2 was 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) 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. HFE is also considered for the design of emergency control room.

Work on Task Analysis in psychological aspects of C-2 personnel started through contract with National Institute of Psychology, Quaid-e-Azam University, Islamabad.

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-1 has a contract with Energy Conservation Network (ENCONET) for the development of SEOPs. Different analyses required to provide input for the development of SEOPs are now complete and are in the documentation phase. The job will be completed by December 2010. At C-2, development of SEOPs and SAMGs is in progress.

Specific full scope simulator is used in the training and qualification examination of operators. 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 enable 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 made to implement these procedures and instructions. PNRA verifies this during regulatory inspections.

Nuclear installations have performed PSA and submitted the 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 that may be due to procedural lapses or operator errors. These inputs are used to improve procedures and operator training on simulator to minimize human errors. K-1 performed full power PSA with internal fire event. On the basis of PSA results several design improvement were made to enhance plant safety. C-1 has performed PSA Level-1 (full power internal initiating event excluding internal fire and flood). An IPSART mission for C-1 PSA was conducted by IAEA in December 2009. C-1 is now working on incorporation of IPSART recommendations (see Section 14.2.2). After incorporation of IPSART recommendations, C-1 will perform an internal fire and flood PSA and also low power and shutdown PSA. The Human Reliability Analysis has also been carried out and a number of improvements have been suggested which will be implemented accordingly. 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.

Root Cause Analysis (RCA) and Apparent Cause Analysis (ACA) are 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 Corrective Action Program (CAP). Necessary follow-up and implementation of the corrective actions are also ensured under CAP. Events are trended on the basis of types of events (e.g. house keeping events, industrial safety events, equipment failure events, etc.) and also on the basis of causes of events (e.g. design deficiencies, training deficiencies, document deficiencies, etc.). This trending helps in identifying the areas showing adverse trends. Separate investigations are initiated for events showing adverse trends to determine the causes of adverse trends. Annual and six monthly meetings are held with plant management under the supervision of DG (K-1) to discuss safety significant issues. KANUPP Safety Committee (KSC) meets on quarterly basis to discuss pending safety issues. Special KSC meetings are also held to discuss any current issues which may affect the plant safety.

C-1 has also developed "Integrated Corrective Action Plan (ICAP)" which is being implemented since December 2009. ICAP thoroughly investigates any event that occurs at the plant. Its causes are categorized and corrective actions are identified. If the error is found to be human, further investigation is done to identify whether the cause is procedural or due to operator training. Based on the input, corrective actions are taken to prevent similar errors.

C-1 is evaluating Human Factors in first Periodic Safety Review (PSR) in line with international safety standards to determine various human factors that may affect the safe operation of the nuclear power plant. For this C-2 MCR design is taken as reference which is improved based on Human Factor Analysis. C-1 will also assess the adequacy of staffing, training, procedures and man-machine interface. As a result C-1 will be able to identify the weak areas and to take actions to enhance safety against human factors at the plant.

12.3 Verification of Human Factors Considerations by PNRA

PNRA verifies that the human factors are considered throughout the life of a nuclear installation. Firstly, at the design stage it is ensured that human factors are considered in the probabilistic safety assessment, design of main control room, safety parameter display system and remote shutdown panels. Secondly, during operation stage, regulatory inspections include various elements like checking of work conditions such as lighting, labelling, environmental and habitability issues, housekeeping, fitness for duty, etc. PNRA Inspectors witness simulator exercises during training/re-training. They also carry out inspections of operation shift crews to verify compliance with procedures and to assess if the operator actions are in accordance with the procedures and design intent. Human performance evaluation is also an essential element of safety culture. Inspections and reviews of unusual occurrence reports help determine the contribution of human factors in initiation and progression of the event.

While reviewing PSA of all nuclear installations, it is verified that human factors have been adequately considered and all operator actions are modelled in accordance with actual design. Improvements are suggested in procedures and training material to minimize operator errors during normal operation, anticipated operational occurrences and design basis accidents.

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 programs 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 regulatory requirements for the submission of quality assurance programs (QAP) at the time of applying for construction licence and subsequently at the time of applying for first fuel load permit have been stipulated in National Regulations PAK/909. The National Regulations PAK/912 provide basic requirements for establishing and implementing quality assurance programs related to the safety of nuclear power plants. These basic requirements apply to overall quality assurance program of licensee/management, as well as to other separate quality assurance programs in each stage of the life of a nuclear installation. The licensee has to ensure safety in siting, design, construction, commissioning, operation and decommissioning of the nuclear installation. The regulations recognize that all work is a process that can be planned, performed, assessed and improved. These basic requirements apply to all individuals and organizations, including designers, suppliers, constructors, manufacturers and operators of nuclear power plants.

The QAP is required to provide an interdisciplinary approach involving many organizational components and is not regarded as the sole domain of any single group. The QAP is to demonstrate the integration of following components:

a. Managers providing planning, resources and support to achieve the organization's objectives.
b. Staff performing the work achieve quality; and
c. Staff performing assessments to evaluate the effectiveness of management processes and work performance.

13.2 Quality Assurance Activities at Nuclear Installations

PAEC has established QAP at nuclear power plants to achieve its safety objectives. QAP includes organizational structure with defined responsibilities, functions, interfaces, performance evaluation and process control procedures. QAP also includes procedures for reviews and assessment along with documented programs and established goals/objectives.

13.2.1 Quality Assurance at Corporate Level

A Directorate of Quality Assurance (DQA) is in place at corporate level at the PAEC HQ to coordinate QA activities in various PAEC establishments, and to have corporate oversight for QA matters. The Directorate provides guidance to the plant and the corporate management on quality issues and recommends actions for improvements. PAEC has formally issued its Nuclear Safety Policy which encompasses the quality assurance elements such as management's commitment for giving priority to safety over production objectives, compliance with safety regulations and industrial standards for achieving excellent performance in all activities through highly professional and qualified manpower by utilizing all necessary financial and material resources.

13.2.2 Quality Assurance at Nuclear Installations

K-1 and C-1 have established QAP for operation phase 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 for commissioning phase was submitted to and approved by PNRA. Presently, QAP for operation phase of C-2 has been established and submitted to PNRA, which is in the review and approval process. The nuclear installations have established Quality Assurance Divisions (QADs) staffed with appropriately qualified personnel reporting directly to the highest level of the plant management. The QA personnel have been entrusted with 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 following weekly work plans prepared by section in-charge of each area. 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 completion to verify that QA requirements have been fulfilled. QA verification of important plant documents such as operation and maintenance procedures, station instructions, change approvals, etc., is also carried out. PNRA inspectors also occasionally participate in these inspections to ensure safety and to enhance the quality of the work. The non-conformance control system is an essential part of QA which identifies non-conformances and corresponding corrective measures.

The QAD ensures that the work groups clearly understand management expectations to establish and maintain safety 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.

QAP of C-1 is based on National Regulations on the Safety of Nuclear Power Plants Quality Assurance - PAK/912 (Rev.1) and encompasses all items and activities important to safety and availability of the plant. The Quality Assurance and Assessment Division (QA&AD) is staffed with adequately qualified manpower and reports directly to Director General (CNPGS)[32]. In all its activities, QA&AD emphasises the safety and quality culture.

Through planned QA surveillance and audit programs, the QA&AD verifies compliance with the established requirements of QAP. Planned as well as general surveillances are carried out in all plant areas within the scope of QAP. Internal and external audits are performed according to the audit plans and applicable procedures. Follow-up of audit findings is continued till the implementation of required corrective actions.

QA&AD also performs inspections during fuel manufacturing and transportation and controls the activities of contractors of C-1 through audits and surveillance. QA&AD provides support to the plant management during management reviews and assessments. Procedures related to safety and quality undergo a thorough QA review by QA&AD before approval.

C-2 has established an “Overall Quality Assurance Program (OQAP) for Design, Procurement, Construction and Commissioning of Chashma Unit-2” in accordance with the requirements of national regulations. The OQAP was reviewed and approved by

[32] Chashma Nuclear Power Generating Station

PNRA. 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. In addition to OQAP, the licensee has also prepared separate quality assurance programs for commissioning and operation phases. The QA program for commissioning ensures that authorities and responsibilities for the commissioning process are clearly defined and delegated to the individuals performing the work. The interfaces between the groups involved in commissioning have been clearly defined and properly controlled. It also ensures that tests are performed according to the written procedures, with adequate equipment and by qualified personnel.

C-2 has a Quality Assurance Department which assists the Director General on QA matters. 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 commissioning organizations is also audited by C-2 to ensure compliance with QAP.

C-2 has submitted its Quality Assurance Program for the operation phase also as part of the submittals required for issuance of fuel load permit. The QAP is under review at PNRA in compliance with the national regulatory requirements on quality assurance.

Regular coordination meetings between PNRA, C-2 and main contractor are held to facilitate resolution of issues and for better interface between these organizations.

13.3 Quality Assurance Activities of Equipment Manufacturing Facilities

Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – PAK/907 (Rev. 0) explain the licensing process for obtaining license to manufacturers of Nuclear Safety Class Equipment and Components. The licensee is required to submit quality assurance plans, process flow diagrams (production technology) and manufacturing schedules so that control points for inspections may be selected. 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 required to be prepared to qualify the processes. Manpower involved in manufacturing and testing is qualified according to 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 inspections of specific areas of QA are performed as and when required in addition to the QA administrative inspections of licensees, contractors and subcontractors performing safety related activities. During these inspections, PNRA verifies compliance with the requirements of national regulations and the license conditions.

The inspections at the sites of nuclear installations are conducted by PNRA Regional Directorates at Karachi and Chashma, while the inspections at the manufacturing facilities are controlled by PNRA Headquarter.

13.5 PNRA Integrated Management System

In order to continuously improve its effectiveness, PNRA has taken initiatives to establish and document its management system in accordance with the requirements and recommendations of internationally accepted standards and guidelines. In this regard, Quality System Manual is being formulated which would describe the establishment, implementation, assessment and continuous improvement of management system at

PNRA through planning, control and effective supervision of its regulatory activities. The requirements for implementation of management system are fulfilled to ensure that PNRA mission for the protection of public and environment from hazardous effects of ionizing radiations is accomplished. A bottom-up approach is being adopted for the development of PNRA integrated management system. Quality policy statement, mission, vision and core values of PNRA have also been documented in the manual. Management processes have been integrated and described in the form of programs, procedures and plans.

Integrated Management System (IMS) of PNRA will provide a single framework for the arrangements and processes necessary to address all the goals of PNRA, and will be an efficient tool to discharge the regulatory responsibilities of PNRA. Implementation of IMS will ensure stakeholders' satisfaction using existing financial and human resources. It will transparently demonstrate PNRA's internal mechanisms which ensure continuous improvement and increasing effectiveness and efficiency of the organization. Management system of PNRA is generally in line with the requirements of the IAEA safety standard GS-R-3. A self assessment of existing management system, based on current IRRS guidelines is being carried out to identify strengths and weaknesses of the system. Implementation of IMS is envisaged to be initiated within the current year and completed by the end of year 2011. In addition, PNRA's internal audit activity is being conducted to ensure compliance of different Directorates to verify the effectiveness of management system.

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

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 well documented and subsequently updated in the light of operating experience and significant new safety information. Such assessments are reviewed by PNRA. Verification by analysis, surveillance, testing and inspections is carried out to ensure that the physical state and operation of a nuclear installation continue to be in accordance with its design objectives, and operational limits and conditions.

14.1 Regulatory Requirements

A detailed regulatory framework exists which ensures comprehensive safety assessment and verification before the commencement of operation. National Regulations PAK/909 delineate detailed procedure for licensing of nuclear installations in three stages, namely, Site registration, construction license and operating license. Regulation PAK/910 prescribes detailed site assessment requirements for site registration (for details refer to section 17.1).

PAK/911 requires that at the design stage of a nuclear installation, a comprehensive safety analysis shall be carried out to identify all sources of exposure and to evaluate radiation doses that could be received by workers at the installation and by the public, as well as potential effects on the environment. The safety analysis shall take into consideration:

i. All planned normal operation modes of the plant
ii. Plant performance in anticipated operational occurrences
iii. Design Basis Accidents
iv. Event sequences that may lead to a severe accident

On the basis of this analysis, the robustness of the engineering design for withstanding postulated initiating events and accidents can be established, the effectiveness of safety systems and safety related items or systems shall be demonstrated, and requirements for emergency response shall be established. Measures shall be taken to ensure that radiological consequences are mitigated. Such measures include: engineered safety features; onsite accident management procedures established by the operating organization; and possibly off-site intervention measures established by governmental civil agencies in order to mitigate radiation exposure if an accident occurs.

A safety analysis of the plant shall be conducted in which methods of both deterministic and probabilistic analyses shall be applied. On the basis of this analysis, the design basis for items important to safety shall be established and confirmed. It shall also be demonstrated that the plant as designed is capable of meeting any prescribed limits for radioactive releases and acceptable limits for potential radiation doses for each category of plant states. The basis of the safety assessment shall be the data derived from the safety analysis, previous operational experience, results of supporting research and proven engineering practices. The licensee shall ensure that an independent verification of the safety assessment is performed before the design is submitted to the regulatory body.

National Regulations PAK/913 require that the licensee performs a systematic safety reassessment of the plant for its entire operational lifetime in accordance with the requirements given in the Regulations PAK/909. In such a reassessment operating experience and significant new safety information from all relevant sources will also be taken into account. The Regulations also include the assessment and verification requirements during operation phase, in particular the assessment and verification of design modifications. It is emphasized that modifications involving plant configuration and the operational limits and conditions, shall conform to the requirements set in the Regulations PAK/911. In particular, the capability of performing all safety functions adequately shall not be degraded.

The requirements for safe management of radioactive waste in the country have been specified in Regulations PAK/915. The licensee has to carry out safety assessments and the activities needed for siting, design, construction, operation and closure, as well as the measures needed in the post-closure phase of radioactive waste disposal facility.

Additional requirements of assessment for licensing beyond design life have also been stipulated in the Regulations.

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 self assessments, reviews of plant safety performance by plant safety committee, quality assurance division, engineering department, health physics division and relevant operation and maintenance departments. Independent reviews and assessments by corporate safety body and international reviews such as WANO peer review, OSART mission, etc. are conducted for reassurance of safety.

Nuclear installations have established effective systems for recording deficiencies identified during the assessment and verification activities, event analysis, corrective actions and maintaining records for authorization and control of temporary changes to the equipment, procedures, etc.

In-Service Inspection (ISI) programs based on the requirements established in the technical specifications are implemented to assess and verify the condition of plant structures, systems and components important to safety at appropriate intervals.

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

14.2.1 Assessment and Verification of Safety at K-1

Safety of K-1 is being assessed and verified through periodic safety reviews, ageing management, in-service inspections, surveillance, and quality assurance programs. K-1 is now operating under license by PNRA beyond its design life. Ageing Management Work plan is based on the international practices in line with national regulatory requirements. In addition to the improvements reported in the previous report, other modifications/improvements were also made which include replacement of oil circuit breakers with SF6 type circuit breakers, and electromechanical type protective relays of transmission lines with state of the art numerical type relays.

A detailed full power Level-1 Probabilistic Safety Assessment (PSA), was performed by K-1 and significant improvements were made based on the results of PSA. Some modifications and improvements implemented during relicensing outage phase-II (RLO-II) using PSA Level-1 results are:

a. Integration of third diesel generator (DE-DG3) in K-1 power supply system.
b. Automatic start of Emergency Feedwater System.
c. Training improvement on restoring process water low pressure header under loss of instrument air.
d. Taking credit of runback success rate for LOOP (Initiating Event) frequency calculation to avoid core damage.
e. Taking credit of calandria spray cooling system to avoid core damage.
f. Revisions of dependencies among operator actions in case of small LOCA.
g. Taking credit of controlled shutdown for LPSW / SSW (Initiating Event) frequency calculation.
h. Taking credit of emergency sump transfer system to avoid core damage.

K-1 Fire PSA was completed under the guidance of IAEA experts. Application of Fire PSA is underway.

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. The safety assessment may also require design modifications which may be temporary or permanent. At C-1, a comprehensive program is established for design modification control, which defines roles and responsibilities of the work units and units involved in the plant modification process.

A set of procedures cover all aspects of design modifications, from the request, prioritization, safety screening, preparation of the design package, review and preparation of installation package to the evaluation of impact, testing/commissioning requirements, documentation revision and modification hand over, etc.

Control of temporary modifications is done through a specific procedure which requires safety screening and evaluation similar to the one for permanent modifications.

The activities related to verification of safety are stipulated by the Technical Specifications which include the surveillance program, periodic testing, In-Service Inspection (ISI) Program, etc. to determine qualitative guidelines for maintaining high availability and reliability of components.

Peer reviews are conducted by organizations such as IAEA and WANO. IAEA IPSART mission was conducted in November, 2009. IPSART recommendations among others include:

a. The implementation of systematic and adequate quality assurance practices;
b. Reconsideration of the initiating events identification process;
c. Justifiable and transparent definition of the success criteria, including documentation of all assumptions and references to supporting analyses;
d. Systematic consideration of secondary effects of High Energy Line Breaks (HELB);
e. Explicit modelling of ATWS sequences;
f. Systematic and detailed analysis of common cause failures;
g. Re-evaluation of the pre-initiator Human Errors (HE) both with extremely high and extremely low probabilities;
h. Increase of the number of Performance Shaping Factors (PSFs) and dependency factors considered in calculation of Human Error Probabilities (HEPs) for post-initiator human errors; consideration of the impact of initiating events on HEPs.

i. More careful and detailed analysis and interpretation of the PSA results.

A dedicated group for ageing management is in place and C-1 has agreement with external organizations for support on Ageing Management activities. Nearing completion of 10 years of operation, C-1 has performed first Periodic Safety Review and submitted the review reports to PNRA for regulatory review and assessment. The scope of the PSR includes all safety aspects of an operating plant, including both on-site and off-site emergency planning, accident management and radiation protection aspects. It has been determined by means of the PSR that the existing safety analysis report remains valid. It also takes into account the plant design, actual conditions of structures, systems, and components, equipment qualification, ageing, deterministic safety analysis, probabilistic safety analysis, hazard analysis, safety performance, use of experience from other plants and research findings, organization and administration, procedures, human factors, emergency planning, radiological impact on the environment and global assessment.

14.2.3 Assessment and Verification of Safety at C-2

The design of C-2 was assessed at various levels for verification of safety. The designer (SNERDI) 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 as owner organization. Modifications in the design followed the same course for approval as for the original design as required by the national regulations. 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. C-2 has now submitted Final Safety Analysis Report by incorporating the commitments made at the PSAR stage. It is under review at PNRA keeping in view the licensees commitments, C-1 operating experience feedback, results of commissioning and actual condition of structures, systems and components.

PNRA has carried out inspections during C-2 manufacturing and installations of C-2 components. Inspections during the commissioning phase are underway by PNRA inspectors at C-2 site.

C-2 submitted commissioning program according to the licensing requirements. PNRA reviewed the commissioning program in accordance with the national regulatory requirements, experience feedback of C-1, and international operating experience. On the basis of the review, modifications were suggested which mainly include; extending the scope of the tests of some systems such as emergency diesel generator, compressed air system, fuel conveyor car, etc. Addition of acceptance criteria in summary of tests and thorough testing of systems installed for severe accident mitigation purposes were also suggested. On the basis of review queries, a revised commissioning program was prepared which was approved by PNRA. Commissioning activities are in progress according to the schedule. PNRA has developed inspection program for commissioning and selected inspection items for commissioning activities. The inspection program is being executed in three types of inspections i.e. Hold “H”, Witness “W” and Record “R” point inspections according to the schedule agreed with the licensee.

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 to take appropriate actions for performance improvement.

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 2010. K-1 participates in the WANO Performance Indicators program also.

C-1 has adopted WANO performance indicators program. A set of selected indicators provides an overall and useful insight into how well C-1 is being managed. Benchmarking with the industry indicates progress and generates the need to initiate change for excellence.

Performance Indicator program is considered as an important tool to help in setting challenging goals for improvements, continuously monitoring performance and progress, and adjust priorities / resources for optimum utilization besides meeting international obligations. The existing program consists of collecting, trending, exchanging, and disseminating performance data for complete set of WANO performance indicators, covering critical safety and operational aspects of the plant. The selected performance indicators include Unit Capability Factor, Unplanned Capability Loss Factor, Forced Loss Rate, Grid Related Loss Factor, Unplanned Automatic Scrams per 7000 hours, Safety System Performance, Fuel Reliability Indicator (FRI), Chemistry Performance Indicator (CPI), Collective Radiation Exposure, etc.

C-1 has also developed Safety Performance Indicators (SPIs) to monitor operational safety of the plant. 75 out of 80 SPIs have been implemented at C-1 and remaining indicators are expected to be implemented by the end of 2010.

14.3 Regulatory Review Process

According to the procedure for licensing of nuclear installations in Pakistan, PNRA performs regulatory review of various licensee submittals such as Site Evaluation Report (SER), Preliminary Safety Analysis Report (PSAR), Final Safety Analysis Report (FSAR), Commissioning Program, Periodic Safety Review (PSR) Report, PSA Report, etc., during various licensing stages.

Formerly, the safety review was performed by PNRA staff with the help of consultants; however, PNRA has now established Centre for Nuclear Safety as its technical support organization to indigenously perform safety reviews and assessments for the licensing process of nuclear installations. Safety reviews are carried out in accordance with national regulatory requirements for siting, design, construction, commissioning, operation and decommissioning of nuclear installations as referred to in the Regulations PAK/909. In those areas where PNRA regulations and regulatory guides do not provide the necessary guidance, the relevant latest US Nuclear Regulatory Commission regulations/guides or IAEA Safety Standards and Requirements along with relevant safety guides may be used.

Review meetings are held between the licensee and regulatory staff to address the queries raised during the review process. After completion of the regulatory review, safety evaluation report is issued that highlights all the major findings of the review and provides a comprehensive assessment of licensee's compliance with the regulatory requirements. This report also indicates non-compliant situations which may form the licensing conditions attached with the regulatory authorizations issued at various stages of licensing process.

Any change in the plant configuration 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 of PNRA before implementation. Accordingly, PNRA reviews and approves the modifications. The design modification review process emphasizes that modifications, involving plant configuration and the operational limits and conditions, conform to the design requirements.

The licensees have been asked to submit PSA submissions along with FSAR and PSR report at the construction license, fuel load permit and license revalidation stages. C-1 and K-1 full power Level-1 PSAs and K-1 Fire PSA were reviewed by PNRA during the reporting period and the PSA recommendations have been implemented. The PSA submissions comply with the national regulatory requirements.

14.4 Verification of Safety by PNRA

Verification of safety of nuclear installations is carried out through regulatory inspections, reviews, analyses and audit calculations. The verification of safety is carried out during all phases, namely, siting, construction, installation, commissioning, operation and decommissioning.

Safety analysis, carried out by the licensee to support the design, is reviewed and audit calculations are conducted on sampling basis using applicable computer codes. The underlying assumptions, modelling techniques, accident sequence quantification, results and uncertainties are verified against the acceptance criteria. Comparison of results with already approved design, where applicable is also considered.

The inspection program of each phase is prepared in line with project schedule under intimation to the licensee. The inspection programs are focused on ensuring that plant construction, equipment manufacturing, installation and commissioning are in conformity with the design intent, and that the operation is within the approved limits and conditions. In addition to planned inspections, reactive/special inspections are also performed in situations requiring special attention or regulatory intervention. PNRA has included safety culture in its inspection program and has performed safety culture inspections at K-1 and C-1 and the follow-ups.

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, event analysis, operating experience feedback, radiological environmental surveillance, etc., are overseen by the regulatory inspectors to verify compliance with the regulatory requirements.

14.5 Safety Reviews and Assessment through External Organizations

C-1 understands the importance of international evaluations and their benefits for enhancing safety and operational performance of the plant. This is done through benchmarking with plants having excellent performance in safety and availability. In view of this, C-1 invited following support missions during 2007.

a. Technical Support Mission from WANO on “Development of Alarm Response Procedures”, July 2007.
b. Technical Support Mission from WANO on "Optimization and Improvement of Preventive Maintenance Program”, August 2007.

Safety of the plant can be measured in several ways, of which one way is the assessment of Core Damage Frequency (CDF) by using Probabilistic Safety Assessment (PSA) methodology. In order to review and verify the methodology adopted by C-1 to complete Level-1 PSA, the PSA has been subjected to IAEA IPSART review as well as comprehensive review which have provided significant confidence. Major areas of improvements identified by IPSART have been mentioned in Section 14.2.2 of this Report. WANO Peer Review Mission was also conducted at K-1 in January 2010.

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

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 measures to ensure that during all operational steps of nuclear installations such as operation, maintenance, refuelling, implementation of design modifications, etc. the exposure to plant personnel, public and environment is kept as low as reasonably achievable and that no individual is exposed to radiations which exceed the prescribed dose limits.

15.1 Regulatory requirements

PNRA is responsible for regulating matters related to radiation protection. PAK/909 requires submission of a radiation protection program and radiological environmental program as part of the prerequisites for issuance of operating licence.

The radiation protection objective described in Regulations PAK/911 states that, "it is to be ensured that in all operational states radiation exposure within the installation or due to any planned release of radioactive material from the installation is kept below prescribed limits and as low as reasonably achievable (ALARA), and to ensure mitigation of the radiological consequences". The safety objectives for design of nuclear installations require that nuclear installations shall be designed and operated so as to keep all sources of radiation exposure under strict technical and administrative control.

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 Regulation also requires that implementation of the radiation protection program shall be ensured by the appointment of qualified Manager Health Physics who shall advise the plant management and shall have authority to participate in establishing and enforcing safety procedures. The qualifications of Manager Heath Physics are also defined in the Regulations. The dose limits for radiation workers and public during normal operation are given in PAK/904 and are reproduced in Annexure – XIV.

15.2 Radiation Protection at Nuclear Installations

According to recently announced Nuclear Safety Policy PAEC is committed to take appropriate steps so that occupational radiation exposure to personnel working in its nuclear facilities is maintained as low as reasonably achievable (ALARA). Moreover PAEC is committed to take all reasonably practical steps to achieve the following two safety objectives:

a. The risk of prompt fatality to an average individual in the vicinity of a PAEC nuclear facility, as a result of an accident in the facility, should not exceed 0.1 % of the sum of prompt fatalities due to other accidents to which the members of the public are generally exposed.
b. The risk of cancer fatalities to population in the area of a PAEC nuclear facility that might result from the operation of the facility should not exceed 0.1 % of the sum of all cancer fatalities due to all other causes

The nuclear installations have developed policies and procedures, for the protection of workers, public and environment from the harmful effects of radiation, in conformance with the national regulatory requirements. It is ensured that in all operational states radiation exposure within the installation or due to any planned release of radioactive material from the installation is kept below prescribed limits and as low as reasonably achievable (ALARA), and that the measures to mitigate the radiological consequences arising from any design basis accident are in place. In this regard all reasonably practicable steps are taken to ensure safe plant operation and to keep radiation doses as low as reasonably achievable (ALARA).

At nuclear installations, monitoring and surveillance of doses to radiation workers are conducted and records maintained. For environmental monitoring, continuous air sampling and ambient dose level monitoring are performed. Environmental samples of air, water, soil, vegetables, fruits, milk, meat, etc., are collected and analyzed for estimation of radionuclide content at frequencies prescribed in the radiological environmental monitoring programs. On-Site and Off-Site environmental monitoring points are selected at different locations. Environmental TLD[33] dosimetery is also performed to record the cumulative dose levels on quarterly basis. PNRA normally reviews the records of sampling and analyses carried out by the licensees. Other organizations may also be involved for independent verification of monitoring of radioactive samples. PNRA is also in the process of establishing its own environmental monitoring laboratory.

15.2.1 Radiation Protection at K-1

At K-1 radiation exposure is controlled by means of job planning, job briefing, frequent radiation surveys, radioactive contamination control, and regular training to keep the doses well below the regulatory limits. In addition, a Health Physics Coordinator is designated for radiation intensive jobs with prime responsibility of taking part in each activity right from planning to execution. Internal radiation dose is controlled by providing suitable respiratory protection equipment, reducing the airborne contamination level and bioassay sampling. 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 plant periphery and in different areas of Karachi. This is done by placing TLD’s and high volume air sampling system away from the plant. Environmental samples from the vicinity of plant are collected and analyzed. The records show that the radiation doses to the public are a small fraction of the limiting values.

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 content 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 radioactive releases from the plant are well below the Derived Release Limits for K-1.

Annual collective dose during 2007, 2008 and 2009 at K-1 was 2320 man-mSv, 3700 man-mSv and 1860 man-mSv respectively. Average individual doses for these years were 2.62 mSv, 4.07 mSv and 2.10 mSv respectively. Annexure–XV graphically represents these doses.

Gaseous radioactive effluents released during 2007, 2008 and 2009 were 86.55 TBq, 175.75 TBq and 90.12 TBq respectively. On the average gaseous releases remained less than 1% of annual release limits.

[33] Thermo luminescent dosimeter (TLD)

The liquid effluents released to sea during 2007, 2008 and 2009 contained 37.80 TBq, 138.01 TBq and 61.90 TBq of Tritium respectively. Generally, these were of the order of 0.16 % of annual release limit for Tritium. Gross beta-gamma radioactivity released to sea was 5.92 GBq, 12.58 GBq and 5.92 GBq respectively. These releases were less than 1.0 % of annual release limit for gross beta-gamma radioactivity. The effluent releases of K-1 are shown graphically in Annexure–XVII.

15.2.2 Radiation Protection at C-1

In order to implement the radiation protection program, C-1 has established the necessary organizational setup headed by Manager, Safety & Health Physics Division. Station health physicists working under him are responsible for implementing the radiation protection program for handling and monitoring radioactive materials, including sources and secondary source materials. This program conforms to National Regulations and includes;

a. Conformance to 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.
e. Record keeping of occupational radiation exposures and reporting to the PNRA.
f. Provision of personnel and other radiation monitoring equipment and their periodic calibration.
g. Establishment of access control points to separate potentially contaminated areas from uncontaminated areas and survey of tools and equipment 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 2007, 2008 and 2009 was 481.161 man-mSv, 592.280 man-mSv and 232.733 man-mSv respectively. Average individual dose for these years remained 0.275 mSv, 0.341 mSv and 0.204 mSv respectively. Annexure–XVI gives a graphical representation of these doses.

At C-1, all liquid and gaseous effluents are monitored before releasing to the environment. Liquid effluents are released from C-1 into the discharge canal, which falls into the Indus River. Gaseous effluents release during 2007, 2008 and 2009 were 4.06 TBq, 0.1 TBq and 5.66 TBq respectively. On the average these releases remained less than the release limit. Liquid effluent releases for the years 2007, 2008 and 2009 were 6.79 TBq, 7.16 TBq and 1.97 TBq respectively. These releases were far less than annual release limit. C-1 effluent releases are shown graphically in Annexure–XVII.

15.3 Classification of Areas and Radiation Zones

According to the requirements of PAK/904, the radiation areas are classified into two parts i.e. Supervised and Controlled areas for the purpose of controlling the occupational exposure. At K-1, Controlled area is divided into 4 zones. Zone 1 contains no radioactive equipment and is kept free of contamination at all times. Zone 2 contains no radioactive equipment and should not become contaminated. However, some contamination may get into this area with the movement of personnel from Zone 3 which includes service area for active equipment and materials that are potential sources of contamination. Zone 4 contains sources of Contamination.

C-1 Radiation Controlled Area (RCA) is classified into 5 radiation Zones as given below;

Table: 15.3-1: Radiation Zones

ZONE DESIGNATION	DESIGN DOSE RATE (10^{-2} mSv/h)	SYMBOL
Uncontrolled areas	≤0.08	None
Supervised areas	≤0.24	None
Controlled areas:		
Zone R1	≤0.8	I
Zone R2	≤2.5	II
Zone R3	≤10	III
Zone R4	≤100	IV
Zone R5	>100	V

15.4 Dose Constraint

To realize the effectiveness of ALARA approach, Dose Constraint factor of 0.3 mSv and 0.26 mSv have been applied for K-1 and C-1 respectively.

15.5 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 performs regulatory inspections and reviews reports of the licensees to verify compliance with radiation protection and radiological environmental monitoring programs. Such inspections are an essential part of annual inspection plan of PNRA Regional Directorates for nuclear installations. During these regulatory activities, various aspects of implementation of radiation protection program are considered. These include development and implementation of ALARA plans for activities involving radiation exposures, compliance with the procedures, provision of personal protective gear to workers, availability and accuracy of personal and area monitoring equipment, radiation dose records for radiation workers and records of radioactive releases from nuclear installations.

It has been observed that the doses to radiation workers remain well below the radiation dose limits and the average dose received by an individual remains less than a fraction of the annual dose limit. Similarly, in the entire operating history of nuclear installations in Pakistan the gaseous and liquid effluent releases have been well below the derived release limits. The licensees report the ambient dose levels at nuclear installations to PNRA quarterly and annually. 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 for the year 2007, 2008 and 2009 are 122, 109 and 115 nGy/hr respectively.

The ambient dose levels at K-1 and C-1 are summarized in Annexure–XVIII.

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, which 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

The National Regulations PAK/909 set the requirement for preparing an emergency preparedness plan prior to introduction of nuclear material into 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 maintain the capability for 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. In addition, an emergency plan is required to be tested in an exercise before the commencement of operation and after some intervals thereafter. Some of these exercises shall be integrated and shall include the participation of as many as possible of the organizations concerned. The plans shall be subject to review and updating in the light of experience gained from the exercises.

Further, the National Regulations PAK/914 "Regulations on Management of a Nuclear or Radiological Emergency" require that licensee shall develop, test, and put in place an infrastructure according to the hazard category as defined in the Regulations. In addition, the licensee shall 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 is aimed at minimizing the radiological consequences for the public, property and the environment arising from such an emergency. In case of severe emergencies, the response at national level is also required by these Regulations.

16.2 Emergency Plans of Licensees

The operating nuclear installations (K-1 and C-1) have developed on-site and off-site emergency plans. These emergency plans describe 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. Emergency plans also give brief details of plant systems, demography and regional climatology. The operating organization, on-site and off-site emergency response organizations are described in the emergency plans covering the role of each responsible person during an emergency situation. Emergency facilities like emergency control centre, auxiliary emergency control centre, communication facilities, radiation monitoring system, post accident monitoring system, medical facilities, decontamination facilities, etc. are described in the emergency plans.

The effectiveness of some elements of emergency plan is demonstrated in an integrated exercise before the commencement of operation of the nuclear installation. The frequency of the exercises is given in Annexure–XIX. Emergency exercises performed at K-1, C-1 and NRECC from January 2008 to Dec 2009 are shown in Annexure–XX. In the integrated exercises, participation of concerned organizations is ensured as far as possible. The plans are updated in the light of experience gained from the exercises and drills to comply with regulatory requirements and changes in the local government organizational structure. Besides emergency drills and exercises, there were also maintenance and inspection activities for the operability of the centres and the equipment used in emergency response. Updating of the documentation in the centres, tests of communication systems and tests of the emergency personnel response are also performed.

In 2008 and 2009, C-1 and K-1 conducted exercises to evaluate their effectiveness according to the approved emergency plans. PNRA witnessed these exercises and issued recommendations for improvement in the emergency preparedness plans. The implementation of K-1 offsite plans according to updated KOFREP was demonstrated during an exercise to fulfil relicensing requirement in June 2010 with the involvement of other Governmental organizations such as Provincial Disaster Management Authority (PDMA), City Government, District Health Authorities, Local Police, etc.

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 specified in relevant plant procedures to be exercised by the 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 comes under control and the plant is brought to a safer mode, SS terminates the emergency with the authorization of Site Emergency Director (SED). According to C-1 On-site Emergency Plan, 'CHASNUPP Emergency Response Organization' (CERO) is responsible for initiation and completion of recovery operation and is regarded as Recovery Organization while Technical Support Centre (TSC) is meant to provide technical support to the MCR crew in case of emergency. Both CERO and TSC are activated by SS in case of emergency.

Emergency Preparedness Plan for C-2 has been submitted to PNRA for review and approval. The on-site plan is plant specific while the off-site plan is site specific. Off-site plan for C-1 and C-2 will be integrated as both share the same site. If the Emergency Preparedness Plan for C-2 is approved by PNRA, then prior to issuance of fuel load permit, C-2 will conduct an integrated drill to demonstrate effectiveness of the plan and to test emergency response.

16.3 Verification of Emergency Plans by PNRA

Verification of emergency plans is conducted through regulatory review and by witnessing periodic emergency drills and exercises conducted by the licensee in the fulfillment of the regulatory requirements. Emergency plan of the licensee is first reviewed to verify that it contains essential elements of emergency preparedness and response in line with the regulatory requirements for issuance of operating license. Later through periodic inspections, it is verified that the implementing procedures are developed, on-site emergency response organizations are equipped with necessary means, and response personnel have adequate qualifications and training. Prior to the conduct of exercise, the licensee prepares and submits 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. PNRA also invites its liaison officers from the relevant Government Departments and Ministries to witness the emergency exercises. 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. In order to verify the accuracy and continuous availability of designated emergency contacts of the licensee and regional offices, PNRA conducts Communication Test Exercises (COMTEX) thrice a year on regular basis. Any change in the emergency contact details is updated at the NRECC.

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 and remains functional round the clock. It is the focal point for regulatory response in case of an emergency (Abroad or Domestic) and also functions as the secretarial arm to Chairman PNRA, who is the National Competent Authority (NCA) for an emergency. NRECC is also 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 National Competent Authority (Abroad and Domestic) and IAEA about a nuclear accident or radiological emergency. The main functions of NRECC are to:-

i. Receive a notification and information concerning the nature of the emergency, national as well as transnational, of potential consequences.
ii. Authenticate and verify notifications or information of a nuclear accident or radiological emergency.
iii. Inform forthwith, after being notified of an event, the NRECC Chain of Command about the received notification.
iv. Communicate received information (consistent with confidentiality limitations) promptly to licensee, public authorities or relevant international organizations.
v. Facilitate and/or co-ordinate the provision of assistance at the national/international level, if it is requested for.
vi. Assist NCA(A) or NCA(D) on recommendations to Government of Pakistan for protective actions like sheltering, evacuation or supply of prophylactics, etc.
vii. Use its best endeavors to promote, facilitate and support the cooperation and coordination between PNRA, licensees, public authorities and relevant international organizations.
viii. Ensure that there are timely, accurate and reliable releases of information to the media, as appropriate, through other relevant directorate of PNRA.

NRECC is adequately equipped with communication facilities. It is supported by two Mobile Radiological Monitoring Laboratory (MRML) vans and various types of radiation detection and personal protective equipment. MRMLs are 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 operation of MRMLs, and training of response personnel. In order to ensure a timely response to nuclear or radiation emergency, PNRA intends to provide MRML to its Regional Nuclear Safety Directorates. In addition, PAEC has its own MRMLs at sites. PNRA has also procured high frequency communication system to link the base station with MRML if these are in areas where normal means of communications may not be available.

During emergencies, the decision for implementation of protective measures is the responsibility of the licensee and is made on the basis of intervention levels, reference levels, etc., defined in the licensee emergency plans which are approved by PNRA. However, the licensee keeps NRECC informed about any protective measures taken. PNRA would be consulted in case of any unforeseen situation. PNRA is also coordinating with the response and law enforcing agencies to familiarize them with their role during a nuclear accident or radiological emergency.

16.5 Training of First Responder

In case of an emergency, the rescue person is always one of the first persons reaching at the scene of accident. The trained rescuers can play important role to avoid spread of contamination and overexposure to the personnel. In order to train the first responders, PNRA has developed liaison with relevant public departments. During 2009, two training courses were arranged at RESCUE 1122 Academy and more than 500 first responders and 80 officers participated in the training to respond to radiological emergency. The training comprised classroom lectures, table top exercises and field exercises. The program also included practical demonstration of different radiation detection and personal protective equipments.

For the use and awareness of the first responders, PNRA has prepared pamphlets and booklets regarding nuclear and radiation emergencies which may be used in case of a nuclear or radiological emergency.

16.6 Training of Medical Professionals in Handling of Radiation Injuries

Overexposure to radiation or radioactive contamination may cause radiation injuries in case of a nuclear or radiological emergency. It is therefore, obvious that medical professionals would be among the first responders in such accidents. PNRA is working towards the development of national capability for the management and treatment of radiation injuries in collaboration with other national organizations and hospitals. PNRA pays special attention to the training of the medical personnel to ensure that adequate level of such capability exists among medical doctors and paramedical staff. In this regard, short courses have been arranged in different hospitals for medical doctors. These courses are based on basic medical techniques for treatment of overexposed and contaminated individuals at the site and in isolated rooms in hospitals in case of a nuclear or radiological emergency.

16.7 Public Awareness

A two prong strategy for implementation of public awareness program has been adopted. First, as part of implementation of offsite emergency plans, the licensees are implementing site specific public awareness programs in areas around nuclear installations. Assistance from other local organizations such as local governments, educational institutions, etc., is sought for providing awareness about emergencies and response of the public. PNRA is also developing public awareness program at national level to educate the public through electronic and print media and other communication means. Subject specific written material has been prepared in the form of leaflets, pamphlets and other literature in Urdu, English and local language for distribution in the public. The literature covers brief introduction of the plant and its safety aspects; need of emergency planning and preparedness; implementation of protective actions and public response during emergency.

16.8 International Cooperation

Pakistan is participating in a number of international projects sponsored by the IAEA in the area of emergency planning and preparedness. Pakistan participates in IAEA ConvEx[34] 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[35] website. These exercises, especially the large scale ones like ConvEx3 , helped in testing the planning and preparedness. The evaluations of the exercises at IAEA have shown that in most cases the system worked as planned and intended. Corrective measures were introduced where the response varies from the expected one.

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)}.

So far bilateral agreements do not exist between Pakistan and neighboring countries regarding emergency preparedness or transboundary effects of nuclear emergencies. The locations of nuclear power plants in Pakistan are quite far from the boarders with neighboring countries. So chance of any transboundary effects from the nuclear accidents or radiological emergencies at nuclear installations in Pakistan is remote. However, as a Contracting 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 in line with the provisions of the Conventions.

16.8.1 Response Assistance Network of the IAEA (RANET)

IAEA Response Assistance Network (RANET) is an integrated system established under the International Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency and is designed to provide international assistance to Member States to minimize the radiological consequences of accidents. Being the State Party to the Convention, Pakistan has registered National Assistance Capabilities (NAC) in the RANET at IAEA in February 2008. During the reporting period, PNRA has arranged a few meetings of RANET team members comprising officials from PNRA, PAEC and other national organizations and hospitals to evaluate RANET abilities against the requirements set by the IAEA.

NRECC was activated to participate in the exercise, ConvEx-2d, conducted at IAEA from August 13 to 14, 2009. The exercise was based on a scenario to test assistance capabilities of the member states registered under IAEA Response Assistance Network (RANET). The designated RANET members from PNRA, PAEC and a local hospital were assembled at NRECC and decided to render assistance according to the scope of the exercise.

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

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

[35] Emergency Notification and Assistance Convention Website

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 Nuclear Regulatory Authority Ordinance 2001 clearly stipulates "No person shall commence construction of any nuclear installation without first obtaining an authorization for the purpose from the authority as may be prescribed by regulations". It is ensured that licensees have developed adequate procedures 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

National Regulations PAK/910 (Rev. 1), "Regulation on the Safety of Nuclear Installations – Site Evaluation" was promulgated in 2008 to establish the requirements for siting of nuclear installations. In addition, Regulations for Licensing of Nuclear Installation(s) in Pakistan – PAK/909 also require provision of "No Objection Certificates" from local, provincial and other federal agencies. Site Evaluation Report (SER) is required at the time of site registration to ensure that the plant complies with the national rules and regulations regarding environment protection, land and water use, etc. PAK/904, PAK/911, PAK/912, PAK/914 and Pak/915 also address siting related aspects of radiation protection, design, quality assurance, emergency planning and preparedness and radioactive waste management.

The siting process of a nuclear power plant covers the entire process of the site evaluation i.e. selection, assessment and pre-operational as well as operational stages. One important aspect of above mentioned regulations is the evaluation of the effects of accidental and routine releases to the environment so that appropriate emergency measures are planned and executed. The site characteristics are assessed on the basis of historical evidences, recorded data, site surveys, detailed investigations and analyses in line with international practices and proven engineering techniques. Generally, site specific data (recorded data) are used. Where site specific data are not available, data 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 instruments are installed at proposed sites.

The operating licenses for nuclear facilities are granted for a period of ten years. For the license renewal, Periodic Safety Review (PSR) is required to be conducted by the licensees, which includes safety factor related to siting. Under this safety factor, a comprehensive re-assessment of site related factors is conducted to encompass changes in the hazards previously determined. In case of any change in the hazards that may pose a threat greater than that determined previously, plant design would be reviewed for its adequacy and/or for any subsequent compensatory measures.

17.2 Environmental Monitoring Program

According to the National Regulations on Licensing of Nuclear Installations PAK/909, licensee has to submit Environmental Monitoring Program duly approved by Pakistan Environmental Protection Agency (EPA). The Environmental Protection Agency is responsible for the prevention and control of environmental issues.

Environmental Impact Assessment (EIA) is carried out for new nuclear power plants by the EPA. The assessment report covers all the environmental features around the site including ambient conditions before, during and after the construction/operation of nuclear power plant. On the basis of assessment reports, no objection certificate (NOC) is issued to the licensee which is a mandatory requirement for site registration by PNRA.

17.3 Nuclear Installation Sites

Pakistan has two nuclear power plants in operation, namely, C-1 (PWR) and K-1 (CANDU). C-2, a PWR, is near completion and is in the process of getting operating license from PNRA. PAEC has also identified additional sites for NPPs in line with the Government of Pakistan Energy Security Plan to increase nuclear energy share up to 8800 MW by the year 2030.

17.3.1 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.

A seismic monitoring system has been installed at the site to help estimate the severity of the seismic event and to enable the plant management to take necessary action.

17.3.2 C-1 Site

There is a regulatory requirement that the plant shall perform its comprehensive safety review called “Periodic Safety Review” after completion of ten (10) years of operation. In PSR, licensee has to demonstrate that plant can be safely operated and meet the current regulatory requirements. In this regard, C-1 has performed systematic safety reassessments of the site of the plant. A detailed site characteristics report has been submitted to PNRA which comprise:

a. Population Distribution
b. Nearby Industrial, Transportation and Military Facilities
c. Meteorology
d. Hydrological Engineering
e. Geology, Seismology and Geotechnical Engineering

In addition, reports regarding other site related safety factors, like external hazards such as high wind, temperature extremes, explosion, aircraft crash, etc., are reviewed by PNRA. The impact of all relevant site related factors on plant and on individuals, society and the environment has been re-evaluated and found acceptable.

17.3.3 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 required by National Regulation PAK/909, C-2 submitted a detailed Site Evaluation Report (SER). The SER comprised geography and demography, nearby industrial transportation and military facilities, meteorology, hydrological engineering and geology, seismology and geotechnical engineering. PNRA reviewed SER on the basis of national regulations and international standards, and the C-2 site was registered. In the second stage of licensing process, Construction License was issued and in the third stage, Fuel Load Permit will be granted on the basis of successful completion of commissioning program and acceptance of Final Safety Analysis Report which is being reviewed by PNRA.

17.4 Verification by PNRA

The site verifications of C-1 and K-1 were performed at the time of their construction. The details were provided in previous reports.

17.5 Transboundary Effects

The nuclear installations in Pakistan are located far away from international boundaries; therefore, a rather low possibility of transboundary 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.

17.6 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 levels (see article 15 for detail).

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 also cover various aspects of design and construction of nuclear installations. The obligations of Article 18 will be met through conformance to these regulations.

18.2 Implementation of Defence-in-Depth Concept

In striving to realize the objectives of its Nuclear Safety Policy, PAEC is committed to designing, constructing, operating and decommissioning its nuclear facilities with appropriate barriers and engineered safety features to prevent or minimize potential radioactive releases.

In order to ensure the safety of nuclear installations, a multi-barrier concept is applied based on the Defence-in-Depth (DID) principle in the design and operation of nuclear installations. All structures, systems and components of nuclear installations are designed in consideration of the following internal and external events at the stage of selecting the site:

Internal events: Loss of coolant accident, main steam and high energy line breaks, internal scattered material (missile) caused by a rotor, fire, flooding, and so on.

External events: Earthquakes, floods, tsunami, cyclones, and other anticipated man-made disasters.

The major contents in applying the defence-in-depth principle are as follows:

a. Nuclear installations are designed to have multiple barriers, such as the fuel pellet, the fuel clad, the reactor vessel, the reactor coolant pressure boundary, and the containment building to prevent the release of any radioactive materials into the environment.
b. A sufficient safety margin is secured in the design so that the probability of any design basis accident is minimized. Concept of independence, redundancy, and diversity are also applied to minimize the consequences of anticipated operational occurrences, events and design basis accidents.

c. The design is such that even if any abnormal state occurs in the nuclear installation, due to failures of equipment, operator errors, or combination thereof, the reactor protection system operates automatically by detecting the abnormal state and initiates the operation of the reactor shutdown system in order to prevent the abnormal state which may lead to a severe accident.

18.2.1 Prevention and Mitigation of Accidents

Following features have been considered in the design of nuclear installations regarding prevention and mitigation of accidents:

a. The reactor core is designed to assure that power oscillations, which can result in conditions exceeding specified acceptable design limits, are not possible or can be readily suppressed.

b. The reactor coolant pressure boundary is designed to have an extremely low probability of abnormal leakage and gross rupture. If any leakage of the reactor coolant takes place, it is promptly detected to prevent a severe accident. It is also designed to permit periodic inspection and testing to assess the structural integrity and leak-tightness.

c. The emergency core cooling system is designed to automatically provide abundant emergency core cooling following any loss of reactor coolant at a rate such that any fuel damage that could interfere with continued effective core cooling is prevented. In case of loss of offsite power, there is provision of house load operation. Cooling through natural circulation up to certain level is also considered. Emergency power sources are also available to accomplish safety functions in case of loss of offsite power. Consideration of station black out is also taken into account to cater to complete loss of power scenario.

d. The reactor protection system is installed to sense accident conditions and maintain the reactor in a safe state by automatically initiating the operation of the reactor shutdown system and the engineered safety features. The reactor protection system is designed with redundancy, diversity, and independence to assure that no single failure of any equipment or channel of the system results in loss of the intended safety functions.

e. The reactor containment is designed so that if any accident occurs, the radioactive material released from the reactor coolant pressure boundary is confined and reduced over a long period. A system is installed in the containment to control the concentration of any combustible gas as it accumulates inside. The safety features including the containment spray system are considered to lower the pressure inside the reactor containment and to eliminate radioactivity.

f. The Emergency Control Centre is established so that if any radioactive material is accidentally released outside the nuclear installation, its effect on nearby population and the environment are controlled.

g. The Safety Parameter Display System (SPDS) is installed in the main control room so that major safety parameters are promptly recognized. The main control room is designed so that even if any serious accident occurs, the operator can safely remain to take the necessary post-accident actions. It is possible in the control room to monitor the operating parameters, the radioactivity inside and outside the reactor containment, the radiation releasing passage, and the radioactivity around the nuclear installation in order to sense the accident conditions and to take appropriate actions.

18.2.2 Application of Proven Technologies

It has been considered that the design of safety related structures, systems and components of nuclear installations use the technologies which are proven.

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, and 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:

- i. Installation of Forced Emergency Injection Water System
- ii. Providing redundancy in existing Emergency Injection System
- iii. Seismic qualification of Emergency Injection Water System
- iv. Improvement in LOCA handling capability outside boiler room
- v. Automatic Boiler Crash Cool Down System
- vi. Seismic retrofitting of SSCs
- vii. Fire prevention and control in cable galleries
- viii. Installation of third emergency diesel generator
- ix. Installation of a system capable of adding heavy or light water to the primary heat transport system
- x. PSA Level 1 and Fire PSA
- xi. Emergency Control Centre and supplementary control room
- xii. Improvement in Control Room habitability
- xiii. Automation of Emergency Feed Water System
- xiv. Anchoring racks of DC battery banks
- xv. Refurbishing Delayed Neutron Activity Monitoring Systems at north and south sides
- xvi. Installation of Critical Safety Parameter Display system in MCR and ECC
- xvii. Modification in Annulus Gas System (AGS) for LBB capability
- xviii. Installation of a screen around the active drainage sumps
- xix. Replacement of C& I loops with state-of-the-art PLC based control loops

The designs of C-1 and C-2 are comparable to other PWRs operating elsewhere in the world and meet the current safety requirements. However, as a result of operating experience, following modifications were made in the design of C-1 during reporting period:

- i. Modification of Irradiation Surveillance Capsules (ISCs) Supporting & Positioning Structure to cater to the effect of flow induced vibrations.
- ii. Low pressure & Low flow alarm suppression of SAF (Auxiliary Feed Water System) Motor Driven Pumps as part of improvement in operator action.
- iii. Modification in Fuel Assembly Bottom Nozzle to install Anti-Debris Filter to enhance fuel reliability.
- iv. Modification for installation of depression monitors on EDGs to enhance monitoring on filter choking / increased reliability of EDGs.
- v. Modification for installation of Flange Connections on Compressed Air System piping to facilitate Leak Rate Test.
- vi. Modification for installation of Flange Connections on Component Cooling Water System piping to facilitate Leak Rate Test.

The operating experience of C-1 has been utilized to improve the design of C-2. More than 160 improvements have been introduced in C-2, on the basis of C-1 feedback, for example:

- In charging system, two lines with separate control valves for RCP Sealing and Pressure control.
- Design of airlocks improved, with better quality seals.
- Main Air Compressors are screw type.
- Emergency Air Compressors are screw type instead of reciprocating and air cooled.
- Component Cooling Water system heat exchangers are plate type instead of U-tube.
- Transformer Deluge system operation logic and system improved.

For consideration of beyond design basis accidents and provision of appropriate and practicable preventive or mitigatory features as required by the National Regulation PAK/911, evaluation is being carried out in the first PSR of C-1.

In C-2 design, in addition to consideration for design basis accidents, PSA was conducted during the design stage and the scenarios having considerable contribution to core damage were identified. The results of design PSA were then considered in the severe accident analysis. As a result of these analyses, the design was augmented with additional features for mitigating the consequences of severe accidents. Some of these additional design features of C-2, which were not there in C-1 design, are the following:

i. Provision of motorized throttle valve in the pressurizer to avoid high pressure core melt ejection and consequent direct containment heating and containment failure at an early stage.

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

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

18.4 Follow-up of IAEA Review of C-2 Design

The design of of C-2 was reviewed by international experts under an IAEA TC Project at PSAR stage. Later, a follow-up review mission was conducted in Vienna in January 2009 and issues related to Chapters 4, 5, 8, 9 and 10 were reviewed against IAEA safety standards and recommendations were made against each issue. These recommendations are now being considered during review of Final Safety Analysis Report.

18.5 Construction of Nuclear Installations

The activities related to construction, installation and commissioning of C-2 are described below.

18.5.1 Construction and Commissioning Activities at C-2 Site

Construction and installation activities were performed by the qualified sub-contractors under the supervision of main contractor in line with the quality assurance program of the licensees. PNRA has also inspected the QA programs of licensee, contractors, and subcontractors during the QA administrative inspections to verify that the elements of the QA programs are in line with the regulatory requirements.

Construction of all buildings and installation of all the equipment in C-2 are now complete. C-2 prepared Pre-Service Inspection (PSI) and In-Service Inspection (ISI) programs for first inspection interval and submitted for regulatory review and approval. The programs were reviewed to verify compliance with the inspection requirements of applicable standards. On the basis of review, modifications were suggested and PSI/ISI Programs were revised accordingly, which were then approved by PNRA. Pre-Service Inspection (PSI) activities of plant components according to the approved program are being conducted to acquire baseline data to be used for comparison during In-Service Inspection (ISI) of the plant.

After completion of construction and installation of equipment, C-2 prepared commissioning program for comprehensive and integrated testing of plant systems and components according to the licensing requirements. PNRA reviewed the commissioning program in accordance with the national regulatory requirements, experience feedback of C-1, and international operating experience. On the basis of review, modifications were suggested which mainly include; extending the scope of testing of some systems such as emergency diesel generator, compressed air system, fuel conveyor car, etc., and addition of acceptance criteria in summary of tests and thorough testing of systems installed for severe accident mitigation purposes. Keeping in view the review queries, a revised commissioning program was prepared by C-2 and submitted to PNRA for approval. Commissioning activities are in progress according to the schedule. PNRA has developed inspection program for commissioning and has selected inspection items for commissioning activities.

18.5.2 Review of Final Safety Analysis Report (FSAR) of C-2

The licensee has submitted Final Safety Analysis Report (FSAR) of C-2 to PNRA in November 2009 which is being reviewed. C-2 FSAR also includes Level-1 PSA report, Severe Accident Analysis and certain improvements over C-1 design as were committed in PSAR. The regulatory review is aimed at verifying compliance with licensee commitments as well as conformance to the requirements of national regulations and applicable standards. PNRA has prepared FSAR review plan extending over a period of one year. The review plan identifies four review phases and important milestones of regulatory review meetings with the licensee involving the personnel from the designer and main contractor. The regulatory review meetings are aimed to address the review queries and seek commitment from the licensee for improvement in plant safety against the review queries. The FSAR review team is also interacting with the resident inspectors and witnessing the important commissioning tests in order to verify licensee's commitments regarding improvement in plant safety. The review of FSAR is expected to be completed by the end of the year 2010. After confirmation for conformance to Regulations, agreed codes & standards and the commitments made during PSAR review, C-2 FSAR will be approved by PNRA.

18.5.3 Manufacturing in Pakistan

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 according to the requirements of relevant regulations, codes and standards. Initially PNRA licensed the manufacturing facility for Safety Class-2 and Safety Class-3 mechanical components. Now, the licensee has upgraded the facility for manufacturing and testing and intends to manufacture Safety Class-1 mechanical components also. In this regard, an application along with necessary documents such as quality assurance program, material specifications, detailed drawings and testing facilities, etc., has been submitted to PNRA. The application is under review and evaluation process for making regulatory decision.

18.5.4 Manufacturing in China

Most of the equipment for C-2 was manufactured in China. Only a few components for C-2 were manufactured in Pakistan. The manufacturers were selected by the main contractor according to the procurement control requirements of its QAP. The QAP of main contractor was developed on the basis of Overall Quality Assurance Program of C-2, and approved by PNRA. C-2 conducted inspections and audits of the manufacturing facilities. PNRA selected safety significant equipment for regulatory inspections. The inspections included QA inspections during manufacturing, testing and qualification of the equipment. During the reporting period, PNRA conducted forty-five regulatory inspections related to manufacturing, fabrication, testing and qualification of different components of C-2.

During manufacturing of Reactor Pressure Vessel (RPV) for C-2, a production weld test coupon was prepared by manufacturer for two circumferential welds (connecting Shell Course with Bottom Head and Nozzle Belt) of RPV. ASME Code 2001 edition was followed for the design and manufacturing of RPV. Narrow gap welding using Submerged Arc Welding (SAW) method was used for these welds. Welding procedure was qualified before the actual welding. The welding was performed as per qualified welding procedure. While performing destructive tests on specimens of weld test coupon, the tests failed in fracture toughness to meet the acceptance criteria for Charpy V-notch and Drop Weight Tests for specimens from weld and heat affected zones (Required value for Charpy V-notch test at -20 °C was > 41J (average) and > 34J (minimum); actual values were 20J and 18J). The NDT performed on RPV welds did not indicate any flaw but RT and UT of weld test coupon indicated some unacceptable flaws.

Keeping in view the uncertainty of quality of two circumferential welds, the manufacturer, in consultation with the designer, prepared a new production weld test coupon from the same forgings following the re-qualified welding procedure and the two circumferential welds were reworked. The main contractor reported the non-conformance and the corrective actions taken to PAEC, which were then reported to PNRA.

For thorough evaluation of the issue, PAEC and PNRA sought the expert opinion from national and international organizations such as Pakistan Welding Institute (PWI), National Centre for Non Destructive Testing (NCNDT) and RESCO of Czech Republic. On the basis of evaluations, it was assured that the reasonable safety margins exist for C-2 RPV for its design life. On the basis of the above evaluations, C-2 was allowed to start the welding of SRC piping subject to increase the volumetric inspection (UT) of two welds of RPV to minimum 200% during the first interval of in-service inspection (ISI) program and submit the results to PNRA for further review.

18.6 Operation in Consideration of Human Factors and Man-Machine Interface

In order to maximize the safety and efficiency of nuclear installations, the main control room, the SPDS, the CPDS[36] the Auxiliary Control Room and Emergency Control Centre are designed so that the results of analysis and evaluation of human factors are reflected therein. (See Article 12 for detail).

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

[36] Critical Parameter Display System

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 plant construction, installation and commissioning 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. In case of K-1, vendor support was not available until 1989, when K-1 joined COG and WANO. Technical help on safety matters is now available from Canada in certain safety related areas. For C-1 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

PNRA issues licences to nuclear installations according to Regulation PAK/909. The licensing process has three stages, namely, site registration, issuance of construction license and operating licence. PAK/909 enlists the documents to be submitted for each licensing stage. As required by the regulations, a nuclear installation can be operated only 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 National Regulations PAK/913 establishes 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.

19.2 Initial Authorization to Operate

Permission to operate a nuclear installation is granted by PNRA in steps. After construction and equipment installation, commissioning program is reviewed and approved on the basis that it encompasses a systematic and integrated testing of systems and components in line with the design and safety requirements. This allows the licensee to start cold commissioning. During this phase, Final Safety Analysis Report (FSAR) is submitted which demonstrates that the plant conforms to the safety requirements and design is according to safety standards. 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. For the case of relicensing, PAK/909 prescribes a procedure for operation beyond design life. The required documentation for the purpose is an updated version of last Periodic Safety Review report, revised FSAR, PSA (Level-1plus) report, decommissioning program, etc. The operating license is normally valid for a period of up to ten years subject to certain conditions.

The relicensing process of K-1 was completed in September 2007. Afterwards, licence was awarded beyond design life to operate at 90 MWe for two years subject to completion of various activities such as:

a. Availability of Emergency Control Centre
b. Sludge lancing of steam generators
c. Submission of PSA Level-1 report and Fire PSA report.
d. Installation of Post Accident Monitoring System
e. Installation of CPDS and SPDS Systems
f. Replacement of Oil Circuit Breakers with SF6 type circuit breakers
g. Fuel Channel Integrity Assessment
h. Development of Emergency Operating Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs)
i. Decommissioning Plan
j. Emergency Preparedness Plan
k. Diversity of Emergency Core Cooling System

After successful completion of some of the above activities, PNRA further extended the operating license (beyond design life) up to December 2010 subject to the demonstration of Emergency Preparedness Plan.

C-1 is being operated satisfactorily and has undergone six refuelling outages. The Operating Licence is valid till 31st December 2010. According to regulatory requirements for renewal of ten yearly operating licence, C-1 has submitted Periodic Safety Review (PSR) report. The PSR safety factors mainly include Plant Design, Actual Condition of Structures Systems and Components (SSCs), Equipment Qualification, Ageing, Deterministic Safety Analysis, Probabilistic Safety Analysis, Hazard Analysis, Safety Performance, use of experience from other plants and research findings, Organization and Administration, Procedures, Human Factor Impact, Emergency Planning and Radiological Impact on the Environment. The licensee submittals are under review and operating license will be renewed upon satisfactory approval of PSR safety factors.

C-2 has completed construction and installation phases and commissioning is in progress. As part of requirements for issuance of fuel load permit, Final Safety Analysis Report (FSAR) has been submitted for review and approval. The other submittals of the licensee, as required by the regulations include, PSA Level-1 plus report, technical specifications, radiation protection program, emergency preparedness plan, environmental monitoring program, radioactive waste management program, Pre-Service and In-Service Inspection programs, and physical protection program. According to the schedule, the initial fuel loading is expected by the end of November 2010.

19.3 Operational Limits and Conditions

The operating limits and conditions are developed to ensure that plant is operated in accordance with design assumptions and intent. C-1 has developed technical specifications and K-1 has developed operating policies and procedures (OPPs) 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 operational limits and conditions contain requirements for different operational states including shutdown. These are readily accessible for control room personnel. PNRA, through its inspection program, continuously verifies that the installations are operated within the operational limits and the conditions specified in the technical specifications.

The OPP of K-1 are according to Canadian practices. These are revised as and when required, if the safety analysis and national regulations are amended or design modifications are carried out. Due to safety improvements and upgrades carried out during RLO-1 and RLO-II, changes were made in the OPP related to newly installed systems. In addition, Allowable Outage Times (AOT) related to addition of new systems, were revised using reliability analyses to evaluate test intervals. In particular the Diesel Generator endurance test frequency was modified as a result of reliability analysis. Changes proposed by K-1 in the OPP were agreed to by the PNRA and Revision 5 of OPPs was issued in 2009 after approval of PNRA.

Technical specifications of C-1 are in accordance with USNRC practice and classified as, safety limits; limits on safety system settings; limits and conditions for normal operation and transient operational states and surveillance requirements in the format of Standard Technical Specifications for Westinghouse NPPs (NUREG-0452). In the event that the operation of the plant deviates from one or more of the established operational limits and conditions, the appropriate remedial actions are also defined on the timeline. The licensee is required to undertake review and evaluation of safety limit violations and notify the Authority in accordance with the established event reporting system. These operating limits and conditions are revised as and when required, if the safety analysis and national regulations are amended or design modifications are carried out.

C-2 operational limits and conditions are developed on the format of Improved Standard Technical Specifications for Westinghouse NPPs (NUREG-1431) and are based on actual plant design, safety analysis as well as operational experience of C-1. The operating limits are being verified during the commissioning. These operating limits and conditions are also being reviewed as part of Final Safety Analysis Report. Fuel Load Permit (FLP) will be granted subject to the approval of operating limits and conditions.

19.4 Operating Plant Procedures

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

K-1 prepared several new procedures for operating, maintaining and testing of newly installed or modified systems such as:

a. Emergency Injection Water (IJW) System
b. Forced Emergency Injection Water (FIJW) System
c. Automatic Boiler Crash Cool Down (ABCC) System
d. Emergency Sump Transfer (EST) System
e. Third Diesel Generator System
f. Replacement of C&I loops
g. Emergency Feed Water (EFW) System

The revision and updating of operating plant procedures is a continuous process at K-1 and C-1, and any revisions of these documents is made known to the operating personals and other holders of these documents. The Operating Plant Procedures are in fact Control Room Operating Procedures which are used by the MCR personnel to deal with normal operation, malfunctions and emergency conditions. The major category of the plant operation procedures is System Operating Procedures (SOPs) which are used for operation of plant systems, including those procedures which are important for safety and reliability. These include instructions for energizing, filling, venting, draining, start-up, shutdown, and changing modes of operation of system/equipment. Next category is General Operating Procedures (GOPs) which are used for plant start-up from cold shutdown to full power, and from full power to shutdown to cold shutdown. Next important category is Abnormal Operating Procedures (AOPs) which are used for handling the abnormalities and transients. These procedures include explanation of the alarm annunciation, source detector element code, immediate automatic actions, immediate operator actions, and subsequent operator actions.

At C-1, Emergency Operating Procedures (EOPs) are available to be used to mitigate the consequences of failures and limit the core damage and the dose to plant personnel and the public. Initially plant received Event Based EOPs from the vendor to deal with a number of Design Basis Accidents (DBAs). According to the licensing requirement and present international practice, C-1 has developed a complete set of Symptom Based EOPs to deal with DBAs and BDBAs.

The licensees have well established mechanisms for periodic review and control of these procedures, whereas, procedure changes relevant to safety are reviewed by qualified individuals or group other than the individual/group who prepared the procedure or the procedure change.

19.4.1 Procedures for Operation

Procedures are developed for normal operation of the plant to ensure that the plant is operated within the operational limits and 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 usability of procedures with installed equipment and control system is verified during commissioning. Plant personnel engaged in operation are adequately trained and re-trained in the use of these procedures.

C2 has developed operating procedures which are being verified for technical accuracy. These are being validated during commissioning phase for being within the limits of technical specifications. Operating experience of C-1 has been taken into account for developing these procedures. C2 operating personnel are participating in commissioning activities to get them familiarized and trained in operating procedures. The operating personnel will practice these procedures on Full Scope Training Simulator (FSTS) before actual plant operation. Training and retraining of operating personnel on FSTS is also an essential element of training program.

19.4.2 Procedures for Maintenance and Inspections

According to regulatory requirements, maintenance, testing, surveillance and inspection programs should be in place before the commencement of operation and should be updated, as needed. Surveillance and testing of systems and components important to safety is a part of plant technical specifications and all the maintenance, inspections, surveillance and testing is performed according to approved plant procedures. These procedures are prepared by taking into consideration the design data, equipment specifications, quality assurance principles and ALARA principle. These are subject to revision within the time period specified in each document. These procedures are prepared, reviewed, validated, issued and modified in accordance with established administrative procedures.

19.4.3 Procedures for Modification Management

Approved procedures are in place to manage and control modifications in the plants. Both permanent and temporary modifications are controlled through implementation of these procedures. The licensee management has established a procedure for updating documents as soon as possible after modification, installation and testing. Responsibilities for the revision of all documents such as drawings, procedures, safety analysis report, operational limits and conditions, system description, training material including simulator, vendor equipment manuals and spare parts lists are clearly assigned.

19.4.4 Emergency Operating Procedures

PAK/913 requires developing either Event Based or Symptom Based operating procedures for abnormal conditions and design basis accidents. Emergency operating procedures and guidance for managing severe accidents are also required.

At C-1, Event Based Emergency Operating Procedures were provided by the vendor. C-1 has developed Symptom Based Emergency Operating Procedures also. The scope of the SEOPs is to provide procedural guidance for operators to deal with accident conditions up to the point of core damage. Thus the SEOPs generally provide actions for a wide spectrum of operating conditions, ranging from abnormal operation up to accidents exceeding the design basis of the nuclear power plant.

At K-1, Emergency Operating Procedures (EOPs) have been developed. First Draft of Severe Accident Management Guidelines (SAMGs) has also been prepared.

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 OPPs. PAK/913 requires 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 in 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 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 support of vendor and designer is available for C-1 and C-2 under lifetime support agreement. In addition, support from vendor country organizations for maintenance, in-service inspection, refuelling operations, etc., are also available. CNPO has signed an agreement with C-1 to provide technical support regarding development of an effective ageing management program and training of plant personnel.

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 and WANO. Technical help on safety matters is currently available from Canada in certain areas such as fuel channel integrity assessment and updating the KFSAR.

A contract has been signed with AECL, Canada for sludge lancing of steam generators and purchase of fuel channel inspection equipment under an IAEA technical cooperation project on “Long Term Safe Operation of KANNUP”. Blister Susceptibility Assessment was carried out by M/s Kinectric, Canada through COG.

For indigenous development of review and assessment of licensees’ submittals, PNRA has established its own technical support organization with technical competencies in areas of review and assessment, probabilistic safety analysis (PSA), accident analysis, system and structural analysis, materials and plant systems and quality assurance. PNRA has also signed Memorandum of Understanding (MOUs), training agreements with various National and international level technical organizations such as PSQCA, NSC, NNSA, VUJE (Slovakia) , KINS[37] (Republic of Korea), CHASCENT, etc. for technical support and personnel training. In addition, a project namely Safety Analysis Centre (SAC), has been approved by the Government with the objective to develop expertise in mathematical modelling and simulation. This will add to the existing safety analysis capability of the TSO.

19.7 Program to Collect and Analyze Operating Experience

C-1 has a system of national and international operating experience feedback through analysis of events at national level and events reported through the IAEA, WANO, QNPC, SNERDI, CNPO, etc. on various safety related issues as well as best practices. In addition, C-1 has access to the IAEA Incident Reporting System (IRS) and INES. Engineering Department of C-1 is responsible for collecting and analyzing the operating experience from within the installation and from other installations (including non-nuclear installations) operating in the country. It also utilizes international experience feedback to identify necessary actions. 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. QNPP Phase-I is reference plant for C-1, thus operating experience of QNPP-1 is quite relevant to C-1. For example, to protect fuel assemblies against hazards induced due to metallic parts and debris, QNPP is using fuel assemblies with anti-debris filters installed at bottom nozzle since cycle 8. As the manufacturer and designer for fuel assemblies of C-1 and QNPC are the same, C-1 also decided to implement this design modification. The

[37] Korea Institute of Nuclear Safety (KINS)

designer had also recommended using fuel assemblies with anti debris filters. Similarly improvement in reactor internals design was carried out at C-1 in the light of QNPP-1 experience.

K-1 interacts on-line with COG, WANO and IAEA networks to exchange Operating Experience (OPEX) Feedback information. Methods of using operating experience are structured to provide applicable information to concerned plant Divisions / Sections. Information received from these networks is screened for relevancy and applicability at K-1 by OEF Section and disseminated to relevant Divisions/Sections for review and follow-up actions. If the information is found applicable, it is incorporated through changes in procedures, systems or equipment, etc., in order to prevent recurrence of 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 NPPs.

The operating experience of management issues, unexpected degradation, design weaknesses, external hazards not considered earlier, etc., is shared through peer reviews conducted within and outside Pakistan under auspices of IAEA, WANO, COG, etc.

PNRA verifies the licensee’s programs to collect and analyze operating experience through reviews of safety analysis reports and inspections. During annual inspection of nuclear power plant, PNRA verifies whether the operating organization analyzes the operating experience and takes necessary actions. In addition PNRA has access to the IAEA International Reporting System (IRS) on operating experience feedback and International Nuclear Event Scale (INES). PNRA collects and analyzes the international operating experience feedback to identify necessary actions. PNRA requires the licensee to benefit from relevant international operating experiences at other nuclear installation to enhance safety and reliability.

19.8 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 2008 related to finding foreign material in a fuel coolant channel of K-1, which was rated at INES Level-1. Similarly, when a safety significant event of interest to others in the nuclear industry, occurs in a nuclear installation it is reported to the Incident Reporting System (IRS) also. Five events have been reported to IRS since 2008. All of these events were below INES Level-0.

19.9 Safety Performance Evaluation

K-1 has developed Performance Indicators to monitor operational safety. K-1 is also contributing to WANO Performance Indicator Program.

C-1 has developed safety performance indicators (SPIs) to monitor operational safety of the plant. 75 out of 80 SPIs have been implemented at C-1 and remaining indicators are expected to be implemented by the end of 2010. Some of the SPIs include scrams, unplanned power changes, safety system unavailability (emergency power AC system), safety system unavailability (high pressure injection system), safety system unavailability (heat removal system), safety system unavailability (residual heat removal system), reactor coolant activity, emergency response organization drills, exercise performance, emergency response organization (ERO) participation, alert and notification system reliability, etc.

Safety performance indicators trends are reported in Technical Reports of the plant. Peer reviews are conducted under auspices of IAEA and WANO.

19.10 Radioactive Waste Management

According to Regulations 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 decommissioning of its facilities. To fulfil this requirement, the licensee is required to:

a. Avoid the use of unnecessary hazardous / toxic materials.
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. Requirements are also defined 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.

At C-1, the gaseous and liquid radioactive waste management systems are designed with reliability and diversity. The concept of ALARA is employed in collecting and treating radioactive waste generated during normal operation and anticipated operational occurrences. Radioactive gaseous and liquid effluents are discharged to the environment in conformity with the control limits prescribed in the Regulations. The monitoring systems continuously operate to detect the radioactivity of effluents. Solid waste treatment system is designed for collection, storage, decay and treatment of radioactive concentrate and spent resin produced during the plant normal operation and maintenance. Borated concentrate, low level concentrate, chemical drain and mud produced in Nuclear Auxiliary Building can be mixed with cement in a metal drum in order to convert “wet waste” to solid piece so as to minimize the radioactivity leakage during storage, transfer and disposal. Spent resin from different systems is collected into different holdup tanks for receiving, storing and decaying according to their radioactivity levels. The tanks have sufficient capacity to accept 10 years generation of resin waste.

The draft national policy on control and safe management of radioactive waste is in the process of finalization. The policy covers control and management of all radioactive waste generated in the country irrespective of its origin, except for operational radioactive liquid and gaseous effluents (waste discharges), which are permitted to be released to the environment routinely under the authority of PNRA. The radioactive waste management policy serves as national commitment to address country’s radioactive waste control and management issues in a well coordinated manner.

19.11 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 capacity limit. Due to good chemistry in spent fuel storage bay and low oxidation rates, no ageing is visible on the structural material used in stacking the fuel bundles and the spent fuel under water appears to be in good physical condition. It has been planned to extend operational life of K-1 up to 2019. The present spent fuel storage bay is inadequate to accommodate the spent fuel that would be generated during the extended life of the plant. To handle the storage problems, K-1 has planned to construct spent fuel dry storage facility within the plant premises. It has also planned to enhance the storage capacity of existing spent fuel storage bay by increasing the fuel trays from 18 to 24 in a seismically qualified High Density Tray Racking (HDTR) System. So far two HDTRs have been placed in the storage bay and spent fuel trays have been loaded into these racks. Manufacturing of further racks is in progress.

At C-1, spent fuel storage facility can meet storage requirements for 15 years. An additional facility will be constructed at an appropriate time. At C-2, spent fuel storage facility will be able to meet storage requirements for 15 years and additional facility will be constructed after 8 years of plant operation.

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

Annexure–I: Existing Nuclear Installations

	K-1[38]	C-1[39]	C-2[40]
Status	Operating	Operating	Under Commissioning
Location	Karachi, Sindh	Chashma, Punjab	Chashma, Punjab
Type	CANDU	PWR	PWR
Capacity (gross)	137 MWe	325 MWe	340 MWe
First fuel loading	July 1971	November 22, 1999	November 29, 2010 (expected)[41]
First criticality	August 1971	May 03, 2000	April 2011 (expected)
Date of operation	December 1972	September 25, 2000	2011 (expected)

[38] Karachi Nuclear Power Plant Unit 1
[39] Chashma Nuclear Power Plant Unit 1
[40] Chashma Nuclear Power Project Unit 2
[41] Date of first concrete pour – 28 December 2005

Annexure–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 Diameter Design pressure	4 feet and 5 inch thick concrete walled circular building capped with concrete dome of 19 inch thickness 115 feet 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 channel	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 Material Length	 Horizontal vessel with integrated dump space Type 304L-ASTM A 240 Austenitic Stainless Steel 16′ 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 Flow Pump type	08 4670 igpm Centrifugal, vertical
Turbine type	Tandem compound
Heat sink	Sea water from Arabian Sea
Forced Injection Water (FIJW) system Pumps Pump flow Pump discharge head pump type	 02 360 igpm 900 feet Centrifugal

Annexure–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

Annexure–IV: C-2 Design Parameters

Gross electrical output	340 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

Annexure–V: Summary of Activities Performed during RFOs at C-1 after 4th Review Meeting

Activities	RFO-5	RFO-6
Total jobs planned	3303	3264
Total jobs completed	3250	3201
Maintenance jobs	2914	2818
ISI jobs	132	133
Modifications	24	13
Surveillance tests	180	180
Deferred jobs	36	63
Additional jobs completed which were identified during outage	4550	2444
Planned radiation collective doses & Max individual	<645 man mSv ≤10 man mSv	≤ 500 man mSv ≤10 man mSv
Received radiation collective doses & Max individual	665.9 man mSv 8.2 man mSv	558.261 man mSv 7.339 man mSv
Outage duration (planned/actual)	168/173.2 days	63.67/64.31days
Major problems faced	1. During lifting of Upper Internals it was noticed that two Rod Cluster Control Assemblies (RCCAs) were also being lifted along with Upper Internals. Problem was revealed by underwater camera; lifting stopped immediately. Emergency procedure prepared and RCCAs unlatched and restored to Fuel Assemblies successfully. 2. During Visual Inspection foreign materials found in 15 spent fuel assemblies; all the foreign materials retrieved from these fuel assemblies.	1. Decontamination of Reactor Coolant Pump B (RCP-B) internals. 2. Steam Generators cover studs removal. 3. Crane problems (polar crane, fuel manipulator crane and gantry crane) 4. Up-ending device problems during fuel loading.

Annexure–VI: Summary of Activities related to Ageing Management at K-1

1. Activities in Mechanical Area

- Plant Main Chillers
- Service Air Compressors
- Condenser Tubes Replacement (partial).
- Replacement and Refurbishment of nuclear and conventional systems valves & pumps
- Tube bundles of CPH-HX2 / SH-HX1
- Sampling chambers tubing of Delayed Neutron System for failed fuel detection.
- Containment dampers
- AD-PM8, PM9, MH-PM1, PM3 and PM5
- CH-P1
- HDCP pumps
- Tubes of SA-CP2 and CP3 after cooler
- Radiator core of DE-DG2
- Vibration detector/software has been purchased from DNPER for vibration analysis of rotating machines.
- Radiator of Transformers (GE-T1, DE-T2)

2. Activities in Control & Electrical Area

- Plant Radiation Monitoring Equipment
- Plant Regulating Computers
- Alarms Annunciation, Logging, Special Computations
- Replacement of Measurement and Control loops.
- Replacement of CR120 Relays
- Replacement of few Safety Loops relating to Reactor Protection & Engineered Safeguards
- Up-gradation of T/G Machine Monitoring System
- Plant Communication System Improvements
- Positioner and transmitter of BFW-CV51 to BFW-CV56
- Transmitter of PH4F
- Fuel channel RTDs
- Extension of 132 KV Switchyard
- Replacement of Neutron Power measuring instruments (partial)
- 4160V Magna blast circuit breakers
- Replacement of OCBs (GE-B1/B2/B3) with SF6 breakers
- Replacement of Transmission lines protective relays
- AK-2-25 type circuit breakers
- Replacement of EC units of LV AK type circuit breakers MVT conversion kits
- Replacement of Agastat relays

- Inspection tools for feeders has been received from M/s Kinectrics and used for inspection of 02 feeders
- Replacement of safety related solenoid valves (SOVs)

3 Activities in Civil Area

- Physical inspection of the plant buildings.
- The inspection of the tendon gallery of the containment building to assess the overall condition of the concrete tunnel and the grouting materials.
- Strength assessment of containment building through finite element and leak rate test at 11 psig.
- Replacement of eroded elastomeric lining along the steam line due to elevated temperature.
- Repair of deteriorated operating floor soffit of pump house.
- Severely damaged concrete floor over the boulder of the water intake channel was rebuilt.

Annexure–VII: C-1 Periodic Safety Review – List of Safety Factors

PLANT

Plant design

Actual condition of SSCs

Equipment qualification,

Ageing

SAFETY ANALYSIS

Deterministic safety analysis,

Probabilistic safety analysis,

Hazard analysis.

PERFORMANCE AND FEEDBACK

Safety performance

Use of experience from other plants and research findings

MANAGEMENT

Organization and administration,

Procedures

Human Factors

Emergency planning

ENVIRONMENT

Radiological impact on the environment

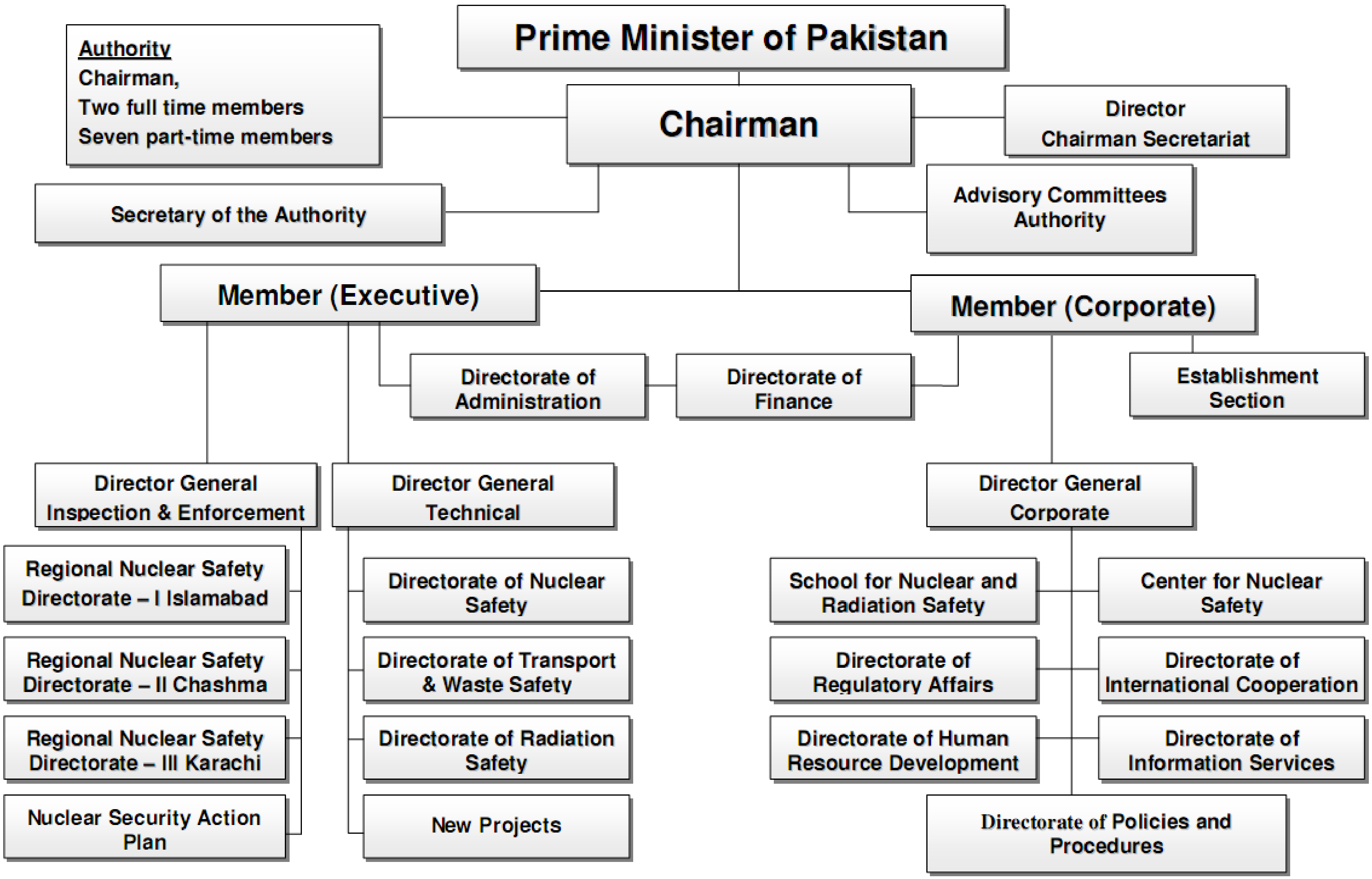
Annexure–VIII: Highlights of C-2 FSAR Review

Total Duration of the Review :	07-12-2009 to 29-11-2010
Total Number of Review Phases :	Four
➢ Review Phase 1 :	07-12-2009 to 30-12-2010
➢ Review Phase 2 :	11-01-2010 to 20-03-2010
➢ Review Phase 3 :	31-03-2010 to 30-04-2010
➢ Review Phase 4 :	28-06-2010 to 27-08-2010
First Review Meeting :	07-06-2010 to 17-06-2010
➢ Total Number of Issues discussed	893
➢ Total Number of Issues Resolved	811
➢ Total Number of Issues Pending	82
Final Review Meeting :	04-10-2010 to 09-10-2010
Submission of Safety Evaluation Report :	November 12, 2010
Issuance of Fuel Load Permit :	November 29, 2010

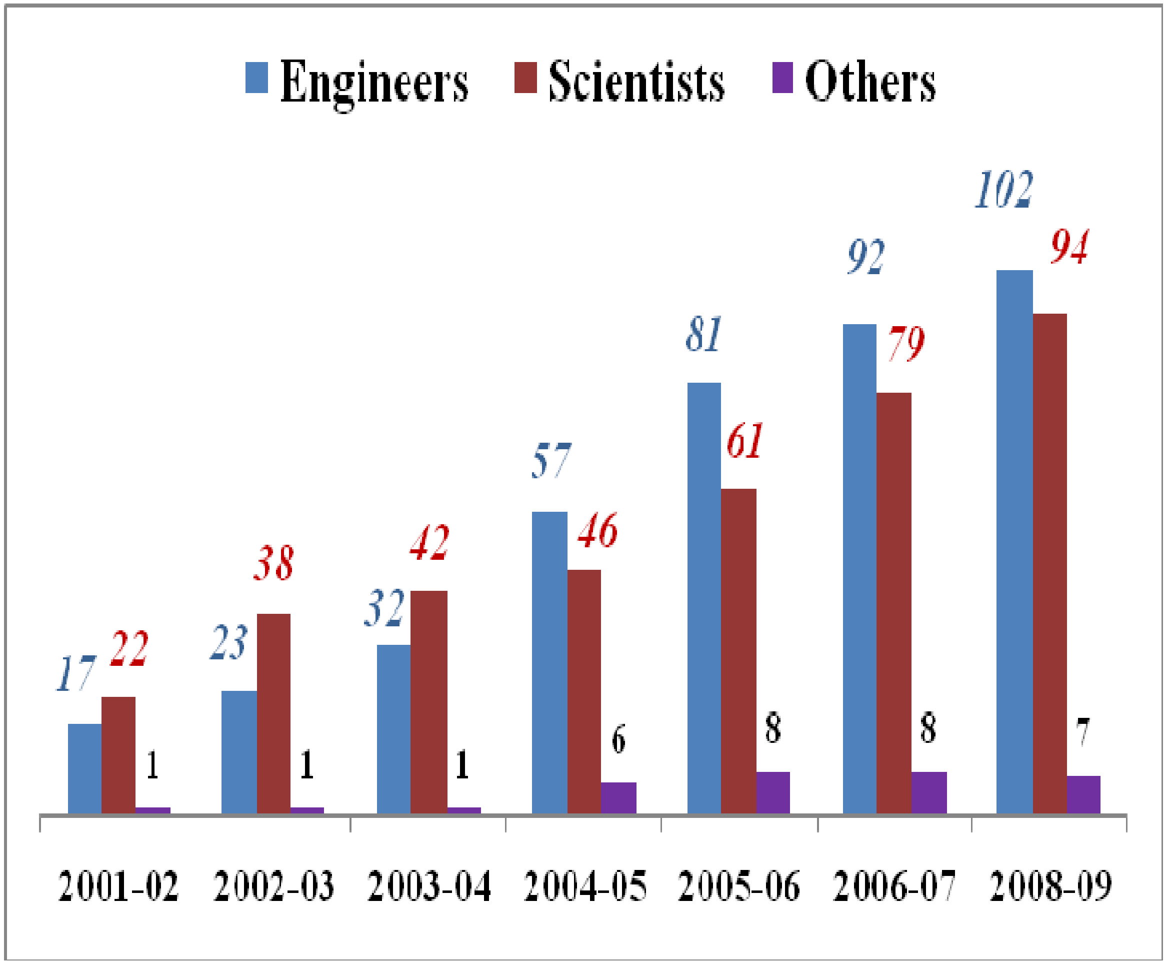
Annexure–IX: National Regulations (Gazette notified)

No.	Regulation No.	Title	Date of Issue
1.		Pakistan Nuclear Regulatory Authority Ordinance	22 Jan 2001
2.	PAK/900	Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority	03 Nov 2008
3.	PAK/904	Regulations on Radiation Protection	05 Oct 2004
4.	PAK/907	Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers	01 Sep 2008
5.	PAK/908	Regulations for the Licensing of Radiation Facilities other than Nuclear Installations	05 Oct 2004
6.	PAK/909	Regulation for Licensing of Nuclear Installations in Pakistan	21 Sep 2001
7.	PAK/910	Regulations on the Safety of Nuclear Installations – Site Evaluation	01 Sep 2008
8.	PAK/911	Regulation on the Safety of Nuclear Power Plant – Design	11 Jan 2002
9.	PAK/912	Regulations on the Safety of Nuclear Power Plant – Quality Assurance	10 Sep 2003
10.	PAK/913	Regulations on the Safety of Nuclear Power Plants – Operation	22 Dec 2004
11.	PAK/914	Regulations on Management of a Nuclear or Radiological Emergency	01 Sep 2008
12.	PAK/915	Regulations on Radioactive Waste Management	02 Aug 2005
13.	PAK/916	Regulations for the Safe Transport of Radioactive Material	20 April 2007

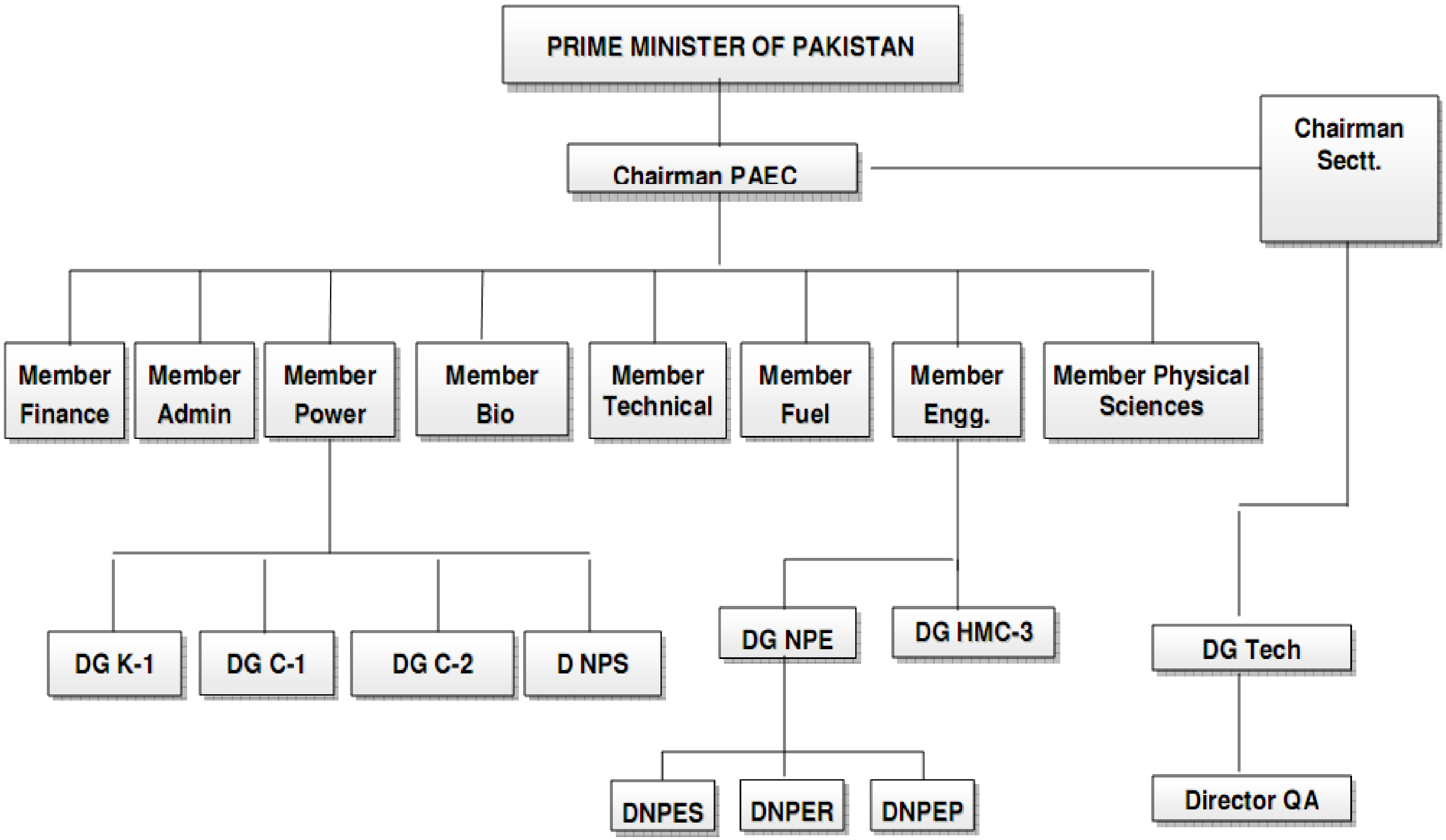
Annexure–X: Organization Chart of Pakistan Nuclear Regulatory Authority



Annexure–XI: Year Wise Manpower Strength at PNRA, 2001- 09



Annexure–XII: Abridged Organization Chart of Pakistan Atomic Energy Commission (as Applicable to Nuclear Installations)



Annexure–XIII: PNRA Performance Indicators

Indicator 1. Acceptable level of safety being maintained by licensees

Indicator 2. Regulations and procedures in position and understood by licensees

Indicator 3. Continuous improvement of performance

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

Indicator 5. Human resource development, and competent and certified regulatory staff

Indicator 6. Legal provisions for enforcement, i.e., dealing with non-compliance or licence conditions violations

Indicator 7. Performance of functions in a timely and cost-effective manner

Indicator 8. Well established Quality Management System

Indicator 9. Availability of adequate resources for performing the functions

Indicator 10. Confidence of the operating organization

Indicator 11. Confidence of the general public

Indicator 12. Confidence of the Government.

<u>Grading Scale for Performance Indicators</u>

Green	Satisfactory
White	Minimally acceptable
Yellow	Needs improvement
Red	Unsatisfactory

Annexure–XIV: Dose Limits for Exposures Incurred From Practices

ANNUAL DOSE LIMITS FOR RADIATION WORKERS

Organ or Tissue	Dose Quantity	Dose Limit (mSv)
Whole body	Effective dose	20*
Lens of the eye	Equivalent dose	150
Extremities (hands and feet) or Skin (average dose over 1 cm^2 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)

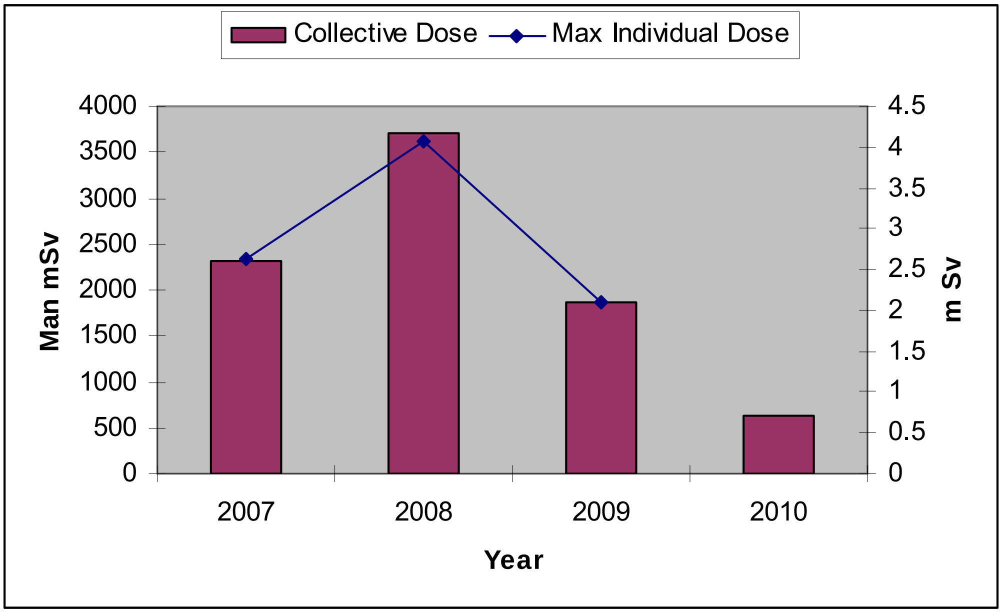
Organ or Tissue	Dose Quantity	Dose Limit (mSv)
Whole body	Effective dose	6
Lens of the eye	Equivalent dose	50
Extremities (hands and feet) or skin (average dose over 1 cm^2 of the most highly irradiated area).	Equivalent dose	150

ANNUAL DOSE LIMITS FOR PUBLIC

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

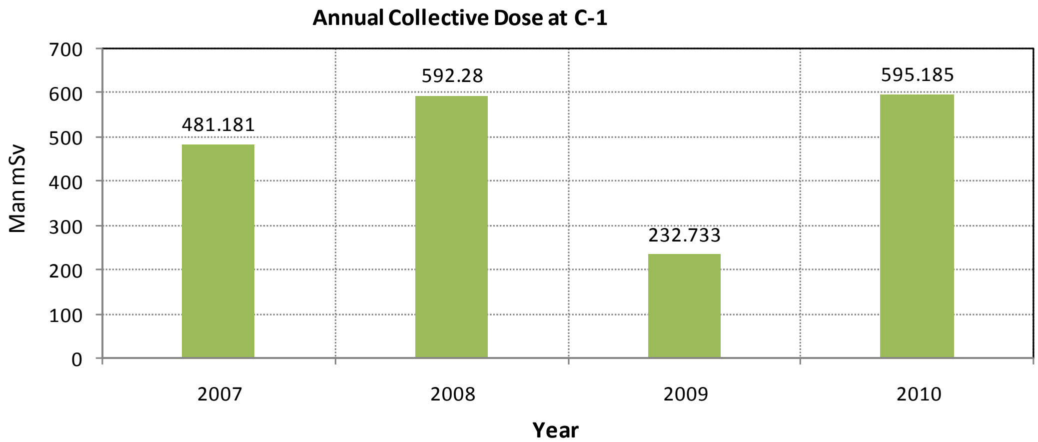
* In special circumstances, an effective dose of up to 5mSv in a single year provided that the average dose over five consecutive years does not exceed 1mSv/year.

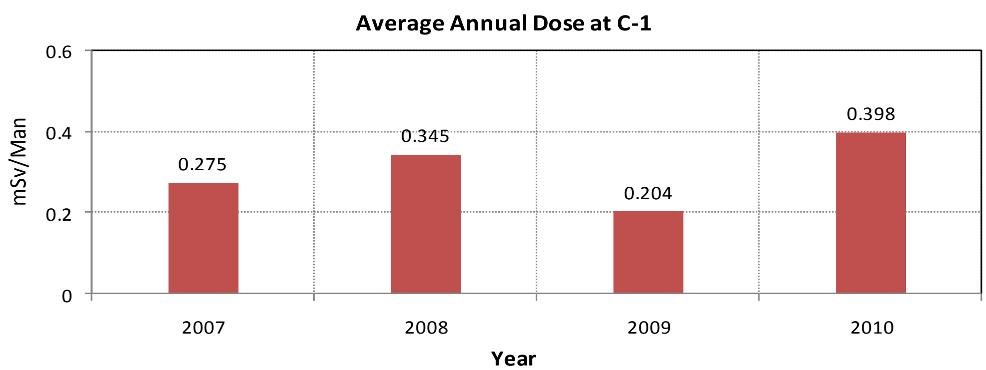
Annexure-XV: Occupational Exposures at K-1, 2007-10



Note: Data is up to May 2010

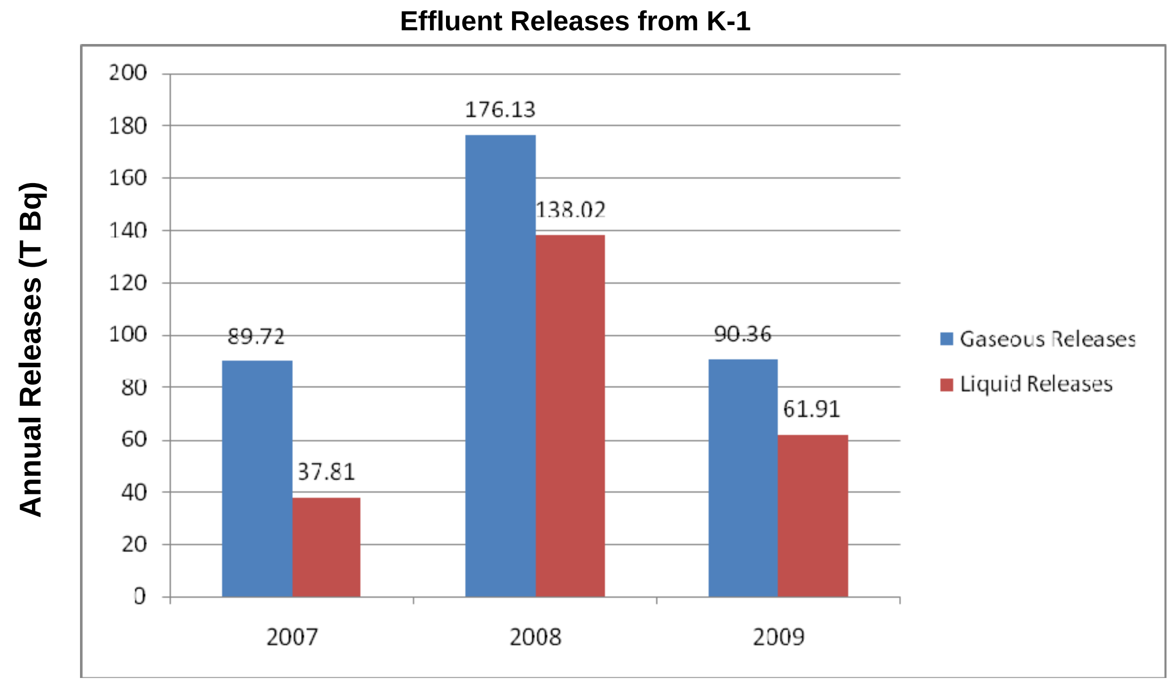
Annexure–XVI: Occupational Exposures at C–1, 2007-10

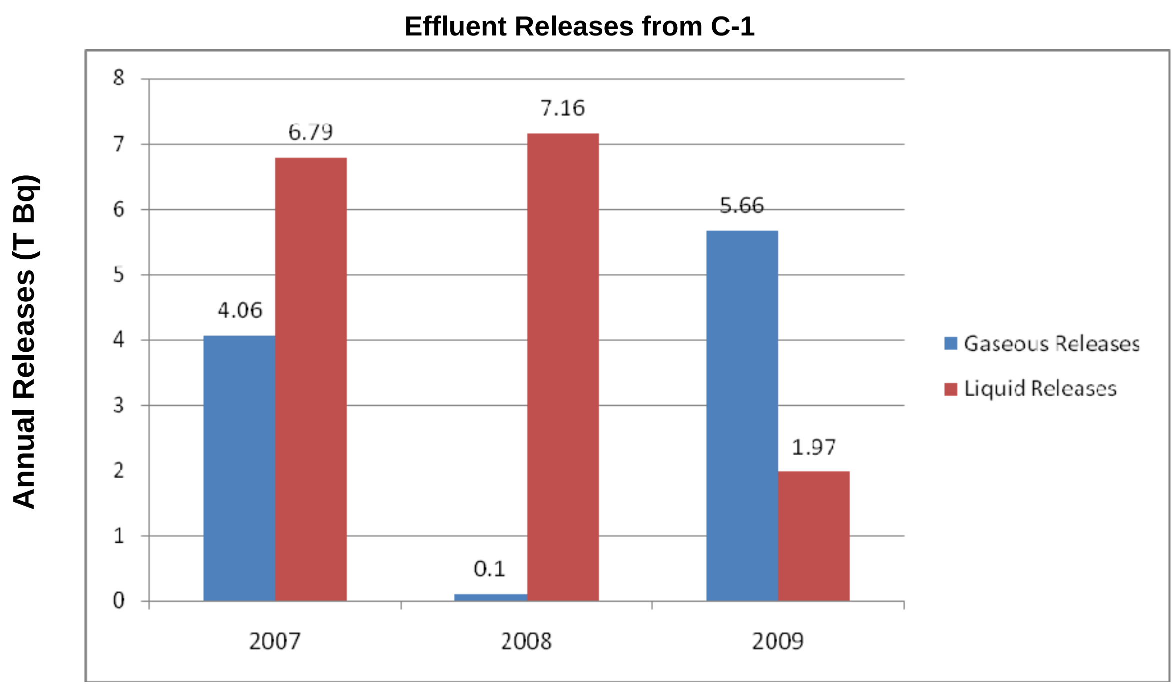




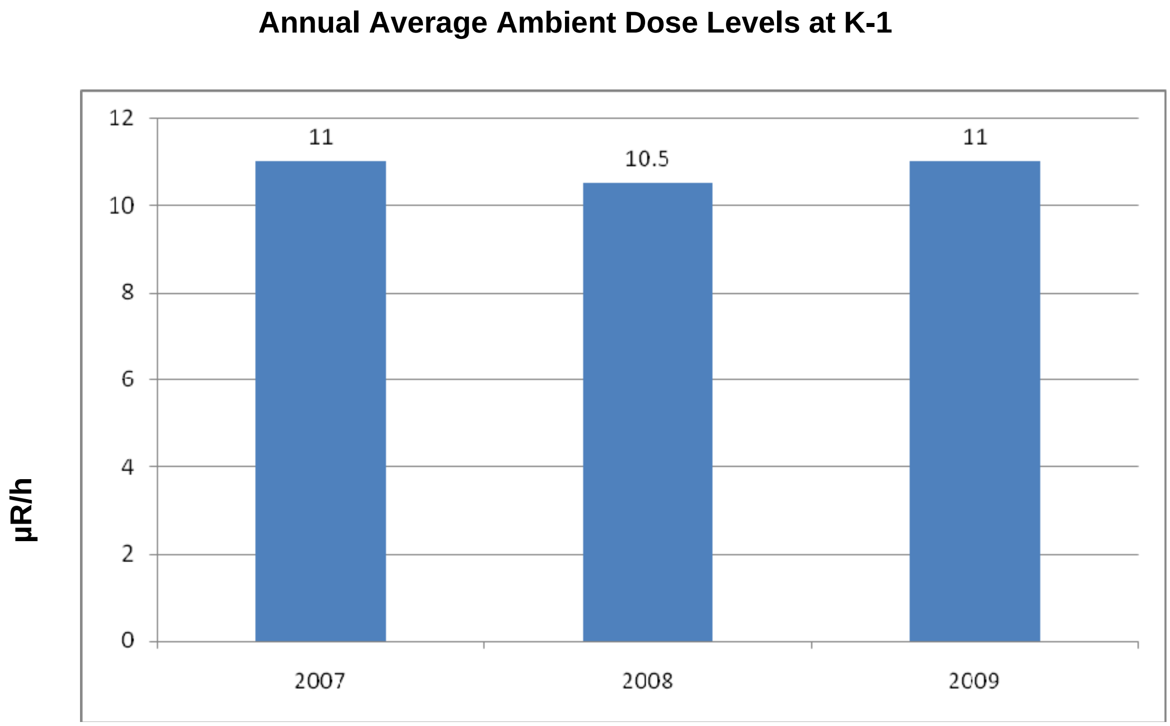
Note: Data is up to May 2010

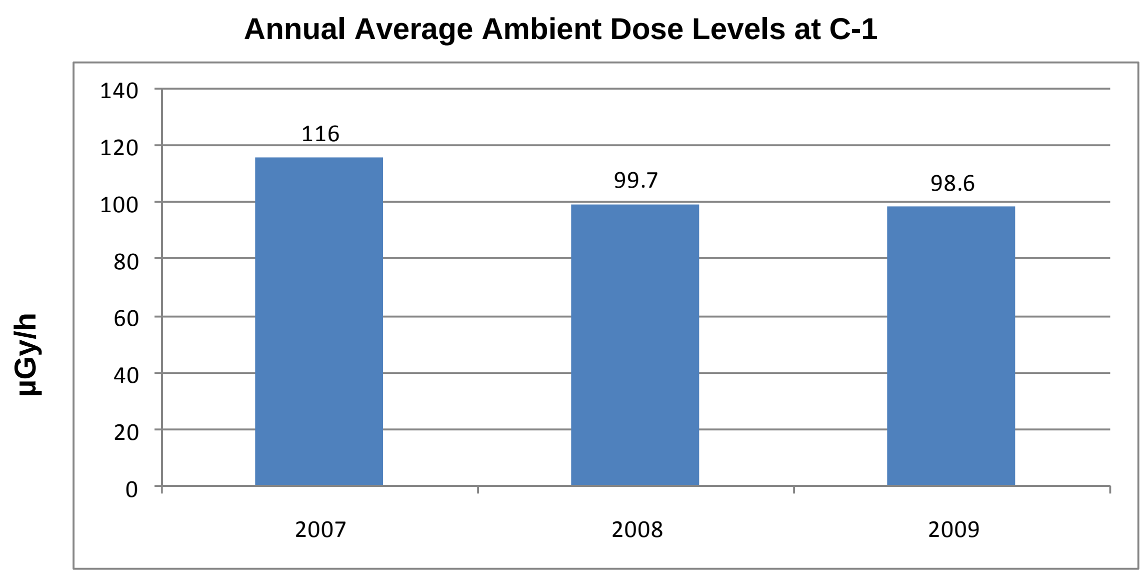
Annexure–XVII: Effluent Releases from K-1 and C-1, 2007-09





Annexure–XVIII: Annual Average Ambient Dose Levels Around Nuclear Installations, 2007-09





Annexure–XIX: Frequency of Various Types of Drills/Exercises at K-1 and C-1

No.	Type of Drill/Exercise at K-1	Frequency
1	Radiological Emergency Exercise	Annually
2	Radiological Survey Drill	Quarterly
3	Air sampling drill (of the Assembly Areas)	8 weekly
4	Class A Fire drill Class B Fire drill Class E Fire drill	Monthly Annually Annually
No.	**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 every two years (Alternate with FSIE)
7	Full Scale Integrated Exercise (FSIE)	Once every two years (Alternate with PE)
8	Personnel contamination control drill	Twice a year
9	Environmental dose assessment drill	Twice a year
10	Emergency class assessment drill	Annually
11	Post accident sampling analyses drill	Annually

Annexure–XX: 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.	November 2007	Annual Radiological Emergency Exercise
2.	December 2008	Annual Radiological Emergency Exercise
3.	December 2009	Annual Radiological Emergency Exercise
4.	June 2010	Annual Radiological Emergency Exercise

2. Emergency Exercises Performed at C-1

Sr. No.	Date of Exercise	Type of Exercise
1.	Dec 2007	Partial Emergency Exercise
2.	Dec 2008	Integrated Emergency Exercise
3.	May 2009	Unannounced Emergency Exercise
4.	December 2009	Partial Emergency Exercise

3. IAEA ConvEx Exercises

Sr. No.	Date of Exercise	Type of Exercise
1.	March 2008	ConvEx 1a
2.	May 2008	ConvEx 2b
3.	July 2008	ConvEx 3
4.	October 2008	ConvEx 2a
5.	May 2009	ConvEx 2b
6.	July 2009	ConvEx 1a
7.	August 2009	ConvEx 2d
8.	October 2009	ConvEx 2a

Annexure–XXI: List of Abbreviations

5NR	Fifth National Report
ABCC	Automatic Boiler Crash Cool Down
ACA	Apparent Cause Analysis
ACIURI	Advisory Committee for Improving Utility - Regulatory Interface
AGS	Annulus Gas System
ALARA	As Low As Reasonably Achievable
AMP	Ageing Management Program
AOP	Abnormal Operating Procedures
AOT	Allowable Outage Time
ARP	Alarm Response Procedure
ASME	American Society of Mechanical Engineers
ATWS	Anticipated Transient without SCRAM
BDBA	Beyond Design Basis Accidents
C & I	Control and Instrumentation
C-1	Chashma Nuclear Power Plant Unit 1
C-2	Chashma Nuclear Power Plant Unit 2
CAA	Civil Aviation Authority
CANDU	Canada Deuterium Uranium
CAP	Corrective Action Program
CDF	Core Damage Frequency
CERO	CHASNUPP Emergency Response Organization
CHASCENT	Chashma Centre for Nuclear Training
CHASNUPP	Chashma Nuclear Power Plant
CNPGS	Chashma Nuclear Power Generating Station
CNPO	China Nuclear Power Operation Technology Corporation
CNS	Convention on Nuclear Safety
COG	CANDU Operators Group
COMTEX	Communication Test Exercises
ConvEx	Convention Exercise
CPDS	Critical Parameter Display System
CPI	Chemistry Performance Indicator
CSS	Committee on Safety Standards
DBA	Design Basis Accidents
D G	Director-General
DNPS	Directorate of Nuclear Power Safety
DQA	Directorate of Quality Assurance
DNPER	Directorate of Nuclear Power Engineering, Reactor
ECC	Emergency Control Center
EDG	Emergency Diesel Generator
EFW	Emergency Feed Water
EIA	Environmental Impact Assessment
ENAC	Emergency Notification and Assistance Convention
EOPs	Emergency Operating Procedures
EPA	Environmental Protection Agency
ERO	Emergency Response Organization
EST	Emergency Sump Transfer
FIJW	Force Emergency Injection water
FLP	Fuel Load Permit
FRI	Fuel Reliability Indicator
FSA	Focused Self Assessment
FSAR	Final Safety Analysis Report
FSTS	Full Scope Training Simulator
GIK	Ghulam Ishaq Khan Institute of Engineering

HE	Human Error
HELB	High Energy Line Break
HEP	Human Error Probabilities
HFE	Human Factor Engineering
HRA	Human Reliability Analysis
HRD	Directorate of Human Resource Development
HSI	Human System Interface
IAEA	International Atomic Energy Agency
ICAP	Integrated Corrective Action Plan
ICD	Directorate of International Coordination
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronic Engineers
IJW	Emergency Injection water
IMS	Integrated management system
INES	International Nuclear and Radiological Event Scale
INPO	Institute of Nuclear Power Operations
IPP	Independent Power Producers
IPSART	International PSA Review Team
IPTC	In-Plant Training Center
IRRS	Integrated Regulatory Review Services
IRRSAT	International Regulatory Review Self Assessment Tool
IRS	Incident Reporting System
ISC	Irradiation Surveillance Capsules
ISD	Directorate of Information Services
ISI	In-service inspection
ISO	International Organization for Standardization
K-1	Karachi Nuclear Power Plant Unit 1
KANUPP	Karachi Nuclear Power Plant
KESC	Karachi Electric Supply Corporation
KINPOE	Karachi Institute of Power Engineering
KINS	Korea Institute of Nuclear Safety
KM	Knowledge Management
KOFREP	K-1 off-site radiological emergency plan
KSC	KANUPP Safety Committee
LAN	Local Area Network
LBB	Leak before Break
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
LPMS	Loose Part Monitoring System
LPSW	Loss of Process Salt Water System
LUMS	Lahore University of Management Sciences
MCR	Main Control Room
MOU	Memorandum of Understanding
MRML	Mobile Radiological Monitoring Laboratory
NAC	National Assistance Capabilities
NCA	National Competent Authority
NCA(A)	National Competent Authority (NCA) for an emergency Abroad
NCA(D)	National Competent Authority (NCA) for an emergency Domestic
NCNDT	National Centre for Non-Destructive Testing
NEPRA	National Electric Power Regulatory Authority
NERS	Network of Regulators of countries with Small Nuclear Programs
NGA	Next Generation Attenuation
NNSA	National Nuclear Safety Administration
NOC	No Objection Certificate
NRECC	National Radiation Emergency Coordination Centre

NSC	Nuclear Safety Centre
NSD	Directorate of Nuclear Safety
NSLD	Nuclear Safety and Licensing Division
NTDS	National Transmission and Dispatch Company
NUSCC	Nuclear Safety Standards Committee
NWP	National Warning Point
OEF	Operational Experience Feedback
OGRA	Oil and Gas Regulatory Authority
OPEX	Operational Experience
OPP	Operating Policies and Procedures
OQAP	Overall Quality Assurance Program
OSAG	Operational Safety Analysis Group
OSART	Operational Safety Review Team
OSRC	Operational Safety Review Committee
PAEC	Pakistan Atomic Energy Commission
PARR-I	Pakistan Research Reactor – I
PARR-II	Pakistan Research Reactor – II
PDMA	Provincial Disaster Management Authority
PDT	Post Diploma Training
PEPCO	Pakistan Electric Power Company
PGA	Peak Ground Acceleration
PIEAS	Pakistan Institute of Engineering and Applied Sciences
PIM	Pakistan Institute of Management
PINSTECH	Pakistan Institute of Nuclear Science and Technology
PLC	Programmable Logic Control
PNRA	Pakistan Nuclear Regulatory Authority
PPD	Directorate of Policies and Procedures
PPRA	Public Procurement Regulatory Authority
PSA	Probabilistic Safety Assessment
PSAR	Preliminary Safety Analysis Report
PSDP	Public Sector Development Program
PSF	Performance Shaping Factors
PSI	Pre-Service Inspection
PSQCA	Pakistan Standards and Quality Control Authority
PSR	Periodic Safety Review
PWI	Pakistan Welding Institute
PWR	Pressurized Water Reactor
QA	Quality Assurance
QA&AD	Quality Assurance and Assessment Division
QAD	Quality Assurance Division
QAP	Quality Assurance Program
QAU	Quaid-e-Azam University
QNPC	Qinshan Nuclear Power Company
RAD	Directorate of Regulatory Affairs
RANET	Response Assistant Network
RAS	Regional Asia
RASSC	Radiation Safety Standards Committee
RCA	Root Cause Analysis
RCA	Radiation Controlled Area
RCC-M	French Pressure Vessel Code
RFO	Refueling Outages
RLO	Relicensing Outage
RMWO	Radioactive Waste Management Officer
RNSD	Regional Nuclear Safety Directorate
RSD	Directorate of Radiation Safety

RT	Radiographic Testing
RWP	Radiation Work Permit
S&HPD	Safety & Health Physics Division
SAC	Safety Analysis Centre
SAF	Auxiliary Feed Water System
SAMG	Severe Accident Management Guidelines
SAP	Self Assessment Program
SAR	Safety Analysis Report
SARRP	Safety Analysis Report Review Program
SAT	Self Assessment Tools
SED	Site Emergency Director
SEOP	Symptom based Emergency Operating Procedures
SER	Site Evaluation Report
SG	Steam Generator
SLD	Safety and Licensing Division
SNERDI	Shanghai Nuclear Engineering Research and Design Institute
SNRS	School of Nuclear and Radiation Safety
SOER	Significant Operating Experience Reports
SOP	System Operating Procedures
SPDS	Safety Parameter Display System
SPI	Safety Performance Indicators
SRC	Reactor Coolant System
SS	Shift Supervisor
SSC	Structures Systems and Components
SSW	Standby Salt Water System
TC	Technical Cooperation
TLD	Thermo Luminescent Dosimeter
TNA	Training Need Assessment
TRANSCC	Transport Safety Standards Committee
TSC	Technical Support Centre
TSO	Technical Support Organization
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USNRC	United States Nuclear Regulatory Commission
UT	Ultrasonic Testing
WANO	World Association of Nuclear Operators
WAPDA	Water and Power Development Authority
WASCC	Waste Safety Standards Committee
WSD	Directorate of Transport and Waste Safety