सत्यमेव जयते

Government of India

NATIONAL REPORT

to

THE CONVENTION ON NUCLEAR SAFETY

Fifth Review Meeting of Contracting Parties, April 2011

August 2010

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Foreword

The Government of India ratified the Convention on Nuclear Safety on March 31, 2005. This is the second National Report being submitted by India for review by the Contracting Parties, pursuant to Article 5 of the Convention on Nuclear Safety, which entered into force on 24 October 1996. The Report demonstrates how Government of India has fulfilled its obligations under Articles 6 through 19 of the Convention.

This National Report was prepared in accordance with the "Guidelines Regarding National Reports under the Convention on Nuclear Safety" issued as information circular INFCIRC/572/Rev.3. Accordingly, all land-based nuclear power plants including storage, handling and treatment facilities for radioactive materials attached to the NPP and are directly related to the operation of nuclear power plants are covered in the national report.

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List of Acronyms

ACCGD	Advisory Committee on Code, Guides & Associated Manuals for Safety in Design of NPPs
ACCGASO	Advisory Committee for Codes, Guides & Associated Manuals for Safety in Operation of NPPs
ACCGORN	Advisory Committee for preparation of Code & Guides on Governmental Organization for the Regulation of Nuclear & Radiation facilities
ACCGQA	Advisory Committee for Codes & Guides for Quality Assurance for Nuclear Power Plants Safety
ACIFS	Advisory Committee for Industrial and Fire Safety
ACOH	Advisory Committee on Occupational Health
ACPSR	Advisory Committee for Project Safety Review
ACRDCSE	Advisory Committee for Regulatory Documents on Civil and Structural Engineering
ACNS	Advisory Committee on Nuclear Safety
ACRDS	Advisory Committee for Regulatory Documents on Nuclear Power Plant Siting
ACRS	Advisory Committee on Radiological Safety
ACSDFCF	Advisory Committee on Safety Documents relating to Fuel Cycle Facilities other than Nuclear Reactors
AEC	Atomic Energy Commission
AERB	Atomic Energy Regulatory Board
AGS	Annulus Gas System
AHWR	Advanced Heavy Water Reactor
ALARA	As Low As Reasonably Achievable
AMD	Atomic Minerals Directorate for Exploration and Research
AOO	Anticipated Operational Occurrence
BARC	Bhabha Atomic Research Centre
BHAVINI	Bharatiya Nabhikiya Vidyut Nigam Limited
BRIT	Board of Radiation & Isotope Technology
BRNS	Board of Research in Nuclear Sciences
BSD	Biennial Shutdown
BWR	Boiling Water Reactor
CESC	Civil Engineering Safety Committee
CSED	Civil & Structural Engineering Division
CMG	Crisis Management Group
CSRP	Committee for Safety Research Projects
DAE	Department of Atomic Energy
DRD	Direct Reading Dosimeter
EMCCR	En-Masse Coolant Channel Replacement
ECCS	Emergency Core Cooling System
EOP	Emergency Operating Procedure
EPZ	Emergency Planning Zone
EZ	Exclusion Zone
ESL	Environmental Survey Laboratory
FAC	Flow Assisted Corrosion
PFBR	Prototype Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FSAR	Final Safety Analysis Report
HBNI	Homi Bhabha National Institute
HPU	Health Physics Unit
HWB	Heavy Water Board
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection

IGCAR	Indira Gandhi Centre for Atomic Research
IPSD	Industrial Plants Safety Division
IRE	Indian Rare Earths Limited
ISI	In-service Inspection
ITSD	Information and Technical Services Division
KAPS	Kakrapar Atomic Power Station
KGS	Kaiga Generating Station
LCO	Limiting Conditions for Operation
LOCA	Loss of Coolant Accident
LSSS	Limiting Safety System Settings
MAPS	Madras Atomic Power Station
MoEF	Ministry of Environment and Forests
NDMA	National Disaster Management Authority
NEA	Nuclear Energy Agency
NFC	Nuclear Fuel Complex
NPCIL	Nuclear Power Corporation of India Limited
NPP	Nuclear Power Plant
NPSD	Nuclear Projects Safety Division
NTC	Nuclear Training Centre
OED	Off-site Emergency Director
OPSD	Operating Plants Safety Division
PCB	Pollution Control Board
PDSC	Project Design Safety Committee
PHWR	Pressurised Heavy Water Reactor
PIE	Postulated Initiating Events
PSA	Probabilistic Safety Assessment
PSAR	Preliminary Safety Analysis Report
PSR	Periodic Safety Review
QMS	Quality Management System
RAPS	Rajasthan Atomic Power Station
RPR	Radiation Protection Rules
RSD	Radiological Safety Division
SARCAR	Safety Review Committee for Application of Radiation
SARCOP	Safety Review Committee for Operating Plants
SDS	Shutdown System
SEC	Site Evaluation Committee
SED	Site Emergency Director
SER	Significant Event Report
SRI	Safety Research Institute
SSC	Structures, Systems and Components
STAR	Stop Think Act Review
STD	System Transfer Document
TAPS	Tarapur Atomic Power Station
TIFR	Tata Institute of Fundamental Research
UCIL	Uranium Corporation of India Limited
USNRC	United States Nuclear Regulatory Commission
WANO	World Association of Nuclear Operators

1. INTRODUCTION

1.0 GENERAL

Integrated energy policy of India considers the role of nuclear energy as vital for long term energy security and sustainable development of the country. To increase the nuclear power capacity in the country, India pursues multi track approach for development and deployment of nuclear power plants through indigenous technologies and also import of reactors from abroad. India is also pursuing various programmes in radiation and isotope technologies for societal benefit in the areas of food preservation, development of superior mutant varieties of seed/crops, nuclear medicine for diagnostics and radiation therapy, industrial radiography, sewage and waste management etc. These programmes have been making significant contributions to India's development.

All nuclear and radiation facilities in India are sited, designed, constructed, commissioned and operated in accordance with strict quality and safety standards. Principles of defence-in-depth, redundancy and diversity are followed in the design of all nuclear facilities and their systems/components. A system of independent review and scrutiny of all important aspects has been an integral part of the management control, right from the beginning. The Atomic Energy Regulatory Board (AERB) is the national regulatory body having powers to frame safety policies, lay down safety standards & requirements and powers to monitor & enforce safety provisions in nuclear and radiation installations and practices.

1.1 NATIONAL NUCLEAR POWER PROGRAMME

A major step in the formulation of the Atomic Energy Programme in India was the passing of the Atomic Energy Act in 1948. This act was subsequently repealed and a new Act, the Atomic Energy Act of 1962 was passed by the Parliament. Atomic Energy Commission (AEC) was first constituted in 1948 and reconstituted with current terms of reference in 1958. AEC lays down the policies for the national nuclear programme. The Department of Atomic Energy (DAE) of the Government of India established in 1954, is responsible for execution of policies laid down by the AEC. DAE is engaged in research, technology development and commercial operations in the areas of nuclear energy, related high technologies and also supports basic research in nuclear science and technology. The organizational structure for Atomic Energy in India is shown in Annex 1-1.

For developing a strong research and technology development base and to achieve self reliance in the area of nuclear science and technology, a research and development centre was established at Trombay, in 1954, which was later renamed as Bhabha Atomic Research Centre (BARC). Research reactors APSARA (1956), CIRUS (1960), ZERLINA (1961) and DHRUVA (1985) and some critical facilities were set up at the Centre. A number of additional facilities and laboratories were built to extend the necessary R&D support to the national nuclear power programme and its associated fuel cycle activities. Over the years, BARC has developed into a frontline multidisciplinary research centre and a strong technical support organization for nuclear power programme of the country.

The strategy adopted under the Indian nuclear power programme optimizes the utilization of the modest uranium reserves and the vast thorium resources available in the country for long term energy security of the country.

Presently, there are nineteen NPP units in operation in India, with an installed capacity of 4560 MW. Four more units with a capacity of 2720 MW are under construction. Further, four units of 700 MW PHWRs have been launched. In addition, a number of new NPPs are planned to significantly increase the nuclear power base from the current levels.

The list of NPPs in operation and under construction is given in Table-1 and Table-2 respectively.

The first NPP in the country, TAPS units 1&2, based on boiling water reactors (BWR), supplied by General Electric, USA, became operational in the year 1969. These units have completed about 40 years of operation. During the years 2000 to 2006, these plants underwent safety assessments for continued long term operation. Based on the review, a number of upgrades were implemented during the refuelling outages of individual units and in a simultaneous long shutdown of both the units during November 2005 to January 2006.

The mainstay of India's nuclear power programme has been the PHWR. Two 200 MW units (RAPS 1&2) were established in the 1970s, at Rawatbhata in Rajasthan, with the technical cooperation of AECL (Canada). Subsequently, in 1980s, two 220 MW PHWRs (MAPS-1&2) were constructed at Kalpakkam in Tamilnadu, with indigenous efforts. Among these, presently RAPS unit-2 and MAPS units 1&2 are operational and have undergone safety upgrades.

Based on the experience gained from constructing and operating RAPS and MAPS reactors, India developed a standardised design of 220 MW PHWRs. This design incorporated state of the art features viz. integral calandria & end shields, two independent fast acting shut down systems, high pressure emergency core cooling system, water filled calandria vault and provision of double containment with vapour suppression pool. Four reactors of this standardised design were built, two each at Narora in Uttar Pradesh (NAPS 1&2) and Kakrapar in Gujarat (KAPS 1&2). These plants became operational through the 1990s. Subsequently eight more units of standardised 220 MW PHWRs were built, four each at Kaiga in Karnataka (KGS units 1-4) and Rawatbhata in Rajasthan (RAPS units 3-6). These units though retaining the basic standardised 220 MW PHWR design incorporated a few modifications such as locating the steam generators fully inside the primary containment, complete pre-stressed concrete construction for the primary containment and a more compact site layout. The first four of these reactors (KGS units 1&2 and RAPS units 3&4) became operational in the year 2000. Unit-3 of KGS became operational in 2007 and RAPS 5&6 became operational in 2010. Unit 4 of KGS is undergoing commissioning and is expected to be operational soon.

In 1990s, India undertook the design and development of 540 MW PHWR. Two reactors based on this design were set up at Tarapur (TAPS units 3&4). These units became operational in 2005-2006.

First round of WANO peer review has been completed for all the operating NPPs which had started operation before 2006 and second round has been completed for four stations (KAPS, NAPS, KGS 1&2 and RAPS 3&4). In addition pre-startup review was carried out for TAPP-3, RAPP-5 and KGS-4. TAPS-3 was the first plant under construction in Asian region which was subjected to such a review.

Improvising on the 540 MW PHWR design, India has also developed a 700 MW design with limited boiling in the coolant channels. The construction of four such units is expected to start soon, at the Kakrapar and Rawatbhata sites.

Indian small and medium size reactors with their proven track record and commercial viability provide optimal power solution where medium size electricity grids are in operation.

In addition, India has undertaken construction of two VVER based NPPs (2X1000 MW), at Kudankulam (KK-1&2) in Tamilnadu. These are being built with the co-operation of

Russian Federation, with an objective of faster increase in the nuclear power capacity. These reactors incorporate several advanced safety features. The commissioning activities have been started in KK-1 and the unit is likely to start commercial operation in 2011.

A Fast Breeder Test Reactor (FBTR) 40 MWth at Kalpakkam has been in operation since 1985. The carbide fuel used in this reactor has been successfully irradiated to a burn up of 165,000 MWd/Tonne. The technology development for the 500 MW Fast Breeder Reactor has been completed. Currently a 500 MW Prototype Fast Breeder Reactor (PFBR) is under construction at Kalpakkam and is expected to be completed in 2012. The PFBR is being built with the design and technology developed at the Indira Gandhi Centre for Atomic Research (IGCAR) and is the forerunner of the future fast breeder power reactors.

India has taken a number of steps towards development of necessary technology for utilization of thorium in the nuclear power programme. A research reactor KAMINI, a 30 kWth neutron source reactor using uranium-233 derived from irradiated thorium as fuel, has been in operation since 1997. BARC has developed the design for the Advanced Heavy Water Reactor (AHWR) of 300 MW capacity. This is a vertical pressure tube type reactor utilising heavy water moderator, boiling light water coolant, thorium-plutonium based fuel and incorporates several innovative concepts and passive safety systems. AHWR derives about two-third of its power from thorium. This reactor is conceived as a technology demonstration project for utilising thorium for electricity generation. The reactor also provides a platform to demonstrate several unique passive safety features which are introduced in the reactor to achieve the highest levels of safety. Technologies thus demonstrated in AHWR will be relevant for future next generation reactors that will meet the further enhanced safety requirements for locating them in close proximity to population centres. Pre-licensing design safety review of the AHWR has been completed by AERB. A number of critical R&D activities have been taken up in BARC in connection with the development of AHWR. BARC has recently commissioned a critical facility to validate the physics design of AHWR.

1.2 EMERGING SCENARIO

The installed electricity generating capacity in India as of March 2010 is 160 GW. With this capacity India is globally fifth largest producer of the electricity. The annual per capita electricity consumption is, however, about 700 kWh. The contribution from nuclear energy to the overall electricity generation is about 3%. The Indian Integrated Energy Policy -2006 emphasizes the need to increase the electricity generating capacity at an accelerated pace to meet the demand of the rapidly growing economy. The contribution of nuclear energy is also proposed to be enhanced to about 63 GW by 2032.

Consequent to the approval by the IAEA Board of Governors on 1 August 2008 of the ‘Agreement between the Government of India and the International Atomic Energy Agency for the Application of Safeguards to Civilian Nuclear Facilities’ (INFCIRC/754) and the decision of the Nuclear Suppliers Group - ‘Statement on Civil Nuclear Cooperation with India’ of 6 September 2009 - Government of India signed Inter- Governmental Agreements / Memorandum of Understanding / Joint Declaration for co operation in nuclear energy with several countries. With these enabling agreements, India is planning to set up Light Water Reactors with foreign collaboration.

The Government has accorded ‘in-principle approval’ of the sites for setting up 20 new NPP units (10 PHWRs of 700 MW and 10 LWRs of 1000 MW or higher) in the first instance. This will be followed up by setting-up of more reactors of the same design and at the same sites. Pre-project activities have been initiated at the sites with a view to start the projects in about 2012. Recognizing the necessity for developing indigenous capability to support this growth, setting up / augmentation of facilities to manufacture major components by the leading industry partners has been initiated. The opening up of nuclear trade with

India has also encouraged many global equipment suppliers to tie up with Indian industry for establishing manufacturing hub in India for global nuclear requirements.

1.3 NUCLEAR FUEL CYCLE

India's nuclear power programme is based on a closed fuel cycle. India has adopted this approach considering the objectives of maximum utilisation of the energy potential of available resources and minimisation of high level waste.

Comprehensive fuel cycle technologies and facilities addressing the needs of both front end and back end have been developed and are in operation. Front end facilities including mining, milling & processing of ore and for fuel fabrication are operated by Uranium Corporation of India Limited (UCIL) and Nuclear Fuel Complex (NFC) respectively. The back end technologies & facilities for reprocessing of spent fuel for extraction of plutonium & uranium and the associated fuel fabrication facilities have been developed by DAE and are in operation.

India has also developed necessary technologies for safe management of the radioactive wastes arising out of the nuclear fuel cycle. This includes the vitrification technology for conditioning and fixation of the high level waste produced during spent fuel reprocessing in a glass matrix. The vitrified high level nuclear waste is stored in exclusive storage and surveillance facilities, pending its final disposal in a geological repository. The vitrification plants and storage & surveillance facilities for the vitrified waste packages are in operation.

1.4 INDUSTRIAL INFRASTRUCTURE FOR NUCLEAR POWER

In the early phases of the nuclear power programme, Indian industry needed significant up-gradation and efforts for undertaking manufacturing and precision machining jobs to the quality standards of nuclear industry. Since then, the Indian engineering industry has achieved significant enhancements in capabilities and quality standards. Today almost all ferrous and non ferrous materials, components and equipment required for nuclear power plants are manufactured indigenously.

India has heavy engineering and manufacturing facilities in both public and private sectors. It is capable of manufacturing equipment / components like coolant tubes, calandria tubes, calandria and endshields for PHWRs, steam generators, turbines, electrical equipment, heat exchangers, pumps, pressure vessels, fuelling machines etc. This also demonstrates the indigenous capability in precision machining techniques for such components. The developments in manufacture of electrical machines, electrical and electronic accessories, and Control & Instrumentation items such as large size motors, high quality conductors, sophisticated control panels and computer based control systems progressed in line with requirements of nuclear power projects. Concurrently with the development of manufacturing technologies, non-destructive examination techniques and equipment for these techniques have also been mastered utilizing optical instruments, laser technology etc.

The production of heavy water and manufacturing of fuel bundles starting from mining is done through Governmental organizations viz. Heavy Water Board, Uranium Corporation of India Ltd. and Nuclear Fuel Complex.

The Indian industry has been closely involved in the development of all facets of nuclear power plants such as civil, mechanical, reactor components and processes, electrical, control and instrumentation and has eventually gained valuable skill-set and maturity in this regard. The maturity of the industry and its capability to take up mega package contracts has contributed significantly in the reduction of gestation time of nuclear power projects in India.

1.5 HUMAN RESOURCES DEVELOPMENT

Realising the importance of having adequate number of well trained scientists and engineers, a training school at BARC was established in 1957. Subsequently Nuclear Training Centres (NTC) were set up by the Nuclear Power Corporation of India Limited (NPCIL). These NTCs are fully equipped with necessary infrastructure for implementing training programmes for each category of plant personnel i.e. engineers, supervisors and technicians. Simulators for training of key operation personnel are established at various sites.

To meet the expanding needs of human resources, training schools have also been set up at the Raja Ramanna Centre for Advanced Technology, Indore (2000), Nuclear Fuel Complex, Hyderabad (2001) and IGCAR, Kalpakkam (2006). To date, nearly 9000 engineers and scientists have been trained in these training schools.

In the year 2005, the Government established the Homi Bhabha National Institute (HBNI). One of the objectives of this Institute is to nurture an environment for attracting high quality professionals to pursue further studies in the areas related to nuclear science and technology from within DAE and elsewhere. DAE has also nurtured good linkages with the universities and academic institutes in the country, to promote collaboration in research & development activities in the areas associated with nuclear science and technology. Currently there are a number of universities and other institutes in the country, offering academic programmes in areas related to nuclear technology and radiological safety.

AERB has also placed considerable emphasis on human resource development right from its inception. The main emphasis has been on maintaining adequate and competent manpower. Appropriate recruitment policy to induct talented manpower, organisation of training programmes and knowledge management towards maintaining competence and efficiency have been the main features of HRD in AERB.

Dedicated Knowledge Management groups have been set up in all organisations of the DAE to pool and disseminate the available knowledge base and further augment it to meet the challenges in future.

Engineers and scientists from different organisations related to nuclear energy, also participate in several international meetings and training programmes conducted by the International Atomic Energy Agency (IAEA) and other organisations, for exchange of information and experience, to further enrich their capabilities.

1.6 REGULATION OF NUCLEAR FACILITIES

Atomic Energy Regulatory Board (AERB) was established in 1983 using the provisions of the Atomic Energy Act, with the necessary powers and mandate to frame safety policies, lay down safety standards & requirements and monitoring & enforcing the safety provisions. The regulatory framework established by AERB has evolved into an effective mechanism for safety monitoring, surveillance and enforcement. AERB has obtained ISO 9001:2008 certification for its activities pertaining to consenting, regulatory inspections and development of regulatory safety documents.

AERB exercises the regulatory controls on the utilities engaged in the establishment and operation of NPPs through the consenting process. This system provides for issue of a licence/consent/clearance by AERB for a specified purpose on satisfying itself that utility complies with all the regulatory requirements. This is ensured through detailed reviews of the applications from the utility, regulatory inspections and other available means. For construction of NPPs, AERB follows a scheme of stage-wise consents, which extends from 'siting' to the 'licence for operation'. During the operational phase of the NPP, the plants are subjected to a regular programme of safety surveillance and monitoring for continuing appraisal of safety. For periodic renewal of the licence for operation and during Periodic Safety Review (PSR) of NPP, safety is assessed based on operating experience feedback and against the current safety standards & practices.

1.7 COMMITMENT TO THE CONVENTION ON NUCLEAR SAFETY

In line with the objectives of CNS, India gives utmost attention to ensure safety of operating personnel, public as well as environment. The principle of 'safety being the overriding priority' encompasses the entire gamut of activities associated with nuclear power plants (NPPs), i.e. siting, design, construction, commissioning, operation and decommissioning.

A systematic approach using well-defined safety principles is followed in the design of the nuclear power plants to provide the required safety features adopting principles of defence-in-depth, diversity, redundancy and physical separation. Nuclear Power Plants are constructed in accordance with the design intent, ensuring adherence to required quality standards. Commissioning of the systems to test and demonstrate adequacy of each system and the plant as a whole by actual performance tests to meet the design intent is carried out before commencing operation of the plant. Operation of the plant is carried out by formally trained and licensed personnel. All the key control room positions viz control engineer, assistant shift charge engineer and shift charge engineer are manned by graduate engineers. The plant is operated as per approved procedures and following the operational limits and conditions for various system parameters laid down in the technical specifications for operation that are thoroughly reviewed and approved by AERB. Further, during consents for various stages, additional conditions are specified if necessary. All these measures are intended to ensure safe operation of the plants, safety of occupational workers, members of public and protection of environment.

All nuclear power plant sites in India are capable of managing the radioactive wastes generated there. Adequate facilities have been provided for handling, treatment and disposal of wastes generated from plant operation at these sites. Management of radioactive wastes is carried out in conformity with the regulatory guidelines.

Establishment and verification of appropriate emergency response plans is a mandatory prerequisite for all the NPPs in India. These plans provide for on-site and off-site emergency response and involve local district and plant authorities. The preparedness of the agencies involved is verified through periodic exercises. AERB reviews these plans and participates as observer during these exercises.

1.8 NATIONAL REPORT TO THE 5TH REVIEW MEETING OF CNS

This report is prepared generally in line with the guidelines contained in information circular INFCIRC/572/Rev.3 on "Guidelines regarding National Reports under the Convention on Nuclear Safety".

In the fourth review meeting of CNS, India had identified certain challenges and the planned measures to further improve safety. Detailed account on the approach adopted to address them is given in the relevant chapters of the report. The intent of the recommendations adopted at the plenary sessions of the 4th review meeting has been addressed. Future activities for further enhancement of safety have also been brought out.

The national report of India to the 5th review meeting of CNS amply demonstrates India's commitment to the obligations of the Convention on Nuclear Safety.

Table – 1

NPPs in Operation as on August 2010

Station Unit	Type	Gross Capacity (MW)	Operator & Owner	Reactor Supplier	Commencement of Operation
KGS-1	PHWR	220	NPCIL/NPCIL	NPCIL	Nov-2000
KGS-2	PHWR	220			Mar-2000
KGS-3	PHWR	220			May-2007
KAPS-1	PHWR	220			May-1993
KAPS-2	PHWR	220			Sep-1995
MAPS-1	PHWR	220			Jan-1984
MAPS-2	PHWR	220			Mar-1986
NAPS-1	PHWR	220			Jan-1991
NAPS-2	PHWR	220			Jul-1992
RAPS-1*	PHWR	100	NPCIL / DAE	AECL, CANADA	Dec-1973
RAPS-2	PHWR	200	NPCIL/NPCIL	AECL/ DAE	Apr-1981
RAPS-3	PHWR	220		NPCIL	Jun-2000
RAPS-4	PHWR	220			Dec-2000
RAPS-5	PHWR	220			February 2010
RAPS-6	PHWR	220			March 2010
TAPS-1	BWR	160		GE, USA	Oct-1969
TAPS-2	BWR	160			Oct-1969
TAPS-3	PHWR	540		NPCIL	Aug-2006
TAPS-4	PHWR	540			Sep-2005

**** Unit under shutdown since 2004.***

Table – 2

NPPs under Construction as on August 2010

Station/ Project	Type	Gross Capacity (MWe)	Operator & Owner	Reactor Supplier	Start of Construction
KGS-4	PHWR	220	NPCIL/NPCIL	NPCIL	May-2002
KK-1	PWR	1000	NPCIL/NPCIL	ASE, RUSSIA	Mar-2002
KK-2	PWR	1000	NPCIL/NPCIL		Mar-2002
PFBR	PFBR	500	BHAVINI	BHAVINI	Oct-2004

Annex 1-1 Organisational Structure for Atomic Energy in India

Atomic Energy Commission

Atomic Energy Commission (AEC) is the apex body of the Central Government for atomic energy that provides direction on policies related to atomic energy. The members of AEC include, among others, some eminent scientists & technocrats, secretaries of different ministries and senior most officials from the office of the Prime Minister. The AEC reports to the Prime Minister.

Atomic Energy Regulatory Board (AERB)

Atomic Energy Regulatory Board (AERB) is the national regulatory body having powers to frame safety policies, lay down safety standards & requirements and powers to monitor & enforce safety provisions in nuclear and radiation installations and practices. AERB reports to AEC.

Department of Atomic Energy

Development and implementation of nuclear power and related nuclear fuel cycle activities and research & development activities are carried out in various units under the DAE. The DAE organisation is divided into four major sectors, viz. Research & Development sector, Industrial sector, Public Sector Undertakings and Services & Support sector. The DAE also provides for the interaction needed between the production and R&D units. The organisations engaged in the area of Atomic Energy in different sectors are as given below and the organisation structure is shown in figure 1.1

i. Research and Development sector includes Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Atomic Minerals Directorate for Exploration and Research (AMD), Raja Ramanna Centre for Advanced Technology (RRCAT) and Variable Energy Cyclotron Centre (VECC). Board of Research in Nuclear Sciences (BRNS) and National Board for Higher Mathematics (NBHM) provide funding to universities and other national laboratories. Homi Bhabha National Institute (HBNI) is an institute having academic programmes which are run by the R&D centres and grant-in-aid institutions.

ii. There are several grant-in-aid institutes like Tata Institute of Fundamental Research (TIFR), Institute for Plasma Research (IPR) and Saha Institute in Nuclear Physics under DAE.

iii. Industrial sector includes Government owned units of Heavy Water Board (HWB) for the production of heavy water, Nuclear Fuel Complex (NFC) for the fabrication of nuclear fuel, zircaloy components and stainless steel tubes, and Board of Radiation & Isotope Technology (BRIT) for processing and supply of radioisotopes and developing technologies for radiation and isotope applications.

iv. Public Sector Enterprises along with their activities under the control of DAE are as follows:

- Nuclear Power Corporation of India Limited (NPCIL) engaged in the design, construction, commissioning and operation of the nuclear power plants;
- Uranium Corporation of India Limited engaged in mining, milling and processing of uranium ore;

- Indian Rare Earths Limited engaged in mining and separation of beach sand minerals to produce ilmenite, rutile, monazite, leucoxene, zircon, silimanite and garnet and chemical processing of monazite to obtain thorium and rare earths;
- Electronics Corporation of India Limited engaged in design and manufacture of control and instrumentation equipment related to atomic energy and also to other sectors;
- Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) for setting up fast reactor based nuclear power plants.

Nuclear Power Plants were initially set up and operated by Power Project Engineering Division (later Nuclear Power Board), a unit directly under the Government of India since the late 1960's, when the construction of the first nuclear power station was commenced. This unit was converted into a corporation in September 1987, thereby forming Nuclear Power Corporation of India Limited (NPCIL), a wholly owned company of Government of India. Formation of NPCIL was a step to facilitate the required degree of operational freedom and to mobilise funds from the Indian capital market to finance new nuclear power projects.

In October 2003, the Government of India had set up another wholly owned enterprise namely the Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), with the objective of construction, commissioning and operation of the first 500 MW PFBR. Construction of the PFBR is presently in an advanced stage.

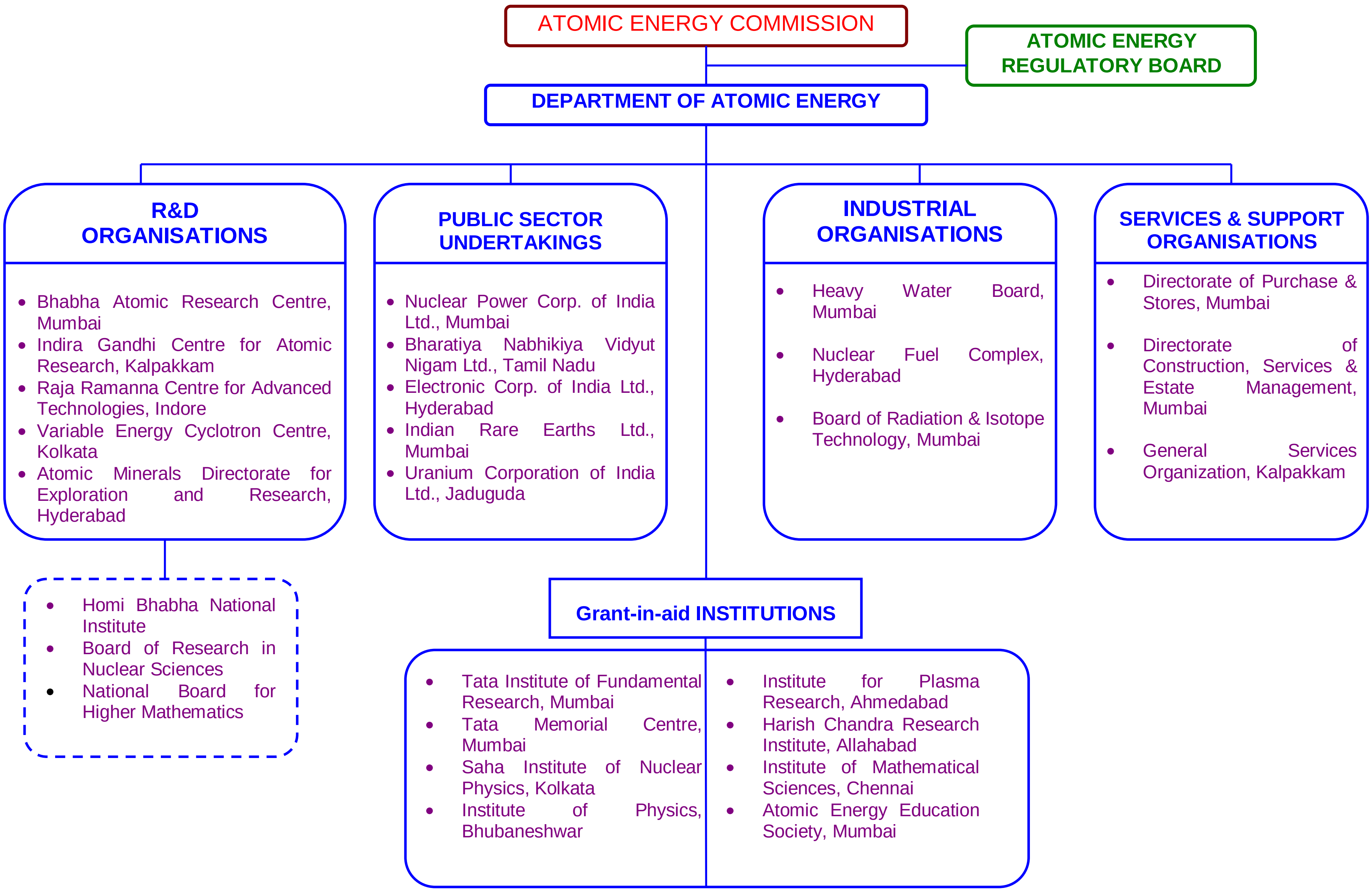


Figure-1.1 Organisational Structure for Atomic Energy in India

2. SUMMARY

2.0 GENERAL

In India, all activities related to atomic energy including those for electricity generation through nuclear power are governed by the Atomic Energy Act – 1962 as amended from time to time and the rules made thereunder. Atomic Energy Regulatory Board (AERB), the regulatory body constituted under the provisions of the act has the necessary powers and mandate to frame policies, lay down safety standards & requirements and to monitor & enforce all the safety provisions. AERB exercises the regulatory control over the activities related to nuclear and radiation facilities including the nuclear power plants (NPPs) through the consenting and regulatory inspection & enforcement processes. Regulatory requirements related to safety in nuclear power plants are given in AERB safety codes. Revision of the regulatory requirements prescribed by AERB is covered in this chapter. Also, included in this chapter is the progress on planned measures to improve safety as presented in the previous review meeting and also the future safety related activities.

2.1 REVISION OF REGULATORY REQUIREMENTS

AERB regulatory documents like safety codes, guides, standards and the regulatory requirements specified through AERB directives are revised and updated as and when needed. Recently AERB has revised its safety codes related to design of Pressurised Heavy Water Reactor based NPPs, quality assurance in NPPs and NPP operations. The codes have been revised based on operating experience and current national/International practices. The IAEA safety standards were extensively used while revising the codes. Some of the salient revisions in regulatory requirements are described below.

i) AERB Safety Code on Design of Pressurised Heavy Water Reactor based Nuclear Power Plants AERB/NPP-PHWR/SC/D (Rev. 1): 2009

The code on design of NPPs was revised by AERB in 2009. The IAEA safety standard 'Safety of Nuclear Power Plants: Design Requirements No NS-R-1' was extensively used in revising the AERB code.

The new provisions in the code include the requirements for consideration of severe accidents, use of system design capabilities beyond originally intended functions and available means including support from other units at the same location to mitigate the consequences of severe accidents. Additional requirements have been introduced for use of both deterministic and probabilistic approaches in safety assessment.

Design requirements for dealing with ageing of structures, systems and components important to safety have been included in the code. Requirements related to moderator system, use of computers in systems important to safety, emergency control centre and grid-plant interaction have also been included. The requirements on equipment qualification and human factors in design of a plant have been updated.

ii) AERB Safety Code on Quality Assurance in Nuclear Power Plants AERB/NPP/SC/QA (Rev. 1): 2009

The code on Quality Assurance in NPPs was revised by AERB in 2009. The IAEA safety standard 'The Management System for Facilities and Activities, Safety Requirements No GS-R-3' was appropriately used in revising the AERB code.

The revised code includes new requirements for resource management, configuration management, infrastructure and work environment, safety culture, management commitment, communication, managing organizational change and improvement of QA programme.

iii) AERB Safety Code on Nuclear Power Plant Operation AERB/NPP/SC/O (Rev. 1): 2008

The code on operations of NPPs was revised by AERB in 2008. The IAEA safety standard 'Safety of Nuclear power Plants: Operation, Requirements No NS-R-2' was extensively used in revising the AERB code'.

The revised code includes requirements of operational experience feedback, plant life management and probabilistic safety assessment. Nuclear security requirements such as availability of approved site-specific manual on security, mock drill on security and measures as appropriate to prevent unauthorized access have been included. Plant life management considerations for continued operation are also covered.

iv) Exclusion Zone for Nuclear Power Plants

Exclusion Zone (EZ) is an area upto a specified radius around the NPP where no public habitation is permitted. This zone is physically isolated from outside areas by fencing and is under the control of the plant management. The minimum exclusion zone for the NPPs was specified as 1.5 km.

On the basis of advanced safety features of NPPs of today's design, a proposal for revising the regulatory requirement and to reduce the size of exclusion zone was made to AERB. The proposal was evaluated taking into consideration the radioactive releases during design basis accident and the resultant dose to the public considering all radiation exposure pathways including inhalation and ingestion, at the exclusion zone boundary without taking credit of any countermeasures. The security considerations related to the size of the EZ were also assessed. Based on thorough evaluation of the proposal and all the related aspects, AERB has now stipulated that the size of the EZ shall not be less than 1 km from the centre of the reactor for the new reactors.

2.2 PROGRESS ON CHALLENGES AND PLANNED MEASURES TO IMPROVE SAFETY

A number of challenges and planned measures to improve safety were identified in our presentation to the fourth review meeting. The following sections describe the progress made in these areas:

i) Augmenting human resources of AERB

The scientific and technical manpower in AERB is being augmented at various levels taking into consideration the expanding nuclear power programme and increasing number of radiation facilities in the country. The sanctioned staff strength of AERB has been increased by about 70 % and the recruitments are being made progressively. Progressive augmentation of AERB scientific and technical manpower is being done through fresh recruitments, transfer of experienced personnel from operating plants and R&D institutes such as BARC and IGCAR and induction of engineers through AERB Graduate Fellowship Scheme (AGFS) in academic institutes.

ii) Reliability and Safety of Digital I&C

NPPs in India have been progressively employing digital I&C systems. The safety aspects related to these items were reviewed by AERB. Based on these reviews, it was decided to develop a safety guide on reliability and safety of digital I&C systems. AERB has now issued safety guide AERB/SG/D-25 on “Computer Based Systems of Pressurised Heavy Water Reactors”. In development of the guide, international standards (including IEC, IEEE etc.) and various national and international documents were considered. This guide lays down the guidance for the design of digital I & C system to assure a high level of reliability and safety which can be verified and validated. The guide is largely technology neutral. The guide covers development life cycle, safety case, regulatory requirements and regulatory review process related to digital I&C.

In conformance with the guide, NPCIL has prepared engineering procedures to define the work methods for design, development, testing and commissioning of computer based systems. NPCIL has an independent verification and validation committee to carry out the V&V process for the applicable computer based systems. These V&V reports are further reviewed by AERB. The requirements of the guide are also followed during configuration changes at the operating NPPs.

iii) Licensing of NPPs of new designs

PHWR based NPPs have been the mainstay of our nuclear power programme. Initially, India constructed twin unit stations with 2X 220 MW reactors. With the standardisation of this design from NAPS onwards, regulatory review and licensing for subsequent reactors of this type were also standardised.

In the 1990’s India undertook design and development of 540 MW PHWR based NPPs which had several first of a kind systems. Two reactors of this design were constructed at Tarapur (TAPS 3&4). These reactors started operating in 2005 and 2006. India has also developed 700 MW PHWR design with limited boiling in the coolant channels and the reactor will be having several new features. India is also constructing a 500 MW PFBR at Kalpakkam. The Licensing of 540 MW reactor and the ongoing review for licensing of 700 MW PHWR and 500 MW PFBR have given AERB valuable experience for licensing of reactors of new design.

Two VVERs of 1000 MW each (KK1&2) of Russian design are under construction at Kudankulam. The licensing review of this reactor has also provided AERB valuable experience for safety review of LWR’s of new designs of foreign origin as well.

The licensing process for reactors of foreign origin will be governed by AERB safety code ‘Regulation of Nuclear and Radiation facilities’ AERB/SC/G and associated guides and will take into account experience of safety review of design and operation of indigenous reactors as well as experience with safety review of PWR – VVER units and current safety standards. The reactors should meet the applicable safety and regulatory requirements in India and in general, IAEA safety requirements, in addition to those specified by the licensee.

iv) Reliability of passive systems

Advanced nuclear reactor designers incorporate several passive systems to improve safety. Acceptance of these systems could be a challenge to regulatory bodies. Several studies have been taken up in BARC, as well as in IGCAR in collaboration with AERB-Safety Research Institute (SRI), for assessment of reliability of such systems. These assessments require consideration of probability of deviation of process parameters and their combinations leading to system performance failure (i.e. functional failure probability), in addition to classical consideration of hardware failure probabilities. For the assessment of functional failure probability, thermal-hydraulic codes are run with several combinations of values of influencing process parameters, so as to generate failure response surface in parametric space, demarcating the failure and success regions. The variations in influencing parameters are assigned probability density functions, and their effect on system failure probability is assessed using Monte-Carlo simulators applied in the backdrop of the above generated failure surface.

Functional failure is then estimated as ratio of number of simulators leading to 'failures' to total number of simulations. The IGCAR-SRI approach for functional failure probability estimation for various system configurations adopts certain refinements involving 'response conditioning methods' suitable for high-dimensional problems with complex failure surfaces for functional failure estimation. The studies conclude that for computationally expensive thermal-hydraulic estimations, subset simulation based 'response conditioning method' provides consistent and computationally efficient reliability estimates.

The BARC approach (christened APSRA – Assessment of Passive System Reliability) is based on the premise that causes of deviations in influencing parameters can usually be ascribed eventually to failure of mechanical components. Hence in this approach, after the failure surface is generated, the problem reduces to classical treatment of combinations of hardware failures.

Application of such assessments for regulatory purposes has not yet taken place in a significant manner, but are likely to play increasing role in licensing of new designs in future.

v) Severe accident management programme

Symptom based Severe Accident Management Guidelines (SAMG) are being evolved for Indian PHWR based on deterministic analysis of severe accident progression and PSA Level-1 and 2 studies. The key requirements for the actions and the guidelines are worked out based on the severe accident analysis. Indian standardised PHWR technology provides relatively large time for the actions to be taken under such conditions owing to large water inventory in calandria and calandria vault. Severe accident progression is outlined through indigenous severe accident analysis code-SEVAX, which is going through the rigorous code comparison exercise presently underway through IAEA coordinated research programme. The other participating countries in this CRP are Canada, China, Republic of Korea and Romania.

Various actions have been focused towards retaining the core debris in calandria vessel with the provision of long term cooling arrangement and to maintain the containment integrity. SAMGs also address various options to arrest severe accident progression and monitor the core status and success of mitigation actions. In order to arrest severe accident progression, physical barriers are identified at which it is possible to logically halt progression of severe accident. The barriers so identified are coolant channel, calandria, calandria vault and containment. Five core damage states are identified which can be correlated with each of the above mentioned barriers. With reference to these core damage states (and hence severe accident progression barriers); three sets of guidelines for managing (preventing and mitigating) severe accidents are made.

Severe Accident Prevention Guidelines
- Inject into primary heat transport system

Severe Accident Mitigation Guidelines
- Maintain calandria heat sink
- Maintain calandria vault heat sink
- Control conditions in reactor building

Severe Accident Ultimate Guidelines
- Reduce containment pressure
- Control containment atmosphere flammability / hydrogen
- Mitigate fission products release

As part of severe accident management, it is ascertained that calandria, calandria vault and end shields have adequate capability to relieve steam and to ensure long term decay heat removal. Adequacy of instrumentation and means to monitor severe accident progression/ efficacy of SAMG actions is also ensured.

The SAMG generic document is being prepared for standardised 220 MW and 540 MW Indian PHWRs, comprehensively covering all aspects of SAM programme. After review of the document, implementation of backfits as necessary will be taken up.

The requirements for severe accident handling are embedded in the design of 700 MWe PHWR being constructed in India. These include:

- Inventory addition (light water) in calandria
- Inventory addition in calandria vault
- Injection (light water) in to primary cooling system
- Injection in to end shields.
- Hydrogen management

vi) PSA (Level-2, Shutdown, External events)

A comprehensive Level-1 Shutdown PSA is completed for KAPS-1, 2. Shutdown PSAs for other operating stations will be taken up progressively. The seismic, fire and flood PSA for KAPS-1, 2 is in progress.

Level-2 PSA for 220 MW PHWR (KAPS-1, 2) was completed earlier. With current improvements in severe accident & containment analysis and preparation of SAMGs, PSA Level-2 for KAPS is being revisited. Level-2 PSA for other 220 MW PHWRs is expected to be similar. After completion of Level-2 PSA for 220 MW, it is planned to take up PSA Level-2 study of 540 MW design (TAPS-3, 4).

vii) En-masse Coolant Channel Replacement (EMCCR) of NAPS-2 and KAPS-1

EMCCR activities for NAPS-2 were started in December-2007. All coolant channels and heat transport system feeders have been replaced. The unit is likely to restart during 2010-2011. EMCCR activities for KAPS-1 were started in July-2008. All coolant channels and heat transport system feeders have been replaced. Both the units are likely to start in 2010.

viii) Life management of Zr-Nb pressure tubes

With replacement of pressure tubes in NAPS-2 and KAPS-1, all the operating PHWRs in India now have pressure tubes made from Zirconium-2.5% Niobium alloy, which have low initial hydrogen and a significantly lower rate of hydrogen / deuterium pick up as compared to Zircaloy-2 coolant channels installed earlier. An elaborate approved programme for in-service inspection for monitoring status of the coolant channels in all reactors has been finalized. The programme includes requirements and acceptance criteria for both pre-service inspections (PSI) as well as in-service inspections (ISI). The present ISI programme requires all NPPs to carry out the first ISI campaign between two and four years of start of operation and the subsequent inspections every six years. Most of the reactors, particularly the ones that have seen longer period of operation have undergone inspection campaigns, generally in line with the currently approved ISI programme.

The requirements of the ISI programme address the known generic degradation mechanisms, viz. hydrogen / deuterium ingress, irradiation creep & growth and degradation of material properties. The ISI programme also specifies the requirements with respect to material surveillance.

The in-service inspections carried out so far in various units have shown that there are no immediate concerns of life limiting nature with respect to Zirconium – Niobium coolant channels in Indian reactors. Degradation mechanisms which impact the service life in the long term have been identified and suitable action plans are implemented for life management. Following are the two main degradation mechanisms:

a) Axial creep / growth among pressure tubes

During the axial creep measurement campaigns significant differences have been observed in the axial elongation of some of the adjacent coolant channels in the core. This may cause interference between the feeders and feeder coupling hardware of the channels belonging to same feeder bank preventing free expansion of coolant channels. The status of the channels and the clearances are being monitored regularly during biennial shutdowns. Strategy has been developed to deal with this issue. The issue is further elaborated in section 6.1.5 (a).

b) Diametric creep / growth in pressure tubes:

At Kakrapar-2, coolant channel inspection results indicated that the diametric creep in some of the inspected coolant channels may be higher than anticipated. The thermal hydraulic studies carried out for assessing the effect of these observations on Minimum Critical Heat Flux Ratio (MCHFR) indicated that significant margins would still be available and there was no immediate safety concern. Various studies and assessments are being done for deciding the acceptable service life of pressure tubes and the future action plan for life management of these channels. The issue is further elaborated in section 6.1.5 (b).

ix) Primary Heat Transport System Feeder thinning

In PHWRs, the thinning of the reactor outlet feeders of Primary Heat Transport System takes place mainly due to high fluid velocities and operating temperature in the vicinity of boiling point of the fluid. A number of measures have been taken to mitigate the thinning phenomena, including the following:

- In all new feeders, material is changed to the one having 0.20 to 0.24% chromium
- All outlet feeders of 32mm NB size have been replaced with 40mm NB size in the FAC vulnerable portion,
- The thickness of elbows in all new feeder installations has been increased.
- In order to facilitate proper UT thickness gauging, the weld joints near high pressure coupling have been ground flushed in the feeders that have been replaced at RAPS-2 and are being replaced at other stations. This has also been incorporated in the feeder fabrication procedure for all future feeder installations.
- Primary coolant pH is being maintained at all stations between 10.2 to 10.4

x) Flow Assisted Corrosion (FAC) of Secondary System Piping

Comprehensive action plan has been prepared to mitigate/ manage secondary cycle FAC. In the first phase of the program, all NPPs have collected baseline data for a large number of components (around 3500) pertaining to high-energy system piping of secondary cycle by UT thickness measurements. These baseline data collected in initial examination for operating plants and in pre-service inspection (PSI) for projects are recorded for component's life evaluation purpose. The basis for selection of components for this examination includes:

- All pipes & fittings in upstream as well as downstream of restriction orifices, flow elements, control valves, bypass valves, motorized valves, non-return valves, manual valves, steam traps, etc. up to a distance of 1.5 m and the first fitting on immediate downstream.

- All nozzles of equipment, pumps and their pipes & fittings up to a distance of 1.5 m and the first fitting on immediate downstream.
- All piping components such as reducers, expanders, bends, elbows, tees and branch connections in high energy systems,
- Additional areas as per feedback from any NPPs.

The second phase of the program is to be conducted periodically, generally in BSD (Biennial Shut Down) of a plant. In this phase all components from FAC vulnerable locations and the components noticed with less thickness are to be examined for each operating station. All such components are covered in six years' period. The management actions for FAC for upcoming plants include the following:

- To use better FAC resistant material instead of carbon steel in FAC prone lines/ portion of piping of high energy systems.
- To provide higher corrosion allowance for pipes and pipe fitting in FAC prone lines/ portion of piping of high energy systems.
- To develop piping layout to minimize flow disturbances.
- To implement FAC monitoring program at project stage by collecting thickness data of piping components through PSI.

xi) Development of Seismic Qualification Program by Experience Database

The earthquake experience based data on the civil structures, piping, cable tray & ducting systems and mechanical, electrical, Instrumentation & Control equipment has been collected from 9 industries and 18 electrical substations located around Koyna (1967; 6.5,magnitude), Bhuj (2001, 7.6 magnitude) and Muzaffarabad (2005, 7.6 magnitude).

It is observed that the performance of the equipment such as tanks, pumps, valves, compressors, diesel generators,, fans and blowers, chillers, heating and ventilation air conditioning ducts, cranes, transformers, switchgears, motor control centres, battery chargers and inverters, distribution panels, motor generators, cable trays, glass partition, ducting, instrumentation and control panels, instrumentation devices like relays, temperature and pressure sensors, switches, meters etc was good. In general, damage was observed in transformers, battery banks, false ceilings, lighting fixtures and brick walls. Falling of brick wall on to the equipment or piping or failure of equipment due to improper or no anchorage of the equipment were observed in some cases where equipment failed. The failures were in terms of loss of structural integrity or pressure boundary integrity or loss of functional performance. The failures were seen in rigid piping systems due to seismic anchor movement.

The data covers a wide diversity of seismic input to equipment in terms of seismic motion i,e amplitude, duration, and frequency content. A detailed analysis of the response of the structures and equipment is in progress to arrive at the seismic capacity of the equipment common to general industries and the Indian NPPs.

2.3 OBSERVATIONS FROM SUMMARY REPORT OF THE 4TH REVIEW MEETING

Fourth review meeting of the contracting parties to CNS, had identified the issues and challenges that were common to many contracting parties. Based on the discussions in the plenary sessions of the 4^{th} review meeting, the 'summary report' of the meeting focused on the key topics like 'Legislative and regulatory framework', 'Safety management and safety culture', 'Staffing and competence', 'probabilistic safety assessments', 'ageing management and life extension', 'periodic safety review', 'licensing of NPPs with new and different technologies' and certain general observations related to ‘openness and transparency’ and avoiding complacency regarding safety. These recommendations have been adequately addressed in the relevant chapters of the report and are briefly described below.

‘Legislative and regulatory Framework’ in India is well established as described in Chapters on Article-7 (legislative and regulatory framework) and Article-8 (regulatory Body).

‘Safety management and safety culture’ are important issues in all activities related to nuclear and radiation facilities and hence these issues are addressed in all the relevant articles. For development and management of safety culture, NPCIL has an internal document issued as head quarter instruction (HQI-7006) titled ‘Guidelines for developing strong safety culture’. The document was revised in early 2010. At NPCIL Headquarters’ the Directorate of Quality Assurance (QA), Directorate of Engineering and Procurement, Directorate of Safety, R&D and knowledge management have obtained ISO-9001: 2008 certification.

Development of human resources for nuclear power programme and its regulation has also been a continuous process in India. The country has well established process to recruit and train personnel for NPP design, operation as well as regulation. ‘Staffing and competence’ in AERB and NPCIL are covered in Chapters on Article-8 on Regulatory Body and Article-11 on financial and human resources respectively. The staff strength of AERB and NPCIL is about 211 and 11842 respectively. In addition, premier national R&D centres and academic institutes provide expert technical support.

PSA inputs are increasingly used to supplement deterministic analysis. From utility perspective, PSA applications include technical specification modifications, risk based plant configuration control, improved operator training, assessment of procedures providing basis to severe accident management guidelines. In the revised AERB code on design, Level-1 PSA (full power, internal events) is a mandatory requirement. During design stage, PSA is being used to support and evaluate design. Use of PSA is made for evaluating design back fits and upgrades. Periodic safety review includes review of an updated PSA.

Comprehensive ageing management programmes are established in all the Indian NPPs. The results of these programmes are reviewed before plant start-up after a biennial shutdown and during every renewal of licence for operation. Activities related to ageing management and safety upgrades in the existing nuclear installations are described in chapter on Article-6. Periodic Safety Review (PSR) is a regulatory requirement and is carried out every ten years. During PSR, NPP safety is assessed against the current safety standards & practices and feedback from operating experience. In addition, AERB conducts a review of NPP every five years for licence renewal. This is described in detail in chapter on Article-14.

India has a well established framework of emergency management. The emergency exercises are carried out as per prescribed frequency. Further details on the emergency plans are covered in Chapter on Article-16 on ‘Emergency Preparedness’. Since Indian NPPs are located far away from the borders of neighbouring countries, no trans-boundary implications are expected.

Openness and transparency are two key attributes of AERB to achieve confidence of the stake holders. AERB provides all necessary information to its stakeholders through its periodic newsletters, annual reports, web-site (www.aerb.gov.in), press releases/ briefings and TV interviews. AERB mandate includes such steps as necessary to keep the public informed on major issues of radiological safety significance. The openness which includes formal sharing of information with any member of the public on request is a statutory responsibility under the “Right to Information” Act, 2005. AERB clearly explains the decision-making process to its stake holders. AERB involves the stake holders in development of regulatory documents. AERB also solicits the participation of the utility during safety review process based on which the final decisions are taken. Regulatory awareness programme conducted by AERB includes seminars, discussion meetings, conferences and feedback meetings. Thus continuous efforts are made by AERB to reach out the stakeholders. The utility also provide annual reports, quality and safety policies on its web site (www.npcil.org). On all important issues and developments, NPCIL organises press briefings and issues press releases. NPCIL is also involved in a number of corporate social activities around the NPP sites. On commercial side, information on tenders is available on NPCIL website. Right to Information Act 2005 is also applicable to the utilities.

The NPCIL management and AERB emphasizes that the achievement of high level of safety is through a continuous process which needs periodic re-evaluation of safety goals. This principle has led to safety practices like establishing a strong operating experience feedback program including reporting and analysis of low level events and near misses at each NPP, review of the external operating experience, sharing of safety management practices through management and working level interactions, review of training and retraining programmes. Safety status of all the NPPs in the country is monitored and reviewed on continuous basis both by NPCIL and AERB. All the prescribed regulatory requirements are adhered to and the compliance is monitored by AERB. India has made progress in all the regulatory challenges and planned measures to improve safety identified during the 4th review meeting of the Convention. In addition, future safety related activities are identified and are described below.

2.4 FUTURE SAFETY RELATED ACTIVITIES

2.4.1 Safety Activities Identified during 4th Review Meeting of CNS

India had identified certain challenges and planned measures to improve safety during the presentation made in the fourth review meeting. While the progress on these challenges and planned measures is presented in section 2.2, India will continue its efforts for further improvements in 'External event PSA for 220 MW PHWR NPPs', 'Severe Accident Management Guidelines (SAMG)' , 'Licensing of new designs of reactors' and 'Human resource augmentation at the regulatory body and at the utility'.

2.4.2 New Identified Activities

2.4.2.1 Maintenance of Equipment Qualification in older NPPs

A comprehensive equipment qualification programme for PHWR units is prepared based on current national and international standards, which notably includes IEEE, IEC, ASME, IAEA and AERB requirements. This is being done in response to AERB recommendations emerging subsequent to PSRs of older NPPs with regard to present status of qualification of critical equipment. The SSCs required under design basis accident conditions were identified and were categorized on the basis of their mission time and location. All the identified SSCs were assigned to either of the following classes for the purpose of their equipment qualification;

- to be qualified by testing on sample basis.
- to be modified and then tested.
- to be replaced with those meeting requirements.
- Justification for their continued use based on their location, design specification, etc.

The approach of equipment qualification was reviewed and accepted by AERB. Test procedures have been formulated and sample testing of equipment for RAPS and MAPS is in progress at national facilities.

2.4.2.2 Containment model

A containment model test facility has been built at Tarapur. This model is a scaled (1:4 size) representation of the pre-stressed concrete Inner Containment (IC) structure of 540 MW PHWR of TAPP-3&4. The main objective of the containment model testing is to study the ultimate load capacity and failure modes under high pressure to bench mark and validate various computer codes and analysis methodologies in elastic and in-elastic regimes for the extremely low probability beyond design basis postulated hypothetical accidents resulting in over-pressurization of the containment structure. In addition, containment leakage behaviour under various conditions will also be studied. The data generated would give confidence for design of the future containment, safety evaluation, testing and commissioning of power reactors being constructed.

A pre-test discussion meet was held in 2009 at Mumbai in India which was attended by representatives from University of Innsbruck (Austria), Cervenka Consulting (Czech Republic), CEA (France), Fortum Nuclear Services (Finland), Korea Power Engineering Company and Korea Electric Power Research Institute (South Korea), University of Edinburgh (UK), AERB, BARC and NPCIL'.

In July 2010, the model was pressurized up to 0.5 kg/cm^2 and the leak search was carried out on the entire surface of the model, construction joints and around the openings to identify and plug the minor leakages. Displacement and strain data were collected during the dummy runs as part of the commissioning activity. In August 2010, the model successfully reached the design pressure (0.1413 MPa) during trial pressurization commissioning. The structural data from various sensors (~1200 nos) in the elastic range was collected in addition to the data for the leakage rate evaluation.

2.4.2.3 Experimental Programme in Tarapur R&D Facility

Keeping in view the expanding nuclear power programme and a large number of plants of different types and age in operation, "in-house R&D efforts" are required for continued enhancement of nuclear safety, reduction in unit-energy-cost of nuclear power and reduction in construction completion time and cost of NPPs. The thrust areas of technology development through in-house R&D efforts in NPCIL in the nuclear systems are focused on

- Safety Study Experiments
- New reactor process/equipment development
- Product development
- Rehabilitation Technologies & Remote Tooling
- Construction Technologies
- Endurance Studies
- Ageing & Degradation Studies

Some of the specific development activities undertaken are

- Setting up experimental test facilities such as NPCIL thermal hydraulic test facility for validation of safety analysis codes and AHWR Test facility.
- Setting up hydrogen recombiner test facility: Efficacy of the passive catalyst recombiner devices being developed for mitigation of hydrogen that would be deployed in the containments of nuclear reactors will be tested in this facility.
- Setting up of fuelling machine integrated test facility for calibration & qualification testing of the Fuelling Machines for 700 MW PHWRs. Provisions are also made in the design for testing coolant channel inspection machines. AHWR fuelling machine test facility is also being setup.

- Experimental primary containment clean-up system loop for safety studies.
- Safety experiments for simulation of new design like passive decay heat removal system and containment spray system.
- Coolant channel mock up facilities have been established and experiments conducted for evaluation of energy absorption by integrated yoke studs-yoke-feeders assembly of standardised 220 MW PHWR Units.
- Setting up of reactivity devices test facility.
- Self-powered neutron detectors for 700 MW PHWRs are being specifically developed. These will be in-pile tested for sensitivity evaluation and design qualification before adopting them for reactor use.
- Remote inspection, maintenance, emergency handling and refurbishment / repair technologies including laser based tools & special imaging techniques for EMCCR as well as critical problems faced in different units.
- Environmental ageing test facilities comprising of thermal chambers, humidity chamber, gamma irradiation chamber are established. LOCA Chamber test facility is also set-up recently.
- Flow assisted corrosion loop for ageing and degradation studies.

2.4.2.4 Regulatory review of 700 MW PHWR design

The conceptual design review of the 700 MW PHWR has been completed by AERB and Preliminary Safety Analysis Report (PSAR) is under review. Regulatory consent for excavation for construction of two units has been granted. With this, the excavation work for 700 MW PHWRs based on the indigenous design has started at KAPP 3&4. In order to initiate other construction and commissioning activities, detailed design review is a key regulatory activity as the 700 MW design has certain first of a kind features and systems. This will also provide a framework for licensing of future 700 MW PHWR NPPs.

2.2.2.5 Periodic safety reviews of NPPs

In the next 5 years a number of NPPs are due for PSR. These include TAPS-3 & 4 (due in 2011), RAPS-3&4(due in 2012), KGS-1&2 (due in 2012), NAPS-1&2 (due in 2013) and KAPS-1&2(due in 2014). Carrying out these PSR will be a challenging task for the utility and its review by the regulatory body. The activity will provide insights from 220 MW PHWR of varied ages and the first PSR for 540 MW PHWR.

2.4.2.6 Revision of AERB safety code on siting

AERB Code on 'Siting of NPPs' has been taken up for revision based on the new technological developments and insights from external events.

2.4.2.7 Commissioning of two VVERs at Kudankulam

Two units of 2x1000 MW, VVER of Russian design are being constructed at Kudankulam. The commissioning activities have also started. In the envisaged nuclear power capacity addition programme for the country, LWRs are slated to provide a significant contribution. Construction, commissioning and operation of these reactors will provide very useful experience for the planned expansion of nuclear power program. The experience will also be useful in developing regulatory documents for LWRs. AERB has developed a safety guide for commissioning of LWRs.

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 the 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 shutdown may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

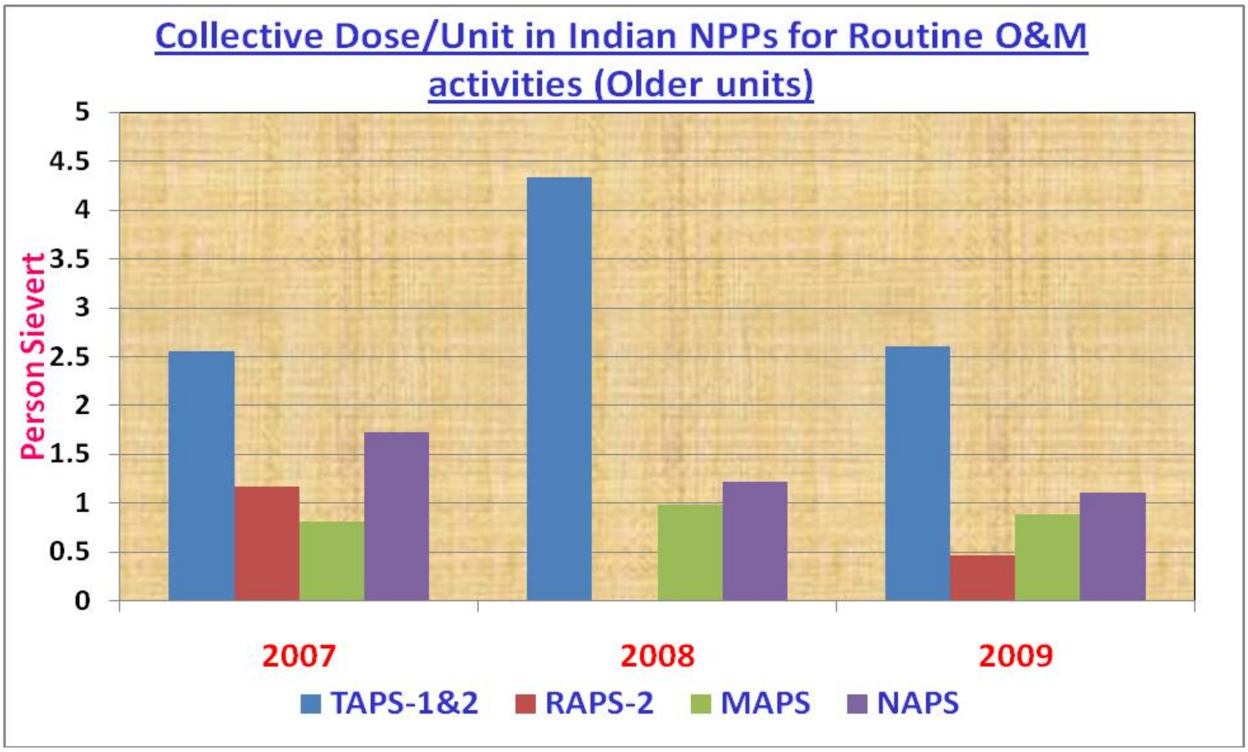
6.0 GENERAL

Nuclear Power was ushered in India in 1969 with commissioning of Tarapur Atomic Power Station (TAPS), comprising two boiling water reactors. Subsequently several Pressurised Heavy Water Reactor (PHWR) based Nuclear Power Plants (NPPs) were set up starting with Rajasthan Atomic Power Station (RAPS unit-1&2). At present nineteen nuclear power reactors are operating in India. Currently two light water reactors and one fast breeder reactor are under different stages of construction.

Nuclear Power Corporation of India Limited (NPCIL) is currently operating all existing operating plants. It is a public sector enterprise, under the administrative control of the DAE, for the design, construction and operation of nuclear power stations for generation of electricity. The mission of NPCIL is to generate and develop nuclear power as a safe, environmentally benign and economically viable source of electrical energy to meet the increasing energy needs of the country.

High safety standards are maintained in all spheres of nuclear power generation right from the inception of the programme in the country. For ensuring this, a comprehensive, independent and effective safety review mechanism has been evolved over a period of time. The concept of third party review and subsequently, that of a formal regulatory review have always been associated with design, construction, commissioning and operation of NPPs. These mechanisms have resulted in progressive improvements in the safety and reliability of units over the years. Every event in an operating NPP is reviewed and lessons are learnt. Analysis of internationally reported events and their applicability to Indian NPPs is checked and accordingly the systems, procedures and aspects related to training & safety culture are further improved. For implementing any safety significant changes in the design and procedures during operation, an elaborate review and approval system is in place. The inputs from operational experience are utilised for design improvements in the new reactors for improving safety and reducing doses to public and occupational workers.

Each station is required to plan and prepare annual budget for collective exposure of occupational workers and get it approved by AERB. The budget preparation takes into account the operational experience, in-service inspections, surveillance checks, bi-ennial maintenance activities and any other major upgrades planned. The stations are required to intimate to AERB, in case the collective dose approaches 80% of the approved budget. If the collective exposure during the year exceeds the approved budget, the station has to provide adequate justification. Figures 6.1 & 6.2 give collective doses received during normal operation and maintenance (O&M) activities, in older and new plants in last three years.



RAPS-2 was shutdown from July 2007 to August 2009 for EMFR

Figure 6.1

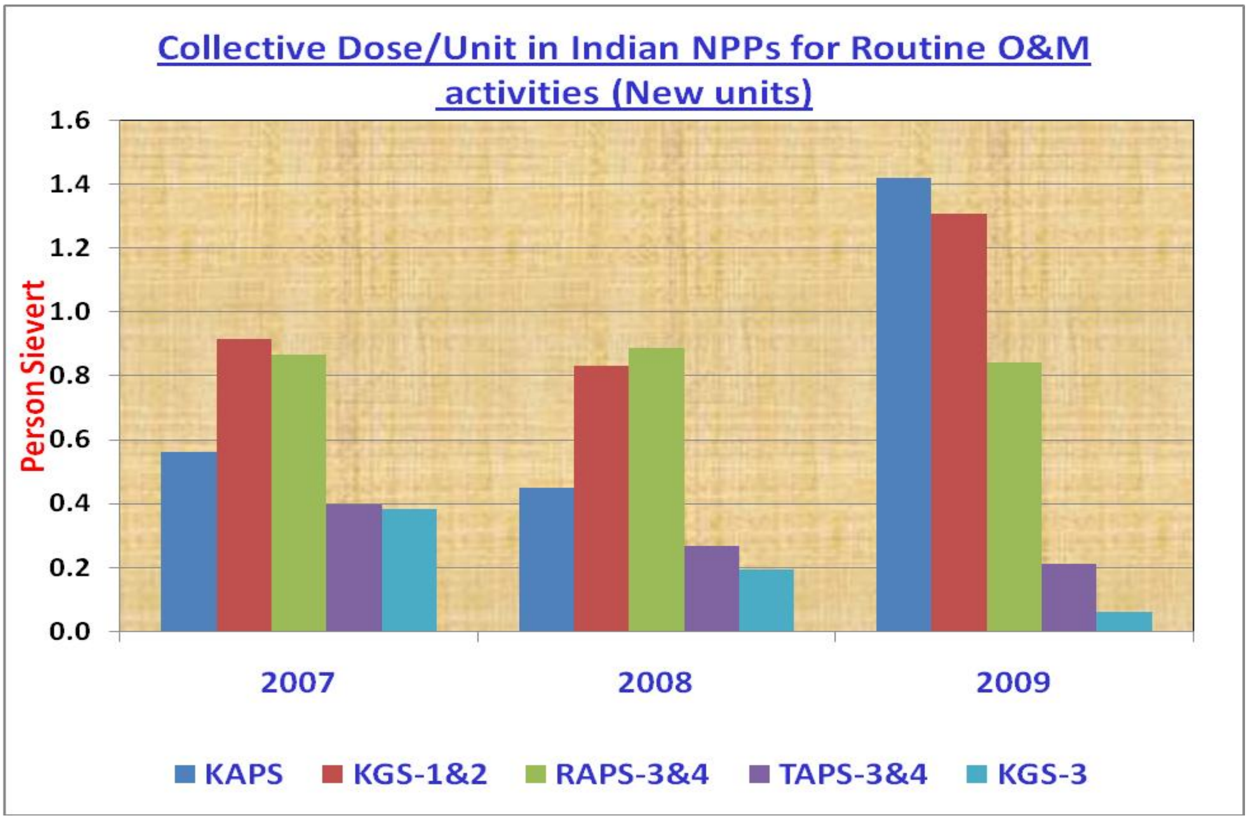


Figure 6.2

In addition to the collective doses to the workers, the radiological impact of NPPs on the environment is also monitored. An Environmental Survey Laboratory (ESL), which is established by BARC at a new site well before commencement of operation of NPP, carries out the assessment of radiological impact of NPP operation and verifies compliance with the radiation exposure limits set by AERB for the members of the public. The area up to a distance of about 30 km is covered under the environmental survey programme. The estimated doses to the public at the exclusion boundary of the Indian NPP sites continue to remain well within limits prescribed by AERB. Figure 6.3 give the environmental dose to public due to NPPs for last three years.

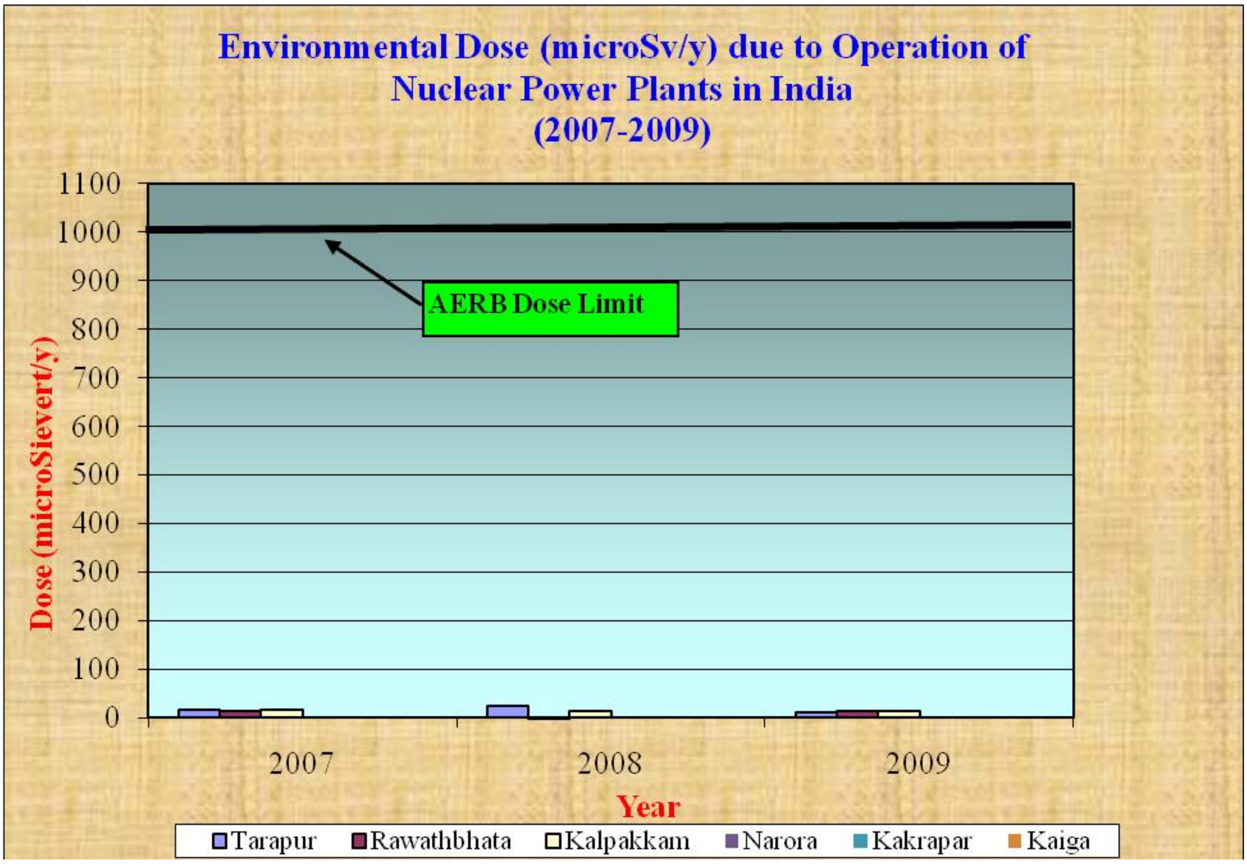


Figure 6.3

Environmental Survey Laboratory (ESL), managed by BARC, is independent of NPP management. Further detail on radiological safety and environmental surveillance is given in Chapter on Article 15: Radiation Protection.

The monitoring of doses to the workers, public and environment assure that safety practices in various aspects of NPP operation are well implemented. However, as a part of abundant precaution well thought out formal emergency preparedness plans are in place at all NPPs. Based on these plans, the exercises for Plant Emergency, Site Emergency and Offsite Emergency are carried out with a frequency of four in a year, once a year and once in two years respectively. Further details on emergency preparedness are given in Chapter on Article 16: 'Emergency Preparedness'. Apart from these measures, each plant is closely monitored by utility and AERB through reviews, inspections, surveillance and other means to identify any developing weakness. Backfits and upgrades are carried out where ever needed. Subsequent sections describe some of the recent measures in different operating NPPs.

6.1 SAFETY MEASURES IN OPERATING NPPs

Operating nuclear installations in India are subjected to continuous regulatory/utility appraisal of safety as per the established requirements. The operational performance and significant events are reviewed and the required modifications are implemented by the utility.

A periodic safety review (PSR) by AERB of operational and safety performance of NPPs which includes factors like changes in safety standards, ageing, new information, etc. are carried out at the time of renewal of licence or major refurbishment or for plant life extension. Such reviews bring out requirements for modification and safety up-gradation, if any. Following these reviews, a number of NPPs have undergone such safety upgrades. In the following paragraphs, current status of each plant along with a brief description of such reviews and consequent safety upgrades has been brought out.

The operational performance of all the NPPS operated by NPCIL has remained satisfactory over the years. The overall weighted average Availability Factor for NPCIL during last few years is brought out in the charts below:

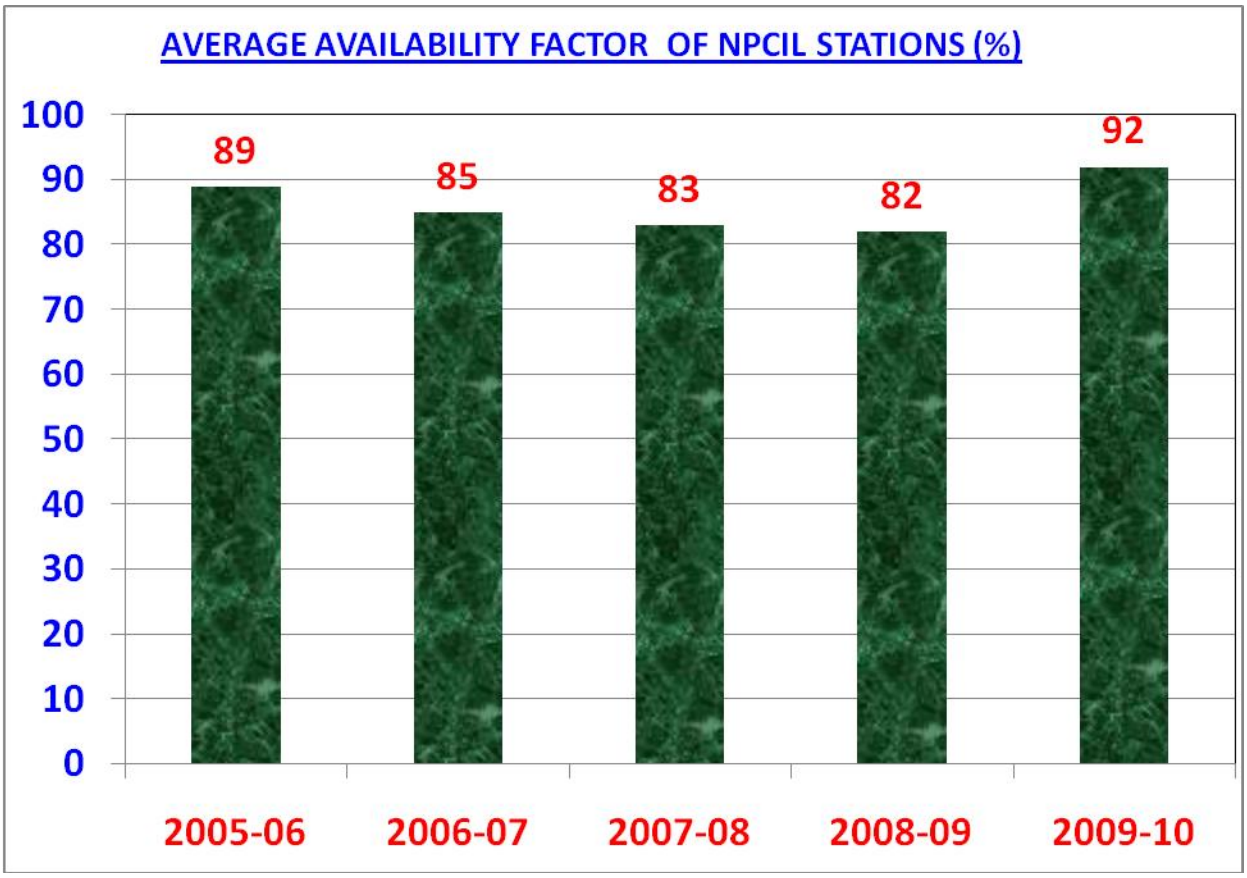


Figure 6.4

6.1.1 Tarapur Atomic Power Station-1&2 (TAPS-1&2)

TAPS-1&2, the first nuclear power station in India started operation in the year 1969. This is a twin unit BWR station, supplied by GE of USA. Since 1984, the reactors are being operated at 160 MW, as against the original rating of 210 MW, owing to tube leakages in the secondary steam generators and their subsequent isolation. The performance of the units has remained steady over the years.

After the station had completed about 30 years of operation, AERB initiated a comprehensive assessment of safety of TAPS units, for their continued long-term operation. This assessment covered the following aspects:

- Review of design basis of plant systems and Safety analysis, vis-à-vis the current requirements.
- Seismic Re-evaluation.
- Review of Ageing Management and residual life of Systems, Structures and Components (SSCs).
- Review of operational performance.
- Probabilistic Safety Assessment.

The original safety analysis of TAPS was reviewed with respect to (a) adequacy of original analytical techniques, (b) list of events analysed, (c) plant design/configuration changes that have taken place over the years. Based on this review, the safety analysis was redone using current analytical methodologies/computer codes. The Safety Report was also updated to reflect (a) design modifications/back-fits, (b) results of fresh analysis performed and (c) adequacy of coverage.

Based on above studies and assessments, several upgrades such as modification in the emergency power supply system, segregation of shared systems as far as practicable, strengthening of the emergency feed water supply to the reactor, provision of supplementary control centres/points, strengthening of supporting arrangements at some places from seismic considerations, up-gradation of fire protection system, etc. were identified. A number of upgrades were implemented in the plant during the refuelling outages of individual units and in a simultaneous long shutdown of both the units during November 2005 to January 2006.

After successful completion of all the identified activities, the units were restarted in February-2006.

6.1.2 Rajasthan Atomic Power Station (RAPS) Units-1&2

The construction of RAPS-1&2 was started at Rawatbhata in Rajasthan during sixties as a collaborative venture with Canada. These units are based on the design of the CANDU reactor at Douglas Point, Canada. RAPS-1 commenced commercial production of electricity in December 1973. RAPS-2, with significantly improved design for the primary heat transport system, was commissioned in April 1981.

RAPS-1, which has had a chequered history of operation since its commissioning, remains under shutdown since October, 2004. A comprehensive review of all aspects of RAPS-1, including techno-economic viability was carried out by NPCIL for its continued operation. Presently, the unit is under shutdown state and all the plant systems are being preserved in accordance with the approved procedures. The core is defueled and heavy water has been drained from PHT and moderator system.

The performance of RAPS-2 has remained satisfactory over the years since its commissioning. The pressure tube material employed in this reactor was Zircalloy-2 (Zr-2), known for its problem of hydriding due to its tendency of accelerated hydrogen pick up during later years of operation. It was decided to undertake en-masse coolant channels replacement (EMCCR) when it completed 8.5 full power years of operation in 1994. All 306 coolant channels made of Zr-2 alloy were replaced with Zr-2.5% Nb tubes. The design of the garter spring spacers on the coolant channel was changed from loose fit to tight fit, in order to preclude the problem of in-service shift of the spacers from their design locations. The number of garter spring spacers in the later design was increased to four per channel from the earlier two per channel, to reduce the length of unsupported span of the pressure tube and to reduce the extent of pressure tube sag and its probability of contacting the calandria tube.

The long shutdown for EMCCR was also utilized for several safety upgrades and design modifications like

- Retrofitting of High pressure Emergency Core Cooling System (ECCS)
- Provision of Supplementary Control Room
- Provision of dedicated instrument air system for essential loads during LOCA.
- Segregation and Rerouting of power and control cables for safety related loads
- Installation of Flood Diesel Generator
- Up gradation of Fire Protection System
- Calandria Vault Dew point monitoring system

In view of the in-house and international experience, station had instituted a comprehensive programme for health assessment of Primary Heat Transport (PHT) system feeders, which are prone to flow assisted corrosion and thinning. Accordingly, all the vulnerable locations on outlet feeders were being subjected to UT thickness measurement routinely during every bi-ennial shutdown. Based on the observations made and residual life assessments carried out, it was decided to undertake en-masse replacement of all PHT system feeders. The unit was shutdown in July-2007 for en-masse replacement of the feeders (EMFR).

The existing feeder pipes in RAPS-2 were made of carbon steel conforming to the specification of ASTM A106 Gr.B. These were replaced with pipes made of SA-333 Grade 6 material. Also, higher thickness elbows of Sch 160 were used in place of Sch 80. In order to have better resistance against FAC, chromium content in the range of 0.22% to 0.25% was specified for replacement components. During the EMFR outage, the inspections related to ageing management, revision of safety analysis and seismic re-evaluation were also carried out and reports were submitted to AERB for review.

PSR of RAPS-2 was also carried out during this time. The major highlights with regard to review of PSR were as follows:

i. Inspections related to long term ageing management of SSCs, including inspections of civil structures, calandria vault internals, support bellows of calandria & end-shields, boiler hairpins and control & power cables indicated that their condition is satisfactory.
ii. Complete revision of Safety Report of RAPS Unit – 2, based on the current plant configuration and the use of latest analytical methods was carried out.
iii. PSA (level-1, full power, internal events) studies were carried out. The review of the PSA indicated that there is no significant concern with regard to continued operation of the unit.
iv. NPCIL also carried out seismic re-evaluation of RAPS 1&2. The retrofits identified during the seismic re-evaluation were implemented at RAPS Unit -2. These were related to strengthening of support for cable trays, strengthening of masonry walls, and anchoring of main control room panels, deaerator storage tank & DG battery chargers.

After satisfactory completion of the review process and completion of EMFR campaign, AERB authorized restart of the unit in September-2009.

6.1.3 Madras Atomic Power Station (MAPS)

Madras Atomic Power Station (MAPS), a twin-unit PHWR plant, each with 220 MW capacity, is located at Kalpakkam on the East Coast of India about 60 km south of the city of

Chennai. The design of MAPS was developed indigenously and several new features compared to RAPS-1&2 were incorporated. Partial double containment and the concept of suppression pool for vapour suppression to limit the containment peak pressure during loss of coolant accident were introduced. Also, in the backdrop of problems with the end shields in RAPS unit-1, the end shield material was changed from 3.5% Nickel Carbon Steel to SS 304L for MAPS-2.

As per original design, both the units had coolant channels made of Zr-2 alloy with two loose fit garter springs. A well-structured assessment and life management programme for Zr-2 pressure tubes was in place for operation of the reactors. This involved periodic inspection of a large number of coolant channels and collection of sliver samples for estimation of hydrogen pick up for ensuring fitness for continued service. In view of the assessments made, it was decided to take up EMCCR in these units also. Accordingly, MAPS-2 completed en-masse coolant channels replacement project during January-2002 to July-2003, and MAPS-1 during August-2003 to January-2006. The Station was also subjected to periodic safety review as per the requirement of AERB/SG/O-12. Additionally, seismic re-evaluation was also addressed as a result of PSR. Based on these reviews, following important safety upgrades were also implemented during the shutdown for EMCCR.

- Introduction of high pressure emergency core cooling system
- Addition of supplementary control room
- Segregation of power and control cables
- Replacement of MG sets with static UPS in Class II power supply system
- Dedicated instrument air system for identified loads
- Addition of Calandria Vault dew point monitoring system
- Augmentation of fire protection system

Apart from the above safety upgrades, hair pin heat exchangers in the steam generators were replaced. Feeder elbows were also replaced in MAPS-1. Following failure of calandria moderator inlet manifolds of MAPS 1&2 in 1988-89, the MAPS units power was restricted to 75% FP to limit the tube sheet temperatures within permissible limits. In order to restore the original moderator heavy water flow pattern in the calandria, three moderator inlet spargers were installed at the lowest coolant channel lattice positions in these units. After the commissioning of the spargers, 100%FP operation of both the units was restored.

6.1.4 Narora Atomic Power Station (NAPS)

This station located at Narora in District Bulandshahr, Uttar Pradesh has the first two 220 MW units based on standardised Indian PHWR design. The units were designed with several new features like double containment, two independent and diverse shutdown systems, full tank calandria with water filled calandria vault, integral end shield & calandria with Zr-2 pressure tubes employing four loose fit garter springs. The gap between pressure tubes and calandria tubes forms a closed annulus, achieved through provision of bellows. The annulus is purged with CO_2 and monitored for dew point for pressure tube leak detection. The units are also provided with closed loop process water-cooling system. Mushroom type steam generators with incoloy 800 tubes were employed first time in NAPS in NAPS. The performance of these units has remained satisfactory over the years.

Narora-1 was shutdown on October 31, 2005 for EMCCR and other up-gradation activities. Zircaloy-2 pressure tubes with four loose garter springs were replaced by Zr-Nb (2.5%) pressure tubes and four tight-fit garter springs. The PHT feeders were also replaced by new feeders made of SA 333 Grade-6 material that has higher resistance to flow assisted corrosion. Some of the major upgrades carried out were permanent venting provision for end shields, replacement of moderator pumps with canned rotor pumps, replacement of fire alarm system, and replacements of RTDs in channel temperature monitoring system and several other modifications to resolve obsolescence issues. After completion of all related activities, the unit was re-commissioned and has been operating satisfactorily since 25th February, 2008.

EMCCR activities for NAPS-2 were started in December-2007. All coolant channels and PHT system feeders have been replaced. Modifications/upgrades carried out in NAPS-1 were also carried out in NAPS-2. Re-commissioning of various systems has been undertaken and the unit is likely to be restarted in 2010.

6.1.5 Kakrapar Atomic Power Station (KAPS)

This station located at Kakrapar in District Surat, Gujarat comprises of two 220 MW units based on standardised Indian PHWR design. The design features are similar to those at NAPS. However, based on the information available on the performance of Zr-2 pressure tubes, the material of pressure tubes in KAPS unit-2 was changed to Zr-2.5%Nb and four tight fit garter springs were provided. Improvements were also made in control and instrumentation system as per the state of the art technology available. The performance of the units over the years has been satisfactory.

In view of the observations during in-service inspections, residual life assessment for coolant channels and completion of about 10.1 years of full power operation, EMCCR activities were taken up in KAPS-1 in July-2008. Zr-2coolant channels have now been replaced with Zr-2.5%Nb tubes and four tight fit garter springs have been provided. All feeders in PHT system have been replaced. In addition, upgrades similar to those in NAPS are also being implemented. The unit is likely to be restarted in the in 2010. AERB will carry out further review of all activities carried out, including upgrades; before permission is granted for re-start of KAPS-1.

Some of the observations during review for renewal of licence for operation of KAPS Unit-1&2 for five years are summarized below.

a) Differential axial elongation of coolant channels

KAPS-2 has pressure tubes made of Zr 2.5% Nb material. During the axial creep measurement campaign carried out in BSD-2006, significant differences were observed in the axial elongation of some of the adjacent coolant channels in the core. The observations suggest that the adjacent coolant channels displaying differential expansion are made of material with different chemical compositions. The differential elongation in the adjacent coolant channels may cause interference between the feeders and feeder coupling hardware of the channels belonging to same feeder bank preventing free expansion of coolant channels. Similar phenomenon has been noticed in other operating units (RAPS-2, KGS-1&2 and RAPS-3&4) having Zr-Nb coolant channels. For long term life management of coolant channels, NPCIL developed a strategy involving (a) periodic monitoring of axial creep (b) repositioning of the channels towards fixed end to establish the required gaps at floating end for the set of channels having lower margins on differential elongation (c) defuelling and wet quarantining of the channels elongating faster to retard its elongation. As per the above programme, the status of the channels and the clearances are being monitored regularly in every BSD.

b) High diametric creep in coolant channels of KAPS Unit -2

During the BSD in February, 2009, inspection results indicated that the diametric creep in some of the inspected coolant channels is higher than anticipated. The issue of higher than anticipated diametric creep and its implications with respect to continued operation were reviewed in detail. The conservative thermal hydraulic assessments carried out by NPCIL and BARC to study the effect of increase in diameter of channel, on Minimum Critical Heat Flux

Ratio (MCHFR) indicated that significant margins would still be available, even with diametric creep exceeding 3% and there was no immediate safety concern. In view of these observations NPCIL had undertaken various studies and assessments for deciding the acceptable service life of pressure tubes and the future action plan for life management of Zr-2.5% Nb pressure tubes. The studies identified for this purpose include (a) assessment of MCHFR for diametric creep more than 3%, (b) structural integrity assessment for coolant channels under increased diametric creep.

6.1.6 Kaiga Generating Station (KGS-1&2)

This station located at Kaiga, in District Uttar Kannada, Karnataka comprises of two 220 MW units based on improved version of standardised Indian PHWR design. The major improvements in the design over the standardised 220 MW PHWR design are (a) full double dome containment (b) introduction of unitised concept for control room, (c) valve-less primary heat transport system and (d) state-of-the-art control and instrumentation system.

6.1.7 Rajasthan Atomic Power Station (RAPS) Unit-3&4

This station located at Rawatbhata, in District Chittorgarh, Rajasthan comprises of two 220 MW units of design similar to KGS-1&2. These units were also commissioned in the year 2000 and the operational performance has been satisfactory since then.

6.1.8 Tarapur Atomic Power Station (TAPS) Unit-3&4

The 540 MW PHWR units, set up at Tarapur are evolved from standardized Indian 220 MW PHWR with essentially similar safety design features. Certain modifications were necessitated due to larger core, which includes global and local power control through liquid zone control system, two loops of primary coolant system, and pressurizer. The safety systems of 540 MW units, include two independent, diverse, fast acting, physically separated shutdown systems (SDS), emergency core cooling system and double containment with associated engineered safety features.

AERB granted the initial licence for operation of these units after an extensive review of the commissioning results. TAPS-4 commenced its commercial operation in September 2005 and TAPS-3 in August 2006. The performance of the units since commissioning has been satisfactory.

6.1.9 Kaiga Generating Station (KGS) Unit-3&4

This station, comprising of two 220 MW, is also located at Kaiga, adjacent to the KGS-1&2, KGS-3 started commercial operation from 6th May-2007. Major commissioning activities for KGS-4 have been completed and the unit is likely to become operational in the financial year 2010-11.

Since the commencement of commercial operation, KGS-3 has experienced teething troubles including some major equipment failures, some of which are briefly described below.

a) Generator Stator

In August 2007, while unit-3 was operating at 87% full power, TG tripped on “Stator Earth Fault Protection”. Subsequent investigations revealed the main cause as the breaking of Teflon tubes from stator water outlet header of stator conductor inside the generator, which led to escape of hydrogen from the generator to stator water system. This caused cavitation of stator water pump leading to reduction of stator water flow to stator core. After some time, Generator tripped on earth fault protection due to loss of Insulation Resistance (IR) in Y-phase.

Based on the indications of the extent of damage, it was decided to replace the generator.

b) Leak from End Shield

The Indian PHWR has Annular Gas Monitoring System (AGMS) for early detection of leak from the coolant channels. The annular space between each pressure tube and calandria tube is monitored for presence of moisture through rise in dew point. In June-2007, tri-junction weld in one of the lattice positions started leaking resulting in water from end shield getting into AGMS. South end fitting of channel O-10 and the coolant channel were cut and removed to facilitate access to leak location. Further investigations were carried out to confirm the defect location and its characterization. Remote tools were designed & fabricated for the weld repair. Mock-ups were developed for qualification of the tools, procedure and manpower. The repair was successfully carried out in Decembr-2007.

After replacement of the generator and repair of the end shield leak, the unit was synchronized to grid in April-2008.

6.1.10 Rajasthan Atomic Power Station (RAPS) Unit-5&6

This station located at Rawatbhata, in District Chittorgarh, Rajasthan comprises two 220 MW units of design similar to KGS-3&4. RAPS-5 started commercial operation from 4th February-2010 and RAPS-6 from 31st March-2010. The units are undergoing stage wise regulatory review for achieving rated power operation.

6.2 ASSESSMENTS PERFORMED FOLLOWING SIGNIFICANT EVENTS

As part of operation safety experience feedback programme established, events occurring within the country and abroad are reviewed regularly. Comprehensive safety reviews are also carried out both by the utility and AERB in response to major events. Through these reviews important lessons are learnt and wherever applicable improvements in design, procedures, training, safety culture, etc are made.

6.2.1 Inadvertent Opening of Instrumented Relief Valve (IRV) at NAPS-1

An incident of inadvertent partial opening of one of the primary heat transport system IRV occurred during NAPS-1 operation. The investigations brought out that the IRV actuator diaphragm failed due to improper tightening of the bolts carried out earlier to arrest a minor air leak. The operator tripped the pressuring pumps prematurely without waiting for automatic actions. Due to reduction in PHT pressure, Emergency Core Cooling System actuated and the reactor containment got isolated. The Emergency Operating Procedure did not foresee partial opening of IRV as well as delayed isolation of BCD.

Several corrective actions were taken after the event. These included revision of maintenance procedures for valve actuators, revision of EOP for IRV opening, retraining of operators on stimulator etc. The lessons learnt from this event were shared with all NPCIL units and necessary corrective actions were implemented.

6.2.2 PHT System Instrumentation Tubing Failures due to Fretting

During January to March 2009, three events of heavy water leak due to fretting damage to Primary Heat Transport (PHT) instrumentation tubing took place in different NPPs. The events took place in the feeder cabinet area which houses tubes for delayed neutron monitoring (DNM) and instrumentation for flow and pressure monitoring in PHT system.

Thorough survey of feeder cabinets in all the affected units was carried out to assess the condition of PHT tubing. The inspection results indicated interference of some instrument tubes with adjacent feeder piping and other components. Suitable re-routing of tubes was done to ensure a minimum gap of 7-8 mm with adjacent components.

In view of the incidents, enhanced visual inspections are planned in feeder cabinets every two years, to ensure adequate gap among instrument tubes and nearby components. A comprehensive assessment and corrective action program has been implemented at all the NPPs to eliminate fretting damage to instrument / DNM tubing in PHT system.

6.2.3 Incident of Tritium Uptake at KGS-1&2

On 24/11/2009, routine bioassay sample analysis in health physics lab indicated off normal tritium uptake for some of the workers. It was observed that the persons not involved in any radioactive job/handling heavy water during the period had also received uptake. The general radiological conditions in both the KGS units were normal. Suspecting a common cause problem, water samples from all drinking water coolers, wash rooms and showers were collected and analyzed. The analysis of the drinking water cooler located in service building near clothing crib revealed presence of Tritium. This water cooler was immediately isolated and cordoned off.

The bioassay sample analysis for all the radiation workers (about 800) was completed and 92 persons were found to have received tritium uptake exceeding 4 MBq / litre (equivalent to 2 mSv). The exposure to two plant workers marginally exceeded the annual AERB limit of 30 mSv.

The investigations carried out indicated that some heavy water containing tritium was deliberately added to the drinking water cooler with malafide intent. In light of the incident, necessary preventive measures have been implemented and actions taken at all stations to secure heavy water sources.

6.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Since the inception of the atomic energy programme in the country, priority has been given to the adoption and maintenance of high safety standards. Safety status of the NPPs is regularly monitored by an established system and also during renewal of licence for operation every five years. Replacements and modifications of the structures, systems and components important to safety are carried out. Up-gradations are also carried out to resolve obsolescence issues. Every event is promptly reviewed and lessons are learnt. Analysis of international events and their applicability is checked and accordingly the systems, procedures, aspects related to training and safety culture are further improved. All the reactors operating in the country have shown improvement in their performance and their safety records have been excellent. Therefore, the country complies with the obligations of Article 6 of the Convention on Nuclear Safety.

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 licence:**
    iii. **a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;**
    iv. **the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.**

7.0 GENERAL

India is a Union of States. It is a Sovereign Socialist Democratic Republic with a parliamentary system of government. The Constitution provides for a Parliamentary form of government which is federal in structure. The Constitution distributes legislative powers between the Parliament and State Legislatures as per the lists of entries in the Seventh Schedule of the Constitution. The subject 'atomic energy and the mineral resources necessary for its production' are placed in the union list in this. The laws pertaining to atomic energy are enacted by the Parliament and enforced by the Central Government.

7.1 ESTABLISHING AND MAINTAINING LEGISLATIVE AND REGULATORY FRAMEWORK

Atomic Energy Act 1962 and rules framed there under provide the main legislative and regulatory framework pertaining to atomic energy in the country. The act was enacted to provide for the development, control and use of atomic energy for the welfare of the people of India and for other peaceful purposes and for matters connected therewith. The Act also provides Central Government with the powers to frame rules or issue notifications to implement the provisions of the Act. The rules framed under the Act are laid on the floor of both the houses of the Parliament. In addition to the provisions of the Atomic Energy Act, the provisions of several other legislations related to environment, land use, etc have also to be met for locating and operating Nuclear Power Plants (NPPs). The provisions of these acts are enforced by Central or State Government, as the case may be. Some of the important legislations that have a bearing on the establishment of NPPs are summarised below

7.1.1 Atomic Energy Act 1962

The following paragraphs briefly describe the salient provisions of this act.

i. Powers of the Central Government in the domain of atomic energy

Section 3 of the Act describes the powers of Central Government in the domain of atomic energy including the powers (i) to produce, develop, use and dispose of atomic energy; (ii) to provide for the production and supply of electricity from atomic energy, (iii) to provide for control over radioactive substances or radiation generating plant in order to (a) prevent radiation hazards; (b) secure safety of public and plant personnel and (c) ensure safe disposal of radioactive wastes; etc. The Central Government is also empowered to fulfil the responsibilities assigned by the Act either by itself or through any authority or Corporation established by it or a Government company.

ii. Control over Mining or Concentration of Prescribed Substances

Section 4 to section 13 of the act gives wide-ranging authority to the Central Government for harnessing and securing the prescribed substances useful for atomic energy.

iii. Control over production and use of atomic energy

Section 14 of the Act gives the Central Government control over production and use of atomic energy and prohibits these activities except under a licence granted by it. Subsection 2 of this section gives the Central Government powers to refuse licence or put conditions as it deems fit or revoke the licence. Sub section 3 of this section of the Act also gives the Central Government powers to frame rules to specify the licensees the provisions in the areas of

a. control on information and access,
b. measures necessary for protection against radiation and disposal of by-products or wastes
c. the extent of the licensee's liability and
d. the provisions by licensee to meet obligations of the liability either by insurance or by such other means as the Central Government may approve of.

iv. Control over radioactive substances

Section 16 of the Act gives the Central Government power to prohibit the manufacture, possession, use, transfer by sale or otherwise, export and import and in an emergency, transport and disposal, of any radioactive substances without its written consent.

v. Special Provisions as to safety

Section 17 of the Act empowers the Central Government to frame rules to be followed in places or premises in which radioactive substances are manufactured, produced, mined, treated, stored or used or any radiation generating plant, equipment or appliance is used. This section gives the Central Government authority to make rules to prevent injury being caused to the health of the persons engaged or other persons, caused by the transport of radioactive or prescribed substances and to impose requirements, prohibitions and restrictions on employers, employee and other persons. It also gives the Central Government authority to inspect any premises, or any vehicle, vessel or aircraft and take enforcement action for any contravention of the rules made under this section.

vi. Special provisions as to electricity

Section 22 of the Act gives the Central Government the authority to develop national policy for atomic power and coordinate with national & state authorities concerned with control and utilization of other power resources for electricity generation to implement the policy. It authorizes the Central Government to fulfil the mandate either by itself or through any authority or corporation established by it or a Government Company.

vii. Administering Factories Act, 1948

Section 23 gives the Central Government authority to administer the Factories Act, 1948 to enforce its provisions including the appointment of inspection staff in relations to any factory owned by the Central Government or any Government Company engaged in carrying out the purposes of the Act.

viii. Offences and Penalties

Section 24 of the Act gives provision for imposing penalties. Whoever contravenes any order or any provision of the Act shall be punishable prosecution with imprisonment, or with fine, or both.

ix. Delegation of powers

Section 27 of the Act gives the provision for the Central Government to delegate any power conferred or any duty imposed on it by this Act to any officer or authority subordinate to the Central Government, or state government, as specified in the direction.

x. Power to make rules

Section 30 of the Act gives the provisions for the Central Government to frame rules for carrying out the purposes of the Act.

7.1.2 Indian Electricity Act 2003

Indian Electricity Act, 2003, consolidates the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry. The act prohibits any person from transmission or distribution or trading in electricity unless he is authorised to do so by a licence issued under section 14, or is exempt under section 13 of the Act.

7.1.3 Environment (Protection) Act 1986

The Environment Protection Act, 1986 provides for the protection and improvement of environment and matter connected therewith. All projects or activities, including expansion and modernization of existing projects or activities, require prior environmental clearance from the Central Government in the Ministry of Environment and Forests (MoEF) on the recommendations of an Expert Appraisal Committee (EAC).

7.1.4 Factories Act 1948

The Factories Act is a social legislation which has been enacted for occupational safety, health and welfare of workers at work places. The administration of the provisions of the Factories Act 1948, in the units of Department of Atomic Energy (DAE) is done through Atomic Energy (Factories) Rules, 1996.

7.1.5 Other Applicable Legislations

The other applicable legislation for locating and operating NPPs in the country include

a. The Water (Prevention & Control of Pollution) Act, 1974
b. The Air (Prevention & Control of Pollution) Act, 1981
c. The Water (Prevention & Control of Pollution) Cess Act, 1977
d. Indian Explosive Act 1884, and Indian Explosive Rule, 1983
e. Disaster Management Act, 2005

7.1.6 International Conventions related to Nuclear Safety

India is party to Convention on Early Notification of a Nuclear Accident (1986), and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (1986) and Convention on the Physical Protection of Nuclear Material (1987), International Convention for Suppression of Acts of Nuclear Terrorism (2005) and complies with their obligations. The Government of India ratified the Convention on Nuclear Safety on March 31, 2005.

7.2 PROVISIONS OF LEGISLATIVE AND REGULATORY FRAMEWORK

7.2.1 National Safety Requirements and Regulations

7.2.1.1 Subordinate Legislation for Nuclear safety

The national legislative requirement on nuclear and radiological safety for all activities related to atomic energy program and the use of ionising radiation in India is provided by Sections 3 (e) (i), (ii) and (iii), 16, 17 and 23 of the Atomic Energy Act, 1962. Also, exercising powers under section 30 of the Act, the Central Government has framed rules to implement the provisions of the Act which are subordinate legislation for regulation. These cover radiological safety, management of radioactive wastes, administration of Factories Act and prescription of qualifications of persons employed in installations dealing with radioactive substances or use of any radiation generating plant, equipment or appliance.

Chairman, Atomic Energy Regulatory Board (AERB) is the 'Competent Authority' to exercise the powers conferred on it as per the rules framed under the safety provisions given in the Act.

I. Rules Framed under the Atomic Energy Act, 1962

Under the Atomic Energy Act 1962, the Central Government promulgated the following rules:

i. Atomic Energy (Radiation Protection) Rules 2004, GSR 1691: These rules give requirement of consent for carrying out any activities for nuclear fuel cycle facilities and use of radiation for the purpose of industry, research, medicine, etc.

ii. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987, GSR 125: establishes the requirements for the disposal of radioactive waste in the country.

iii. Atomic Energy (Control of Irradiation of Food) Rules, 1996 G.S.R 254: The irradiation of food in the country is regulated as per rules Atomic Energy (Control of Irradiation of Food) Rules, 1996 .

iv. Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules, 1984, GSR 781. These rules regulate the activities pertaining to mining, milling, processing and/or handling of prescribed substance.

v. Atomic Energy (Arbitration Procedure) Rules, 1983: These rules were framed to regulate arbitration procedure for determining compensation.

II. Atomic Energy (Factories) Rules, 1996

The Central Government exercising the powers conferred by sections 41, 49, 50, 76, 83, 112 and all other enabling sections of the Factories Act, 1948, read with sections 23 and 30 of the Atomic Energy Act, 1962, had framed the Atomic Energy (Factories) Rules, 1984 to administer the requirement of Factories Act in the nuclear establishments to ensure industrial safety. These rules were revised in 1996 and superseded by Atomic Energy (Factories) Rules 1996. G.S.R 253. (The Gazette of India Part II Sec 3(i) June 22, 1996)

III. Rules arising from other Legislations

In addition to above, the safety requirements of other applicable legislations also need to be met for establishing and operating NPPs in India. The central or state agencies, as the case may be, have been identified to regulate the safety provisions of these acts and the applicants are required to obtain necessary clearances from these agencies. Some of the important applicable legislations are mentioned here.

i. Environment Protection Act,1986, and Environment (Protection) Rules,1986, which provides safety requirement and regulation for the protection of environment, requires prior environmental clearance from Central Ministry of Environment and Forests (MoEF) for establishing nuclear power stations. Public hearing is conducted as per the 'procedure for conduct of public hearing' given in the gazette notification from MoEF. The hearing is conducted on the environmental and social impact of the nuclear power station. The hearing allows public to express its views and receive answers to its questions.

ii. The Pollution Control Boards (PCB), ensure implementation of the following legislations related to the protection of the environment in the country.

   a. The Water (Prevention & Control of Pollution) Act, 1974
   b. The Air (Prevention & Control of Pollution) Act, 1981
   c. The Water (Prevention & Control of Pollution) Cess Act, 1977
   d. The Hazardous Waste (Management, Handling and Transboundary Movement), Rules 2008.

iii. The Indian Electricity Act, 2003 and Indian Electricity Rules, 2005 covering various aspects of electrical safety also apply to NPPs. The Electricity Inspector of Electricity Board of the concerned state is designated as the authority to implement the provisions of these acts & rules.

iv. The Indian Boilers Act, 1923 also applies to the boilers used at NPPs and the authority to implement the provision of this act vests with the Boiler Inspector of the state under which the plant is located.

v. Indian Explosives Act 1884 and Indian Explosives Rules 1983 provide the Central Government power to prohibit manufacture, possess, use, sell, transport of explosives except under a licence granted by it. The Directorate of Explosives regulates the provision of this Act and the rules for use and storage of materials such as Diesel, Chlorine, compressed air, fuel oil etc.

Annex 7-1 gives a list of the important legislations and the agencies identified to regulate them.

7.2.1.2 AERB Safety Codes and Guides

One of the mandates of AERB is to formulate safety requirements for nuclear and radiation facilities. For NPPs, AERB has issued Safety Codes for Regulation, Siting, Design, Operation and Quality Assurance and also several safety guides and manuals under these Codes. Safety codes establish objectives and set minimum requirements that have to be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. Safety Guides provide guidelines and indicate methods for implementing specific requirements prescribed in the Codes. Safety Manuals elaborate specific aspects and contain detailed technical information and procedures. During the preparation of these documents, the safety requirements recommended by IAEA and the regulatory agencies of other countries are also considered. The safety documents are reviewed and updated periodically based on experience and scientific developments and to harmonize these with the recommended current safety standards of IAEA. The existing good practices are also incorporated.

AERB also issues safety directives on dose limits for radiation workers and members of public which are in line with the recommendation of the International Commission on Radiological Protection (ICRP).

7.2.1.3 Process of Developing and Revising Safety Codes and Guides

As mentioned above, one of the mandates of AERB is to develop safety codes and guides for regulation of nuclear and radiation facilities. The need for a development / revision of a safety document is identified by the various Divisions of AERB. Having identified the document to be prepared / revised, a Safety Document Development Proposal (SDDP) is prepared and circulated within AERB for comments. The SDDP is reviewed by advisory committees for development of safety documents as applicable (please refer section 8.1.2.4 in Article 8). The SDDP of the document for NPPs is further reviewed by Advisory Committee on Nuclear Safety (ACNS) and is finally approved by Chairman, AERB. The SDDP for safety codes is approved by the Board of AERB. Based on the SDDP, the draft of the document is prepared by a working group constituted for the purpose. The document is reviewed and approved following the same procedure as for the SDDP.

AERB follows a system of "multi-tier committees" to prepare safety documents. The system ensures that the documents are based on expert opinion and are unbiased. The specialists from AERB, user organisations, technical institutions like Indian Institutes of Technology, national research laboratories and universities are members in the various committees.

7.2.2 System of Licensing

7.2.2.1 Requirements and Legal Provisions of Licensing under the Atomic Energy Act

Section 14 of the Act specifies the requirement of obtaining licence from the Central government for production and use of atomic energy. Section 16 of Act prohibits the manufacture, possession, use, transfer by sale or otherwise, export and import and in an emergency, transport and disposal, of any radioactive substances without obtaining the consent of the Central government. Further, Section 17 of the Act gives the Central Government power to prescribe the requirement for safety and waste management.

The Competent Authority grants the Regulatory Consent / Licence in accordance with the provisions of the Section 16 and 17 of the Atomic Energy Act, 1962 and the Rule 3 of the Radiation Protection Rules, 2004. Rule 3 of the RPR 2004, prescribes that a licence from the Competent Authority is necessary for handling any radioactive substance. Rule 3 of the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987, stipulates that an Authorisation from the Competent Authority is required for disposal or transfer of radioactive wastes. Rule 4 of Atomic Energy (Factories) Rules 1996 prescribes that 'Approval' of the Competent Authority shall be obtained for using any premises as a factory for purposes of the Atomic Energy Act 1962. Chairman, AERB is the competent authority designated by the Central Government for issuing consents/licenses as applicable under the above said rules.

AERB issues the licence to an NPP and carries out safety monitoring, inspection and enforcement activities under the provisions of above legislations. AERB code of practice ‘Regulation of Nuclear and Radiation facilities (AERB/SC/G: 2000)’ specifies the minimum safety related requirements/obligations to be met by a nuclear or radiation facility to qualify for the issue of regulatory consent / licence at every stage leading to eventual operation.

These licenses are issued by AERB on the basis of its review and assessment. Compliance to the regulatory requirements is verified by conducting periodic regulatory inspections. In general AERB adopts a multi-tier review process for new projects and operating NPPs. The code also elaborates on regulatory inspection and enforcement to be carried out by the Regulatory body in such facilities. For NPPs, the consents are issued for the major stages like Siting, Construction, Commissioning and Decommissioning and licence is issued for Operation. After the issuance of licence for operation, AERB establishes the system of regulatory review and assessment by way of reporting obligations, periodic safety review and regulatory inspections & enforcements. Annex 7-2 typically indicates various requirements for locating and operating NPPs in India and Annex 7-3 shows the hierarchy of the regulatory framework.

The detailed licensing process in India is described in Article 14 on Assessment and Verification of Safety.

7.2.2.2 Consenting Process for Nuclear Power Plants

AERB safety code on 'Regulation of Nuclear and Radiation Facilities AERB/SC/G: 2000' gives the mandatory requirements/obligations to be met by a nuclear or radiation facility, to qualify for the issue of regulatory consent/licence. The Safety Guide "Consenting Process for Nuclear Power Plants and Research Reactors" AERB/NPP&RR/SG/G-1:2007 defines the regulatory consenting process for all the major stages of a nuclear power plant/research reactor. It covers in detail the information required to be included in the submissions to AERB, mode of document submissions and their classification, and areas of review and assessment for granting the regulatory consent. The major stages of consenting process for NPPs/Research Reactors are Siting, Construction, Commissioning, Operation and Decommissioning. AERB may also consider pre-licensing safety review.

Safety in siting, design, construction, commissioning and operation of the facilities is ensured primarily through regulatory actions including grant of consent for activities and imposition of conditions on the applicant. AERB performs these actions on the basis of its review and assessment. In general, a three-tier review process is followed by AERB before any major activity concerning NPP, is granted consent. In certain cases AERB may opt for alternative review process as deemed necessary. Detailed review methodology is given in section 14 of this report.

7.2.3 System of Regulatory Inspection and Assessment

Regulatory Inspection is one of the responsibilities and functions of AERB. The Regulatory inspection and assessment process ensures:

i. compliance with the safety provisions of the primary and subordinate legislations and other consenting conditions;
ii. that nuclear facilities are sited, constructed and operated in conformity with design intent duly approved by AERB;
iii. that safety-related structures, components and systems are of approved quality based on acceptable standards; and
iv. the facilities operate within the approved Technical Specifications for Operation and the respective operating personnel are competent to operate the facility safely.

7.2.3.1 Legal Provision for Regulatory Inspection

Section 8 of the Act gives the Central Government powers to enter and inspect any mine, premises and land for the purpose of the Act. For the purpose of safety, subsections 4 and 5 of Section 17 of the Act gives the Central Government powers to inspect any premises, vehicle, vessel or aircraft and take enforcement actions to prevent any contravention of the rules framed under the provision of this section. The provisions of Atomic Energy (Radiation Protection) Rules 2004, Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and Atomic Energy (Factories) Rules, 1996 are also enforced by AERB. A system of regulatory inspection is established to verify compliance with the rules. The powers to inspect and take enforcement actions for industrial safety are drawn from the provisions of section 8 & 9 of the Factories Act 1948. AERB Code of practice in Safety on Regulation of Nuclear and Rdiation facilities AERB/SC/G : 2000 and safety guides and manuals issued there under provides the details regarding the system of regulatory inspection and enforcement.

Other governmental bodies like PCB, MoEF also carry out inspection from time to time for enforcement of the requirements relating to conventional pollutants, environmental aspects etc.

7.2.3.2 Inspection Strategies and Assessment Method

The regulatory inspection strategies are comprehensive and developed within the overall regulatory strategy to ensure that nuclear and radiation facilities comply with the regulatory requirements. Inspections are carried out as necessary during all stages of consenting process. The extent to which inspection is performed in the regulatory process depends upon the importance of the consenting stages with respect to safety and potential, magnitude or nature of the hazard associated with the type of activity.

AERB undertakes inspection activities as per its inspection schedule or as warranted by any event. For all routine/planned regulatory inspections the areas and frequencies of inspection are specified. AERB can also carry out surprise inspections.

Verification of overall safety performance also requires inspections that focus on a relatively broad range of subject areas, with adequate depth and frequency. Each planned inspection has specific objectives, which are identified in advance and informed to the plant management and the inspection personnel. On the other hand, during regulatory inspection following an event, specialists carry out an in-depth review of the areas relevant to the event.

The observations made during regulatory inspections are categorized according to their safety significance. Inspection findings and utility response are reviewed in AERB and enforcement actions as deemed necessary are taken.

7.2.3.3 Inspection Programme

Regulatory inspection programme of AERB is described in the safety guide “Regulatory Inspection and Enforcement in Nuclear and Radiation Facilities” AERB/SG/G-4. The inspection programme includes the following:

i. developing required procedures for the effective conduct and administration of the inspection programme;
ii. conducting, as necessary, planned inspections during all stages of the consenting process and throughout the service life of the NPP as well as on decommissioning;
iii. verifying the Consentee's compliance with the regulatory requirements and otherwise assuring continuous adherence to safety objectives;
iv. carrying out reactive inspections in response to events
v. documenting its inspection activities and findings;

The regulatory inspection includes both planned and reactive inspections. Inspections are carried out throughout the life cycle of a NPP, and where necessary, includes inspections of vendor facilities and activities too. Planned inspections are conducted every quarter for NPP projects and twice in a year for operating NPPs. Planned inspections include examinations of actual physical status of NPPs, various procedures, records and documents, surveillance tests, and interviews with the utility personnel.

7.2.4 Enforcement of Applicable Regulations and Terms of Licences

AERB has the necessary legislative power to frame safety regulations, establish licensing conditions. It has also established regulatory mechanism to enforce them.

7.2.4.1 Legal Provision and Power for Enforcement

Subsections 4 and 5 of Section 17 (Special provisions as to safety) of the Act gives the Central Government powers to inspect and take enforcement actions to prevent any contravention of the rules. Atomic Energy (Radiation Protection) Rules 2004 and Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987 identify AERB as the enforcement authority. AERB also enforces the provisions of Atomic Energy (Factories) Rules, 1996 for industrial safety of the plants under DAE. The powers to inspect and take enforcement actions for industrial safety are drawn from the provisions of section 8 & 9 of the Factories Act 1948. AERB Code of practice 'Regulation of Nuclear and Radiation facilities AERB/SC/G:2000' and safety guides issued under it provides the details regarding the system of enforcement.

7.2.4.2 Elements for Enforcement Actions

Several graded enforcement options are available to AERB to ensure that the consentee takes timely corrective actions. The actions taken by the Regulatory Body are based on aspects such as safety significance of the deficiency, seriousness of violations, the repetitive nature and/or deliberate nature of the violations. Enforcement actions by the Regulatory Body arise from review of documents submitted by the consentee or findings during review or inspection. The enforcement actions include one or more of the following:

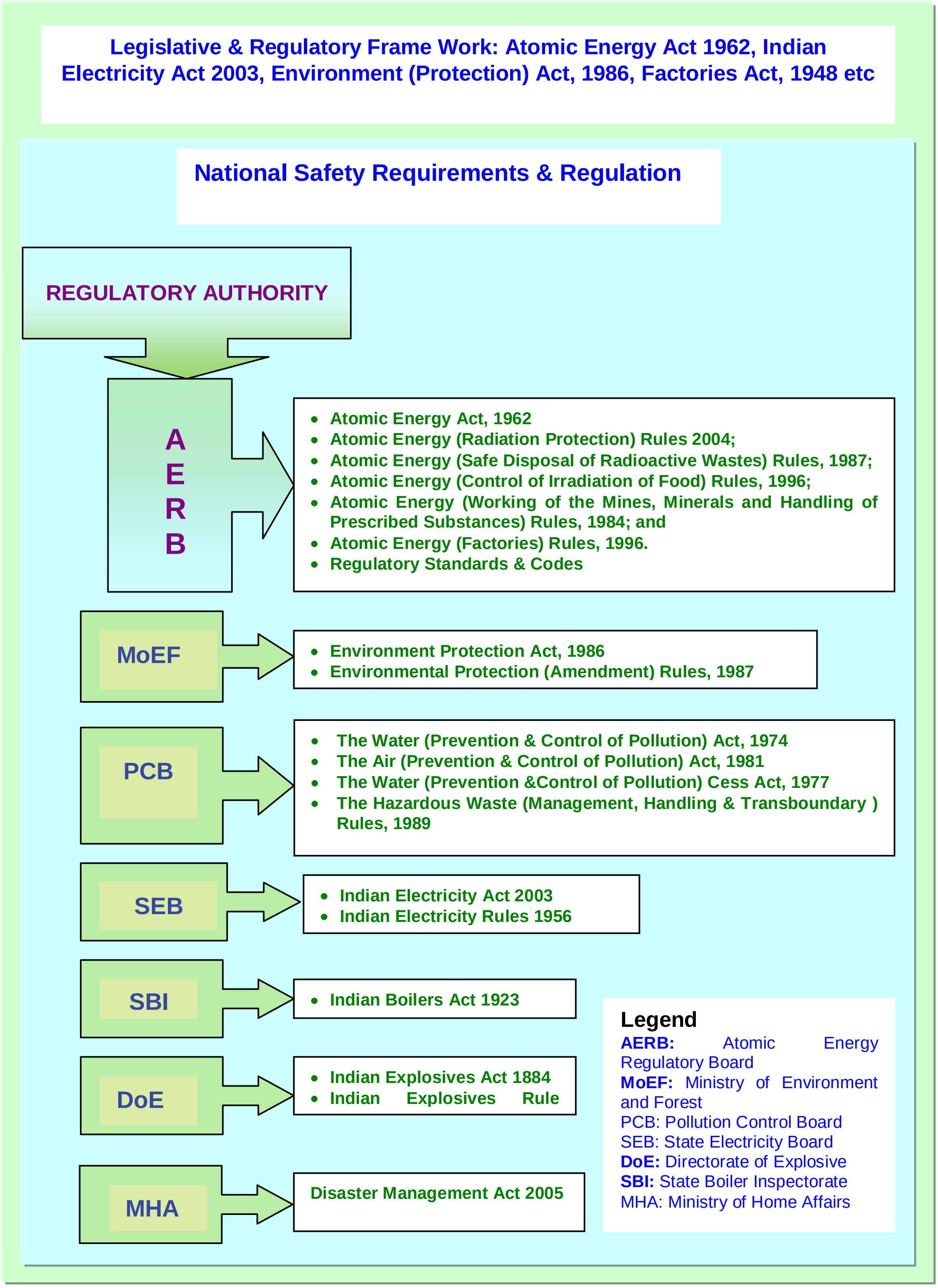
i. a written directive for satisfactory rectification of the deficiency or deviation detected during inspection;
ii. written directive for improvement within a reasonable time frame;
iii. orders to curtail or stop activity;
iv. modification, suspension or revocation of operating consents; and
v. penalties.

Some of the enforcement measures taken by AERB during the past three years are brought out in Article 14 (refer item 14.2.3)

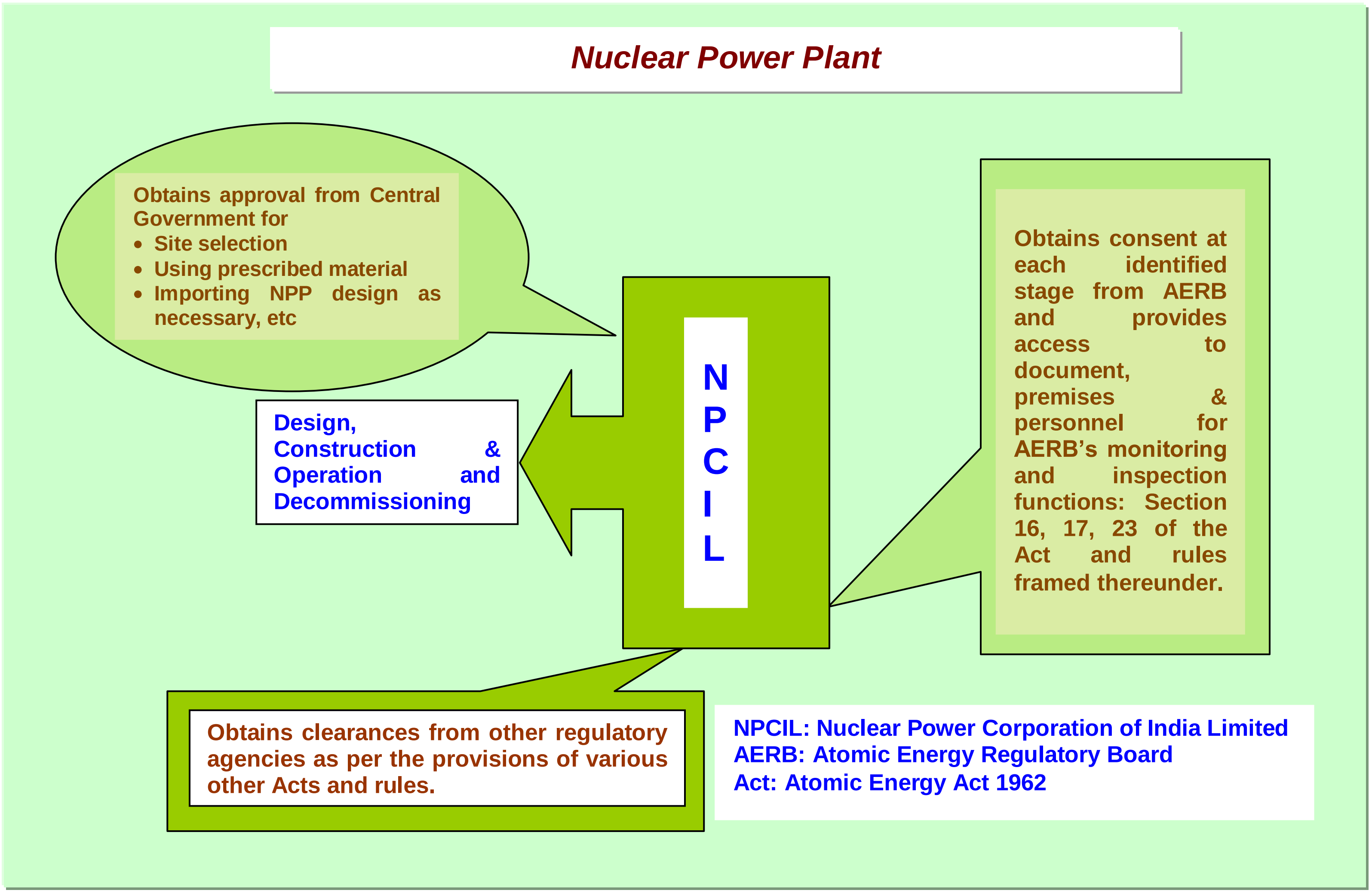
7.3. COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Since the inception of the atomic energy programme in the country, an elaborate legislative and regulatory framework is in place. The national safety requirements pertaining to atomic energy emanate from the Atomic Energy Act 1962 & rules issued there under. Acts and rules explicitly bring out the requirement of licensing, inspection & enforcement. The system of licensing, inspection and enforcement has been established. AERB code of practice on regulation of Nuclear and Radiation Facilities and several guides issued under the Code gives the process of regulation of safety in the country. The Legislative and Regulatory framework in the country is comprehensive to harness the benefit of Atomic energy in a safe and secured manner. Hence, India complies with the obligations of Article 7 of the Convention on Nuclear Safety.

Annex 7-1: National Safety Requirements and Regulation



Annex 7-2: Requirement of Approvals for Locating NPPs



Annex 7-3: Regulatory Framework – Hierarchy

ACTS

- Atomic Energy Act 1962
- Factories Act 1948
- Environment (Protection) Act 1986
  Disaster Management Act 2005
  The Water (Prevention & Control of Pollution) Act, 1974
  The Air (Prevention & Control of Pollution) Act, 1981
  The Water (Prevention & Control of Pollution) Cess Act, 1977
  Indian Electricity Act, 2003
  Indian Boilers Act, 1923
  Indian Explosives Act 1884

RULES

- Atomic Energy (Radiation Protection) Rules 2004
- Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987
- Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances)Rules, 1984
  Atomic Energy (Control of Irradiation of Food) Rules, 1996
- Atomic Energy (Factories) Rules, 1996
- Environment (Protection) Rules 1986
  The Hazardous Waste (Management & Handling), Rules 1989
  Indian Electricity Rules, 2005
  Indian Explosives Rule 1983

CODES

- Code of Practice on Regulation of nuclear and radiation facilities (AERB/SC/G)
- Code of Practice on Safety in NPP Operation AERB/SC/O
- Code of Practice on QA for Safety in NPPs AERB/SC/QA
- Code of Practice on Siting for Safety in NPP siting AERB/SC/S
- Code of Practice on Design for Safety in PHWR Based NPP AERB/SC/D

GUIDES

- AERB Safety Guides AERB/SG/G-1 to G-8
- AERB Safety Guides under Code of Practice on Operation AERB/SG/O-1 to 15
- AERB Safety Guides under Code of Practice on QA AERB/SG/QA-1 to 9
- AERB Safety Guides under Code of Practice on Siting AERB/SG/S-1 to 11
- AERB Safety Guides under Code of Practice on Design AERB/SG/D-1 to 25

AERB Safety Manuals

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 fulfil 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.**

8.0 GENERAL

The Government of India, exercising the powers conferred by Section 27 of the Atomic Energy Act 1962 established the Atomic Energy Regulatory Board (AERB) in 1983, to carry out regulatory and safety functions with regard to nuclear power generation and use of ionising radiations in the country. The authority of AERB is derived from the presidential notification (gazette notification) for establishment of AERB and rules promulgated under the Atomic Energy Act, 1962. The mission of AERB is to ensure that the presence of ionising radiation and the use of nuclear energy in India do not cause unacceptable impact on the health of workers, members of the public and the environment.

AERB is entrusted with the responsibility for regulating activities related to nuclear power generation, nuclear fuel cycle facilities, research, industrial and medical uses of radiation. AERB also regulates industrial safety as per the provision of Factories Act 1948 and the Atomic Energy (Factories) Rules 1996, for the plants and facilities managed by the constituents of DAE.

8.1 ESTABLISHMENT OF THE REGULATORY BODY

8.1.1 Mandate and Duties of Regulatory Body

The basic regulatory framework for safety for all activities related to atomic energy program and the use of ionising radiation in India is derived from Sections 16, 17 and 23 of the Atomic Energy Act, 1962. These provisions have been described in detail in Chapter on Article 7. AERB carries out certain regulatory and safety functions of these sections of the Act. The mandate for AERB brought out in the presidential (gazette) notification issued by the Central Government in the year 1983 inter-alia includes:

a. Powers to lay down safety standard and frame rules and regulations in regard to the regulatory and safety requirements envisaged under the Atomic Energy Act,1962.
b. Powers of the Competent Authority to enforce rules and regulations framed under the Atomic Energy Act, 1962 for radiation safety in the country.
c. Authority to administer the provisions of the Factories Act, 1948 for the industrial safety of the units of DAE as per Section 23 of the Atomic Energy Act, 1962.

The functions & responsibilities of AERB are summarized below:

i. Develop safety policies in nuclear, radiological and industrial safety areas.
ii. Develop Safety Codes, Guides and Standards for siting, design, construction, commissioning, operation and decommissioning of different types of nuclear and radiation facilities.
iii. Grant consents for siting, construction commissioning, operation and decommissioning, after an appropriate safety review and assessment, for establishment of nuclear and radiation facilities.

iv. Ensure compliance of the regulatory requirements prescribed by AERB during all stages of consenting through a system of review and assessment, regulatory inspection and enforcement.
v. Prescribe the acceptance limits of radiation exposure to occupational workers and members of the public and approve acceptable limits of environmental releases of radioactive substances.
vi. Review the emergency preparedness plans for nuclear and radiation facilities and during transport of large radioactive sources, irradiated fuel and fissile material.
vii. Review the training program, qualifications and licensing policies for personnel of nuclear and radiation facilities and prescribe the syllabi for training of personnel in safety aspects at all levels.
viii. Take such steps as necessary to keep the public informed on major issues of radiological safety significance.
ix. Promote research and development efforts in the areas of safety.
x. Maintain liaison with statutory bodies in the country as well as abroad regarding safety matters.

Deriving powers and functions specified in the gazette notification, AERB Safety Code, AERB/SC/G:2000 on "Regulation of Nuclear and Radiation Facilities" establishes the regulatory practices in the country. List of AERB guides issued under this code is given in Annex 8-1.

8.1.2 Structure of Regulatory Body

8.1.2.1 The Board

The governing Board of AERB consists of a Chairman, four Members and a Secretary. Chairman, AERB is the Chairman of the Board. Chairman, Safety Review Committee for Operating Plants (SARCOP) is also an ex-officio member of the Board. Secretary of the Board is an employee of AERB. The other members of the Board are serving or retired eminent persons from the government, academic institutes or national laboratories.

The Board formulates the regulatory policies and decides on all-important matters related to Consent, renewal of consents, enforcement actions, major incidents, etc. Chairman AERB, functions as the executive head of the AERB secretariat. The Board reports to Atomic Energy Commission (AEC). Atomic Energy Commission is the apex body of the Central Government for atomic energy that provides direction on policies related to atomic energy. The members of AEC among others include some eminent scientists & technocrats, secretaries of different ministries and senior most officials from the office of the Prime Minister. The AEC reports to the Prime Minister.

AERB sends periodic reports to AEC on safety status including observance of safety regulations and standards and implementation of the recommendations in all DAE and non-DAE units.

8.1.2.2 Advisory Committees

The Board is supported by several advisory committees in its regulatory functions. The advisory committees, Safety Review Committee for Operating Plants (SARCOP) and Safety Review Committee for Application of Radiation (SARCAR) are the two apex level committees for ensuring safety. SARCOP monitors and enforces safety regulations in NPPs & other Nuclear and Radiation Facilities identified by the Central Government. SARCAR is the safety monitoring and advisory committee of AERB that reviews safety aspects related to the application of radiation sources and equipment in industry, medicine, agriculture and research for non-DAE units as well as during transportation of radioactive materials in public domain.

The Advisory Committee for Nuclear Safety (ACNS) advises AERB on generic safety issues affecting the safety of nuclear installations. It is also mandated to conduct the final review of draft safety documents like safety codes, guides and manuals pertaining to siting, design, construction, operation, quality assurance and decommissioning of Nuclear Facilities.

The Advisory Committee on Occupational Health (ACOH) advises AERB on the matters of occupational health in the DAE industrial units. The Committee also recommends requirements in each unit with respect to infrastructure for the occupational health activities including medical officers as well as appropriate facilities.

The Advisory Committee for Industrial and Fire Safety (ACIFS) advises AERB on generic industrial and fire safety issues and recommends measures on industrial safety aspects for prevention of accidents at all DAE installations including projects under construction.

Advisory Committee on Radiological Safety (ACRS) advises on generic safety issues concerning radiological safety in application of radiation sources in medicine, industry, education and research.

8.1.2.3 Organisation of AERB

AERB has its office located in Mumbai to assist it in its regulatory functions. It comprises of seven technical divisions. These are: Operating Plants Safety Division (OPSD), Nuclear Projects Safety Division (NPSD), Safety Analysis and Documentation Division (SADD), Radiological Safety Division (RSD), Civil & Structural Engineering Division (C&SED), Information and Technical Services Division, (I&TSD) and Industrial Plants Safety Division (IPSD). The organisation of AERB is given in Annex 8-2. The functions of the technical divisions of the secretariat are briefly summarised below: -

Operating Plants Safety Division

- Enforcement of Atomic Energy (Radiation Protection) Rules, 2004 in operating NPPs
- Enforcement of Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 in operating NPPs and other Nuclear and radiation facilities
- Safety Review of Nuclear Power Plants and Research Reactors
- Issuance of Technical Specifications for operation of Plants and Facilities
- Licensing of Operating and Management Personnel
- Regulatory Inspection of operating NPPs
- Review of Emergency Preparedness at NPPs
- Renewal of Licence for operation of NPPs
- Authorisation for Radwaste Disposal

Nuclear Projects Safety Division

- Enforcement of Atomic Energy (Radiation Protection) Rules, 2004 in NPP projects
- Enforcement of Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 in NPP projects
- Design Safety Review of Nuclear Power Projects
- Regulatory Inspection and Safety Audit of Nuclear Power Projects

Safety Analysis and Documentation Division

- Development of safety documents
- Safety analysis and assessment including Probabilistic Safety Assessment

Radiological Safety Division

- ❖ Enforcement of Atomic Energy (Radiation Protection) Rules, 2004 in radiation installations other than Nuclear Fuel Cycle Facilities
- ❖ Safety Review of Accelerators and Irradiators
- ❖ Transportation of Radioactive Material
- ❖ Enforcement of Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 in radiation installation other than Nuclear Fuel Cycle Facilities

Civil and Structural Engineering Division

- ❖ Civil & Structural Engineering issues related to Operating Plants and New Projects.
- ❖ Inspection and Enforcement of Civil & Structural Engineering safety
- ❖ Earth Science and Earthquake Engineering Aspects
- ❖ Review of Siting application

Industrial Plants Safety Division

- ❖ Industrial and fire Safety Review
- ❖ Regulatory Inspection related to Industrial Safety
- ❖ Licensing of Personnel
- ❖ Occupational Health of Workers
- ❖ Inspection and Enforcement of radiological safety in fuel cycle facilities other than NPPs

Information and Technical Services Division

- ❖ Public Information
- ❖ Technical Services
- ❖ Organisations of Governing Board meetings and follow up of decisions.
- ❖ Training of AERB staff

The Directors of the above divisions are members of the AERB Executive Committee, which meets periodically with Chairman, AERB and takes decisions on important policy matters related to the management of the Secretariat of the Board.

8.1.2.4 Technical Support

AERB constitutes advisory committee for project safety review for assessment of safety of the NPP for siting, construction and commissioning of the NPP projects. At present, the following Advisory Committees are functioning.

- Advisory Committee for Project Safety Review for PHWR based NPPs and PFBR (ACPSR-PHWR/PFBR)
- Advisory committee for Project Safety Review for Light Water Reactors (ACPSR-LWR),
- Advisory Committee for Project Safety Review for Fuel Cycle Facility (ACPSR-FCF), Advisory Committee for Project Safety Review of Fast Reactor Fuel Cycle Facility and Demonstration Fuel Reprocessing Plant, IGCAR, Kalpakkam (ACPSR-FRFCF),

AERB has several other committees to advise it for developments of safety documents.

- Advisory Committee on Nuclear Safety (ACNS)
- Advisory Committee for preparation of Code & Guides on Governmental Organization for the Regulation of Nuclear & Radiation facilities (ACCGORN),

- Advisory Committee on Code, Guides & Associated Manuals for Safety in Design of NPPs (ACCGD),
- Advisory Committee for Codes, Guides & Associated Manuals for Safety in Operation of NPPs (ACCGASO),
- Advisory Committee for Codes & Guides for Quality Assurance for Nuclear Power Plants Safety (ACCGQA),
- Advisory Committees for Regulatory Documents on Nuclear Power Plant Siting (ACRDS),
- Advisory Committee on Safety Documents relating to Fuel Cycle Facilities other than Nuclear Reactors (ACSDFCF),
- Advisory Committee for Regulatory Documents on Civil and Structural Engineering (ACRDCSE),

These Advisory Committees consist of experts from AERB, BARC, IGCAR, national laboratories, and industrial and academic institutions in the country. The Advisory Committees, as appropriate, are supported by various other committees in their activities. The administrative and regulatory mechanisms, which are in place, ensure multi-tier review by the experts drawn at national level.

The technical support to AERB comes mainly from the Bhabha Atomic Research Centre (BARC). BARC provides strong technical support in the areas of development of safety documents, radiological and environmental safety, review and assessment of safety cases and inspection and verification functions. Some of the other important areas where BARC provides extensive technical support to AERB are Reactor Physics, Reactor Chemistry, Post-irradiation Examination, Remote Handling and Robotics, Control and Instrumentation, Shielding, Thermal Hydraulics, Probabilistic Safety Assessments, Seismic Evaluation, Quality Assurance and In-service Inspection. AERB also utilizes the expertise available with other research & academic institutions like the Indira Gandhi Centre for Atomic Research (IGCAR), Council for Scientific & Industrial Research (CSIR) and various Indian Institutes of Technology (IITs) in its review and assessment functions. AERB also appoints consultants having long experience in the national nuclear programme in various capacities for supporting it in the regulatory activities. AERB may also invite experts from other organisations having specific expertise. Another important resource for AERB's safety review and safety documents development work is the large cadre of retired senior experts.

8.1.2.5 Human Resources

The staff of AERB mainly consists of technical & scientific experts in different aspects of nuclear and radiation technology for meeting the requirement of consenting, safety review, research, inspections and analytical works. Besides AERB's own staff, required expertise is drawn from Technical support organisations, academic institutions and retired experts. As brought out earlier (please refer section 2.2 (i)), the sanctioned staff strength of AERB has been increased by about 70% and the recruitments are being made progressively.

Fresh technical & scientific staff are inducted from various training schools and nuclear training centres (please refer 1.5) as well as from Indian Institutes of Technology. Direct recruitment of experienced professionals is also done through open advertisements. The recruitment and training process is as follows;

i. Engineering graduates are absorbed after basic training in nuclear training centres at NPP sites. They undergo 2 years field training at NPPs to gain the system knowledge including simulator training before obtaining the NPP operations licence. Some are also trained in construction/commissioning activities of NPP to obtain the field experience.

ii. Engineering/Science graduates are also absorbed after their basic training from training Schools. They are given on-job training at operating NPPs. They generally pursue specialisation in the areas of reactor physics, nuclear and radiological safety, transport safety and waste management and also complete post graduation in their field.

iii. AERB sponsors a few students on yearly basis to complete the post graduation from Indian Institute of Technology. They are further trained in nuclear technology and given on-job training at NPPs after which they are assigned analytical works. AERB through its Safety Research Institute sponsors some persons for Post Doctoral courses to develop expertise in the areas of regulatory interest. AERB also encourages persons to do there higher studies in the field of nuclear engineering.

In addition, AERB organizes in-house orientation training programs for newly inducted staff. This program covers the legislative and regulatory framework (Acts, Rules, Codes, Guides and Manuals), functioning of AERB, regulatory processes followed and basic aspects of nuclear, radiation and industrial safety in nuclear and radiation facilities. These training programs are of approximately two months duration.

Refresher courses are conducted in-house on various topics of regulatory and safety aspects. AERB colloquia are organised frequently on topics of current interests and on new developments in various fields. The staff is provided opportunity to participate in conferences, seminars, and workshops in India as well as abroad to keep them abreast of the new developments in the areas of relevance. In addition, seminars / technical talks are arranged by the respective divisions of AERB to encourage more and more interaction with the members of other divisions.

8.1.2.6 Financial Resources

AERB has full powers to operate its budget, which it prepares and submits to the Central Government for approval. The Central Government allocates the budget in the separate account heads of AERB. The budget of AERB in the year 2010-2011 is about 245 million rupees. This budget does not include the cost of Technical Support provided by different organisations.

8.1.2.7 Safety Research

A large part of safety research important to regulatory activities is carried out by BARC, the main technical support organisation. AERB also has its own Safety Research Institute (SRI) at Kalpakkam near the city of Chennai. This institute is working in upfront areas of research for regulatory purposes. Some of the current areas of research are system analysis for fragility and qualification for seismic evaluation, reliability of passive systems, and coupling of system thermal hydraulic code with 3-D neutronics codes, fire modelling studies and using remote sensing techniques for data base generation for environmental assessment. The institute helps building up competent human resources of high merit for regulatory purposes. It also organizes workshops and seminars on specific safety topics of current importance.

AERB also promotes and funds radiation safety research and industrial safety research as part of its programme and provides financial assistance to universities, research institutions and professional associations for holding symposia and conferences on the subjects of interest to AERB. AERB Committee for Safety Research Programmes (CSRP) frames guidelines for the same and also evaluates and monitors the research projects.

8.1.2.8 Quality Management in Regulatory Body

AERB activities are conducted as per the Safety Code, AERB/SC/G, on "Regulation of Nuclear and Radiation Facilities" and various guides issued under it. These documents give in detail the consenting process, obligations of the consentee, conduct of regulatory review &

assessment, inspection regime & enforcement provisions for the nuclear power plants, Research reactors, other nuclear fuel cycle facilities and radiation facilities. AERB has developed a Quality Assurance programme through which activities of each division are assessed for conformance to the prescribed procedures. In recognition of this programme, AERB has obtained ISO 9001:2008 certifications for its activities pertaining to consenting, inspection and development of safety documents.

8.2 STATUS OF THE REGULATORY BODY

8.2.1 Government Structure and the Regulatory Body

The laws pertaining to atomic energy are enacted by the Parliament and enforced by the Central Government. The Atomic Energy Act 1948 was the first legislation for the atomic energy in the country. In the same year, the Government of India constituted a high powered Atomic Energy Commission to implement the Government policy with regard to atomic energy. Subsequently in the year 1954, Government of India created Department of Atomic Energy (DAE). With the creation of DAE, AEC was reconstituted in accordance with the Government resolution dated March 1, 1958, to advise the Central Government on matters pertaining to Atomic Energy. Later, Central Government set up the Atomic Energy Regulatory Board (AERB) in 1983 and delegated to it the power to exercise the regulatory and safety functions envisaged under the Atomic Energy Act 1962. AERB updates the AEC through annual report on all safety related matters pertaining to nuclear and radiation related activities in India.

8.2.2 Obligations of the Regulatory Body

The presidential (gazette) notification, forming the regulatory body, issued by the Central Government in the year 1983 empowers AERB for issue of consents, regulatory inspection and enforcement of safety provisions for nuclear and radiation facilities in India. According to the same notification, the functions of AERB also include

i. Development of necessary rules and regulations to implement the provisions of the Act in the area of nuclear and radiation safety.
ii. Prescribing acceptable limits of radiation exposures and environmental releases of radioactive substances.
iii. To take necessary steps to keep the public informed on major issues of radiological safety significance

8.2.3 Effective Separation between Regulation and Promotion Activity

The Atomic Energy Commission (AEC) is a very high level body dealing with only policy matters concerning nuclear energy in the country. The responsibility of siting, construction and operation of NPPs and nuclear fuel cycle facilities rests with the Department of Atomic Energy (DAE). The DAE fulfils this responsibility through its units like NPCIL and BHAVINI for NPPs, and through units like Uranium Corporation of India Ltd. (UCIL) for mining and milling of uranium and Nuclear Fuel Complex (NFC) for fabrication of fuel etc. All these are government owned corporations.

AERB is a separate body constituted by the Central Government specifically for exercising certain regulatory and safety functions envisaged under the Atomic Energy Act 1962. This structure provides total and effective separation to AERB in its regulatory work.

8.3 CO-OPERATION WITH INTERNATIONAL BODIES

i. International Atomic Energy Agency (IAEA)

AERB has been actively participating in the activities of IAEA. The staff of AERB participates in various Technical and consultants meetings organised by IAEA on a range of topics for fuel cycle activities, radiation facilities, transportation of radioactive materials and illicit trafficking of radioactive materials. AERB has been participating in IAEA Coordinated Research Programme (IAEA-CRP).

AERB is the national coordinator for IAEA -International Nuclear Event Scale (INES) and IAEA - Incident Reporting System (IRS). AERB participates in all activities related to the functioning.

These interactions help AERB in keeping abreast with the developments in the related fields, safety issues and the evolving safety standards. The experience helps AERB in developing national standards and guidelines.

ii. CANDU Senior Regulators Forum

AERB is a member of the forum for the CANDU Senior Regulators for exchange of information on issues specifically related to safety of PHWRs, based on which corrective actions as may be necessary are implemented in Indian NPPs.

iii. VVER Regulators Forum

VVER Regulators Forum is for exchange of information and experience on issues specifically related to safety of Russian VVERs. AERB is a member of this forum. AERB's participation in this forum helps in understanding events and generic safety issues in VVER reactors, based on which corrective steps as may be necessary are initiated in KK NPP, which is under construction in India.

iv. United States Nuclear Regulatory Commission (USNRC)

Cooperation in nuclear safety between AERB and USNRC was resumed in February 2003. Since then ten meetings have been held between AERB and USNRC both in India and USA. The objective of these meetings continues to be furthering the dialogue regarding Nuclear Safety between US and Indian Governments.

The safety related topics pertaining to Nuclear Power Plants discussed during the meetings were Fire Safety, Ageing Management and Licence Renewal, Emergency Operating Procedures, Risk Informed Regulation and Design Modifications, Passive Systems Reliability Evaluations, Long Term Performance of Concrete Structures, Thermal Hydraulics and Severe Accidents. Standard problem exercises have also been taken up by AERB and USNRC.

v. ASN, France

A formal cooperation between AERB and French Nuclear Safety Authority (ASN) France (erstwhile Nuclear Installation Safety Directorate (DSIN)), for exchange of information and cooperation entered in force in 1999 and was subsequently renewed in 2004.

vi. Radiation Safety Authority, Russia

AERB and the Federal Nuclear and Radiation Safety Authority of Russia ROSTECHNADZOR entered into an agreement for cooperation in the field of safety regulation of nuclear energy for peaceful purposes. This agreement came into force on February 15, 2003 and is valid till Kudankulam NPP begins regular operation. Four Workshops have been held between AERB and ROSTECHNADZOR for information exchange on nuclear safety.

vii. Nuclear Energy Agency

Recently, India has also been invited to participate in the activities of some of the committees of NEA and their working groups. Indian participation in NEA activities will be in a progressive manner. Indian experts have already participated in the meetings of Committee on Safety of Nuclear Installations (CSNI) and Committee on Nuclear Regulatory Activities (CNRA) of NEA. Indian experts have also been nominated to participate in the activities of their working groups.

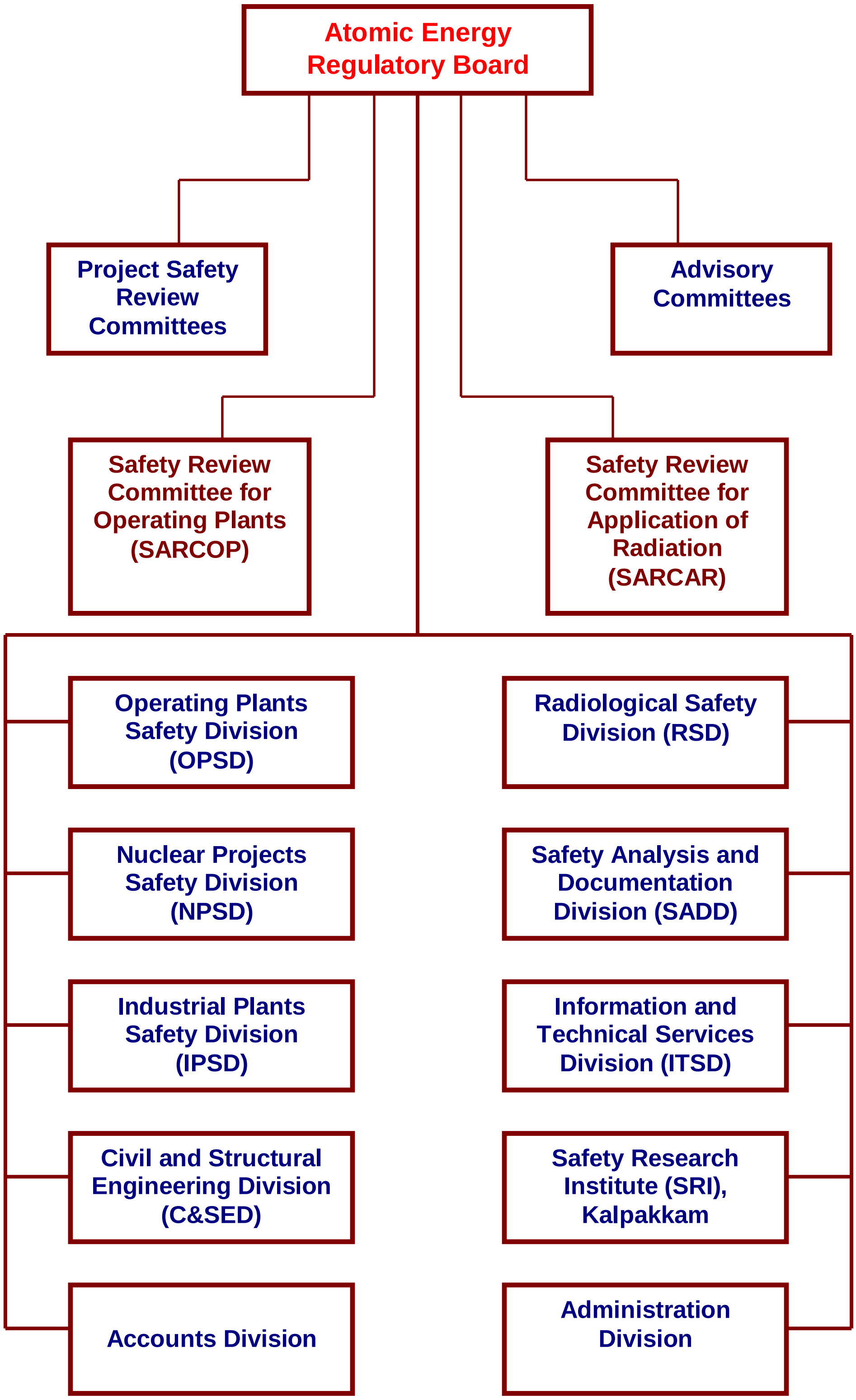
8.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

As atomic energy programme in India is expanding, the regulatory body also has to keep pace with the developments. Since its constitution in 1983, AERB has built up its technical and managerial capabilities to meet these requirements. The position of AERB in the government set up ensures administrative and financial independence in its functioning. Technical support is drawn from various national laboratories as well as from other national academic and research institutions. The Central Government provides the financial resource to AERB according to its proposed budget. There has never been shortage of finance towards fulfilling its mandate and responsibilities. The statutory and legal provision of the Act & various rules framed there under and the powers conferred by the gazette notification provides AERB with the authority for its independent and effective functioning. Hence, India complies with the intent and spirit of Article 8 of the Convention.

Annex 8-1: AERB SAFETY GUIDES UNDER THE CODE ON REGULATION

AERB Code / Guide No.	Title
AERB/SC/G; 2000	Regulation of Nuclear and Radiation Facilities
AERB/NPP&RR/SG/G-1; 2007	Consenting Process for Nuclear Power Plants and Research Reactors
AERB/NF/SG/G-2; 2006	Consenting Process for Nuclear Fuel Cycle Facilities and Related Industrial Facilities other than Nuclear Power Plants and Research Reactors
AERB/SG/G-4; 2002	Regulatory Inspection and Enforcement in Nuclear and Radiation Facilities
AERB/SG/G-5; 2000	Role of Regulatory Body with respect to Emergency Response and Preparedness at Nuclear and Radiation Facilities
AERB/SG/G-6; 2001	Codes, Standards and Guides to be Prepared by the Regulatory Body for Nuclear and Radiation Facilities
AERB/SG/G-7; 2001	Regulatory Consents for Nuclear and Radiation Facilities: Contents & Format
AERB/SG/G-8; 2001	Criteria for Regulation of Health and Safety of Nuclear Power Plant Personnel, the Public and the Environment

Annex 8-2: ORGANISATION STRUCTURE OF AERB



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.

9.0 GENERAL

One of the important functions of the Atomic Energy Regulatory Board (AERB) is to develop safety policies in nuclear, radiation and industrial safety areas. Towards this, AERB has issued the Safety Code, AERB/SC/G: 2000, on “Regulation of Nuclear and Radiation Facilities”, which establishes the obligations of the licensee towards safety.

Nuclear Power Corporation of India Limited (NPCIL) is a Public Limited Government company under the Companies Act 1956, fully owned by the Government of India. It undertakes design, construction, operation & maintenance and decommissioning of NPPs in the country. The mission of NPCIL is to develop nuclear power technology and to produce nuclear power, as a safe, environmentally benign and an economically viable source of electrical energy to meet the increasing electricity needs of the country. The Government of India has also established another company Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) in 2003, fully owned by it to pursue construction, commissioning, operation and maintenance of subsequent Fast Breeder Reactors for the generation of electricity.

Utilities responsible for design, construction, operation and maintenance of NPPs are solely responsible for safety. It is the responsibility of the utility and their constituent units to perform their activities as per the regulatory requirements and demonstrate to the regulatory body that all the activities of NPPs meet the established safety norms.

The report describes, inter alia the systems and organizational set-ups in NPCIL. All high level requirements/obligations as applicable to NPCIL are also applicable to BHAVINI. Hence, all aspects discussed in the report relating to NPCIL are also to be read as applying to BHAVINI too. However, as NPCIL is currently involved with light water and heavy water reactors and BHAVINI with fast breeder reactor, specific requirement related to the respective reactor technologies would be different. Presently, BHAVINI is involved in construction of Fast Breeder Reactor at Kalpakkam and does not operate any nuclear facility.

9.1 NATIONAL LAWS AND REGULATIONS REGARDING RESPONSIBILITY OF LICENCE HOLDER

Atomic Energy Act 1962 and the rules framed there-under provide the main legislative and regulatory framework pertaining to atomic energy in the country and provide for the development, control and use of atomic energy for the welfare of the people of India and for other peaceful purposes and matters connected therewith. ‘Atomic Energy (Radiation Protection) Rules, 2004’ issued under the Atomic Energy Act defines the ‘Responsibilities of Licensee’. As per the rules, the Licensee shall ensure compliance with the safety Standards and Safety codes issued by the competent authority (AERB) from time to time.

AERB Safety code on ‘Regulation of Nuclear and Radiation facilities AERB/SC/G:2000’’, brings out requirements and obligations to be met by nuclear or radiation facility to qualify for issue of regulatory consent at every stage. As per the safety code, the licensee is solely responsible for ensuring the safety in siting, design, construction, commissioning, operation and decommissioning of a Nuclear Power Plant and shall demonstrate to regulatory body that the safety is ensured at all the times.

9.2 RESPONSIBILITIES OF LICENSEE AND MEANS TO FULFILL OBLIGATIONS

The applicant seeking consent shall submit all the necessary information to the regulatory body as laid down in the requisite regulation in support of the application for consent. It shall be the responsibility of the licensee to make proper arrangements with vendor(s) and/or contractor(s) to ensure availability of all the required information. It shall also be the responsibility of the applicant to keep the regulatory body constantly informed of all relevant additional information or changes in the information submitted earlier. The licensee is responsible for any false statement in the application for consent or in the supplemental or other statement of facts required of the applicant.

The licensee has the responsibility for compliance with the stipulated requirements, regulations and conditions referred or contained in the consent or otherwise applicable. The licensee is responsible for carrying out the activities in accordance with the approved Quality Assurance program and to ensure that every step is carried out keeping safety as the overriding priority. The responsibility of the licensee includes:

i) The licensee shall make sure that the operation of NPP is carried out according to the relevant laws, regulations and condition of the licence granted.
ii) The licensee shall develop, preserve, update and maintain a complete set of records related to the safety of the plant, including those referred to in the applications, and those required by applicable Acts and rules framed there-under and the licence, and shall not dispose of them except as authorised by the regulatory body.
iii) The licensee shall provide the authorized representatives of the regulatory body full access to personnel, facilities and records that are under the control of consentee.
iv) The licensee shall keep the regulatory body fully and currently informed with respect to any significant events or potential for significant event or changes in the considerations, information, assumptions, or expectations based on which the consent was issued.
v) The licensee shall take such corrective actions or measures as required by the Regulatory body for safety.
vi) The licensee shall not undertake any activity beyond those authorised in the licence, without the prior approval of the regulatory body.
vii) The licensee shall report all accidents and events related to safety as may be required by the regulatory body.
viii) The licensee shall keep the Regulatory Body informed of the personnel changes in defined station management positions.
ix) The licensee shall ensure that an adequate level of safety will be maintained during operation through proper operational and maintenance procedures and administrative control where required.
x) The licensee shall establish policies to achieve high standards of safety and promote safety culture in the organisation.
xi) The licensee shall make sure that the organizational structures and training & qualification of the operating personnel are adequate to achieve required level of safety and meet the regulatory requirement.
xii) The licensee shall make sure that the stated procedures for surveillance, operation, maintenance and emergency planning are up to date and followed.
xiii) The licensee shall make sure that radiation protection of the public and the plant personnel is according to the radiation protection regulation. Radiation doses to the public & plant personnel and radioactive discharges from the NPPs are consistent with the principle of As Low As Reasonably Achievable (ALARA).
xiv) The licensee shall make sure that after a stoppage mandated by the regulatory body, the cause of stoppage has been resolved to the satisfaction of the regulatory body.
xv) The licensee shall make sure that the conditions for renewal of consent as prescribed by the regulatory body are met.

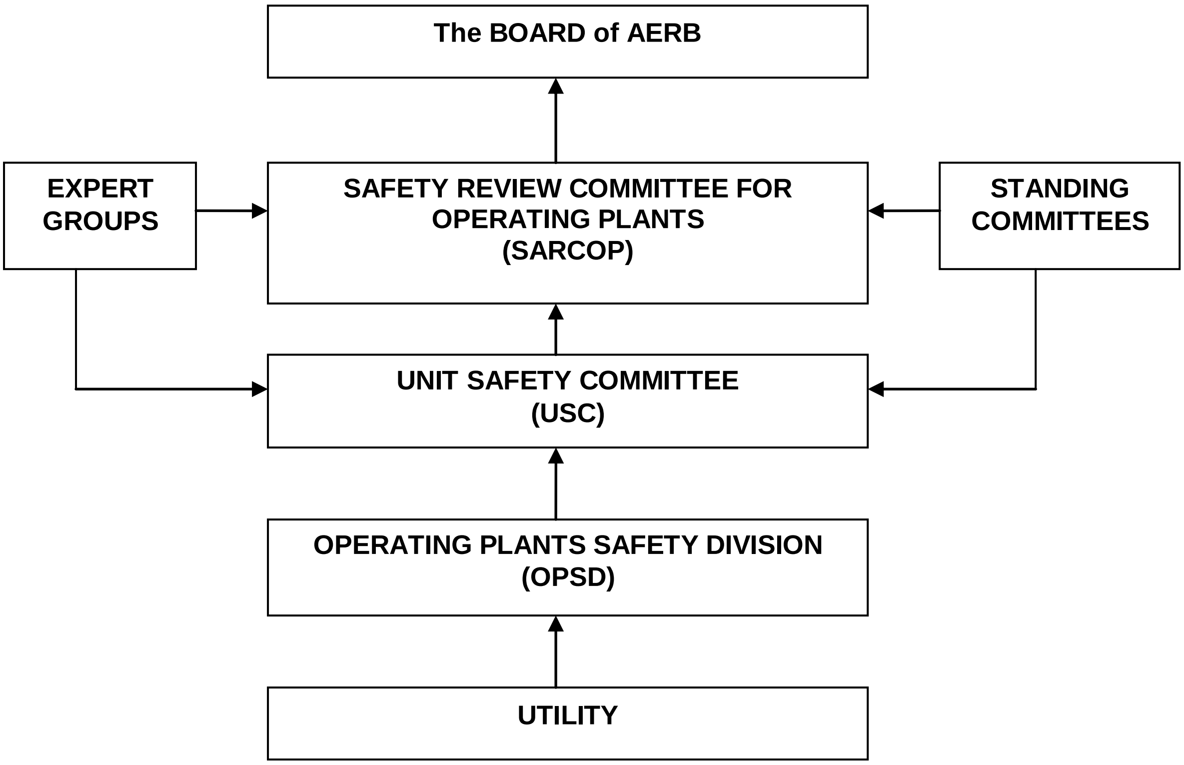
The utility has enunciated its commitments in the safety policy to fulfil the above responsibilities. The Quality Management System elaborated in the document “Corporate Quality Management System Requirements” provide the necessary directives for implementation, maintaining, assessment, measurement and continual improvement of the management system for compliance with the regulatory requirements and intents in all phases of the NPPs. The chapter on Article-13 on Quality Assurance describes the Safety Management System of NPCIL. The chapter on Article-14 describes the assessments and verification of safety carried out within the utility. A typical organisation put in place at an operating NPP to discharge its responsibilities is given in chapter on Article-19 on Operation.

9.3 REGULATORY MECHANISMS TO ASSESS SAFETY PERFORMANCE OF UTILITY

The regulatory control for assurance of safety during all the stages of NPPs is exercised by AERB through a system of consenting, which authorises the specified activity and prescribes requirements and conditions. The AERB prescribes the safety requirements for all stages of NPPs through its regulatory documents, directives and licensing conditions and ensures their compliance by utilities.

For NPPs under construction as well as during operation, AERB monitors safety and ensures compliance with the regulatory requirements by establishing mechanisms of review and assessment, regulatory inspection and enforcement. The licensing process for the NPP is described in detail in Chapter 14 on ‘Assessment and Verification of Safety’ of this report. A typical mechanism for regulatory control of an operating NPP is described below.

i. AERB follows a multi tier review system of safety committees to carry out review and assessment for different stages of licensing.
ii. For each operating NPP, the Unit Safety Committee (USC), the Safety Review Committee for Operating Plants (SARCOP) and the Board of AERB constitute the multi tier review organs for regulatory control.
iii. The USC constituted for every station or a group of stations having NPPs built to the same design, assists SARCOP in the review and assessment function to ensure comprehensive safety review on a regular basis.
iv. SARCOP is an executive committee for monitoring the safety status and enforcing the regulatory norms applicable to the Nuclear Power Plants in operation and other associated facilities.
v. SARCOP has also established various Standing Committees and Expert Groups to review and submit its observations and recommendations to USC and SARCOP on the subjects referred to them.
vi. The Operating Plants Safety Division (OPSD) is the nodal agency within AERB for coordinating the functioning of various safety committees and synthesising their decisions.
vii. This system of safety committees function on the principle of "regulation by exception" following a graded approach and are based on principles and requirements laid down by AERB.
viii. The safety issues of greater significance are considered in the higher-level safety committees for resolution. The decisions of these committees concerning major policy issues and important consents require endorsement of the governing Board of AERB.
ix. The multi-tier review mechanism followed for an operating NPP is shown below.



The USC and SARCOP periodically review the safety performance of the respective units to derive assurance that the NPPs are being operated within the conditions specified in the licence for operation and that the priority to safety is the corner stone of the policy of operating organisation. OPSD carries out the periodic regulatory inspection, both announced and unannounced, to verify the compliance of regulatory requirements at NPPs. The areas of review, assessment, regulatory inspections and enforcements are described in Article 14.

9.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The responsibility for the design, construction, operation and maintenance of NPP for producing electrical energy in a safe manner has been assigned only to Government Companies. 'Atomic Energy (Radiation Protection) Rules, 2004' and the AERB Safety Code, AERB/SC/G, on "Regulation of Nuclear and Radiation Facilities" clearly assigns the responsibility of safety to the licence holder and spells out the obligations of the licensee towards safety. AERB through its multi-tier system of review and assessment ensures that the licensee meets its responsibility towards safety. Hence, India complies with the obligations of the Article 9 of the Convention on Nuclear Safety.

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.

10.0 GENERAL

The Atomic Energy Regulatory Board (AERB), the regulatory body and the utilities have a stated formal policy, which emphasizes priority to safety in all their activities. Adherence to the safety policies nurtures and maintains the safety culture developed over years of experience. The requirements for a strong safety culture are laid down in AERB codes for quality assurance and operation.

10.1 REGULATORY REQUIREMENTS TO PRIORITIZE SAFETY

AERB Safety Code on ‘Quality Assurance in Nuclear Power Plants’ [AERB/NPP/SC/QA (Rev. 1), 2009] requires that utility management shall promote and support a strong safety culture by:

a) Ensuring a common understanding of the key aspects of the safety culture within the organisation;
b) Providing the means by which the organisation supports individuals and teams to carry out their tasks safely and successfully, taking into account the interactions between individuals, technology and organisations;
c) Reinforcing a learning and questioning attitude at all levels of the organisation;
d) Providing the means by which organisation continually seeks to develop and improve its safety culture.

AERB Safety Code on ‘Nuclear Power Plant Operation’ (AERB/NPP/SC/O) which lays down the requirements for safe operation of NPP requires that

a) The management shall inculcate safety culture in plant personnel and develop a policy which gives safety the utmost priority at the plant, overriding the demands of production.
b) Training shall be oriented to develop safety consciousness and safety culture at all levels of the plant organisation structure.
c) The management programmes relating to operation review and audit should aim at ensuring that an appropriate safety consciousness and safety culture prevails.

Utilities comply with the AERB requirements by issuing and adhering to their safety policies and according the highest priority to safety in all their activities.

10.2 SAFETY POLICIES AND PROGRAMMES

The NPPs in India are designed, constructed, operated and maintained by the fully owned utilities of Government of India. Utilities responsible for design, procurement of manufactured equipment and components, construction, commissioning and operation of NPPs in India, carry out their functions with a commitment to safety and regulatory requirements. Well-established safety principles and procedures are adhered to by utility to give priority to safety in all its activities. Priority to safety is embedded in the corporate mission statement of utility and each NPP carries out its prime function as per the declared safety policy, covering both nuclear and conventional safety aspects. The consultants and contractors that carry out assignments and activities for utility also follow the safety and quality assurance norms of utility.

Utility has management systems in place to ensure that safety is accorded priority in its activities.

NPCIL issued its safety policy (rev 1) in 2002, as Headquarter Instruction HQI-7003. The management of NPCIL accords utmost importance to Nuclear, Radiological, Industrial and Environmental Safety overriding the demands of production or project schedules. Its objectives are :

- To maintain high standards for safety within plant as well as in the surrounding areas.
- To ensure that health, safety and environmental factors are properly assessed for all NPPs.
- To ensure that all employees, contractors, transporters working for NPPs adhere to safety requirements while carrying out their responsibilities.
- To keep the public at large informed about the safety standards and regulatory practices that are being adopted at NPPs.

The management of each NPP has also issued their safety policy in conformity with corporate safety policy. Each NPP ensures that their work place is safe and their employees including that of contractor's adopt safe working procedures. Individual unit also ensures that they have effective on-site and off-site emergency plans, which are implemented and rehearsed periodically so that in the unlikely event of any accident, the impact on the public and environment is minimized. Some of the important activities for implementation of safety policies are:

- Setting up targets for safety performance parameters and their periodic monitoring.
- Carrying out of different levels of safety audits and reviews viz. Internal, corporate, regulatory and international like WANO peer review.
- Assessment and enhancement of safety culture.

All Indian NPPs have obtained ISO-14001 and ISO18001 for their Environment Management System. At NPCIL Headquarters' the Directorate of Quality Assurance (QA), Directorate of Engineering and Procurement, Directorate of Safety, R&D and knowledge management have obtained ISO-9001: 2008 certification. As a part of this International Standardisation, both these Directorates have issued policies, which have a strong bearing on safety of NPPs. BHAVINI also issued its safety policy in 2005 which gives paramount importance to safety.

For pursuing the stated safety policy, certain general safety principles are followed in all aspects pertaining to NPPs and their regulation. A strong safety culture is developed at the utility.

10.3 GENERAL SAFETY PRINCIPLES

Nuclear installations are designed and operated by keeping the safety objectives as a priority goal. The Codes, Guides and Standards issued by the Regulatory Body are the primary bases for utility to derive the details of principles, practices and policies for safety in design and operation of NPPs. These Codes, Guides and Standards have evolved over years based on similar documents issued by IAEA, other regulatory bodies and Indian experience.

The broad concepts of 'Defence-in-Depth' and ALARA with respect to radiation exposure during normal plant operation are the main guiding principles followed in design and operation of plants.

The management systems / Quality Assurance practices as detailed in Article 13 assure that the safety requirements are implemented and adhered to during design, construction, operation and maintenance.

In general, the following safety principles, practices and procedures are adhered to during design and operation.

10.3.1 Design, Construction & Commissioning

All through the process of design, manufacturing, construction and commissioning the QA systems (please refer chapter on Article 13) are implemented effectively to assure that implementation of safety principles has been given due priority.

i) Engineering and Quality Assurance divisions of NPCIL are ISO 9001:2008 certified. A thorough systematic approach and culture is followed in the design, review and approval.
ii) Safety Design criteria defined in the different design documents are reviewed and approved by AERB. The Safety design criteria also take into account feedback from the operating experience. The design is based on national and international codes and guides.
iii) The detailed safety design is presented through design notes, design manuals and drawings. QA procedures are followed for preparation, review and approval of all design documents.
iv) Proper control is exercised for implementing design changes and 'as-built' drawings are maintained.
v) For each system commissioning procedures are prepared to verify design through individual equipment and integrated tests. During commissioning, base line data is collected for future reference.
(vi) For computer based systems, independent verification and validation is carried out as per approved procedures/ practice.

A Safety Review Committee within NPCIL and BHAVINI regularly reviews the safety related design documents to ensure that safety principles are adhered to in design. This committee reviews features relating to safety in new designs, design changes in already approved safety and safety related systems, the Technical Specifications for Operation which translates the design requirements to safe operating policies, feedback from any safety related event at operating units etc. The review also assures that the outcome of regulatory reviews has been effectively considered.

10.3.2 Operation

The requirements for safety in operation of NPPs as covered in chapter on Article 19 ensure that the safety margins are not exceeded during any disturbance in the plant. The safety policies, safety culture and the good operating practices include:

i. In the operations regime, ALARA is the governing principle. Dose limits for normal plant operation are specified in line with ICRP recommendations.
ii. Plant operation is carried out within the limits specified in the Technical Specifications approved by AERB. Adequate margins between safety limits and operating parameters are maintained by appropriate interlocks and administrative measures. Proper protections are provided against the operating parameters reaching the safety limits.
iii. Plant is operated by only the qualified and licensed staff.
iv. Collective dose budgets are prepared by utility and approved by AERB for normal operation and special maintenance campaigns.
v. Equipments and instruments are subjected to regular surveillance.
vi. In-service inspection is carried out according to the approved ISI document at all NPPs.
vii. NPPs are periodically subjected to corporate safety audit, regulatory inspection and peer reviews.
viii. Plant operation and incidents are reviewed by Station Operation Review Committee (SORC) at NPP level.

ix. For all significant events, root cause analysis is carried out.
x. For non-standard jobs involving safety, special procedures are made and regulatory approval is obtained.

The Station Health Physics Unit maintains a close watch on radiological status and events at plant. They also provide periodic report to AERB (please refer chapter on Article 15). The Station Operation Safety Committees (SORC) constituted by NPCIL at each of the NPP regularly reviews the important safety issues. The station management keeps AERB informed of the outcome of these reviews. The station authorities shut down the plant if any specified operation limits & conditions in Technical Specification are not met.

The QA group at station and the technical audit engineer give independent feedback to the station management on operation and maintenance of plant. NPCIL's corporate QA group also conducts periodic audits. Each station is subjected to a peer review conducted by a group drawn from other stations owned by NPCIL. These are in addition to the WANO peer reviews.

Various well-defined procedures that exist within NPCIL and which address issues related to safe operation are detailed below:

i. The normal plant operation is governed by Technical Specifications for operation, which is approved by AERB. Protection system actuation set points are defined through Limiting Safety System Settings (LSSS) and the set points are tested as per frequency defined in Technical Specification for operation. The Safety Limits, Limiting Condition of Operation (LCO's) for various systems and their surveillance frequency are also part of the Technical Specification. Further, fall back actions and countermeasures are also defined in case normal configuration of certain redundant equipment is not met for a predefined limited period. Plant is shutdown and brought to the defined safe status in case the conditions specified in the Technical Specification are not met.
ii. For routine operations, NPPs maintain Operating Procedures cum Check Lists (OPCC), Maintenance Procedures, Operating Instructions, QA Procedures, ISI Procedures etc.
iii. Event based Emergency Operating Procedures (EOPs) are prepared for NPPs covering internal and external events. These EOPs are part of licensing and to the extent possible are implemented on simulators for training purposes. Symptom based EOPs are under advance stage of development for PHWRs.
iv. The Emergency Preparedness Plans for both on-site and offsite emergencies have been drawn up at all NPPs. These plans are subject to periodic rehearsals as part of preparedness and also include provisions for implementing counter measures in public domain.

10.4 SAFETY PRINCIPLES OF THE REGULATORY BODY

AERB is entrusted with the responsibility for regulating activities related to safety in nuclear installations. The safety principles followed by AERB are as follows:

i. Permits activities according to the mandate given to it, through a system of licensing . AERB stipulates and enforce the conditions of licence.
ii. While AERB considers standards and recommendations of international organisations and the best practices of other countries, it takes into account the Indian conditions while developing safety standards and requirements for the country.
iii. Encourages compliance to safety guides but accepts other approaches if safety objectives and requirements can be met.
iv. Adopts the principle of "management by exception" following a graded approach through a system of safety committees where issues of greater safety significance are given consideration in higher-level safety committees for resolution.
v. Encourages self-regulation by the licensee.

vi. Considers licensee as a partner in safety and extends all necessary assistance in the interest of safety, where appropriate.
vii. Encourages participation of licensee in the regulatory process.
viii. Conducts periodic inspections and channels its resources according to the safety performance of the licensee.
ix. Encourages licensee to achieve high level of safety culture.
x. Learns from the experience feedback and adapts to improve its functioning and effectiveness.
xi. Conducts its activities in an open and transparent manner.

AERB carries out a multi-tier review for the new and operating NPPs through a system of safety committees. The activities of siting, design, construction, commissioning, operation and related regulatory consents follow procedures and policies prioritizing safety.

10.5 SAFETY CULTURE AND ITS DEVELOPMENT

In order to develop a strong safety culture in a systematic way an internal document called Head Quarter Instruction (HQI-7006) titled ‘Guidelines for developing strong safety culture’ was issued by NPCIL in 2010. This HQI requires periodic assessment of safety culture and introduction of suitable programmes for strengthening the areas where weakness in safety culture is identified. The assessment of safety culture is primarily based on collecting information on perception of staff of NPPs on various attributes of safety culture through a questionnaire (please also refer 12.3 (iii))

Arrangements for safety management, safety monitoring and self-assessment, independent safety assessments are elaborated in Article 14.

10.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Safety is given overriding priority by all organisations engaged in activities directly related to nuclear installation. The regulatory body and utilities have stated safety policies that give utmost priority to nuclear safety. Principles, practices, procedures and the review mechanisms adopted towards meeting the objectives of these policies ensure that the safety is given an overriding priority in all the activities related to safe operation of NPPs. Therefore, India complies with the obligations 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.**

11.0 GENERAL

This chapter describes 'Financial and Human Resources' of the utility only. The resources of AERB are described in Chapter on Article 8 'Regulatory Body'.

11.1 FINANCIAL RESOURCES

The Nuclear Power Corporation of India Limited (NPCIL) is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE) of Government of India. NPCIL was formed in September 1987 by converting the erstwhile Nuclear Power Board, a Central Government department into a government owned corporation in accordance with the provisions of Atomic Energy Act-1962. At the time of formation of NPCIL, all the assets (except the first unit of Rajasthan Atomic Power Station RAPS–1) were taken over by NPCIL. RAPS-1 has been retained as a Government owned unit, being managed by NPCIL on behalf of the Government. The main objective of the company has been to produce electricity using nuclear fuel resources.

NPPs under construction and operation were fully funded by Government of India earlier. The formation of NPCIL facilitated operational flexibility and the ability to borrow capital from the market so that the financial resource base can be increased to step up the nuclear power programme.

NPCIL is a wholly owned company of Government of India and is registered under Indian Companies Act-1956. The company has a fully subscribed and paid up share capital of US$ 2336 Million (Rs.101450 Million). The company has reserves in excess of about US$ 2717 Million (Rs.124980 Million). The gross block of the company at its inception [comprising of TAPS 1&2, RAPS – 2 and MAPS 1&2, totalling 960 MW] was only US$ 99.6 Million (Rs.4480 Million) which has now grown to [4460 MW] about US$ 3900 Million (Rs.180000 Million) as on end March 2010. NPCIL is a profit making company and has been paying dividends of the order of 20% to 30% to the Government of India.

The financial resources of NPCIL are budgetary support from Government of India, borrowings from capital market and internal surpluses. NPCIL raises finances for the construction of new projects through a combination of government budgetary support, market borrowings (in the form of short term and long term debt instruments) and internally generated resources by sale of electricity. In the last 5 years, the NPCIL had not availed the budgetary support from Government as its internal surplus was sufficient to meet the equity requirements for the on going projects. It has adequate internal surplus to take up additional 8000 MW of generation capacity. In case the growth envisaged is higher, then only external infusion of equity will be required. Adequate financial discipline and prudence are exercised in borrowing money from the market. Gestation periods of the projects are progressively optimized so as to keep financing cost including interest during construction, at a reasonable level. Due diligence is exercised about debt obligations and there is no default in repayment of principal and/or interest. The credit rating of NPCIL by agencies like CRISIL, CARE, is AAA denoting the highest safety, which helps the company to borrow money from the capital market at the most competitive rates.

BHAVINI is a fully owned Enterprise of Government of India. Mandate of BHAVINI is to construct commission and operate the first 500 MW PFBR at Kalpakkam in TamilNadu and follow it up with future FBRs. The government will finance 76% of the cost of PFBR through equity, 4% equity will come from NPCIL and remaining 20% will be obtained through market borrowings.

11.1.1 Operation and Maintenance

NPCIL, as the owner of NPPs has the absolute obligation to provide adequate finances for running the nuclear power plants in a safe manner as per the requirements of Atomic Energy Regulatory Board (AERB) and its own mission.

NPCIL generates its revenue primarily by sale of electricity. Its present annual revenue is typically US$ 800 Million (Rs.36000 Million). In line with the provisions of the Atomic Energy Act 1962, the tariff for electricity from each station of NPCIL is notified by DAE in consultation with Central Electricity Authority. The parameters such as the capital cost, the market borrowings, input costs are factored into arriving at the various components of tariff.

NPCIL sells its electricity to 21 State Electricity Boards (SEBs) / distribution companies primarily located in Northern, Western and Southern regions of the country. The monthly bills based on the approved tariff along with the fuel price variation adjustment are raised on State Electricity Companies at the end of the month based on the metering done by the system operator and accounted for by the Regional Power Committee. The State Electricity Companies hold a revolving letter of credit in favour of NPCIL for their monthly power bills and payments are received during the subsequent billing month.

The Operation and Maintenance (O&M) expenditure for each station is budgeted every year. It is being funded by internal resources generated by the NPCIL every year. In addition, whenever it is necessary to finance any major works/purchase or replacement of major components, the resources are raised through borrowings or from internal surplus/ budgetary support as appropriate. Since the tariff is similar to the principle of cost plus basis, O&M expenditures are covered through tariff in addition to recovering the capacity charges such as giving a return on equity capital and providing depreciation subject to the units operating at normative capacity factors. The internal surpluses are deployed for the nuclear power plants in operation as may be required and for nuclear power projects under construction. The financial resources are budgeted on a yearly basis and in five-year plans. Adequate financial planning and forecasting is done for the complete life of the plant to ensure availability of financial resources throughout the life of the plant. Thus there is no constraint, either existing or foreseen, on financial resources for the safe operation and maintenance of the NPPs.

11.1.2 Renovation and Modernization (R & M)

R&M activities for NPPs in operation are of two types. The first involves routine replacement of operation and safety related components and equipment based on their performance requirements in which expenditure is relatively small. Expenditure on this type is met through the revenue budget of the respective stations and is covered by the tariff as part of O&M expenditure. The second type involves funding for major safety up-gradations in line with the regulatory requirements generally based on a PSR for continued operation of the unit or refurbishment of the major components of the plant because of operation requirements or technological obsolescence (R&M activities are brought out in chapter on Article-6). Such activities involve shut down of reactor for extended periods of time and involve major expenditure.

Recognizing that renovation and modernization activities would entail major expenditure, a renovation and modernization levy of about US 0.1 cent (5 paise) per unit was started in the year 1996 primarily with the intent of carrying out the renovation and modernization of older generation reactors. The money collected through R&M levy was kept in a committed reserve account. R&M levy was started in 1996 and after accumulating adequate reserves, the same was stopped from 1st December 2003. Situation will be reviewed from time to time, taking into account the adequacy of resources available with the corporation. In case, in future, the reserves are found to be inadequate, the consumers of electricity (SEBs) who are already familiar with concept, may be approached for its re introduction.

A holistic analysis on expenditure and resource mobilization in regard to all the units in operation is done at NPCIL Corporate Office by proper financial planning, monitoring and resource mobilization.

11.1.3 Decommissioning and Waste Management

The commercial life of NPP has been taken at 25 years. With improvements in design methodologies and better understanding of safety margins, retrofitting, better materials and equipment, the reactors can now operate safely for much longer periods of 40 to 60 years.

Out of the 19 operating nuclear power reactors, the two boiling water reactors at Tarapur are the oldest. They were commissioned in the year 1969 and have been progressively retrofitted. Similarly, the PHWR based NPPs have been undergoing renovation and modernization programmes. In this connection, En-masse Coolant Channel Replacement (EMCCR) and En-masse Feeder Replacements and necessary safety up-gradations of RAPS-2, MAPS-1&2, NAPS 1&2 and KAPS-1 have been completed as applicable. These major jobs have given a very good insight of technical capabilities and financial requirements for decommissioning.

Realizing the quantum of financial resources that will be required in future for de-commissioning of reactors, a de-commissioning levy at the rate of US Cents 0.044 (2 paise) per unit is being collected as part of tariff. The present de-commissioning fund appears to be adequate to take care of de-commissioning expenses. The provisions in this regard will be reviewed in future, based on experience and technological development. Tariff of Nuclear Power Plants in India is fixed once in every 5 years. In future the levy could be revised if need arises through such reviews.

Routine radioactive waste management during the operation of the NPPs is included as part of the O&M expenses. Since Indian energy security policy necessitates adoption of the closed nuclear fuel cycle, the fuel is considered as the property of the Government. The spent fuel from the first stage is taken by the Government from NPCIL either for reprocessing or for storage as necessary for the subsequent stages of the programme. The re-processing of spent fuel and the associated waste management are carried out by the Central Government.

11.2 HUMAN RESOURCES

Availability of qualified and trained manpower for the nuclear power programme has been one of the greatest strengths in India. Realizing the importance of qualified and trained manpower, DAE started Human Resource Development programme in early 50s, well before the launching of nuclear power programme in the country. A training school at Bhabha Atomic Research Centre (BARC) was established in August 1957. University qualified engineers and science graduates were recruited on an annual basis and they were trained in the BARC

Training school, a premier institute for training in nuclear science and technology through one-year rigorous training course including theoretical and practical aspects of nuclear engineering and sciences. Subsequently when the training needs for the operating nuclear power stations arose, the Nuclear Training Centres (NTCs) were set up at the NPP sites. The core of the manpower for the nuclear power programme came through these training centres. These personnel had also the benefit of experience in the construction and operation of the research reactors. In addition, experienced manpower from conventional power and industry were inducted. This combination provided the base from which subsequent developments took place.

The country's universities, engineering diploma institutes and industrial training Institutes form the basic educational infrastructure from which engineers/scientists, technicians and skilled tradesmen are recruited and subsequently trained to suit the job needs.

Networking with the Indian Institutes of Technology has been strengthened and post-graduate courses in nuclear engineering have been started at several institutes. Sponsored post-graduate program called 'DAE Graduate Fellowship Scheme' were started at all the IITs. Board of Research in Nuclear Sciences (BRNS) under DAE provides another avenue for networking by sponsoring research projects in the field of Nuclear Science and Engineering at various educational institutes. 'Homi Bhabha National Institute' established under DAE pursues post-graduation and PhD programs in areas of nuclear science and technology.

Dedicated Knowledge Management groups have been set up in all organisations of the DAE to pool and disseminate the available knowledge base and further augment knowledge base to meet the challenges of the future. Engineers and scientists of BARC and NPCIL participate in several international training programmes conducted by the IAEA and other organisations to further enrich their capabilities.

11.2.1 Arrangements and Regulatory Requirements for Human Resources at NPPs

NPCIL's technical manpower includes engineering graduates from prestigious engineering colleges/universities in the country. Freshly recruited engineers go through one year of training in DAE/BARC Training School or in Nuclear Training Centres of NPCIL. After such training, they are placed at NPCIL Corporate Office for functions like design, QA, procurement etc, or construction sites or operating units based on the needs and suitability for the job. While persons appointed at NPCIL Corporate Office are encouraged to do M.Tech / MBA course in their areas of specialization, those at plant sites are regularly/periodically trained for taking up higher responsibilities. They undergo licensing/ qualification examination before they are actually assigned the higher responsibility. In addition, NPCIL also carries out direct recruitment. Engineering diploma holders with 3-4 years of Diploma Course in Engineering (after High School ,10+2) conducted by the polytechnic institutions and tradesmen with two year industrial training after high school conducted by industrial trade institutes are other levels of recruitment. NPCIL provides challenging work environment and excellent quality of life at its residential colonies. Infrastructure facilities like health, education and transportation are adequately taken care of and recreational facilities are also provided to motivate personnel to continue their career with NPCIL. Off-site support from the NPCIL Corporate Office is provided to NPPs based on requirement. During the past three years NPCIL has recruited 300 Technical personnel at various levels and the present staff strength of NPCIL is 11842.

The initial manpower required for construction, commissioning and operation of the Fast Breeder Reactor has been inducted from NPCIL and IGCAR. BHAVINI has also undertaken recruitment of graduate engineers and people at various grades. IGCAR training centre will cater to training school needs for Fast Reactors. The operation staff is currently in training at FBTR, NPCIL plants and on the commissioning training at PFBR. The qualification and licensing of the staff will be in line with the norms established by regulatory body for operation of PFBR.

The assessment of the demand for recruitment of the manpower for the projected growth of nuclear power generation capacity generally starts with the clearances obtained for the new projects. It is pertinent to mention that since the nuclear power programme in the country has been a continuous one and the structured recruitment and training programme has always kept pace with the requirement. With the availability of large number of science and technology institutes in the country, the supply constraints are not likely to be faced for the projected growth of the nuclear power programme. In addition to the above, the country also has a large pool of retired experts in nuclear science, whose services are frequently utilised for specific areas of the nuclear power programme.

The regulatory requirements for staffing, qualification, training and retraining of staff for NPPs are given in AERB safety Code, on 'Safety in Nuclear Power Plant in Operation' (AERB/SC/O, Rev.1): 2008 and AERB Safety Guide, on 'Staffing Recruitment, Training, Qualification & Certification of Operating Personnel of NPPs' AERB/SG/O-1. The Radiation Protection Rules (2004) and AERB regulatory documents give the requirements regarding the qualification, training and retraining of personnel working in the radiation areas.

11.2.2 Competence Requirements and Training Needs of NPP Personnel

Detailed procedures for staffing, qualification, training and retraining of staff for NPPs are approved by AERB. The operating station organization of a typical Indian PHWR NPP has six levels (Management Level and Level I to Level V) in five major functions viz. Operation, Maintenance, Quality Assurance, Technical Services and Training functions. Level-I, II &III control room positions are for Shift Charge Engineer (SCE), Assistant Shift Charge Engineer (ASCE) and Control Engineer respectively. These positions for operation and fuel handling operations require licensing by AERB. Operations personnel normally working in field (levels IV, V) are certified by the plant management. Special recruitment and training procedures are established and being followed before deputing the contract workers in NPPs.

NPCIL has qualified and trained manpower meeting the job requirements at all levels, be it technicians, supervisors or engineers and scientists. The strength of NPCIL as on 31st March 2010 was 11842 out of which 9085 belong to technical and scientific cadre. Competence requirements and training needs of all key persons are ensured before they are deployed for carrying out the safety related activities in nuclear installations

The Corporate Training group focuses on development of trainers and training systems using SAT (Systematic Approach to Training) methodology. Various NTCs implement orientation-training programmes for each category i.e. engineers, supervisors, and technicians, recruited as trainees based on approved recruitment and selection procedure. The course contents and other administrative guidelines for initial and retraining have been established for each category of employee. NTC's are equipped with necessary infrastructure for implementing the courses as per approved syllabi. Based on Job-Task-Analysis, tasks for each position have been defined and a performance oriented checklist against each task is developed for effective assessment of On-Job training. The Corporate Training group is responsible for ensuring uniform standards of training at each training centre by developing guidelines for orientation training programme. For ensuring uniform standards of assessment, licensing examinations are coordinated by the corporate office.

Around100 training officers are posted in all the training centres to look after the initial induction training, qualification and re-training requirements at stations. Additionally, for imparting training in a specific field / area, experts from stations, as well as other organisations including regulatory body are invited. The trainers have operation and maintenance experience. Some of the trainers are licensed operators who also provide training on simulators.

A total financial resource of approximately 2% of the revenue budget is allocated to all training centres in NPCIL towards training, qualification, retraining and training infrastructure requirement.

11.2.3 Training of Operations Staff

The training and licensing scheme of the operating staff is as per AERB requirement. Presently, NPCIL has six NTCs and two Station Training Centres, where engineers and workmen are trained. NPCIL has full-scope training simulators at RAPS, Kaiga, Tarapur and Kudankulam. Soft panel based fuel handling training simulators are also deployed at NTC-RAPS and NTC-TAPS-3&4. These training simulators provide valuable training to the operating personnel. Symptom based EOPs are being modelled in these simulators.

11.2.3.1 Induction and Initial Training

This involves verification of completion of entry-level competency requirement to enter certification stage of licensing / qualification.

(i) Academic Qualification and Experience

The personnel occupying positions at level I, II and III need to be graduate engineers with relevant work experience of 8, 6 and 3 years respectively. Those who are diploma in engineering can occupy positions at level IV and V after having relevant work experience of 9 and 4 years respectively. Similarly, requirements have been established for personnel occupying level IV & V from other streams of education.

(ii) Training

Successful completion of' appropriate Orientation Training programs of 1, 1½ and 2 years duration is an essential entry Level pre-requisite for those entering directly at Level- III, IV & V respectively. Training mainly focuses on providing sound foundation on nuclear reactor fundamentals, a typical station specific equipment and system knowledge, training towards 'nuclear and industrial' safety, radiation protection, radiation emergency preparedness and work controls.

11.2.3.2 Licensing, Qualification and Certification Programme

(i) Authorisation Based Training

After completing the initial training, a candidate for acquiring licence at level III and qualification at level IV is required to complete the authorisation based training programs such as Radiation Protection Training , Standard Protection Code (SPC) and Electrical Authorisation (as applicable) before taking up final certification examinations.

(ii) On Job Training (OJT)

To gain the job experience, task based checklists are developed for Level – III, IV and V. If a task could not be performed on plant systems/ equipment due to lack of opportunity, alternate methods like performance on simulator or on mock-up or through technical discussions including enactment of the procedure (virtual conduct of the task) is to be deployed. Those due to acquire first time licence at level-III should have acquired minimum of three months of control room experience under supervision after completion of eighteen month on job training and participated in at least one start up / shut down activity at the plant.

(iii) Simulator Training

Simulator training mainly provides experiential learning of control room operation. Training is based on the approved guidelines for frequent, important and difficult tasks covering normal operations i.e. start-ups / shutdowns and handling of anticipated operational occurrences" (AOOs) including emergency operating procedures (EOPs) related to main plant. In respect of fuel handling system operations, it provides necessary practice of safe FH operation and handling of AOOs. In the absence of plant simulator at a plant, the requirement of simulator training is met by providing training at a simulator located at a plant having similar design.

(iv) Licensing / Certification Stage

Licensing examinations for Level-III and II for Main plant / Fuel Handling (FH) operation personnel are conducted under the control of NPCIL Corporate Office. Prior to this, walkthrough for these personnel is conducted under plant control. The last stage of verification is final assessment interview for medically fit candidates, conducted under AERB control for Level-III, II and I for main plant, Level-III, and II for FH operation personnel. Qualification process (written examination, walkthrough and final assessment interviews) for Level IV &V is done under plant control.

For the first time licensing, candidate has to satisfy all the entry-level requirements as detailed above before appearing for the written examination for levels III & II. The walkthrough test is conducted when a candidate has qualified in all the applicable written examinations and is applicable for Level-II, III. Through this test, the practical knowledge of the candidate is evaluated by a minimum of three field examiners. The evaluation process covers various phases of plant/systems operation covered in the 'walk through' checklist to provide assessment for the candidate's physical, practical and procedural knowledge of Systems, Structure and Components of NPPs.

Medical fitness tests as per approved guidelines are conducted for all candidates appearing for licensing, as a pre-requisite for the final assessment interview.

A candidate after successfully completing the pre-requisites of licensing procedure appears before the Final Assessment Committee. Final Assessment for level–I, II & III position is conducted by an AERB committee constituted for the purpose and based on their performance the candidate is licensed for the given position. For Level IV & V position, this task is performed by a Committee constituted by NPCIL.

(v) Certification

The personnel occupying level-IV & V positions in control room are certified by the plant management and the process of certification is performed under its control.

(vi) Management Training for level-1 position

This is an essential entry level pre-requisite for Level-I candidates only and a candidate for Level-I has to successfully complete the 'Management Training' programs such as Codes and Guides of regulatory body, Quality Assurance aspects of NPP Operation, Safety culture, Operation Management, Personnel Management, Procedural knowledge related to administration and finance, vigilance and security aspects.

(vii) Senior Management Qualification

Senior Management Qualification is covered under specific instructions issued by NPCIL for meeting the regulatory requirements. The aim of this qualification is to assess candidates through written examinations and interviews for their technical knowledge and overview of safety management. AERB qualifies the successful candidate after a final assessment interview conducted by its committee. The management structure at the NPP is included in the Technical specifications for operation approved by AERB. Accordingly any change in management structure has to be reviewed and approved by AERB.

11.2.3.3 Retraining/Re-Licensing Process

(i) Re-training Process

This is applicable for all licensed positions as a pre-requisite for Re-licensing**.** The retraining duration for licensed positions is at least four weeks per year during the validity of licence. During re-training, efforts are made to train the entire crew together as a team on simulator exercises. The course content covers refresher of fundamentals and safety practices, modifications made in the plants and procedures, RCA, Safety Analysis, good practices and EOPs and simulator retraining/ alternate retraining in lieu of simulator retraining.

(ii) Re-Qualification Process

A licence / qualification is valid for three years. A candidate needs to be re-licensed/ re-qualified before the last date of validity of the licence/ qualification. A person licensed for a particular position can be re-licensed to the same position provided he meets the prerequisites such as medical fitness, Electrical Authorisation and mandatory re-training programs as applicable and is found fit by the final assessment committee.

(iii) Re-authorisation Process

Persons absent from the licensed position duty continuously for more than one month are re-authorized after a formal assessment to ensure that they are updated with plant specific changes introduced during the absence with respect to plant modifications, procedural changes and incidents/events, etc.

11.2.4 Plant Simulators

Each Nuclear Power Station has a training centre. The training centre can be either a Station Training Centre (STC), which is for captive use of the station for plant specific training, or a Nuclear Training Centre (NTC), which has a STC plus a centralized nuclear orientation school for induction training as well as advanced training facility such as simulator. These training centres conduct approved training programmes under supervision of corporate training group of NPCIL.

At present, there are four full-scope simulators. Two are located at RAPS, one each at KAIGA and Tarapur. One simulator at RAPS caters to imparting training for personnel working in old plants i.e. RAPS-1&2 and MAPS, while the other simulators at RAPS-3 & 4 and Kaiga site are based on the design of standardised 220 MW reactors and cater to the requirements of all the other 220 MW PHWRs. The fourth located at Tarapur, is based on the design of 540 MW PHWR TAPP-3&4. VVER based simulator has been commissioned and in operation at Kudankulam site to take care of the training requirements of 1000 MW reactors of VVER design. With these simulators, NPCIL is able to provide simulator training to all the operating personnel working in NPPs. In addition, there are three soft panel based Fuel Handling System

(FHS) simulators at KAIGA, RAPS and TAPP-3&4 for imparting training in Fuel handling operations.

These simulators are capable of providing training on frequent, important and difficult tasks covering normal operations i.e. start-ups / shutdowns and handling of “Anticipated Operational Occurrences” (AOOs) including Emergency Operating Procedures (EOPs) related to Main Plant. In respect of Fuel Handling System operations, it provides necessary practice of safe FH operation and handling of AOOs

To ensure effective simulator training, dedicated trainers who are required to maintain their supervisory licence (level-II) are deployed to ensure maintenance and effective utilization of the simulator for achieving optimum training.

11.2.5 Training of Maintenance and Technical Support Staff

NPCIL has qualified and trained manpower meeting the job requirements at all levels, be it technicians, supervisors or engineers and scientists. Competence requirements and training needs of all key persons are ensured before they are deployed for carrying out the safety related activities in nuclear installations.

Arrangement for initial training, qualification and retraining of maintenance and technical support staff also exists at all NPPs in line with operation staff. By ensuring the maintenance of operational licence and qualification of personnel deployed in Technical Services, Training and Quality Assurance sections their rotations have become feasible.

11.2.6 Improvements to Training Programmes

NPCIL regularly organises special training programmes for experienced operation engineers conducted by international organisations like WANO on a variety of topics such as “Operations Decision Making”, “Advanced Simulator Instructor Training”, etc and also provided them opportunity to interact with their peers working in NPPs abroad. Within the organization, workshops are organized to share operating experiences e.g. “Just-In-Time” type operating experiences etc.

Training centres at all NPPs conduct regular training courses and refreshers courses to cover new insights from safety analysis, operating experience, industrial/fire safety, radiological safety and regulatory issues etc to maintain the personnel competency. Only qualified and licensed trainers along with line managers and experienced operation engineers are maximally utilised to impart training to fresh and experienced operations persons to provide insights to safety analysis and operating experience.

Updated e-training manuals ensure that licensed personnel have easy and assured access of these manuals any time they desire. The training centres are equipped with various mock ups and training aids such as cut-away-view of complex mechanisms e.g. Fuelling machine ram assemblies, separator assemblies, breakers of various types, Control valves etc. Computer based training packages (mostly in-house) are utilized to promote understanding of difficult dynamic devices.

11.2.7 Sufficiency of Staff at Nuclear Installations

Key personnel for O&M are identified and located prior to commencing commissioning operation and the full staff strength is progressively built up. O&M personnel gain valuable experience during commissioning of the Unit. Recruitment, Training and Qualification processes proceed in a planned manner so that the required complement of trained and qualified staff stipulated by AERB guide AERB/SG/O-1: 1999 is in position prior to start-up of the unit.

Minimum staff requirements are met as a part of Limiting Conditions of Operation (Technical Specifications) and any non-compliance may attract the regulatory enforcement. In addition, there is administrative control regarding the number of senior managers to be present at NPPs to ensure safety of NPPs.

11.2.8 Use of Contract Personnel

The contractors' competencies to meet desired task /work requirement is evaluated during pre qualification of a contractor/vendor agency after which only the agency becomes eligible for submitting tenders documents/offers. Some of the attributes considered for pre qualification are technical capability, financial status, resources (Man & Machine/Infrastructure back up), Quality assurance organization, safety organization, ISO certification etc. Feed back regarding credentials, past work experience and in-house design capability is also obtained for assessment of contractor's competency.

Contractor's personnel are not allowed to carryout any jobs without departmental supervision. They are not deployed for carrying out any operations in the control room and vital areas.

As per RPR 2004, workers including contract personnel should have appropriate training and instructions in radiation safety, in addition to the appropriate qualification and training required for performing their intended tasks. Licensee shall maintain complete and up-to-date records regarding their qualification and training.

11.2.9 Regulatory Review and Control Activities

The training procedure and programmes are subjected to audit by NPCIL corporate office as well as by AERB for verification of adherence to the procedures. For each training & qualification related activity, NPCIL has developed standards/ guidelines in consultation with AERB so as to meet the regulatory standards. Training & retraining, licensing & re-licensing, qualification & re-qualification of the plant personnel are carried out in accordance with the procedures approved by AERB and are described in section 11.2.3 above.

Plant managers also have to acquire management certification based on AERB approved guidelines. The licensing procedure prepared based on regulatory documents provides various standards including the methodology to deal with the exceptions, assumptions etc. The checklists are always kept current through periodic revision.

To facilitate effective re-training to the licensed engineers, as per the regulatory requirement, availability of 6-crew at each station is ensured. This provides uninterrupted opportunity for one crew to undergo training at respective training centres.

11.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

From the information provided above in this Article, it is evident that adequate financial resources are available to support the safety of each nuclear installation throughout its life. There is a well-developed system to assess the needs, generate and provide financial resources. The performance of the NPPs, operating base, centralized management, tariff mechanism, credit worthiness of the utility, etc are factors strongly in favour of meeting the obligations of this Article. With regard to human resources, an early start well ahead of the launching of the nuclear power programme has enabled a sound framework to be in place. This apart, systematic development has also been carried out over the years through experience and the evolving needs. The requirements stipulated by AERB through its Codes are quite exhaustive. This has been followed up by the Utility through its own systems and procedures. The necessary training infrastructure has been built to meet the needs. Thus the intent and obligations of this article have been fully met.

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.

12.1 REGULATORY REQUIREMENTS RELATED TO HUMAN FACTORS AND ORGANIZATIONAL ISSUES

AERB Code of Practice on Design for Safety in PHWR based NPPs, AERB/SC/D (Rev.1, 2009) establishes the requirement for design for optimised operator performance. This includes the need for designing working areas and environment according to ergonomic principles and a systematic consideration of human factors and the man-machine interface. Several design safety guides issued under the Code viz. Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants (AERB/SG/D-20) and Radiation Protection in Design (AERB/SG/D-12) provide guidance regarding design for optimum human performance. AERB safety code on operations (AERB/SC/O) also gives requirements to reduce the human errors. AERB has also issued a document on 'Human reliability analysis (methods, data and event studies) for NPPs' (AERB/NPP/TD/O-2).

Organizational factors and managerial aspects have a major impact on the behaviour of individuals. AERB code on quality assurance in NPPs (AERB/SC/QA, Rev1, 2009) cover the managerial commitment to improve human factors to enhance the safety in NPPs. It requires that management shall determine the competence requirements for individuals at all levels and shall provide training or take other actions to achieve the required level of competence.

12.2 HUMAN FACTOR CONSIDERATIONS

12.2.1 Design

The design of systems, structures and components and the plant layout is carried out in accordance with applicable design codes and guides as stipulated by regulatory body and prevalent international practices. The design is aimed at limiting the effects of human errors during normal operating conditions, transients and during maintenance. The man-machine interface is designed to provide the operators with comprehensive and easily manageable information. Wherever operator actions are required, it is ensured that adequate time is available for taking necessary actions. PSA insights are used to identify situations where human error could have significant contribution to CDF and the efforts are made to reduce them by introducing appropriate design changes. The control panels are ergonomically designed. Working areas are designed with due consideration being given providing personnel comfort to avoid the human errors. Availability of a training simulator is a mandatory regulatory requirement for licensing of NPP.

Human factors are considered during the design modification as a part of configuration management. Necessary changes in relevant documents, training, O&M procedures are carried out before issuing the technical bulletin for each of the modifications done.

12.2.2 Operation

The units are operated within the limits specified in the technical specifications. To ensure a high degree of quality in operation of an NPP, all control room operators are graduate engineers who are trained and licensed as per the licensing procedures approved by AERB. All activities including surveillance testing are performed with approved procedures to minimize errors due to human factors. All operations in the control room as well as in the field are carried out only after adequate pre-job briefing and planning. The utility establishes plant configuration control procedures to prevent human errors during outage management, maintenance and implementation of engineering changes.

12.2.3 Training

Training of staff for normal and abnormal operating conditions on full scope simulator is a mandatory regulatory requirement for their licensing. The simulator training focuses on reinforcement of expected behaviours like adherence to procedures and use of tools to prevent human errors like window alarm response sheets, pre-job briefing, three way communication, peer checking, self check-STAR principles and control room team building to minimize probable errors due to human factors. Performances based training, need based training and training at manufacturers place is also imparted for error free maintenance.

Special training courses are also arranged for all the concerned personnel on the design changes that are carried out. The operating staff is trained on the simulator also. Training sessions relevant to human performance are also organized at different plants in coordination with international organisations like WANO.

Training of the NPP staff is described in detail in chapter on Article 11(Financial and Human resources)

12.2.4 Event Analysis

An event reporting system is adopted (also section 19.6) and maintained to report events of varied significance to bring out underlying weaknesses in the system. All the events including low-level events are reported and analysed at various levels in NPCIL. The Significant Event Reports (SERs) are also reviewed in AERB. During these reviews due consideration is given to aspects related to human performance. The lessons learnt and corrective actions taken are disseminated through an operating experience feedback system. The weaknesses and areas of concern including safety culture highlighted by the event analysis are specifically addressed during training /retraining of the operation staff.

The low level events, which are large in numbers, are monitored and trended for identifying latent weaknesses. The remedial measures are implemented by way of design modifications, procedural changes or through specific training modules.

12.2.5 Maintenance

Performance monitoring of maintenance activities with respect to the human factors is carried out on a regular basis. Maintenance activities are carried out adhering to the approved procedures with appropriate stop points to ensure trouble free operation. Use of appropriate tools like training on mock-up facilities, pre-job briefing, three way communication, peer checking, self check-STAR principles are inculcated to minimize probable errors due to human factors. On the job observation and post maintenance review with supporting documentation are carried out for human performance analysis. Easy maintainability, ambient conditions and access to the equipment for carrying out the maintenance are considered during design stage for better human performance.

12.3 SELF-ASSESSMENT OF MANAGERIAL AND ORGANIZATIONAL ISSUES

Self-Assessment and Corrective Action Program has been implemented in all the NPPs with the objective of continuous improvement in plant performance, work practices and safety culture. Human performance, managerial and organizational aspects have been adequately emphasized in the process of self-assessment. The self assessment activities are carried out as per the guidelines given in NPCIL Head Quarter Instruction (HQI) no. 0535 (Revision-0, Issue -1, January 2009). The following self assessment activities are carried out at NPPs:

i. Self Assessments

Routine self-assessments include work space inspections or observations, communications with workers to ensure that expectations are understood properly, identification of performance weaknesses, review, analysis and trending of important operating parameters, review of deficiency reports and low level event reports, event investigation, outage/post job critiques, system/equipment inspections & document review, practice of industrial safety & fire protection, evaluation of plant/utility & external operating experience and periodic management review of performance.

Station Management teams are constituted with a senior officer as team leader to make periodic visits to various plant areas to observe material condition, housekeeping, work practices and also interact with persons working in the field. Station Director also constitutes a team of senior engineers with team members from NPCIL Headquarters / other plants for carrying out internal review. This is done once in a year for four days.

ii. Corporate Review:

Corporate Review is performed once in every two years by a team of experts constituted by NPCIL headquarters. The review is carried out as per Head Quarter Instruction (HQI) no. 0153 (Rev-2, 2008). Most of the team members are qualified reviewers and have attended WANO Peer Review Standard training. Some of the team members have WANO peer review experience also. This review is performed based on the document “Corporate Review – Performance Objectives & Criteria, Revision-0, June 2006”, which is similar to WANO Peer Review Performance Objectives & Criteria. The team reviews eleven main functional areas and seven cross functional areas and submits its report to plant manager and the corporate office. Team leader of the corporate review team makes a detailed presentation in the ACROSS (Apex Committee for Review of Operating Station Safety). The status of corrective actions implemented by the station is submitted to headquarters which is further reviewed by the apex committee at headquarters.

All stations have developed comprehensive corrective action programme to address issues identified during the above self assessment activities, review and analysis of low level events, near misses, events and significant events. These issues are discussed, prioritized, agency for taking corrective actions identified and due date for taking corrective actions are decided. Subsequently, these issues are entered into the corrective action programme of the station. Status of corrective action is periodically discussed in the meeting to ensure their timely completion. Station sends the action taken report to HQ on the issues identified during corporate review. Implementation status of the issues identified in corporate review is also tracked by ACROSS.

iii. Safety Culture

NPCIL has issued Head Quarters Instructions (HQI)-7006 for evaluation and enhancement of safety culture at NPPs. The HQI requires that the management of all NPPs prepare a list of safety culture indicators applicable to their site. The plant management is also required to carry out assessment of safety culture through written questionnaire, interviews and audit activities. The assessment is used to identify good practices and areas for improvements. The aspects related to safety culture are also assessed in the Corporate Review and WANO Peer Review programmes.

12.4 EXPERIENCE FEEDBACK ON HUMAN FACTORS AND ORGANIZATIONAL ISSUES

A NPCIL Head Quarter Instruction (HQI) no. 0540 (R-0, February 2007) provides guidance to plant management for the implementation of a structured operating experience programme (please refer sections 19.6 & 19.7). This helps in identifying further issues and areas related to human factors. To address such issues, suitable training programmes are developed and organized viz. training program on team building, root cause analysis and human performance enhancement. Refresher training programs for operation and maintenance personnel are organized periodically by station training centres at respective NPPs.

12.5 REGULATORY REVIEW AND CONTROL ACTIVITIES

AERB has specified the requirement for addressing aspects relating to human performance in the design of NPPs. These topics form one of the important areas of regulatory review and assessment. During operation phase, AERB establishes a multi-tier system for regular monitoring of safety at NPPs. Events, design modifications for systems important to safety, operational performance and radiological performance are also reviewed as they have close relationship with human factors. During the PSR, human factors are one of the elements reviewed. The regulatory body considers human factor contribution in these areas as one of the indicators for safety culture at the NPPs.

12.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Human factors are given adequate consideration during design and operation of NPPs. Training and retraining of operating personnel, use of simulators, lessons learnt from the events, maintaining a stress free working and living environment, operational feedback and regulatory control have been adequately established. Hence, India complies with the obligations under Article 12 of the Convention.

ARTICLE 13: QUALITY ASSURANCE

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes 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.

13.1 ARRANGEMENTS AND REGULATORY REQUIREMENTS FOR QUALITY ASSURANCE

Quality Assurance Programme in India has evolved following National, International Standards and Codes of practices followed in the Nuclear industry. The AERB Code of Practice on 'Quality Assurance in Nuclear Power Plants (NPPs)' AERB/NPP/SC/QA (Rev. 1), 2009 gives the requirements for the management principles and objectives to be met during the implementation of activities in all the stages of NPPs for assuring safety. Several safety guides issued under the Code provide guidance to achieve the objectives envisaged in the Code. The review and assessment carried out by the AERB during these stages of licensing includes the consideration of applicant's management system, which has been described in Chapter on Article-14 on Assessment and Verification of Safety. The AERB code makes extensive use of IAEA safety standards GS-R-3, on 'The Management Systems for Facilities and Activities' among other documents on the subject. The revised code includes requirements on resource management, configuration management, infrastructure and work environment, safety culture, management commitment, communication, managing organizational change and improvement of QA programme.

Requirements of NPCIL quality management system are given in "Corporate Management System - Quality Management System Requirements". The document emphasises on integrated approach for the management system for Safety, Health, Environment, Security, Quality and Economic requirements. The document is based on AERB codes and guides, IAEA Safety Standard GS-G-3.1 on "Application of Management System for Facilities and Activities" ISO standards and other relevant documents. BHAVINI also has issued its quality policy and maintains an effective quality management programme.

The following paragraphs provide the summary of the corporate management system as established and maintained in NPCIL.

13.2 QUALITY ASSURANCE POLICIES AND MANAGEMENT SYSTEMS

13.2.1 Organisational Policies

The Head of the Utility has issued the "Statement of Policy and Authority" for the Organisation. The statement directs that a management system for Quality in the various phases of the NPPs viz. Design and Development, Procurement, Manufacture, Construction, Commissioning and Operation be adopted so that the safety of the NPPs, plant personnel and public is assured. In the said statement sufficient authority has been delegated to the Heads of functional wings for ensuring implementation, maintenance and continual improvement of the Management System at all time.

13.2.2 Quality Management System

The 'Integrated Quality Management System' elaborated in the "Corporate Management System Document-Quality Management System Requirements" of the utility ensures implementation of the applicable AERB codes and guides. It also considers the relevant IAEA documents. These documents provide the necessary directives for implementation, maintaining, assessment, measurement and continual improvement of the management system for compliance with the regulatory requirements and intents in all phases of the NPPs.

The document has been implemented since last three years. Departments at NPCIL HQs responsible for engineering, procurement, safety and quality assurance functions have been subjected to ISO 9000: 2008 certifications. Similar controls are exercised on vendors and contractors.

13.2.3 Documentation

The policies, management system requirements, authority, responsibilities, procedures, work instructions, reports, processes, activities, data and records and other relevant supporting information describing management of the work, performance and assessment are duly documented and controlled. These documents reflect the characteristics of the processes, activities and their interactions.

The documentation is categorised into three levels as follows.

a) First Tier Document.

This is the “Corporate Management System” document of the Utility describing policy statement, management system, organisation structure and functional responsibilities, accountabilities, levels of authority and processes. This document further defines the interfacing and integration of the various processes and activities.

b) Second Tier Document

This document derives directives from the 1st tier Corporate Management System Document and consists of Management System Manuals and all other related documents translating the corporate policies and commitments to practices and details.

c) Third Tier Documents.

These documents consist of Quality Management/Assurance System Manuals, Procedures, Instructions and Practices of the vendors and contractors of utility to the extent they are relevant in meeting the Corporate Management System Programme.

The above documents are revised periodically.

13.2.4 Process Management

The processes needed to achieve the mission and objectives of the utility are duly identified. These processes are planned, developed, implemented, assessed and continually improved for delivering the products in accordance with the requirements of the Management Systems. The management processes are assessed for integrating the effect of technical, safety, economic, health, environment, security, quality and financial performances, monitoring achievement of the objectives and effectiveness, and taking corrective measures where required. A structured approach is implemented in decision making for meeting the needs of business strategy for product realisation.

Processes and activities involved in design, procurement, construction, operations, and all other supporting processes are duly documented and integrated in achieving the milestones and time schedules in project execution and all related activities. Process requirements, sequence and interaction of processes and activities, criteria and methods needed for implementation and control, process inputs, and process outputs are specified and established and their effectiveness ensured, process flow described and measurement criteria established. Interfaces and activities of various functional directorates are planned, managed, effectively communicated to groups and individual concerned for the specific processes, responsibilities assigned and implemented.

13.2.5 Graded Approach

It is recognised that Systems, Structures and Components (SSCs), processes and services are required to be of specified quality consistent with their importance to safety and use to which they are to be put, and accordingly classified and graded. Management System Programme has provision for such graded approach for different processes, items and services.

13.2.6 Document Control

Personnel preparing, revising, reviewing and approving the documents are specifically authorised for the work and provided with all the relevant information and resources. All relevant documents and records generated in the various phases of NPPs are duly controlled and maintained.

13.3 QUALITY ASSURANCE PROGRAMME

13.3.1 Organisation and Responsibilities

a) Organisation

The Utility is managed by a Board of Directors, headed by the Chairman and Managing Director (CMD). The CMD is responsible for all technical, financial and administrative functions and is assisted by the designated Technical, Financial, Administrative and other Functional Heads.

The Functional Heads are duly assisted by suitable qualified personnel to perform the assigned functions, activities and applicable processes, for establishing, implementing and maintaining the Quality Management System elements in their respective areas of responsibilities.

b) Responsibilities

"Statement of Policy and Responsibility" as defined by the Head of the Utility promotes a culture of conformance with the statutory and regulatory requirements, stakeholders satisfaction, continual improvement and other requirements as elaborated in the corporate level document. The Functional and Unit Heads are responsible for managing, performing and controlling activities and processes to ensure that the products supplied and the services rendered meet the specified requirements. Functional Heads are also responsible for ensuring that the authorised personnel performing the functions are well aware of the organisational objectives, and provide requisite support to the degree necessary in achieving these objectives.

c) Interface Arrangements

Functional interfacing and cross-functional integration of core processes i.e. Design, Procurement, Manufacture, Construction, Commissioning and Operations and also the supporting processes are implemented in a coherent manner to meet the necessary agreed arrangements and responsibilities.

d) Resource Management

Resources viz. personnel, infrastructure, work environment, information, communication, suppliers and partners, materials and finance essential for the implementation and strategy of the utility mission and objectives are identified, provided, maintained and improved for ensuring efficient and effective performance.

Requisite human and financial resources are provided for developing, implementing and maintaining the stated competencies in achieving the stated mission of the Utility. For this purpose suitably skilled, qualified and authorised task performers are deployed, skills continuously upgraded by suitable training processes, thus enhancing their competence level.

13.3.2 Quality Assurance in Design

Engineering Directorate is responsible for design, development and engineering activities undertaken in the Utility. Design from concept to completion is undertaken, reviewed, evaluated, analysed and validated. Design and development processes and activities are performed following the Quality Management System Manual of Engineering Directorate of the Utility developed in line with the 'Corporate Management System Document'.

13.3.3 Quality Assurance in Procurement

Procurement Directorate is responsible for procurement of SSCs for NPPs. The Directorate establishes and implements procurement management processes, consistent with the requirements stated in "Corporate Management System Document". The objective of implementing Management Systems in procurement is to ensure that procurement of SSCs is made from duly qualified and approved Suppliers, and that they meet the applicable regulatory, statutory and other stated requirements specified in the Procurement Document(s),

13.3.4 Quality Assurance in Manufacturing

Management System in manufacturing is to assure that stated requirements for manufacturing for SSCs are complied with. It is the responsibility of each organisation participating in the manufacture and supply of SSCs to establish and implement Quality Management System Programme so that the product meets the design intended requirements. The Manufacturers shall have the Quality Management System duly implemented and maintained. Manufacturers supplying SSCs for the Utility are responsible for the Quality Management processes at their supplier's premises also. The Utility monitors the supplier's Quality Management System Programme by the established verification processes. The Utility or their authorised representative(s), have access to all areas where work involving the concerned contract/purchase order is in progress for carrying out quality surveillance. This includes access necessary to verify implementation of all aspects of the Quality Management System / Quality Assurance Programme, products and to their supplier's premises also.

13.3.5 Quality Assurance during Construction

Quality Management Systems are elaborated in the respective project level document derived from the 1st tier corporate level document for Construction of the NPP, to ensure that civil works, erection, installation and associated testing of Reactor, Piping, Mechanical, Electrical and Control and Instrumentation systems, and SSCs are carried out safely and meeting the specified requirements.

The Head of the NPP construction site is responsible for establishing and implementing the Management systems during project construction. He is duly supported by independent groups headed by competent personnel for the civil, mechanical, reactor, electrical, piping, control and instrumentation works and auxiliary systems. Independent Field Engineering and Quality Assurance Groups are also set up for overseeing design and quality aspects respectively during the construction phase.

13.3.6 Quality Assurance in Commissioning

Commissioning activities commence after completion of respective construction activities. The transfer of responsibility from construction to commissioning is documented through Construction Completion Certificate (CCC) and System Transfer Documents (STDs). All commissioning work is systematically planned, accomplished and documented. Management system implemented during commissioning is to assure that commissioning is performed following stipulated requirements and to demonstrate the functional adequacy of plant, systems, structures, and components. The verification confirms that the acceptance criteria specified in the applicable documents are met and deficiencies, if any, are corrected. For this purpose inspection and conformity checking is done to verify compliance. All specific or general deficiencies are identified, documented, investigated and closed. All corrective and preventive actions as required are implemented on due analysis of non-conformances / potential non-conformances.

A system of planned and documented audit to verify the implementation and effectiveness of QA programme during commissioning phase is provided. Commissioning records are prepared and maintained to provide objective evidence that the Quality Management System program is effective and the stated requirements complied with.

13.3.7 Quality Assurance during Operation

Management Systems implemented during operation assure that the NPPs together with its components and systems are operated safely, in accordance with the design intent and within the specified operational limits and conditions as stipulated in the technical specifications. Head of the Directorate of Operations at the corporate level is responsible for the operating plants. Plant Management at each NPP Station is headed by a Station Director (SD) reporting to the Head of Operations at Corporate level. The SD has the overall responsibility for safe operation of the plant, in implementing all relevant requirements, instructions and procedures laid down by the Utility, Regulatory and Statutory Bodies. Responsibilities and authorities of plant management and functional positions have been stated in the Station Policies for each station. SD is responsible for establishing, implementing and effectiveness of the Management system Programme for safe operation of the station. The QA group at NPP is responsible for inspection, testing, quality control, surveillance, verification, auditing, carrying out of ISI, monitoring and assessing effectiveness of QMS and its improvement, for all activities of station operation, following NPP Station QMS Document.

13.4 IMPLEMENTING AND ASSESSING QUALITY ASSUARANCE PROGRAMMES

The Management System of the Utility has the requisite processes and systems to monitor and measure levels of performance achieved in effective implementation of the QMS (QA programme). The levels of performance are based on use of performance indicators, measuring with reference to the objectives set by the management and delivered product. Measures for continual improvement are initiated in the management system accordingly.

The Senior Management identifies, prevents and corrects management problems that hinder achievement of the Utility objectives. By due assessment process at all levels effective implementation of the company programme is realised. Self-assessment at all levels is considered to be an effective tool to achieve these objectives. All the Managers and Task Performers periodically perform self-evaluation in their areas of work to compare current performance to management expectations in respect of worldwide industry standards of excellence (bench marking), meeting stakeholder requirements and expectations, regulatory and statutory requirements, and to identify areas needing improvement.

The Utility has also obtained ISO certification for operating stations and core functions at HQ.

13.5 REVIEWS AND AUDIT PROGRAM

A system of planned and documented audits/reviews within the Utility organisation like functional directorates, units under construction and operating stations is established and carried out to verify compliance, determine effectiveness of implementation of all aspects of the Management System Programme, for continual improvement of the programme. Similar audits are also carried out in the organisations of suppliers and sub-suppliers.

Internal and external audits are carried out as a part of ISO system to ensure the adherence and functioning of system.

13.6 REGULATORY REVIEW AND CONTROL ACTIVITIES

As mentioned above, the review and assessment by the AERB includes consideration of the applicant's organisation, management, procedures and safety culture, which have a bearing on the safety the plant. It is required that the applicant should demonstrate that there is an effective management system in place that gives the highest priority to nuclear safety and security matters. Specific aspects, which are subject to review and assessment, include:

- Whether the applicant's safety policy emanates from senior management and shows commitment at a high level to safety requirements and the means to achieve them.
- Whether the applicant's organisation is such that it can implement the commitments made in the safety policy, through existence of adequate procedures, practices and organisational structure.
- Whether the applicant has procedures to ensure that there is adequate planning of work, with suitable performance standards, so that staff and managers know what is required of them to meet the aims and objectives of safety policy.
- Whether the applicant has a system in place to periodically audit its safety performance.
- Whether the applicant has procedures in place to review periodically all the evidence on its safety performance in order to determine whether it is adequately meeting its aims and objectives and to consider where improvements may be necessary.
- Whether the applicant has culture, commitment, organisation, systems and procedures, to meet the nuclear security requirements.

The review and assessment by AERB covers all aspects of the applicant's managerial and organisational procedures and systems which have a bearing on nuclear safety such as, operational feedback, compliance with operating limits and conditions, planning and monitoring of maintenance, inspection and testing, production of safety documentation, and control of contractors.

13.7 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The comprehensive Quality Management System (QMS) in the NPCIL organisations has been developed in accordance with the national and international standards and the same is being maintained and further improved through programme of monitoring and assessment of its effectiveness. The regulatory review and assessment activities ensure that there is an effective safety management system in place that gives nuclear safety and security matters the highest priority. Therefore, India complies with the obligations of the Article 13 of the Convention on Nuclear Safety.

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 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.**

14.0 GENERAL

The assessment and verification of safety is an integral part of the nuclear power programme. AERB Safety Code, AERB/SC/G: 2000, on "Regulation of Nuclear and Radiation Facilities" spells out in detail the obligations of the licensee and the responsibilities of the Regulatory body.

The utilities perform their own assessment and verification functions. Utilities carry out these functions during design, manufacturing, construction, commissioning and operation through their Directorates of Engineering, Safety, Projects and Operation. Separate corporate level safety committees for the projects and the operations review all the issues including the results of assessment and verification of safety. All the information generated during the entire design, construction and commissioning phases is documented and handed over to the Plant Management before the commencement of reactor operation.

AERB establishes its programmes for assessment and verification of safety during all the consenting stages viz. Siting, Construction, Commissioning and Operation, and also during regular plant operation. These programmes are based on routine and special reports from the licensee and regulatory inspections carried out by staff of AERB. The objective of assessment and verification programmes by AERB is to ensure that the utility’s own programmes are adequate and satisfactorily implemented. A multi-tier system of safety committees is followed for carrying out regulatory review and assessment during all the consenting stages.

14.1 ASSESSMENT OF SAFETY

14.1.1 Regulatory Requirements for Safety Assessments

14.1.1.1 Consenting Process

AERB Safety Guide AERB/NPP&RR/SG/G-1 on “Consenting Process for Nuclear Power Plants and Research Reactors” explains the entire consenting process for nuclear installations followed in India. The safety guide defines the regulatory consenting process at all the major stages of a nuclear installation. It gives in detail the information required to be included in the submissions to AERB, document submissions, and areas of review and assessment for granting the regulatory consent. Assurance of safety during various stages of NPP is derived through this process. Under the process, consent is issued for siting, construction and decommissioning. Regulatory clearances are issued for intermediate stages during construction and commissioning. Licence is issued for operation of NPPs and other nuclear and radiation facilities. The consents and licenses are issued by AERB on the basis of its safety review and assessment of the submissions made by utility.

Licence for operation of NPP is issued for five years. The renewal of licence for operation is issued by AERB based on safety reviews as specified. These are (a) safety review of application submitted in the prescribed format, three months prior to completion of five years of operation and (b) Review of Report on Periodic Safety Review (PSR) every ten years of operation. Thus in a ten year cycle, NPPs seek two licence renewals for operation, first after five years and the second after ten year based on PSR. In case of NPP of new design, the first PSR is carried out after five years of operation and the subsequent PSRs of these NPPs are carried out at 10 year intervals.

14.1.1.2 Safety Review Mechanisms

i) Utility

In accordance with the regulatory requirements of an independent internal review of design and operational aspects of NPPs, utilities have set up internal review mechanisms. For new designs, design of structures, systems and components is reviewed by persons with appropriate qualification and design experience. In case of repeat design, any change in design involving a new concept (e.g. software based system compared to hardwired system) goes through an independent review. All the issues raised by the independent reviewer are resolved. Subsequently, Safety Review Committee (Projects and Design) of the utility organisation independently reviews the documents and after satisfactory resolution of the identified issues, documents are submitted to AERB. The observations / issues coming out of review in AERB are resolved, documents are revised and re-submitted to AERB for formal clearance. The document finally cleared by AERB forms the basis for the detailed design and further engineering.

Elaborate organisational structure (please refer chapter on Article 19) is established at each plant for reviewing safety aspects during operation. Station Operation Review Committee (SORC) headed by Station Director is established at each NPP. SORC reviews station operations on routine basis to detect potential safety issues. At the corporate level, Safety Review Committee (SRC) for operating NPPs with representation from design, safety, operation and quality assurance groups at utility headquarters reviews all safety related proposals, including engineering changes, which require review and concurrence by regulatory body. The recommendations made by SRC are incorporated before the proposal is forwarded to AERB unit safety committee / SARCOP.

ii) Regulatory Body

AERB adopts a multi-tier review process for safety review and assessment of NPP during all the consenting stages.

During siting, construction and commissioning, the first level of review and assessment is performed by Site Evaluation Committee (SEC), Project Design Safety Committee (PDSC)/Specialist Groups and/or Civil Engineering Safety Committee (CESC), as appropriate. These Committees are comprised of experts in various aspects of NPP safety. The next level of review is conducted through an Advisory Committee on Project Safety Review (ACPSR). This committee is a high-level committee with members drawn from AERB, reputed national laboratories and academic institutions. It also has representation from other governmental organisations like Ministry of Environment and Forests, Central Electricity Authority and Central Boilers Board. This advisory committee reviews the application for consent together with the recommendations of the first level committees on the related consent and gives its recommendations to AERB. After considering the recommendations of first level committee and ACPSR, the Board of AERB decides on the consent. Annexes 14-1 to 14-4 illustrate the review process followed during siting, construction, commissioning and operation stages.

During operation, AERB follows a multi-tier approach involving review at three levels viz. Unit Safety Committee (USC), Safety Review Committee for Operating Plants (SARCOP) and the Board of AERB. 'Unit Safety Committees' consists of representatives from AERB, experts in various aspects of nuclear technology drawn from Technical Support Organisations and representatives from utility. SARCOP is the apex body to decide on the matters of nuclear safety and has members from AERB staff, experts drawn from TSOs, retired experts and one member from the directorate of health and safety of the utility. Chairman, SARCOP is an ex-officio member of the Board of AERB. The third-tier is the Board of AERB, which based on the recommendations of SARCOP, considers major safety issues pertaining to NPPs. Annex 14-5 gives the aspects of safety review during operation of NPP. The system of safety committees function on the principle of "management by exception" following a graded approach. Safety issues of greater significance are further reviewed in higher-level safety committees for resolution. The recommendations of these committees are accepted by AERB after ensuring that they are in line with the safety goals, principles and requirements laid down by AERB.

14.1.2 Safety Reviews during Consenting Process

14.1.2.1 Safety Review for Siting

The first stage of consenting i.e. Siting, involves the review of the various site related safety aspects considering the conceptual design and issuance of siting consent for locating the NPP. This requires submission of a Site Evaluation Report which includes the salient features of the proposed site, site characteristics affecting safety and basic design information of the proposed NPP. The Site Evaluation Report should contain information as per requirements specified in the AERB Code of practice for Siting of NPP (AERB/SC/S) and various other relevant AERB Siting guides.

The objective of the review for this stage is to ensure that the proposed site is engineerable for the construction and operation of an NPP in a safe manner. In evaluating the suitability of a site for locating a NPP, the following major site-specific aspects are considered.

i) Effect of site characteristics including external events (natural and human induced) on the plant
ii) Effect of the plant on the environment and population, and
iii) Implementation of emergency procedures in the public domain.

Other aspects such as foundation, cooling water requirements, thermal and chemical pollution, power evacuation, transportation of over dimensioned consignments, etc, are also considered.

14.1.2.2 Safety Review for Construction

The second stage of consenting i.e. Construction, involves review of the design safety aspects and issuance of construction consent. This requires on the part of the applicant, submission of Preliminary Safety Analysis Report (PSAR) in the prescribed format, the applicant's site construction Quality Assurance manual, construction schedule and construction methodology document for the proposed NPP. As a supplement to PSAR, separate design reports of items important to safety, having relevance to construction authorisation are required to be progressively made available for review before consent for construction is issued. AERB also reviews the documents related to industrial safety such as Job Hazard Analysis Report, Construction Safety Management Manual, etc and monitors their compliance.

Depending on the request from the applicant, AERB may issue the consent for construction as a one time authorisation for total construction activities or as clearance in three stages viz. clearance for excavation, clearance for first pour of concrete and clearance for erection of major equipment. If consent for construction is issued in these clearance stages, PSAR reviews are organized according to the specified requirement for these stages.

14.1.2.3 Safety Review for Commissioning

Commissioning activities in NPP are initiated in parallel to construction during the later period of construction. Various equipment and systems are individually commissioned as and when the prerequisites for their commissioning are met. The first regulatory clearance within the commissioning consent is required when the applicant desires to initiate the integrated commissioning activity e.g. hot conditioning (integral testing and passivation of primary heat transport system) in the case of PHWR based NPPs. Following this, there are a number of intermediate commissioning stages at which also regulatory clearances are required. The consent for commissioning is given in several interim stages as deemed necessary by AERB. Some of these interim stages e.g. containment test, fuel loading, approach to first criticality, low power physics experiments, etc. are witnessed by the representatives of AERB, if required.

For commissioning consent, AERB reviews the final or 'as built design of the nuclear power plant as a whole. AERB satisfies itself that (a) the plant has been built in accordance with the accepted design and meets all the regulatory requirements, (b) the required level of quality has been achieved and (c) the safety review and assessment of all relevant systems including the required tests have been satisfactorily completed.

The review and assessment by AERB also covers all aspects of the applicant's managerial and organizational procedures and systems, including the availability of required trained and qualified personnel for operation, which have a bearing on safety.

AERB requires that at this stage, the utility should establish following programs:

(a) Surveillance, maintenance and in-service inspection programs.
(b) Performance review and operational experience feed back programmes
(c) Programmes for Ageing Management
(d) Training program for operating personnel

14.1.2.4 Safety Review for Licence for Operation

The 'Licence for Operation' is issued for regular operations after review of NPP performance at rated power for a period which is typically 100 days. During this period, specified tests are conducted to confirm behaviour of the plant as per design. To obtain, the licence for regular power operations, the applicant has to submit a Final Safety Analysis Report (FSAR) reflecting the 'as built' design of the NPP approved by AERB and detailed performance reports, in support of the application.

Before granting licence for operation, the regulatory body reviews the results of commissioning tests and performance data at various power levels for their consistency with design information and with the prescribed operational limits and conditions. Inconsistencies, if any, have to be resolved to the satisfaction of AERB

After completion of the reviews, AERB issues authorisation for operation of NPP for a specified period.

14.1.2.5 Safety Reviews during Operation

Operation of the nuclear installations in India is carried out in conformance with the AERB safety code on 'Nuclear Power Plant Operation, AERB/NPP/SC/O (Rev. 1): 2008 and the safety guides made there under (AERB/SG/O-1 to O-15). During regular operation, reviews are carried out to ensure that the operation of the plant is being carried out in accordance with the approved Technical Specifications, AERB codes and guides and the licensing conditions. These reviews include

i. Routine reviews and assessments

The safety supervision during operation mainly includes continual monitoring and assessment of operational and safety performance, radiological safety, maintenance and in-service inspection activities and the results thereof, findings of regulatory inspections, renewal of licence every five years and periodic safety review every ten years.

ii. Periodic safety assessments

As brought out earlier (section14.1.1.1), NPPs seek two licence renewals for operation in a ten year cycle.

For licence renewal once in every five years, utility has to submit application in a prescribed format, which covers operational safety performance, operational experience feedback, physical status of plant and public concern in operational safety. The report is submitted to AERB three months prior to the expiry of the operating licence. AERB conducts a detailed review of the same and issues the licence after being satisfied that the plant could be operated in a safe manner for next five years at the power levels authorised for the plant within the operational limits and conditions specified in "Technical Specifications for Operation" and that the continued operation of NPP till the next renewal would not pose undue risk to the plant, plant personnel, public and the environment.

PSR is carried out in accordance with the guidelines given in AERB safety guide AERB/SG/O-12. Safety assessments performed during PSR takes into account improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feedback of operating experience, probabilistic safety assessments and development in science and technology. Through this process of PSR, the strengths and shortcomings of the NPP against the requirements of current standards are identified. The report on the PSR is subjected to regulatory review in the multi-tier review process for satisfactory resolution of the shortcomings.

Some of the major safety assessments, their results and corrective actions taken are summarised in article 6 of this report.

14.1.3 Regulatory Review and Control Activities

14.1.3.1 NPP Projects

As has been brought out, AERB carries out safety review during various consenting stages like Siting, Construction, Commissioning and Operation. During these stages, there are a number of intermediate commissioning stages at which regulatory clearances are required. These stages act as checkpoints where the results of previous activities and prerequisites for further activities are reviewed till the plant is brought to operational state.

Responsibility of QA & QC during manufacturing, fabrication, construction and commissioning rests with the Utility. Regulatory process calls for setting up mechanisms within the utility to carry out internal audits by specifically constituted groups of various activities/jobs executed by the constructors, vendors, Utility etc. Regulatory Inspection teams check these audit reports in addition to physical verification and scrutiny of various documents/ records related to QA & QC, preservation and storage, industrial and fire safety aspects, adherence to regulatory stipulations etc. Observations and recommendations of Regulatory Inspection are required to be complied with and responded to by the utility. The Utility is asked to check and apply these observations / recommendations suitably on similar types of jobs/ activities.

Regular safety review and assessment for NPPs during construction and commissioning is conducted by the designated AERB staff that also has the responsibility of organizing and follow up of the regulatory inspections. In addition to normal regulatory inspections, AERB also identifies a list of important activities during construction and commissioning as hold points for which the licensee is required to inform the regulatory body in advance for deputing its representative to witness these activities as observers. The reports on these activities including the remarks by AERB observers are taken into account for giving clearance for further work during construction/commissioning. AERB staff participate in all the review and assessment functions, regulatory inspection and witnessing of the important activities. Due to this arrangement of regulatory supervision, all the important activities having bearing on safety get adequate regulatory coverage.

14.1.3.2 NPP Operations

Licence for operation of NPP is issued by AERB for a specified period. During this period, the operational NPPs undergo routine and special safety reviews as described below

a. Reports to AERB

Events and Significant Events are reported to AERB as per the event reporting system (please refer section 19.6). In addition, AERB obtains various reports from the NPPs such as monthly and annual performance reports, report on long outages for carrying out surveillance, in-service inspection & major maintenance and reports of special investigation committees and/or special regulatory inspections following an event of major safety significance.

b. Training and qualification of operating staff

The Technical Specification identifies the qualification levels for operating staff and the management. The curricula of different licensed positions are prepared by the utility and vetted by the regulatory body. The operating staffs undergo system of classroom training, on the job training, checklist, walk through and simulator training and are interviewed by the AERB Committee on Qualification of Operating Personnel. Similarly, AERB evaluates the personnel in the management positions through an AERB Committee on Licensing of the Station Management Personnel for the initial licence and renewal of Licence. The licence is generally valid for three years after which the candidate undergoes a retraining exercise and again appears before the appropriate AERB Committees. The details of the entire training programme are given in chapter on Article 11.

c. Radiological safety status

The Health Physics Unit (HPU) and Environmental Survey Laboratory (ESL) stationed at the site are independent of the plant management. In addition to providing services related radiological monitoring, the HPU at the NPP also advises the plant management on the matter relating to radiological safety. The ESL, which is established at the site before the start of the operation of the reactor, carries out extensive monitoring of air, water, soil, flora and fauna within the plant area, exclusion zone and emergency planning zone. AERB gets periodic reports from the HPU and the ESL on the radiation and environment safety of the NPP. AERB committees review these reports along with the response of NPP management on the same.

d. Management of radioactive waste

The performance of radioactive waste management system established at NPPs is reviewed to ensure that appropriate methods and management practices continue to be in place and the generation of radioactive waste is kept to as minimum as practicable in terms of activity and volume.

e. Design modification in safety and safety related systems

Any design modification in the safety and safety related systems of the plant has to pass an in depth regulatory review and approval procedure. For such modifications, the utility submits the plant modification proposal in the prescribed format, which must be accompanied by a safety assessment report both by the station staff and designers at the corporate level. The modification proposals are then reviewed in USC and SARCOP. AERB may seek the opinion of experts or refer the matter to any of the national laboratories or academic institutions for independent analysis for verification of the claims of the utility.

f. Emergency Preparedness:

The NPPs carry out periodic exercises for plant, site and off site emergency according to the prescribed frequency. The reports of these exercises are reviewed in AERB. Various state and central agencies participate in the offsite emergency exercises. AERB also deputes its representatives as observers to oversee the conduct of the off-site exercise.

In addition to the above, special reviews are undertaken following an event or observations of major safety significance occurring abroad, for their applicability in the Indian NPPs and need for any corrective measures.

14.2 VERIFICATION OF SAFETY

14.2.1 Regulatory Requirements for Verification of Safety by the Licensee

AERB Safety Code on “Design of Pressurised Heavy Water Reactor based Nuclear Power Plants” AERB/NPP-PHWR/SC/D (Rev.1) 2009, requires that a comprehensive safety assessment shall be carried out to confirm that the design, as used for construction and as built, meets the safety requirements set out at the beginning of the design process and the utility shall ensure that an independent verification of design and the safety assessment is performed by an independent group, separate from that carrying out the design, before it is submitted to the regulatory body.

“Code of practice on safety in nuclear power plant operation”, AERB/NPP/SC/O (Rev.1), 2009 establishes requirements related to operation of NPPs and several safety guides issued under this Code, describe and make available methods to implement specific requirements of the Code. The code requires establishment of management programmes related to operation review and audit with the aim of ensuring that an appropriate safety consciousness and safety culture prevails. In accordance with the requirements, an elaborate verification programme is established at NPPs and the adequacy of the programme is periodically monitored. Audits are conducted by plant management and also the utility headquarters to verify that that the safety verification programmes are being followed at the plant. AERB exercises regulatory control over the nuclear power plants following a system of safety monitoring, inspection and enforcement and periodic assessment for renewal of Licence.

14.2.2 Programmes for Continued Verification of Safety

As per the regulatory requirements, the plant management is required to establish the following programmes before a licence for operation is granted:

a) Maintenance Programme - The maintenance programme is put in place to ensure that (i) safety status of the plant is not adversely affected due to ageing, deterioration, degradation or defects of plant structures, systems or components since commencement of operation and (ii) their functional reliability is maintained in accordance with the design assumptions and intent over the operational life span of the plant. The NPP prepares a preventive maintenance schedule for systems, structures and components. In addition, system for trend monitoring of the important equipment is used for predictive maintenance. The preventive maintenance includes daily surveillance and verification, periodic preventive maintenance and predictive maintenance.

b) Surveillance Programme - The surveillance programme for safety systems and systems important to safety are included as part of the Technical Specifications for Operation. Through this, it is verified and ensured that the safety of the plant does not depend upon untested or unmonitored components, systems or structures. The programme includes tests like functional tests, calibration checks for Protection Systems, Emergency Core Cooling System, Containment Systems, Emergency Power Systems and various other important Systems, Structures and Components (SSC) important to safety.

c) In-service Inspection Programme - As per this programme, plant components and systems are inspected for possible deterioration in safety margins and their acceptability for continued operation of the plant and to take corrective measures as necessary. Systems, Structures and Components (SSC) important to safety of the plant are identified in the In-service Inspection manual, which gives the requirements with respect to (a) areas and scope of inspection (b) frequency of inspection (c) method of inspection and (d) the acceptance criteria.

d) Performance Review Programme - The basic purpose of this programme is to identify and rectify gradual degradation, chronic deficiencies, potential problem areas or causes. This includes review of safety-related events and failures of SSC of the plant, determination of their root causes, trends, pattern and evaluation of their safety significance, lessons learnt and corrective measures taken.

e) Establishment of programme related to life management - This programme is used to obtain information on behaviour of the Systems, Structures and Components, as identified for ageing management purpose, under reactor environment and to undertake necessary studies/experiments with respect to their residual life assessment

f) Programme to update Probabilistic Safety Assessment - The programme for collection of plant specific failure data at NPPs is established for evaluation of reliability of safety systems. These data are judiciously used to update the results of PSA studies. The proposals for design modifications or revision in technical specification requirements are required to be supported by the results of PSA studies.

Arrangements for internal review by the Licence holder both during projects and operation are described in section 14.1.1.2.

14.2.3 Regulatory Inspection and Enforcement

(i) Regulatory Inspection

Compliance to the regulatory requirements is monitored by conducting periodic regulatory inspections. The regulatory inspections of NPPs are carried out during all stages of licensing to verify and ensure compliance to the regulatory requirements. During regulatory inspection, documented evidences for compliance to the regulatory requirements are examined. The regulatory inspections are carried out as per the guidelines given in AERB safety guide on 'Regulatory Inspection and Enforcement in Nuclear and Radiation Facilities (AERB/SG/G-4)'. The provisions of the guide are elaborated in safety manual (AERB/NPP/SM/G-1). Depending upon the requirements, AERB staff carries out periodic regulatory inspections as well as special unannounced inspections with specific objectives as deemed necessary.

During construction and commissioning stages, the inspections are carried out at a frequency of four inspections in a year. Regulatory Inspection team consisting of typically eight members carries out inspection for a period of about one week. Composition of team and areas to be inspected are pre-decided, taking into consideration the status of the project. In addition to normal regulatory inspections, AERB also identifies a list of important activities during construction and commissioning as hold points for which the licensee is required to inform regulatory body in advance for deputing its representative to witness these activities.

During operations, these inspections are carried out twice a year. Special regulatory inspections are carried out subsequent to an event, depending on the safety significance or after major modifications in the plant and form the basis for considering clearance for restart of the unit. In addition to these, unannounced inspections are carried out at the discretion of AERB for assessing the prevalent safety status at the NPP on any normal day.

In general, the following areas are covered during a typical regulatory inspection of an operating NPP.

- Operation, Maintenance and Quality Assurance Programme.
- Adherence to the technical specification.
- Compliance to various regulatory recommendations.
- Adequacy of licensed staff at NPPs
- Performance of safety related systems.
- Radiation safety and ALARA practices.
- Emergency Preparedness
- Industrial Safety

Based on the inspection, a detailed inspection report is prepared and the utility is briefed about the findings in an exit meeting. The inspection findings are categorised according to their safety significance.

(ii) Enforcement:

The utility is required to submit an action taken report within a specified time frame on the deficiencies pointed out during the inspection. These submissions are reviewed in AERB for disposition and need for any enforcement action. The regulatory body may also initiate enforcement actions, if in the opinion of regulatory body, the licensee has violated the conditions of the licence wilfully or otherwise or misinformed or did not divulge the information having bearing on safety after specifying the reasons for such actions. The enforcement actions may include one or more of the following.

i) A written directive for satisfactory rectification of the deficiency or deviation detected during inspection;
ii) Written directive to applicant/licensee for improvement within a reasonable time frame;

iii) Orders to curtail or stop activity;
iv) Modification, suspension or revocation of licence; and
v) Initiate legal proceedings under provisions of the Act.

During the past three years AERB asked for satisfactory rectification of the deficiency in a number of cases. Some of these cases were

- During first approach to criticality (after EMCCR) and low power physics experiments at NAPS-1, anomalies in regulating rod worth and lack of response of two calandria vault counters were observed. Following this, Safety Review Committee for Operating Plants (SARCOP) of AERB suspended the start-up activities pending detailed investigations and corrective actions. Subsequent investigations indicated deficiencies in maintenance, commissioning and quality assurance activities.

- An incident of opening of instrumented relief valve of primary heat transport system of NAPS-1 due to rupture of its actuator diaphragm had taken place. The incident resulted in actuation of ECCS, containment box-up and injection of light water into PHT system. SARCOP permitted restart of the unit only after satisfactory completion of investigations related to the thermal hydraulic behaviour of the system, containment pressurisation during the event, operator actions, adequacy of operating/emergency procedures & operator information system and the reasons for opening of IRV among other aspects.

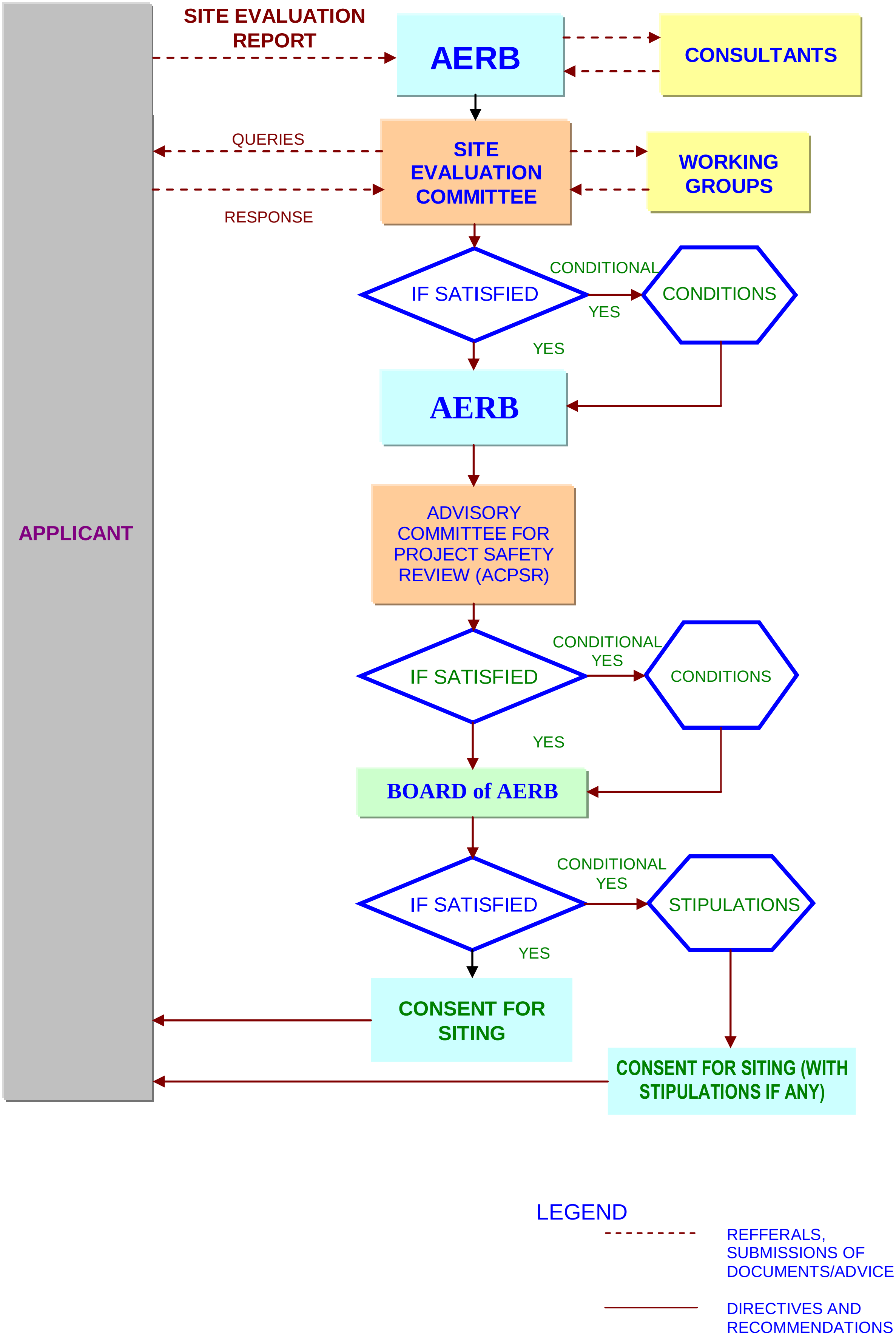
- The construction related activities at KAPP 3&4 were suspended after a fatal accident at the site. An inspection was conducted by AERB and a compliance report was submitted by the site. NPCIL also submitted a corporate review plan for the safety management systems at NPCIL sites. Subsequently, a special inspection was conducted by AERB and permission to restart the work was granted.

However, there were no such instances where orders to curtail or stop activity or suspension of licence was required during the reporting period. During safety review of nuclear power projects and related construction activities many written instructions for improvement within a reasonable time frame were given. All these enforcement requirements were complied with by the utility to the satisfaction of AERB.

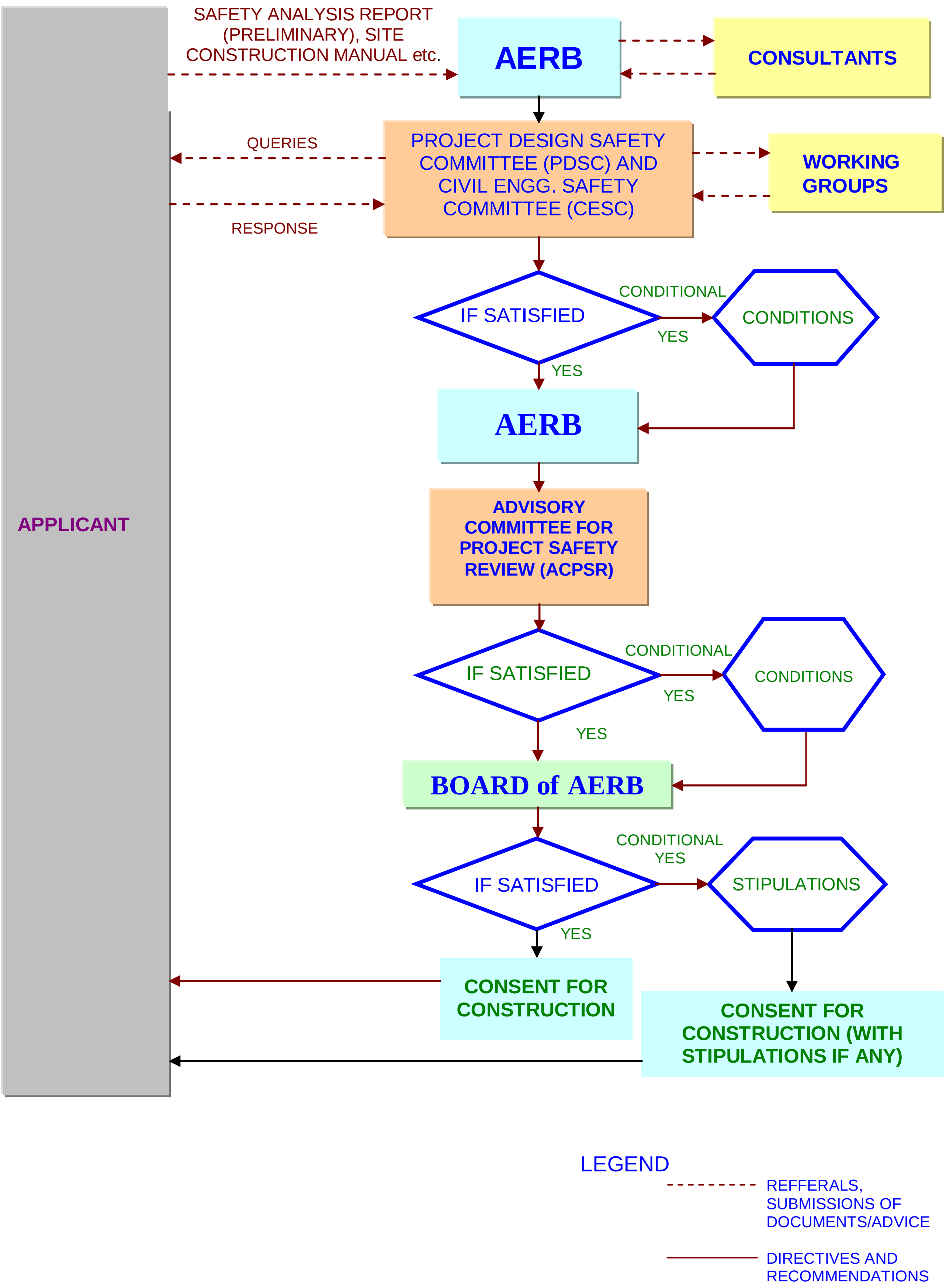
14.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The consenting process established in the country ensures that comprehensive and systematic safety assessments are carried out during siting, construction, commissioning and operation. Changes that take place in the design during construction and commissioning are reflected in the FSAR, which forms one of the licensing documents. All the relevant documents are formally transferred to the plant management by the construction and commissioning groups by way of system transfer documents and construction completion certificate. Design modifications in the safety and safety related systems are carried out only after regulatory review and approval. Independent assessment and verification programmes are established both within the utility and the regulatory body. Adequacy and effectiveness of the assessment and verification programmes at the utility is ascertained by AERB through its regulatory control. During operation stage, the AERB checks that the verification programmes established at the NPP and the utility are adequate to demonstrate that the physical state and the operation of a nuclear installation continues to be in accordance with its design and applicable national safety requirements. Therefore, the country complies with the obligations of Article 14 of the Convention on Nuclear Safety.

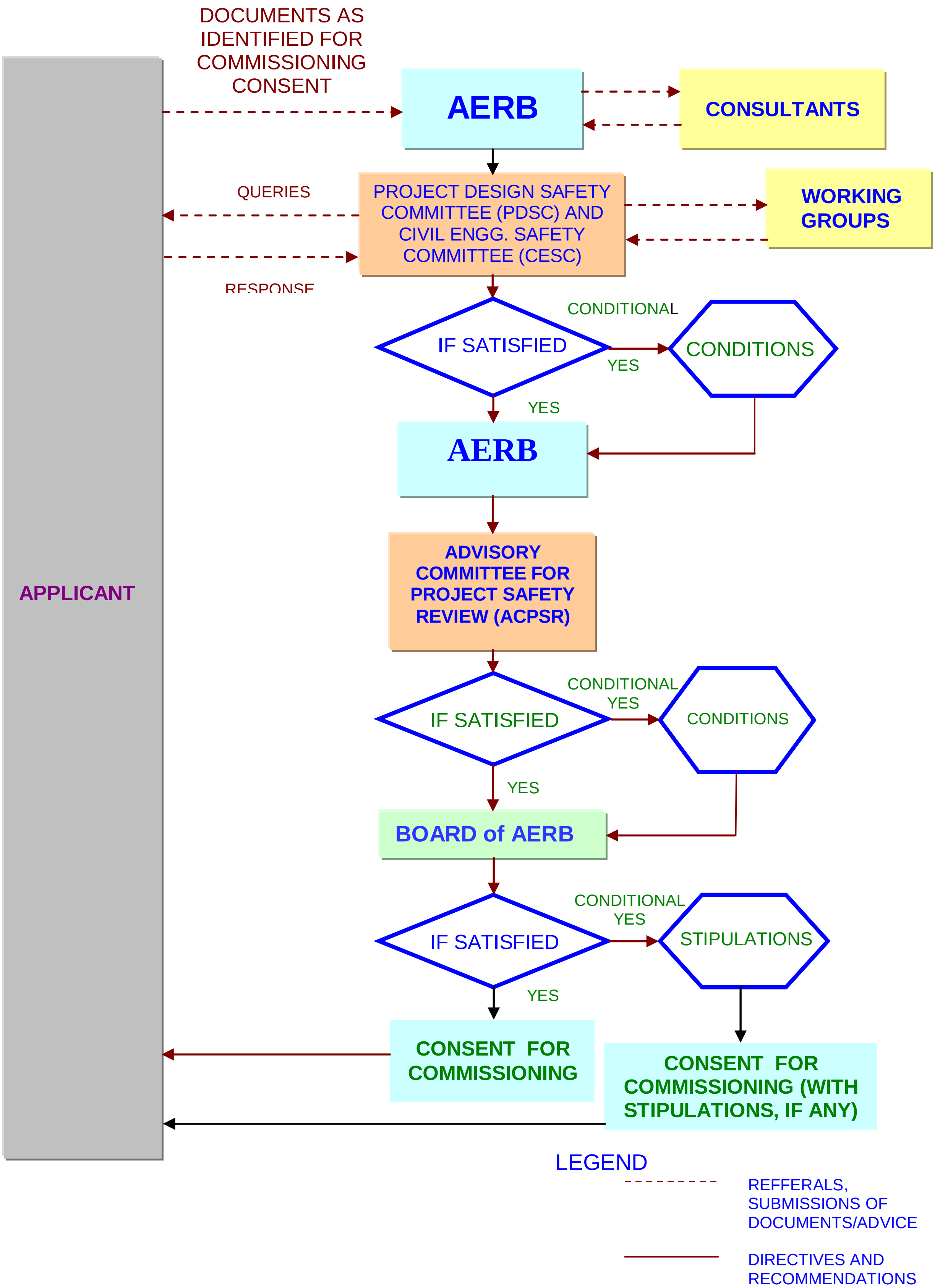
Annex 14-1: Scheme for Consent for Siting



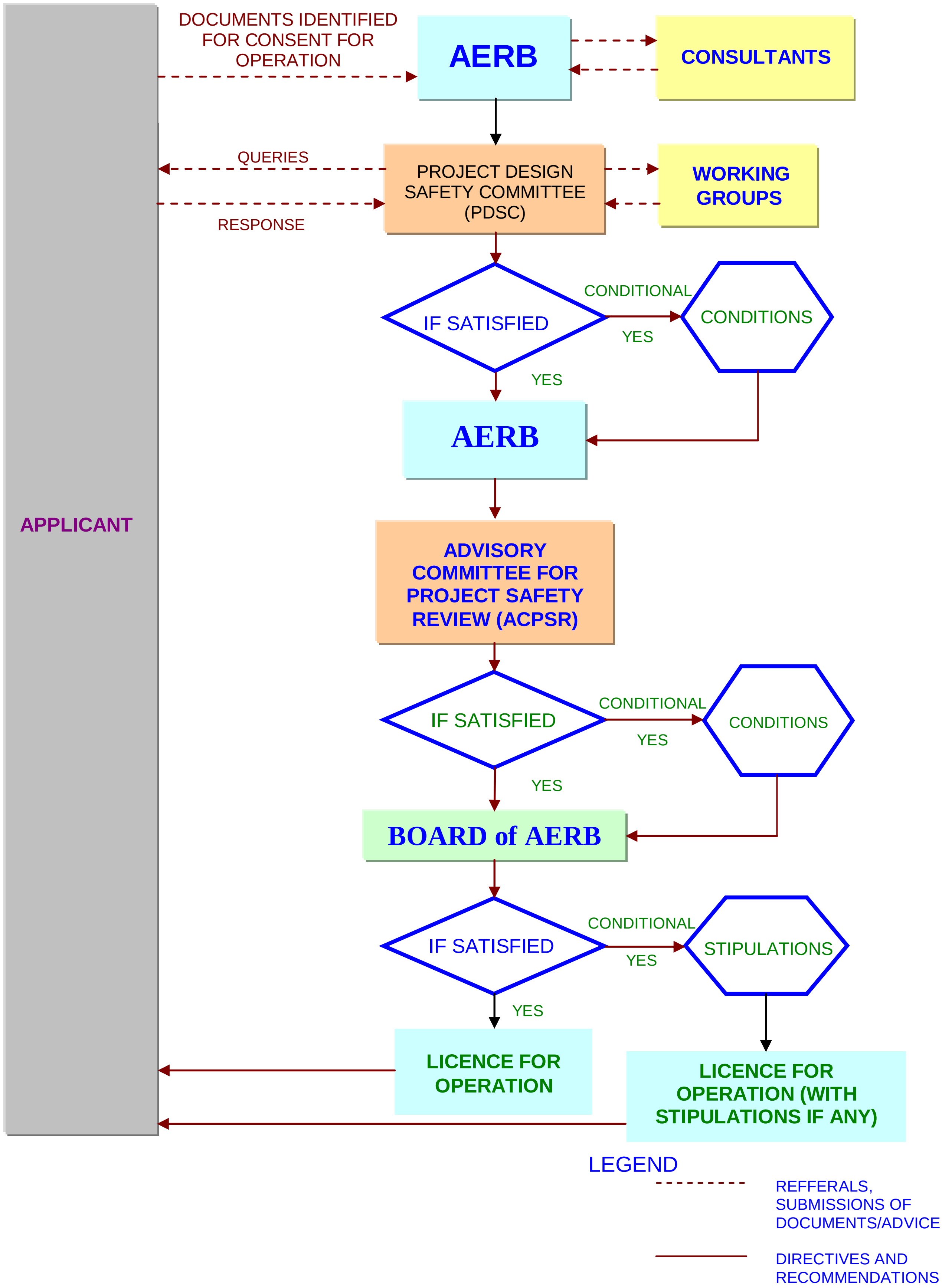
Annex 14-2: Scheme for Consent for Construction



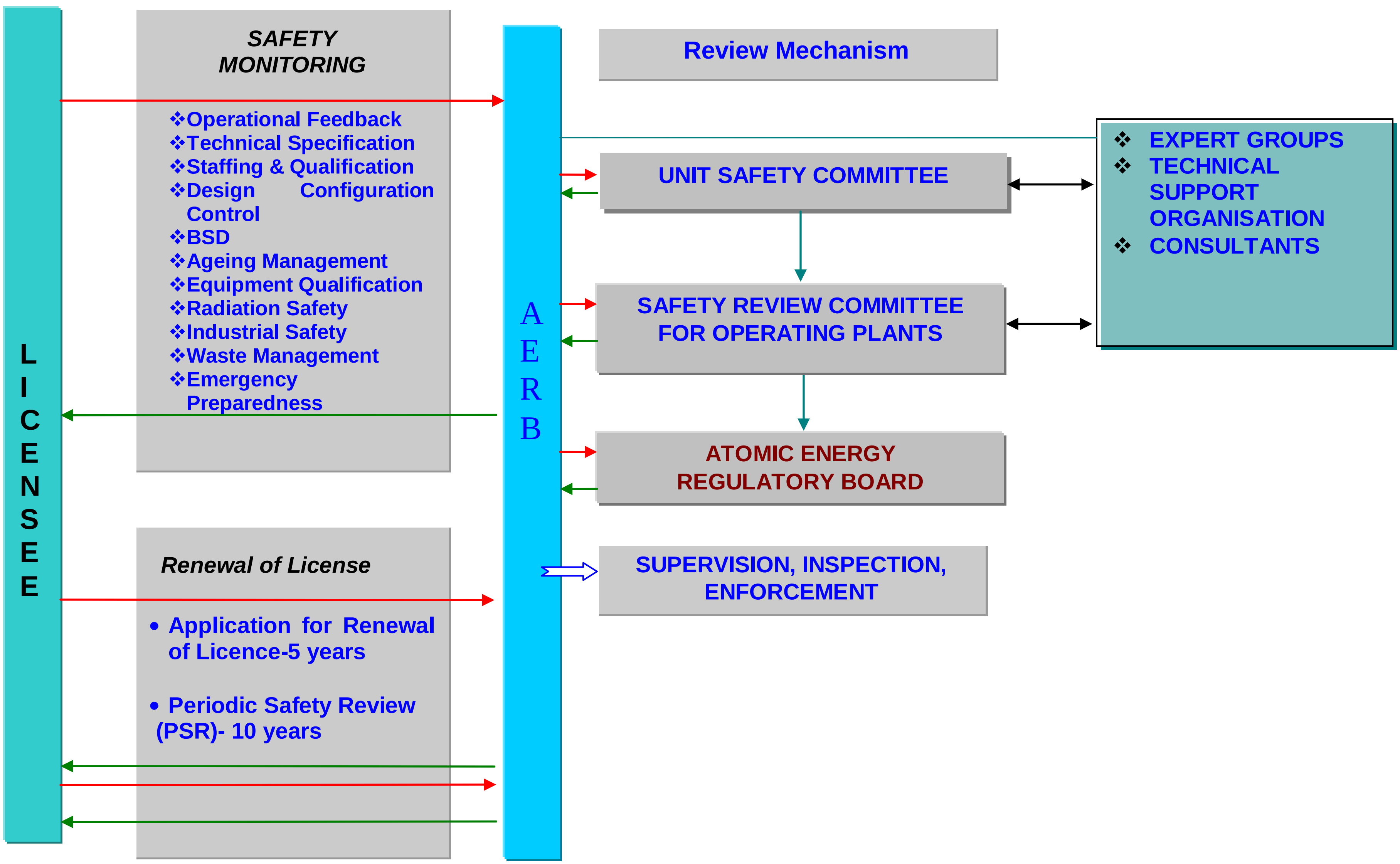
Annex 14-3: Scheme for Consent for Commissioning



Annex 14-4: Scheme for Licence for Operation



Annex 14-5: Safety Review during Operation



ARTICLE 15: RADIATION PROTECTION

Each Contracting Party shall take appropriate steps to ensure that in all operational states 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.

15.0 GENERAL

Radiation Protection infrastructure and programme in all Indian NPPs is on sound footing and is strengthened on continual basis based on experience and technology development. The safety surveillance and regulatory mechanism of AERB in the area of radiation protection is comprehensive, continual and rigorous.

15.1 REGULATORY REQUIREMENTS RELATED TO RADIATION PROTECTION

Atomic Energy (Radiation Protection) Rules 2004 inter alia covers the requirements of radiation surveillance and its procedures, powers of inspection of radiation installation, sealing and seizure of radioactive materials and the duties and responsibilities of Radiological Safety Officers (RSO). In addition, the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987 specify the requirements for safe disposal of radioactive wastes. AERB ensures compliance with the requirements under the above rules by all the nuclear and radiation facilities. Regulatory requirements for radiation protection for NPPs given in various Codes and Guides are as detailed below.

i) The Code of Practice on Design for Safety in Nuclear Power Plants (AERB/NPP-PHWR/SC/D (Rev. 1) 2009) lays down the minimum requirements for ensuring adequate safety in plant design including radiation protection in NPPs. The guidance for implementation of radiation protection in the design of the nuclear power plants consistent with the requirements of the design code is provided in the "Safety Guide on Radiation Protection Aspects in Design for Nuclear Power Plants (AERB/SG/D-12, 2005)". The guide covers the measures and provisions to be made in the design.

ii) The minimum requirements including radiation protection to be met in order to achieve safe operation of a nuclear power plant are specified in the Code of Practice on Safety in Nuclear Power Plant Operation (AERB Code No. AERB/NPP/SC/O (Rev. 1), 2008). The code requires establishment of radiation protection programme prior to the commencement of operation of the NPP to ensure protection of site personnel, members of the public and the environment from the adverse effects of ionising radiation. The programme should cover

- Organisational structure of the health physics unit at the NPP,
- Area/zone classification of plant areas and access control ,
- Exposure control scheme and work procedures,
- Area radiation monitoring and surveys,
- Environmental radiological surveillance and monitoring,
- Determination of external and internal doses,
- Decontamination procedures and methods ,
- Control, handling, storage and transport of radioactive materials including radioactive wastes,
- Control and monitoring of radioactive liquid and gaseous releases,
- Instrumentation and equipment for monitoring,
- Equipment for personnel protection,

- Training/retraining of personnel including temporary workers in radiation protection and emergency procedures,
- Health surveillance of radiation workers,
- Documentation of data on radiological conditions of the plant, personnel exposures and effluent discharges
- Training and qualification of health physics personnel, and
- QA programme.

iii) The guidelines for establishing an effective radiation protection programme are provided in the Safety Guide on Radiation Protection during Operation of NPPs (AERB/SG/O-5, 1999). It focuses on the commitment of the Plant Management to follow the exposure control measures during all operational states and accident conditions at the plant.

iv) The technical and organizational aspects of occupational radiation exposure control under both normal and potential exposure conditions are given in the Safety Manual on "Radiation Protection for Nuclear Facilities (AERB/SM/O-2 Rev.4, 2005) based on which each plant prepares its own "Radiation Protection Procedures" relevant to its design and functioning.

v) The technical specification for operations of each NPP lays down limits for effluent discharge and requirements on availability of radiation monitoring system.

vi) AERB has prescribed the following dose limits for exposures to ionizing radiations for occupational workers.

A. Occupational exposure limits

a. an effective annual dose of 20 mSv averaged over five consecutive years (on a sliding scale of five years, i.e 100 mSv in the five year period).
b. an effective dose of 30 mSv in any year.
c. an equivalent dose to the lens of the eye of 150 mSv in a year.
d. an equivalent dose to the extremities or the skin of 500 mSv in a year.

B. Dose limits for apprentices and students and for pregnant women are prescribed in line with the ICRP recommendations.

C. Dose Limits for members of public

The estimated average dose to the members of the public due to discharge of radioactive effluents from nuclear facilities at a site shall not exceed an effective dose of 1 mSv in a year.

15.2 RADIATION PROTECTION PROGRAM AT NPPs

15.2.1 Design Phase

The design of NPP is done with due regard to materials chosen for manufacturing, plant lay out and shielding requirements to meet the specified regulatory requirements of radiation exposures to the occupational workers and to optimize the collective radiation dose to the plant workers. Plant layout is optimized and areas are classified according to the expected radiation levels and potential for incidence of contamination in the area. Materials used in plant systems are selected in such a way that the activation products arising from the base material or the impurity content does not significantly contribute to radiation exposures during operation and also during decommissioning.

At the design stage adequate provisions for radiation protection are made to keep radiation levels in plant areas below design levels. Design radiation levels in the plant areas are based on the area occupancy by the radiation workers. For areas accessible during reactor power operation the maximum design radiation level is 5 µSv /hr for 8 hours per day occupancy and 40 µSv/hr for 1 hour per day occupancy. Provision of ventilation is made such that the airborne contamination be maintained below 1/10 DAC in full time occupancy areas of the plant. The shielding shall be such that the dose rate in full occupancy areas does not exceed 1 µSv /hr. The NPP is also designed to comply with the specifications on radiation levels in plant areas, maximum radiation dose rates in control room and outside reactor building during accident conditions. It also has an elaborate radiation monitoring system to enable verification of design intent. Radiation Monitoring System consists of area radiation monitors, process monitors, environmental monitors and effluent monitors. These monitors are connected to a Radiation Data Acquisition System (RADAS) which gives history, trend and instantaneous readings of the monitors and displays their alarm state in plant control room and health physics office.

Based on the operating experience, many design modifications for exposure control have been incorporated progressively in the Indian NPPs. Some of the design changes such as water filled Calandria Vault Cooling system, CO_2 based Annulus Gas Monitoring system, valve-less PHT system piping, use of canned rotor pumps, reduction of components in moderator system, use of cobalt-free alloys in in-core components and relocation of equipment from Reactor Building to outside have resulted in significant reduction in exposures.

15.2.2 Operation Phase

Radiation protection programme during the operation of NPPs comprise of organizational, administrative and technical elements. ALARA measures are applied in exposure control of the plant personnel and the public. The plant management makes adequate review of the implementation and the effectiveness of the radiation protection programme. An effective environmental surveillance programme that provides radiological data to evaluate the impact of operation of the NPP on the surroundings areas of the plant site is established at each NPP. The main features of the radiation protection programme at the NPPs are as follows

i Radiation Protection Organisation:

Each NPP has a Health Physics Unit (HPU), headed by a Radiological Safety Officer (RSO) and comprising of a group of trained and experienced radiation protection professionals, RSO in co-ordination with plant management implements the radiation protection programme in the plant. The RSO and alternate RSO of each NPP are designated by AERB under RPR 2004. The HPUs are entrusted with the responsibility for providing radiological surveillance and safety support functions. These include radiological monitoring of workplace, plant systems, personnel, effluents, exposure control, exposure investigations and analysis and trending of radioactivity in the plant systems. The HPU functions under the control of Health and Safety Directorate at the utility Head Quarters and have direct channels of communication with the top plant management in enforcing the radiation protection programme.

ii Infrastructure

The HPU is provided with trained and qualified man-power, adequate number of radiation monitoring instruments for normal and emergency use, laboratories and instrument calibration facility.

The plant design provides for radiation protection facilities such as clothing change room, personnel decontamination facility, equipment decontamination facility, transit waste storage room, storage facility for contaminated equipment/tools, active workshops, protective equipment servicing & testing area, active laundry, radiation data acquisition system and portal monitors.

iii Exposure control and implementation of ALARA

All nuclear plants have radiation safety programs and work procedures intended to control the occupational exposures. Exposures to site personnel are controlled by a combination of radiation protection measures such as:

a. Restricting the external exposure by means of shielding, remote operation, source control and minimizing the exposure time
b. Restricting the internal exposure by means of isolation, ventilation, housekeeping and the use of protective clothing and respiratory equipments
c. Training of personnel
d. Review of work procedures, planning, rehearsing the work on mock ups and dose budgeting;
e. On-the-job monitoring and surveillance of individuals in special works.

. All NPPs have ALARA committees at station level and sectional level. These committees periodically review the plant radiological conditions and exposure status. The committees also review all dose intensive jobs planned at the facility and their recommendations are incorporated in the job planning. In addition, periodic ALARA reviews are conducted at the NPPs to identify areas for dose reduction and to implement corrective actions. The operating experience on radiological events at NPPs in India and in other countries is reviewed and the lessons learned are communicated to all concerned station personnel. In addition, Station Operation Review Committee (SORC) also reviews the radiation exposure control.

Some of the actions/practices implemented for ALARA exposure at the NPPs are given below.

- Optimisation of man power in each job
- Prompt identification and replacement of failed fuel in PHWRs.
- Draining and hot air drying of the D_2O equipment before maintenance.
- Local ventilation with separate supply and exhaust for in-service inspection of moderator heat exchangers for tritium uptake control.
- Coolant chemistry control for Sb-124 activity control.
- Chemical decontamination of coolant system to bring down equipment radiation levels
- Use of just-in-time operating experience

iv Observance of dose limits

The exposure control consists of application of primary dose limits, action levels such as investigation level and operational restrictions. Operational restrictions are established based on dose, dose rate, air activity and surface contamination levels etc. at workplace such that the exposure of workers does not exceed the applicable dose limits. Individual exposures exceeding the investigation levels are investigated and reported to AERB. All cases of exposures exceeding the annual limits are reviewed by an AERB committee.

All the radioactive works are performed under radiological work permit, which contains radiation level, air borne activity and surface contamination data. Accordingly, protective equipment, dose restrictions, time limits and additional precautions, if any, are recommended for controlling the dose.

The temporary workers employed for working in the controlled areas undergo pre-employment medical check-up and training in elementary radiation protection procedures. They are closely supervised by an appropriately qualified person during their work. A separate control limit on dose and investigation levels is prescribed for temporary workers which are lower than that for the regular workers. The annual effective dose limit for temporary radiation workers is 15 mSv.

The external exposure of radiation worker is determined by the use of TL Dosimeters. In areas of high or non-uniform radiation fields, additional dosimetry devices such as direct reading dosimeter, extremity badges (for hands or fingers) are used for control purpose. Neutron monitoring badges as prescribed by the health physics unit are used wherever applicable. Alarming dosimeters are used by individuals during dose intensive work. Evaluation of the committed effective dose of all radiation workers due to tritium uptake in PHWRs is carried out by routine and non routine bioassay. Workers are also subjected to routine whole body counting for assessment of internal contamination.

A computerised dose data management system is used in updating the data for effective dose control. Networking of area radiation monitors for obtaining radiation levels on real time basis is provided in the control room and the Health Physics office.

The average effective dose to plant personnel has been well below the prescribed annual dose limit and there has been no case of annual exposure exceeding 20 mSv during the last three years during routine operations in all NPPs except for an incident because of malevolent act of adding tritium activity in drinking water cooler in the service building at Kaiga Generating Station-1&2. Two workers got tritium uptake resulting in a committed effective dose above 20 mSv, but less than 35 mSv (please refer section 6.2.3).

15.3 RADIOLOGICAL PROTECTION OF THE PUBLIC

AERB has prescribed effective dose (whole body) limit of 1 mSv per year to a member of public due to discharge of radioactive effluents from nuclear facilities at a site.

The sources contributing to generation of radioactive solid, liquid and gaseous wastes and their discharge to the environment are examined with respect to minimization of waste at the source at the design stage itself. The effluent discharges are continuously monitored and restricted within the authorized limits. In addition to the authorized limits of discharge AERB has prescribed “Discharge Constraints” at which the licensee is required to review the situation and report to AERB on the corrective actions planned. The dose to the public resulting from these releases is assessed and if necessary, appropriate design measures to reduce the discharge are introduced.

The design analysis should demonstrate that the calculated dose to the members of the public at the exclusion zone boundary under design basis accident condition does not exceed the reference doses prescribed by AERB.

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15.4 RADIOACTIVE WASTE MANAGEMENT

i. Method of Disposal and Monitoring

Gaseous wastes from reactor building are filtered using pre-filters and HEPA filters and discharged after monitoring, through ventilation exhaust stack. The release rate and integrated releases of different radionuclides are monitored and accounted for to demonstrate that the releases are within the authorized limits.

The radioactive liquid wastes generated in a NPP are segregated, filtered and conditioned as per procedure and diluted to comply with the discharge limits for aquatic environment. The activity discharged is monitored at the point of discharge and accounted on a daily basis. AERB has prescribed limits on annual volume and activity of discharge, daily discharges and activity concentration at the point of discharge from each NPP and are site specific.

The radioactive solid wastes are disposed off in brick lined earthen trenches, RCC vaults or steel lined tile holes, depending on radioactivity content and radiation levels.

ii. Authorized Limits of Discharge

The discharge of radioactive waste from a NPP is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987. It is mandatory for a NPP to obtain authorization under these rules from the Competent Authority for disposal of radioactive wastes.

The regulatory limits (authorized limits) of radioactive effluents are based on the apportionment of effective dose limit of 1 mSv per year to the public arising from nuclear facilities at a site considering all the routes of discharges and significant radionuclide in each route of discharge. Derived limits of effluent discharge corresponding to the dose apportioned for different radionuclide are established taking into account the site specific parameters, design of NPP and the operating experience.

Discharge constraints are set at a much lower value than the authorized limits to achieve effluent releases at ALARA level. The operating data shows that releases from NPPs have been a small fraction of the specified release limits.

15.5 ENVIRONMENTAL MONITORING

The environmental survey around each NPP site is carried out by the Environmental Survey Laboratories (ESLs) of BARC. The basic objective of environmental monitoring and surveillance programme is to assess the radiological impact under all states of the NPP and demonstrate compliance with the radiation exposure limits set for the members of the public by the AERB. This is achieved by carrying out radiological surveillance of the environment by professionals of ESLs. The ESLs are part of BARC and are independent of the utilities and submit periodic reports to the regulatory body on radiological information and the results of environmental surveillance around the NPP.

ESL is established several years prior to operation of a NPP. Extensive surveys are carried out around each nuclear power station to collect data on the dietary intake by the population. During the pre-operational phase, annual intake of cereals, pulses, vegetables, fish, meat, eggs and milk are established by direct survey. Elaborate studies of the topography of the site, land use pattern and population distributions are carried out systematically during the pre-operational phase. Along with the topographical and dietary studies, the ESL also carries out the work of establishing the pre-operational background radiation levels. Extensive micrometeorological data such as wind speed and wind direction, temperature and rain fall are collected for a few years to identify the predominant wind direction and the critical population.

The ESL continues its monitoring and surveillance programme during the operation phase of the NPP. The samples for analysis are selected on the basis of potential pathways of exposure. Areas up to a distance of 30 km distance are covered under the environmental survey programme. From the radioactivity level in the environmental matrices, intake parameters and dose conversion factors, the population dose is estimated. The annual effective dose to the representative person of the public in the vicinity of the NPPs is estimated to be only a few µSv (please refer figure 6.3 in Article 6).

Indian Environmental Radiation Monitoring Network (IERMON) has been established across the country for online detection of nuclear emergency. IERMON provides

- On-line information about radiation levels at various locations in the country to emergency control rooms of DAE facilities.
- Data on background environmental radiation levels and long term shift in the background levels.
- Data for environmental impact assessment following nuclear emergencies.

15.6 REGULATORY REVIEW AND CONTROL ACTIVITIES

AERB enforces control on radiation protection aspects of NPPs through

a) Collective Dose Budget

AERB approves the annual collective dose budget for each NPP. In the beginning of a calendar year, NPPs present the budget proposal along with planned activities for the year. These proposals are reviewed and approved by relevant AERB committees.

b) Review of Radiological Safety Aspects

AERB reviews the report on radiological safety aspects of the plant on a quarterly and annual basis. It is further reviewed by the Unit Safety Committee and SARCOP.

c) Regulatory Inspection

AERB carries out regulatory inspection of all NPPs every six months to verify the compliance with the safety requirements and to check radiological status. During the inspection environmental monitoring data, effluent discharge data, radioactive waste disposal data and quality assurance programme in Radiation Protection are checked.

d) Review of Significant Exposure Cases

Exposure cases exceeding the investigation levels are investigated by exposure investigation committee set-up at each NPP and report is sent to AERB. These reports are reviewed by AERB Safety Committees.

15.7 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Appropriate laws, regulations and requirements regarding radiation protection as applicable to NPPs are in place and are being implemented by the utility. Adequate regulatory control is exercised by AERB, through the regulatory mechanism and respective-organisations, application of dose limits, authorization for release of radioactive effluents, application of ALARA, environmental surveillance and regulatory inspections. Significant experience and expertise have been gained over the years for systematic implementation of radiation protection programme in NPPs. Therefore, India complies with the obligations of Article 15 of the Convention on Nuclear Safety.

ARTICLE 16: EMERGENCY PREPAREDNESS

1. Each Contracting Party shall take the appropriate steps to ensure that there are onsite 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.

16.0 GENERAL

Nuclear power plants (NPPs) in the country are designed, constructed, commissioned and operated in conformity with relevant nuclear safety requirements. These requirements ensure an adequate margin of safety so that NPPs can be operated without undue radiological risks to the plant personnel and members of the public. Notwithstanding these, it is necessary to develop emergency response plans, as a measure of abundant caution. These plans are in accordance with national practices and deals with effective management of any eventuality with a potential to result in undue radiological risk to the plant personnel and the public.

The Plant Management has significant role in preparedness and response to emergencies. It establishes and maintains the necessary emergency resources and procedures by having Plant and Site emergency preparedness plan. Similarly, the District Authority has a plan with respect to off-site emergency. The role, responsibilities and action plans for various agencies required to act during an emergency are detailed in these plans.

16.1 EMERGENCY PLANS AND PROGRAMMES

16.1.1 National Laws, Regulations and Requirements

Emergency preparedness plan has been an essential requirement for operation of nuclear power plants in India from the very beginning of nuclear power programme.

Government of India enacted “The Disaster Management Act, 2005” which provides for the effective management of disasters including accidents involving nuclear power plants (NPP). As per the provisions of this Act, the National Disaster Management Authority (NDMA) has been established with Prime Minister of India as the Chairperson and similar authorities in the states with the Chief Ministers as the Chairpersons. The NDMA has the responsibility for laying down policies, plans and guidelines for disaster management for ensuring timely and effective response to any disaster. In line with the above National Plan, State Plans and District Plans are drawn up by the respective authorities constituted for the purpose. With this new mandate, National Disaster Management Authority has assumed the responsibility of strengthening the existing nuclear/radiological emergency management framework by involving all the stakeholders through a series of mutually interactive, reciprocal and supplementary actions to be taken. These plans include measures to be taken by the concerned agencies for prevention of disasters and for the mitigation of their effects.

Specific requirements with respect to emergency preparedness in NPPs have been formulated by AERB in various Safety Codes and Guides.

(i) AERB Safety Code "Regulation of Nuclear and Radiation Facilities" (AERB/SC/G, 2000) stipulates the minimum safety related requirements including that for emergency preparedness to be met by a nuclear or radiation facility to qualify for the issue of regulatory consent at every stage. Prior to issuance of licence for operation of a NPP, AERB ensures that the approved emergency preparedness plans are in place and tested.

(ii) The Safety Code "Safety in Nuclear Power Plant Operation" (AERB/SC/O, 2008) gives the requirement for development of an emergency preparedness plan and to maintain a high degree of emergency preparedness on the part of the Plant Management. The emergency preparedness programme shall provide reasonable assurance that, in the event of an emergency situation, appropriate measures will be taken to mitigate the consequences. This programme shall be in force before commencement of operation.

(iii) AERB Safety Guide "Role of the Regulatory Body with Respect to Emergency Response and Preparedness at Nuclear and Radiation Facilities" (AERB/SG/G-5, 2000) describes the role of the Regulatory Body during emergencies at nuclear and radiation facilities. It provides necessary information intended to assist the facilities, and other participating/ collaborating agencies, to fulfil the requirements stipulated in the Code. It also elaborates on the Regulatory Body's review and approval process of the emergency response and preparedness plans formulated by the nuclear and radiation facilities and the review of the reports of the emergency exercises carried out to assess the adequacy of the response plans and the associated preparedness.

(iv) The safety guide "Intervention Levels and Derived Intervention levels for Off-Site Radiation Emergency" (AERB/SG/HS-1, 1993) gives the intervention levels (ILs) and derived intervention levels (DILs) for initiating countermeasures in the public domain following a nuclear accident or radiological emergency. The document is currently under revision.

(v) Safety Guide "Preparedness of the Plant Management for Handling Emergencies at NPPs" (AERB/SG/O-6, 2000) supplements the Code of Practice on Safety in NPP Operation. It provides the important considerations relevant to the preparation and implementation of emergency response plans by the Plant Management.

(vi) The regulatory requirements for preparing and maintaining an emergency response plan for Site Emergency is given in the Safety Guide "Preparation of Site Emergency Plans for Nuclear Installation" (AERB/SG/EP-1, 1999). For Off-Site Emergency the Safety Guide "Preparation of Off-Site Emergency Plans for Nuclear Installation" (AERB/SG/EP-2, 1999) is used.

(vii) The safety manual on 'Radiation Protection in Nuclear Facilities' (AERB/NF/SM/O-2, Rev. 4, 2005), issued under the Code of Practice on Safety in Nuclear Power Plant Operation, provides the necessary information to the facilities to carry out the radiation protection function including the emergency preparedness.

16.1.2 Emergency Preparedness Plan

As a mandatory requirement, each NPP prepares an emergency preparedness and response plan. AERB reviews and approve of the emergency response plans and procedures in order to ensure that sufficient means exist to cope with an emergency and it meets the regulatory requirements. AERB evaluates the procedures for emergency detection, classification and decision making as also those for notification, communication, and dose calculation and assessment. Main features of the emergency preparedness plan are as follows:

16.1.2.1 Zoning Concept and Emergency Planning

For drawing up the emergency preparedness plans, the area around the NPPs is divided into three zones as follows.

i) Exclusion Zone:

It is an area extending upto a specified radius around the plant, where no public habitation is permitted. This zone is physically isolated from outside areas by fencing and is under the control of the plant management.

ii) Sterilised Zone

It is the annulus around the exclusion zone and upto 5 km radius from the plant, where only natural growth of population is permitted and developmental activities which lead to growth of population are restricted by administrative control.

iii) Emergency Planning Zone

Emergency Planning Zone (EPZ) is defined as the area around the plant upto 16 km radius providing a basic geographic framework for decision making for implementation of protective measures. The EPZ is divided into 16 equal sectors to provide the maximum attention and relief to the regions affected during an offsite emergency.

16.1.2.2 Classification of Emergencies and related Organisations

In accordance with the severity of the potential consequences, emergency situations are graded as Plant Emergency, Site emergency and Off-site emergency.

i. Plant Emergency

It is an emergency condition in which the radiological/other consequences are confined to the plant or a section of the plant. The declaration and termination of a plant emergency is made by the Plant Emergency Director (normally the Station Director).

ii. Site Emergency

An accidental release of radioactivity confined to the exclusion zone constitutes a site emergency. An assessment of such a situation would imply that protective measures are limited to the site boundary only. The declaration and termination of a site emergency is made by the Site Emergency Director (SED) according to the format of message of the declaration of a site emergency specified in the emergency response manual.

The Site Emergency response manual specifies action plans for activating the emergency personnel, declaring the emergency and alerting the Off-Site Emergency Director

(OED) and protecting the potentially affected site personnel. The protective measures also include evacuation of personnel from the affected parts of the site and radiological monitoring of the environment in the emergency planning zone. After being alerted, the OED takes the necessary steps to cater to a potential off-site emergency.

SED convenes Site Emergency Committee (SEC) meeting on receiving the first report of the initiation of an emergency situation. SEC obtains technical inputs, such as particulars of the accident, radiological monitoring data, wind direction, wind speed etc. The decisions for termination of emergency are based on inputs so obtained. The Station Director of the NPP is usually identified as SED at twin unit stations and the Site Director is designated as the SED at multi unit sites. The chain of command drawn up in the emergency response manual also indicates the alternate SED in the absence of the designated official.

At the utility head quarters an emergency response centre exists. Senior Officers in the corporate head quarters remain in touch with the affected site for providing advice and assistance as required.

iii. Off-Site Emergency

An off-site emergency occurs when the radiological consequences of an emergency situation originating from NPP are likely to extend beyond the site boundary (exclusion zone) and into the public domain. For the purpose of planning off-site emergency, an emergency planning zone up to 16 km radius is specified. The protective measures in public domain are also specified in the Emergency Response Manual. These measures are implemented by OED (District Authority).

The declaration/termination of an off-site emergency is the responsibility of the OED. The SED assesses the effect of any abnormal release of radioactive material extending beyond the site boundary and advises actuation of warning systems (sirens etc.). This will be simultaneously intimated to OED who will then declare off-site emergency and move to the offsite emergency control centre.

The OED is the chairman of the Off-Site Emergency Committee (OEC) and is responsible for convening the OEC when the report of the initiation of an emergency is received. The OEC is an important emergency management organisation which takes all decisions related to management of the emergency in the public domain. It is directly responsible for all off-site emergency actions. Its membership includes the district level chiefs of all public services relevant to management of any emergency in the public domain.

16.1.2.3 Infrastructure for Emergency Response

The existence of infrastructure for conducting various emergency response actions in a systematic, coordinated, and, effective manner is ensured through the following:

i) Plant Control Room

In the initial stages of an emergency, the plant control room provides first hand information about the emergency situation to SEC. If for some reason, the main control room becomes uninhabitable, the status of plant can be monitored from the backup control room.

ii) Emergency Control Centre

An Emergency Control Centre (ECC) for site emergency is suitably located at the site for use by the SEC for directing emergency handling operations and coordination with off-site emergency response, so that control room staff is not distracted from performing control room operations. This building houses emergency equipment centre, treatment area, personnel decontamination area and have sufficient space to accommodate SEC members, rescue teams, health physics staff, emergency maintenance unit staff, stores and industrial safety group. It is equipped with communication system, public address system, emergency equipment/instruments, stationery, standard operating and emergency procedures, design basis reports, P&I diagrams, maps of EPZ, potassium iodate tablets, isodose curves etc.

An emergency control centre for the off-site emergency is located outside the exclusion zone. This control centre is used by OED for directing off-site emergency response operation. It is equipped with the required facilities for handling off-site emergency response operation.

iii) Communication System

NPPs have advanced communication systems for communication with Headquarters, DAE Emergency Control Room, AERB and other concerned authorities/agencies. These systems are available for use at all times. Emergency Communication Rooms (ECRs) are maintained at Mumbai at two different locations. The ECRs are equipped with wireless, telephone, facsimile, satellite communication and electronic mail facilities which are tested daily to ensure their availability.

iv) Assessment Facilities

The Plant Management has the required facilities to assess the nature and severity of a radiation incident and its impact on the environment. These include environment survey vehicles, plant control room instruments, field survey meters, contamination monitors, dosimeters, meteorological data loggers, isodose curves, air samplers, maps etc.

v) Protective Facilities

The plant management provides suitable facilities to protect plant personnel, site personnel and members of public at large. These include assembly areas, temporary shelters, treatment areas, decontamination centre, first-aid centre, respirators, prophylactics, thermo luminescence dosimeters (TLDs), direct reading dosimeters (DRDs) and protective clothing.

vi) Emergency Monitoring:

Detailed emergency monitoring procedure, monitoring capabilities and technical expertise exist at the Environmental Survey Laboratory attached to every NPP site. Meteorological information and model predictions to determine the geographical area likely to be affected by the release of radioactive material is utilized to identify the monitoring and sampling locations. Radiological data required for taking decision on implementation of countermeasures with reference to corresponding intervention levels are generated.

Environmental monitors installed around the nuclear power plant continuously measure and transmit the dose rate in the environment to site/offsite emergency control centre through the main control room.

vii) Emergency Equipment and Supplies

Various facilities and equipment such as emergency equipment centre, personnel decontamination centre, emergency survey vehicle, radio equipment, decontamination kits, respirators, emergency treatment area, first aid centre, stretchers, ambulance, emergency shelters, emergency equipment kits, assembly areas, plant emergency control centre, radiation survey and contamination monitors, protective clothing, direct reading dosimeters, TLDs, communication equipment, standard operating procedures, design basis reports, process &

instrumentation diagrams, emergency power supplies, radiation emergency ward etc. are kept up to date and readily accessible. At regular specified intervals an inventory of various items are taken and verified by the Health Physics Units or other identified agencies. Deficiencies, if any, are promptly corrected by replacement and replenishment as the case may be. Instruments are checked for calibration and the batteries are replaced periodically.

A system of internal auditing by the Quality Assurance group of the NPP and external auditing by the appropriate agency at headquarters is in place for the purpose of checks and counterchecks and used in gauging the effectiveness of emergency preparedness and ensuring compliance with regulatory requirements.

16.1.3 Arrangements for Emergency Response Measures

The emergency response plans of the Plant Management include the action plans, which would be invoked in the event of an emergency. Before the commencement of operation of an NPP, the Plant Management ensures that the following requirements are met:

- The emergency preparedness and response plans for NPP are drawn up and approval of AERB is obtained.
- Necessary training is imparted to the personnel in implementing the action plans.
- The implementability of the plans is confirmed by conducting exercises.

The Plant Management has the responsibility to ensure that an updated emergency response plan exists and that the emergency preparedness is maintained. The emergency response plan provides guidance to the NPP and district authorities to develop and maintain appropriate emergency plans. AERB approves Site Emergency Plans and the concerned State Government approves and issues the Off-site Emergency Plan after review by AERB.

The handling of emergency situations calls for co-ordination amongst various response organisations including different service groups of the NPP. The responsibility for the overall co-ordination in the case of site emergencies rests with the plant management and during off-site emergencies the responsibility rests with the public functionaries such as District and Central Government Authorities. The responsibilities of various response agencies, their sub-units and also the concerned officials are described in the emergency response plans.

The nature and magnitude of the preparedness and response would depend on the specific category or extent of the emergency. The emergency response plans are based on the design basis events and accident conditions due to more severe events though they have a very low probability of occurrence. Analysis of postulated accident scenarios and the projected radiological consequences specific to the NPP form the basis of the response plans.

In accordance with the Crisis Management Plan evolved by the government, DAE has been identified as the nodal authority in respect of nuclear/radiological emergencies in the public domain. For this purpose, a Crisis Management Group (CMG) has been set up in DAE. This group is chaired by Additional Secretary, DAE. The CMG has access to resource agencies to provide advice and organize assistance in the areas of radiation measurement, protection and medical management. The system takes into consideration the statutory requirement, the executive decisions as well as international obligations. The overall plan is that, in the event of any nuclear/radiological emergency in the public domain, the CMG is immediately activated and will coordinate the additional technical resources required by the affected facility to handle the emergency. The CMG co-ordinates between the local authority in the affected area and the National Crisis Management Committee (NCMC) of the Government of India.

16.1.3.1 Implementation of Emergency Measures

The emergency measures consist of emergency actions in respect of notification, alerting personnel, assessment of situation, corrective actions, mitigation, countermeasures and control of contamination. These are detailed in the emergency response manual.

i) Notification

Any emergency situation will be promptly notified to the concerned personnel as per the notification plan. The message conveyed in the notification is required to be clear and concise.

iii) Assessment Action during Emergency

Indicating, recording and annunciating instruments provided in the main control room, radiation surveys, environmental surveys, meteorological data and status of plant are utilized to assess the situation and for predicting projected doses. These assessments enable planning corrective actions and timely implementation of protective measures.

iii) Corrective Actions

These actions are taken to correct plant abnormal situations and to bring the plant under control. The types of corrective actions are decided by the situations prevailing at that point of time.

iv) Meteorological Features and Data for Dose Projection

Each NPP has established facilities to continuously monitor the wind and weather conditions and to obtain dose projections in the public domain that could form the basis for determining the suitable protective measures. Provisions are also available for establishing the source term by actual measurement.

v) Protective Measures

These are actions taken to mitigate the consequences of a radiological event and to protect, site personnel, members of public and livestock from radiation. These include sheltering, administration of prophylactics, control on consumption of contaminated foodstuff and evacuation. It is essential to ensure that the response measures would reduce the overall impact to public to a level significantly lower than what they would be in the absence of such measures. The emergency response manual gives details of the protective measures and the intervention levels approved by AERB for initiating protective measures to limit radiation exposures.

Evacuation is an extreme measure taken after evaluating the risks and benefits of this countermeasure in terms of the averted dose. If radiation levels in the affected zone continue to exist beyond acceptable levels, then relocating the affected population is resorted to.

vi) Contamination Control

The contamination control measures include segregation of highly contaminated persons and decontaminating them, decontamination of vehicles, regulating the traffic, access control to prevent unauthorized entry to affected zone, confiscation of contaminated food stuff and supplying fresh food, banning fishing in contaminated sea/river water, banning the consumption of contaminated water and supplying fresh water, identification of contaminated areas requiring excavation and disposal of contaminated soil, decontamination of contaminated dwellings or their disposal, and destroying the contaminated crops and grass.

16.1.3.2 Assistance to Affected Personnel

In the event of an emergency, the plant management is responsible for providing all necessary assistance to the affected plant personnel in respect of their rehabilitation and treatment, sheltering and evacuation as necessary. The responsibility for providing assistance to persons in the public domain rests with the District Authority and State Government.

i) First-aid

Each NPP site has at least one fully equipped first aid centre manned round the clock by trained personnel for providing first aid to the injured/contaminated persons. This is located as close as possible to the personnel decontamination centre.

ii) Decontamination

Monitoring the contamination and carrying out decontamination of personnel, equipment, facilities and areas within plant and site is the responsibility of the Plant Management. It is also responsible for setting up fixed and mobile facilities for carrying out decontamination with adequate supply of water. While it is the responsibility of the District Authorities to set up such facilities in the public domain, the actual operations are carried out under the guidance of the Plant Management.

iii) Transportation

All necessary resources for transport are mobilized within the plant in the shortest possible time in case of a site emergency to undertake evacuation of non-essential staff. This is done under the supervision of plant management. Adequate stock of diesel oil and petrol is maintained at the NPP at all times to face such an eventuality.

Organizing the transport of evacuees in the affected sectors in the public domain is the responsibility of OED. The District Authorities are empowered to mobilize even private vehicles, if found necessary.

iv) Medical Treatment

The injured and affected site personnel will be treated as necessary in radiation emergency treatment wards in the hospitals managed by NPPs. These wards are equipped with necessary instruments, medicines, operating theatres, beds, decontamination centres etc. and are operational at all times.

The responsibility for treatment of affected persons in the public domain rests with the District Health Authority. However, any guidance needed in the treatment of radiation injuries will be provided by experts of the Medical Division of the NPP and the Department of Atomic Energy.

16.1.3.3 Training and Exercise

The required emergency preparedness is maintained by organizing refresher training courses for site and off-site personnel at regular intervals. The emergency preparedness programme includes conducting periodic rehearsals/mock exercises involving all concerned personnel, updating plant emergency procedures and site and off-site emergency action plans at a specified frequency, making suitable changes in the plan in the light of periodic reviews based on emergency exercises and keeping all emergency equipment and accessories in operational condition.

i) Training

Appropriate training is imparted at regular intervals to all employees of the NPP, to familiarize them with actions that should be taken during an emergency. Similar training courses are also organized for various Public Authorities.

ii) Exercises

Exercises are conducted at regular intervals and in which all concerned agencies take part. Exercises are used for the twin purposes of emergency preparedness and gauging the success of emergency preparedness programme. It is ensured that each Shift Charge Engineer takes part in these exercises at least once a year. The site emergency exercises and off-site exercises are conducted in accordance with the frequency prescribed by AERB. The observations made in each exercise are discussed in the Station Operation Review Committee (SORC) meeting and deficiencies are promptly corrected. The frequency of plant, site and offsite emergency exercises are once in three months, once in a year and once in two years respectively.

Occasionally minor deficiencies in communication system and lack of awareness amongst few contract workers are observed. The observed deficiencies have been rectified. During evacuation, safety of the public belongings is taken care by providing the necessary security for their houses. Based on the feedback from review of the exercise results the access to some villages was improved by providing the roads and other infrastructure.

16.1.4 Regulatory Review and Control Activities

Appropriate laws, regulations and requirements regarding emergency preparedness as applicable to NPPs are in place and are being implemented by the utility. Adequate regulatory control is exercised by AERB, through regulations, approval of emergency response plans of the utilities and taking part in the emergency exercises. AERB reviews the emergency preparedness plans prepared by nuclear and radiation facilities. The implementation of emergency plans has to be demonstrated before criticality of the unit. For multi-unit site the plant / site / offsite emergency plans have to be revised before granting construction consent to the new facility.

Off-site emergency exercises are witnessed by AERB observers to ensure that the emergency planning is adequate and its implementation is effective. The periodic regulatory inspections of the NPPs cover the following:

(a) Updating the emergency preparedness plans
(b) Availability of various communication facilities and their periodic testing;
(c) Inventory of equipment at the emergency control centres and their maintenance;
(d) Availability of trained manpower for emergency actions;
(e) Availability and maintenance of support facilities like fire fighting equipment, ambulance, first-aid, decontamination, and off-site storage of prophylactics, arrangements for medical management of exposed personnel and other resources.
(f) Rectification of deficiencies observed during previous emergency exercises and regulatory inspections.

16.2 INFORMATION TO PUBLIC AND NEIGHBOURING COUNTRIES

16.2.1 Information to Public

Regular training courses are arranged by each NPP for the general public in the surrounding areas by inviting them to the plant. The course contents include an introduction to atomic energy, safety in nuclear industry and about emergency organization in that nuclear power plant. As a part of this public awareness programme, visits to the Emergency Control Centre and the Environmental Survey Laboratory are also arranged. As a means of creating better public awareness on this subject, a short list of 'do's and don'ts' during a emergency is distributed to the general public.

Emergency preparedness plan envisages communication with the media and announcements about the incident, its consequences, protective measures taken by the authorities and advice to the public in the affected and adjoining regions. A pre-designated Information Officer makes arrangements for the reception of media and information briefing.

16.2.2 Transboundary Implications

As per the Indian regulation, the planning for emergency preparedness is carried out for the EPZ, which is designated up to a radial distance of 16 km from the NPP. The population in this zone is kept informed on emergency planning and response. The neighbouring countries are at large distances from the location of operating NPPs and those under construction. Export of food items will be subjected to thorough contamination checks and clearance in accordance with the international guidelines. Hence no transboundary implications are expected (please also refer item 17.4.).

16.3 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Appropriate laws, regulations and requirements regarding emergency preparedness as applicable to NPPs are in place and are being implemented by the utility. Adequate regulatory control is exercised by AERB, through regulations, regulatory inspections, approval of emergency response plans of the utilities and taking part in the emergency exercises. In view of the details described above, obligations of the convention have been complied with.

ARTICLE 17: SITING

Each Contracting Party 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 sub-paragraphs (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 territory of the nuclear installation.**

17.0 GENERAL

The present statutory provisions permit only the Central Government or a company established by the Central Government to set up NPPs in India. Standing Site Selection Committee (SSSC) carries out first order assessment of the site and evaluates the suitability of the various sites proposed by concerned state governments taking into account site related factors such as availability of adequate land, cooling water availability, foundation conditions in general and natural hazards in broad way, socio economic scenario, available infrastructure, population distribution, land use, etc. Based on the recommendation of the SSSC, the Central Government conveys in principle approval of the site.

The process of obtaining siting consent from AERB from safety considerations and clearance from Ministry of Environment and Forests (MoEF) is taken up by utility. A site evaluation committee is setup by AERB for giving consent for siting. The committee evaluates the site from safety consideration and takes into account the type of the NPPs to be setup at the site and gives its recommendations to AERB.

The consent for siting involves review of the various site/plant related safety aspects. The mechanism of review is brought out in chapter on Article-14 on 'Assessment and Verification of Safety'. AERB Code of practice on safety in NPP siting, AERB/SC/S, establishes the requirements for evaluation of a site from safety considerations. Several safety guides issued under the code provide guidance for meeting these requirements (annex 17.1). A site is considered acceptable, when all the site related issues have been satisfactorily resolved, thus giving assurance that the proposed NPP can be built and operated such that the risk to the population and the environment is within acceptable limits.

Setting up of Nuclear Power Plant needs environmental clearance from MoEF, as per the requirement of Environmental Protection Act 1986. Clearances for siting a nuclear installation also need to be obtained from other central and state level agencies like National Airport Authority, State Maritime Boards, Ministry of Defence and Ministry of external affairs, as appropriate besides the agencies mentioned in Article-7.

17.1 EVALUATION OF SITE RELATED FACTORS AFFECTING SAFETY

Based on the requirements specified in AERB/SC/S, utility prepares a site evaluation report covering

a. Salient features of the proposed site
b. Site characteristics affecting safety
c. Interactions of NPP with its environment

In addition, the site evaluation report provides brief design information on the proposed project. It should provide concise information giving an overview of the proposed NPP. The information helps in evaluating the given site in relation to the type, capacity, number of units etc. It also includes overall safety approach, dose limits, bases for emergency preparedness and offsite power supplies.

The regulatory review and assessment of Site Evaluation Report is carried out to determine the potential consequences of interaction between the plant and the site and the suitability of the site for the proposed plant from the point of view of safety. It also includes assessment of availability of roads & access features for emergency response purposes and aspects on security measures with reference to site characteristics. The significant areas of review and assessment as per AERB safety guide AERB/SG/G-1:2007 on "Consenting Process for Nuclear Power Plant and Research Reactor"

i. Geology and soil mechanics
ii. Topography
iii. Hydrology and hydro-geology
iv. Meteorology
v. Natural phenomena such as earthquakes, floods, tsunamis and tornadoes
vi. Potential external man-induced events such as plane crashes, fires and explosions
vii. Failure of man-made structures such as dams and sea walls
viii. Availability of water for plant cooling and ultimate heat sink
ix. Reliability of off-site electrical power

The effect of various site parameters on engineerability of the site in the context of external and man induced events is assessed. For an external event (or combination of events) the choice of values of the parameters upon which the plant design is based should ensure that structures, systems and components important to safety in relation to that event (or combination of events) will maintain their integrity and will not suffer loss of function during or after the design basis event.

Design provisions against external events (human made and natural occurring) are based on the following considerations

i. Design basis flood is evaluated considering combinations of maximum probable precipitation and floods due to upstream dam breaks. Site grade elevation is set at a level higher than the design basis flood level.
ii. Design basis ground motion i.e. peak ground acceleration, response spectrum and spectrum-compatible time history is evaluated from seismotectonic considerations. These are used for design of various structures, systems and components (SSCs).
iii. Effect of Tsunami for coastal sites
iv. Fire load is evaluated and safety of various SSCs is ensured against fire.
v. Consideration of severe weather conditions.
vi. Consideration of aircraft crash

Recently, assessment of the three existing sites for installing additional reactors at Kudankulam, Rajasthan and Kakrapar has been carried out. As an example, assessment factors considered for Kakrapar site are given in annex 17-2.

17.2 ASSESSMENT OF SAFETY IMPACT OF NPP ON THE ENVIRONMENT

The effects of the plant on the environment that could warrant specific design or operational requirements are radioactive effluents (liquid and gaseous), radiation exposure of the public from these effluents and other environmental pollutants. This should be assessed for normal operation, anticipated operational occurrences and accident conditions, taking into account dispersion patterns, present and prospective population distribution, public water supply, milk and food consumption, and radioecology. The acceptable doses to the public are given in chapter on Article-15.

For each proposed site the potential radiological impact on people in the region during operational states and accident conditions is assessed. Base line data required for assessment of radiological impact is collected for various environmental components, viz., air, water, land and biological etc. These include physio-chemical, biological characteristics & activity of ground water and surface water, soil characteristics, composition of vegetation cover, meteorological parameters etc.

The above criteria are implemented as follows:

a) It is mandatory that an exclusion zone, as specified by AERB is established around the plant and this area is kept under the exclusive control of the Plant Management. The public habitation in this area is prohibited. Further, a sterilized zone around the exclusion zone is established and influx of population to this zone is controlled by administrative measures.

b) The site is required to have good atmospheric dispersion characteristics. An emergency planning zone area is established within 16 km radius of site. Information on the population distribution, land and water use, dietary habits, critical exposure pathways is collected and an appropriate radiological model is established for assessment of dose to members of public.

c) The Environmental Survey Laboratory is established at every NPP site much before commencement of operation, for conducting the pre-operational studies and continued meteorological surveillance

d) Environmental clearance from Ministry of Environment and Forests (MoEF) is a precondition for issue of siting consent by AERB. For obtaining environmental clearance from MoEF, Environment Impact Assessment (EIA) Report in a prescribed format is prepared by the utility. The Expert Appraisal Committee (EAC) constituted by MoEF carries out a preliminary review of the EIA report and determines the terms of reference on the basis of the information furnished, site visit if needed and other information that may be available with it. Based on the evolved terms of reference, the utility has to revise the report addressing all the concerns raised by the EAC.

   Public Consultation is an essential pre-requisite for obtaining MoEF clearance in the formulation of a project. This process has two components (i) a public hearing at the site or in its close proximity to be carried out in the prescribed manner and (ii) obtaining response in writing from other concerned persons having a plausible stake in the environmental aspects of the project. Public hearing is conducted as per the 'procedure for conduct of public hearing' given in the gazette notification from MoEF. After completion of the public consultation, the project proponent addresses the environmental concerns expressed during this process and makes appropriate changes in the draft EIA and Environment Management Plans.

   The EAC carries out the detailed scrutiny of the application and other documents like the final EIA report, outcome of the public consultations including public hearing proceedings, submitted by the applicant to MoEF for grant of environmental clearance. This appraisal is made by the EAC in a transparent manner at a proceeding to which the applicant is invited for furnishing necessary clarifications. On conclusion of this proceeding, the EAC makes recommendations to MoEF for grant of prior environmental clearance on stipulated terms and conditions, or rejection of the application, together with reasons for the same.

17.3 RE-EVALUATION OF SITE RELATED FACTORS

During the operating period of the plant, an environmental monitoring programme is established and implemented in accordance with the AERB requirements specified in code of practice in operation and safety guide AERB/SG/O-5, “Radiation protection during operation of nuclear power plants”. At each site, the Environmental Survey Laboratory (ESL) implements the programme. This programme includes comprehensive monitoring of radionuclide contents from various environments to obtain the activity distribution pattern. The samples are collected routinely from specified locations and analysed. Based on the survey and radioactivity data, the public exposure to radionuclide through different routes is estimated. AERB formally reviews the report of ESL with specified periodicity as part of its safety supervision.

As mentioned above, the planned expansion of activities in the sterilised area is regulated by legislative measures or administrative measures by the state government/local authorities etc.

At the time of Periodic Safety Review (PSR), following elements are comprehensively reviewed to determine the continued safety acceptability of the nuclear installation, taking account of changes, if any, in site-related factors given below.

i. Changes in use of land areas around the site
ii. Local population distribution
iii. Off-site population distribution
iv. Site characteristics, particularly flood and seismic, which may pose a hazard
v. Local meteorological conditions.

In addition, the external events taking place at the site are reviewed to check that these are within the design basis of the nuclear installation. Based on the review, the need for providing any additional features is also identified.

17.4 CONSULTATION WITH OTHER CONTRACTING PARTIES

As per the Indian regulation, the planning for emergency preparedness is carried out for the Emergency Planning Zone (EPZ), which is designated up to a radial distance of 16 km from the NPP. The populations in this zone are kept informed on emergency planning and response. The neighbouring countries are at very large distances from the location of operating NPPs and those under construction. Hence there are no trans-boundary implications. India is party to Convention on Early Notification of a Nuclear Accident (1986), and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (1986) and complies with the obligations under these conventions.

17.5 REGULATORY REVIEW AND CONTROL ACTIVITIES

AERB safety guide AERB/NPP-RR/SG/G-1:2007 on “Consenting Process for Nuclear Power Plant and Research Reactor” give the guidelines on the contents of the site evaluation report. A detailed description on these requirements is given in Code of Practice on Safety in Siting of Nuclear Power Plants, AERB/SC/S, and safety guides issued under the Code. AERB requires that site evaluation report should be submitted for siting consent. Regulatory review of application for siting consent is carried out by multi-tier review system of AERB (section

14.1.1.2 (ii)). Staff of AERB carries out regulatory inspections during siting stage and provide inputs to the safety committees for review of the application for siting consent. Also, while making submissions for issue of consent/clearance from the second stage, viz. construction onwards, the applicant should invariably include a status report on compliance with AERB's stipulations if any, made during the issue of the earlier consent/clearance. The siting consent is issued for a limited period.

During Periodic Safety Review, utility is required to carry out review of the site related factors and submit it to AERB as part of PSR.

17.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The Site Selection for locating an NPP is carried out by the Central Government. The utility carries out detailed site investigations and prepares Site Evaluation Report and Environmental Impact Assessment Report for independent evaluation by AERB and MoEF respectively. The comprehensive review and assessment of site related factors ensure that setting up of the NPP will not cause undue risk to the public and the environment. The periodic safety review for renewal of authorisation for operation ensures that important site related factors are periodically reviewed to determine the continued safety acceptability of the nuclear installation. As all the NPPs operating and under construction are located sufficiently away from the national border, formal agreement with the neighbouring countries for sharing of information has not been considered necessary. Hence, the country complies with the obligations of Article 17 of the Convention on Nuclear Safety.

Annex 17-1: AERB Safety Guides under Code of Practice on Siting

AERB/SC/S; 1990	**Code of Practice on Safety in Nuclear Power Plant Siting**
AERB/NF/SG/S-1; 2008	**Atmospheric Dispersion and Modelling**
AERB/SG/S-2; 1998	**Hydrological Dispersion of Radioactive Materials in Relation to Nuclear Power Plant Siting**
AERB/NF/SG/S-3; 2008	**Extreme Values of Meteorological Parameters**
AERB/SG/S-4; 2000	**Hydrogeological Aspects of Siting of Nuclear Power Plants**
AERB/NF/SG/S-5; 2005	**Methodologies for Environmental Radiation Dose Assessment**
AERB/SG/S-6A; 1998	**Design Basis Flood for Nuclear Power Plants on Inland Sites**
AERB/SG/S-6B; 2002	**Design Basis Flood for Nuclear Power Plants at Costal Sites**
AERB/NPP/SG/S-7	**Evaluation of Design Basis for External Human Induced Events for Nuclear Power Plants**
AERB/NPP/SG/S-8; 2005	**Site Consideration of Nuclear Power Plants for Off-site Emergency Preparedness**
AERB/SG/S-9; 1998	**Population Distribution and Analysis in Relation to Siting of Nuclear Power Plants.**
AERB/NPP/SG/S-10; 2005	**Quality Assurance in Siting of Nuclear Power Plants**
AERB/SG/S-11; 1990	**Seismic Studies and Design Basis Ground Motion for Nuclear Power Plant Sites**

Annex 17-2: Overview of factors considered for assessment for siting an NPP
A recent example (section 17.2)

Recently the site evaluation has been considered for setting up 2x700 MWe PHWRs at Kakrapar, which already has 2x220 MWe PHWRs operating in the area. The evaluation of this site was based on the requirements of AERB Code of Safety in Siting and its associated Guides along with the requirements of IAEA-NS-R3. Some of salient features/characteristics evaluated for KAPP 3&4 site were

General:

- Accessibility of site – by rail, road, air or port
- Availability of Construction materials, water and power for construction
- Availability of water for Plant Cooling
- Start-up power and power transmission and distribution

Safety- Related Factors:

- **Foundation conditions** :
    - Nature of Sub-strata – Rocky or Alluvium
    - Depth to Hard Rock, if available
    - Details of Heavy Structures built in the area
- Proneness of the area to slope instability, surface collapse, subsidence or uplift.
- **Seismo-tectonics**: (Potential for surface faulting presence of capable faults and occurrence of major earthquakes in the vicinity).
- Proneness of the area to soil liquefaction
- **Meteorological conditions**
    - Annual Rainfall
    - Extreme Temperature
    - Extreme Wind Speed
    - Extreme Humidity
    - Flooding potential
- **Grade level for plant location**

M**an-induced events:**

- Locations of airport (Civil or Military),
- Facilities Storing or handling Inflammable, toxic, corrosive or explosive materials
- Mining activities in the vicinity
- Military installations (along with distance from site storing ammunitions etc. Within 10 km radius)

Analysis was carried out for radiological impact of operation of the plant on the environment and Population around the site.

ARTICLE 18: DESIGN AND CONSTRUCTION

Each Contracting Party shall take the 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.**

18.0 GENERAL

National laws, regulations and requirements for setting up a NPP are summarised in chapter on Article 7: Legislative and Regulatory Framework. AERB safety code on 'Regulation of Nuclear and Radiation Facilities' AERB/SC/G; 2000 and Safety Guide AERB/NPP&RR/SG/G-1: 2007 on Consenting Process for Nuclear Power Plant and Research Reactor identifies various consenting stages. The consenting process for locating and operating NPP in India is summarised in the chapter on Article 14: Assessment and Verification of Safety. The AERB safety code on 'Design of Pressurised Heavy Water Reactor Based Nuclear Power Plants', AERB/NPP-PHWR/SC/D (Rev. 1); 2009, describes the design approaches and minimum requirements to be met during design of structures, systems and components (SSC) of PHWR based NPPs in India for assuring safety. Various safety guides issued under the Code provide guidance for achieving these requirements. Annex 18-1 gives the list of AERB Guides on Safety in Design. In situations where such regulations are not specifically evolved due to novelty or otherwise, the Regulatory Body may prescribe the internationally available regulation/document acceptable to it for the purpose or in certain circumstances evolve and prescribe case specific requirements.

AERB safety code on ‘Quality Assurance in Nuclear Power Plants, AERB/SC/QA: 2009, provides the principles and objectives for ensuring safety of public and site personnel when establishing an overall quality assurance programme for constituent phases, viz. design, manufacturing, construction, commissioning, operation and decommissioning of NPPs in the country. Various safety guides issued under these Codes provide guidance for achieving the requirements specified in them. Annex 18-2 gives the list of AERB Guides on Quality Assurance.

The details on the utility’s safety management system for ensuring quality requirements during design, fabrication, construction etc are brought out in chapter on Article 13: Quality Assurance.

18.1 IMPLEMENTATION OF DEFENCE IN DEPTH

AERB Code of Practice on ‘Design for Safety in PHWR based NPPs, AERB/SC/D Rev 1): 2009, establishes the requirements for defence in depth in design of NPPs’ (clauses 2.3 and 4.1). The code requires that the design shall comply with the requirements so as to ensure that during normal operation prescribed limits and during accident conditions acceptable limits are not exceeded. To ensure that the overall concept of defence in depth is maintained as far as practicable, the design shall be such as to prevent challenges to the integrity of physical barriers, failure of barrier when challenged and failure of a barrier as a consequence of failure of another barrier. The design shall be such that the first level of defence in depth (prevention of deviation from normal operation and prevent system failure) and at the most the second level (detect and intercept deviations from normal operating conditions in order to prevent anticipated operational occurrences) is capable of preventing accident conditions for all but the most improbable PIEs.

The concept is implemented in the reactor design by means of a series of layers of physical barriers and defense-in-depth levels of protection. Each layer acts as a barrier against breach of safety. Safety systems are also provided with redundancy so as to meet the single failure criteria. Diversity and physical separation of redundant systems is provided to avoid common mode failures. The concept of defence-in-depth is implemented for each system, which have a role in the three fundamental safety functions of Safe Shut-down, Heat removal from core and Confinement of radioactivity-to limit release to the environment.

The confinement of radioactivity is achieved by a series of five independent barriers, namely, Ceramic fuel pellet of UO_2, Fuel cladding of Zircalloy-4, Primary system pressure boundary, Primary containment and Secondary containment. Each of these barriers is designed for the environmental conditions and service loading to which it is subjected to, while performing the respective function. The exclusion zone of 1.5 km and a sterilised zone of 5 km from the plant are additional layers of defence-in-depth.

During normal operation, safety related process systems maintain the relevant plant parameters within set limits. The design of equipment takes care of all normal operating conditions and postulated abnormal transients. The design of these process systems incorporates appropriate detection and control measures to ensure these objectives. Measures such as controlled reduction in power and trips are provided whenever deviations from normal operating conditions are detected. Control and instrumentation systems incorporate appropriate redundancy so that single failure criteria are met.

It is ensured that the structures, systems and components having a bearing on reactor safety are designed to meet stringent performance and reliability requirements. These requirements are met by adopting the following principles:

- The quality requirements for design, fabrication, construction and inspection for these systems are of high order, commensurate with their importance to safety.
- The safety related equipment inside the containment building are designed to perform the desired function even under the elevated pressure and temperature and steam environment condition expected in the event of postulated loss of coolant accident.
- Physical and functional separation is ensured between process systems and safety systems to the extent practicable. This separation is also provided between different safety systems and between redundant components of a safety system. These features ensure that a single local event viz. fire, missile, pipe failure, will not result in multiple component/system failures and the functions required for safety of the reactor are not impaired due to common cause failures.
- Adequate redundancy is provided in the system such that the minimum safety function can be performed even in the event of failure of single active component in the system. In addition to 'single failure criteria' requirement, safety systems are also required to meet specified unavailability targets, evaluation of which takes into account permissible down time of the equipment specified in the 'Technical Specification for the Plant Operation'. Each channel in Reactor Control & Protection Systems is independent of other channels, with separate detectors, power supplies, amplifiers and relays. This arrangement ensures that safety function will be performed reliably by allowing testing and maintenance of a control or protection channel without affecting reactor operation.

- To minimise the probability of unsafe failures, wherever possible, the logics and instrumentation circuits are designed to fail in the safe direction.
- Provisions are incorporated in the design to ensure that active components in safety systems are periodically testable.
- All support systems viz. electrical power supply, pneumatic power supply & cooling water supply, necessary for the satisfactory functioning of the safety systems are from reliable sources such that single component failure does not jeopardize the minimum supply requirements.
- Level-1 PSA is carried out to identify any weak links and areas of improvement in design.

The design of the plant also takes into consideration external events specific to a site. The external events are grouped into natural events and man-induced events. Natural events considered in the design are possible seismic events at the site and extreme meteorological phenomena such as floods, high winds & cyclones, heavy precipitation etc. Man-induced events include hazards from toxic and explosive materials, blasting etc. For each of the events whose potential at the given site is known to exist, a design basis event is established.

The seismic design of the plant considers two different intensities of earthquakes viz. operation basis earthquake (OBE) and safe shutdown earthquake (SSE). The OBE represents the intensity of earthquake for which the plant is designed to remain functional during and after the event. The SSE considers the maximum earthquakes potential of the site and its intensity is decided on the basis of geological and seismo-tectonic data. The structures, systems, and components whose failure could directly or indirectly cause accident conditions, which are required for shutting down the reactor, monitoring critical parameters, maintaining reactor in a safe shutdown condition and removing decay heat on a long term basis, and which are required to prevent radioactive release or to maintain release below limits established by AERB for accident conditions are designed for SSE.

Flooding in inland sites could be caused by heavy precipitation or by the release of large volumes of water due to failure of upstream dams under seismic disturbance or any other cause. The plants are designed for a design basis flood resulting from probable maximum precipitation with a mean recurrence interval of 1000 years. Flooding due to failures of upstream dam is also considered. Failures of dams located downstream may also affect availability of ultimate heat sink and is therefore considered in the design.

For coastal sites, flooding due to cyclones, tsunami and wind waves are considered in the design.

18.2 ADOPTING PROVEN OR QUALIFIED TECHNOLOGY

It is ensured that the quality standards followed for design, fabrication, construction and inspection of SSCs is commensurate with their importance to safety, as required in AERB safety guide AERB/SG/D-1 on Safety classification and Seismic Categorization of components in PHWR based NPPs. All the regulatory requirements specified in the different AERB Codes and other regulatory documents are complied with. If the design, construction, manufacture, inspection and maintenance of civil structures, mechanical, electrical, Instrumentation & Control equipment and systems are done by using the international codes & standards, it should be acceptable to the regulatory body. A typical list of design standards and codes generally followed for civil structures, mechanical equipment, electrical equipment and instrumentation is given in Annex 18-3.

Only proven equipment/components are used in the plant. As per the requirements of codes and standards, all safety related equipment are analysed with state of the art computer codes and are tested for their performance to demonstrate (i) their pressure boundary integrity for pressure bearing components, (ii) the structural integrity for structural support components and (iii) the functional operability for all mechanical, electrical, I&C equipment having moving components.

Wherever first of a kind (FOAK) systems are introduced, safety and system performance are demonstrated by appropriate analysis and supporting R&D programmes or by review of operational experience from other similar applications. All these systems are adequately tested during commissioning to verify that the expected behaviour is achieved. These systems are critically monitored during service to ensure their intended performance.

The equipment which are exposed to radiation and which could experience LOCA conditions are environmentally qualified. All civil structures and mechanical, electrical & instrumentation equipment which are required to perform during earthquake loading are qualified by analysis to demonstrate their pressure boundary integrity or structural integrity for two levels of earthquake i.e. OBE & SSE, depending on the seismic categorisation of the equipment. Equipment which have moving components viz, relays, valves, actuators, starters, push buttons etc. are tested on a shake-table for their functional performance for the two levels of earthquake.

For structural analysis, state of the art codes are used, which are validated with both benchmark classical problems and experimental tests and results.

Computer codes which deal with safety analysis during normal operation and accident conditions such as Thermal hydraulics, Core physics, Neutronics, High temperature phenomena and Core concrete interaction during severe accidents, fuel behaviour and radioactivity release, containment behaviour, etc. have been developed. These codes are developed in-house and are benchmarked with results of experiments conducted at national and international laboratories, by participating in standard problem exercises of IAEA, coordinated research programmes of IAEA and technical exchange programmes.

The primary containment is tested for pressure under MSLB and LOCA conditions.

Digital I & C technologies have matured over the last several years and this has led to their use in nuclear power plants for carrying out functions important to safety. Since several analogue equipment have become obsolete, digital technologies offer a practical replacement for the same. The digital instrumentation and control equipment have been extensively used in the newly built reactors in India. For qualification of this technology for use in NPPs, an elaborate process of Independent Verification & Validation (IV&V) has been implemented in NPCIL.

18.3 DESIGN FOR RELIABLE, STABLE AND MANAGEABLE OPERATION

AERB Code of Practice on Design for Safety in PHWR based NPPs, AERB/SC/D establishes the requirement for design for optimised operator performance. These include

- Redundancy, diversity and fail safe approach for safety critical systems
- Man-machine interface is designed to provide the operators with comprehensive & easily manageable information
- Providing interlocks & automatic actions. Design provides adequate time for operator to take necessary action.
- Ergonomically designed control panels
- Layout to facilitate operability and maintainability
- Working areas and working environment are given due consideration to personnel comfort.

The implementation of the requirements for human factors / human machine interface is addressed in chapter on article 12: Human Factors.

Design safety provisions in 700 MW PHWR and 500 MW PFBR are briefly described in Annex 18-4 & 18-5.

18.4 REGULATORY REVIEW AND CONTROL ACTIVITIES

The prerequisite for issue of consent for construction is the review of the design safety of the proposed NPP. For this, the utility is required to submit Preliminary Safety Analysis Report (PSAR) in a prescribed format. Through the PSAR, the utility

i) provides safety evaluation of the proposed facility and demonstrates that the facility can be built and operated at the proposed site without undue risk to the health and safety of the general public. The evaluation should take into account experience feedback from similar NPPs and experimental results.

ii) provides information such as design bases, site and plant characteristics, safety analyses and conduct of operations, in such a way that the Regulatory Body may evaluate the safety of the plant.

Consideration of postulated initiating events (PIEs) strongly influence the design limits for the safety systems and for most structures, systems and components (SSCs) needed for operation of the plant. The potential radiological consequences for workers, the public and the environment for design basis accidents may be much more severe than those during routine operation. For this reason, a large part of the review and assessment effort is directed to the safety analysis of such low frequency PIEs.

The review and assessment of the safety analysis by the Regulatory Body is carried out to ensure that

(a) the list of PIEs and their frequency is acceptable as the basis for the safety analysis (AERB/SG/D-5 provides the list of PIEs to be considered for PHWR of current design),
(b) the overall plant design is capable of meeting the prescribed and acceptable limits for radiation doses and releases set by AERB,
(c) the design provisions made on structures, systems components (SSC) are consistent with safety requirements derived from the safety analysis.

The regulatory review and assessment includes a check that any data, modelling or computer codes used in the analysis are based on sufficiently well founded knowledge and understanding, and that an adequate degree of conservatism has been built in. The computer codes are validated against experience or experiment. It is ensured that the coding has been done accurately, the input data have been correctly assigned, and that the checks have also been made to ensure that the code has not been corrupted by modifications and is being used in an appropriate manner.

To supplement the PSAR, the utility is also required to provide among other submissions, the following documents to AERB in the prescribed format in a progressive manner for review and approval for the purpose of consent for construction.

i) Quality assurance program for design and fabrication
ii) Applicant's site construction Quality Assurance manual
iii) Construction schedule (major milestones including regulatory clearances)
iv) Construction methodology document for the proposed NPP

v) Design Reports' (DR) of items important to safety
vi) Documents on Industrial Safety during Construction
vii) Qualification and organisation of the applicant and his vendors
viii) Emergency preparedness plan covering the project construction personnel and their colony (for existing sites)
ix) Security aspects relevant to the construction phase

18.4.1 Design

The review and assessment areas of particular significance for design include the following topics (AERB Safety Guide AERB/NPP&RR/SG/G-1 on "Consenting Process for Nuclear Power Plants and Research Reactors')

i) Safety approach of the applicant (objectives and principles) especially the importance given to such topics as accident prevention, surveillance and means of intervention and mitigation, defence in depth, redundancy, physical separation, diversity
ii) Safety classification of systems, structures and components
iii) Compatibility of the design with the site
iv) Design basis ground motion, geo-technical investigations and foundation parameter, meteorological parameter (Hydrology and Hydro-geology)
v) Layout of the nuclear power plant buildings and equipment, in particular, physical separation, easy accessibility to equipment for maintenance and routine surveillance, shielding and protection against explosions, missiles, fire and other natural and man-induced events.
vi) Nuclear Security giving emphasis on Physical Protection System Design.

In carrying out its review and assessment of design prior to issue of licence for construction, the Regulatory Body determines that the proposed design of NPP meets the following safety requirements (AERB Safety Guide AERB/SG/G-1 on "Consenting Process for Nuclear Power Plant and Research Reactor')
.
i) Implementation of defence in depth principle
ii) Emphasis on prevention of DBAs rather than on mitigation of their consequences
iii) Technologies incorporated in the design and construction of a nuclear installation have been proven by experience or qualified by testing or analysis
iv) Implementation of good practices related to human factors and human machine interface

18.4.2 Construction

The review and assessment by the Regulatory Body includes consideration of the applicant's organization and management to ensure that the proposed construction will meet the quality requirements envisaged in the design. The applicant is required to demonstrate that the safety management system put in place is comprehensive and it would ensure that the relevant activities are carried out in a planned and systematic manner and that the quality of work is in accordance with the approved procedures and nuclear industry practices. For this, AERB reviews the QA manuals of the utility for design, procurement, fabrication, construction, commissioning and operation. It is the responsibility of the utility to ensure that the vendors employed by it for carrying out different activities, follow a QA programme commensurate with the safety requirements.

Any change in the approved design of systems, structures and components important to safety due to site related constraints or otherwise requires regulatory approval.

In order to ensure industrial safety during construction, AERB requires that the utility should establish a construction safety management system. For this, AERB reviews various documents related to industrial safety such as Job Hazard Analysis Report, Construction Safety Management Manual, etc and monitors their compliance.

The regulatory inspections of NPPs are normally carried out at a frequency of four inspections in a year during construction. In addition to normal regulatory inspection, AERB also identifies certain critical activities during construction as hold points for which the licensee is required to inform regulatory body in advance for deputing its representative to witness or carry out inspection or tests, as may be necessary.

The availability of system completion certificates and system transfer documents form one of the prerequisite for considering consent for commissioning.

18.5 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

As per the licensing system, the safety in design is comprehensively reviewed prior to issuance of consent for construction. The regulatory review and assessment determines that in the design of NPP, emphasis has been given to prevention of accident rather than its mitigation. The defence in depth principles are as per the intent elaborated in the regulatory documents. Technologies used in the design and construction of the NPPs, are either proven by experience or otherwise qualified by testing or analysis. Human factors and man machine interface have been given important considerations among others in the design of NPPs. The objective of design has been to ensure reliable, stable, safe and easily manageable operation of the plant. Therefore India complies with the obligations the article 18 of this convention.

Annex 18-1: AERB Safety Guides under Safety Code on Design

AERB/NPP-PHWR/SC/D(Rev.1); 2009	**Design of Pressurised Heavy Water Reactor Based Nuclear Power Plants**
AERB/NPP-PHWR/ SG/D-1; 2003	**Safety Classification and Seismic Categorisation for Structures, Systems and Components of Pressurised Heavy Water Reactors**
AERB/SG/D-4; 1999	**Fire Protection in Pressurised Heavy Water Reactor Based Nuclear Power Plants**
AERB/SG/D-5; 2000	**Design Basis Events for Pressurised Heavy Water Reactor**
AERB/NPP-PHWR/SG/D-6; 2003	**Fuel Design for Pressurised Heavy Water Reactors**
AERB/SG/D-7; 1998	**Core Reactivity Control in Pressurised Heavy Water Reactor**
AERB/NPP-PHWR/SG/D-8; 2003	**Primary Heat Transport System for Pressurised Heavy Water Reactors**
AERB/NPP-PHWR/SG/D-10; 2005	**Safety systems for Pressurized Heavy Water Reactors**
AERB/SG/D-11; 2002	**Emergency Electric Power Supply Systems for Pressurised Heavy Water Reactor**
AERB/NPP-PHWR/SG/D-12; 2005	**Radiation Protection Aspects in Design for Pressurized Heavy Water Reactor Based Nuclear Power Plants**
AERB/NPP-PHWR/SG/D-13; 2002	**Liquid and Solid Radwaste Management in Pressurised Heavy Water Reactor Based Nuclear Power Plants**
AERB/SG/D-14; 2002	**Control of Airborne Radioactive Materials in Pressurised Heavy Water Reactors**
AERB/SG/D-15; 2000	**Ultimate Head Sink and Associated Systems in Pressurised Heavy Water Reactor**
AERB/SG/D-18; 2001	**Loss of Coolant Accident Analysis for Pressurised Heavy Water Reactor**
AERB/NPP-PHWR/SG/D-20; 2003	**Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants**
AERB/NPP-PHWR/SG/D-21; 2007	**Containment System Design for Pressurised Heavy Water Reactors**
AERB/SG/D-22; 2000	**Vapour Suppression System (Pool Type) for Pressurised Heavy Water Reactor**

AERB/NPP-PHWR/SG/D-23; 2009	**Seismic Qualification of Structures, Systems and Components of Pressurised Heavy Water Reactors**
AERB/SG/D-24; 2002	**Design of Fuel Handling and Storage Systems for Pressurised Heavy Water Reactors**
AERB/NPP-PHWR/SG/D-25; 2010	**Computer Based Systems of Pressurised Heavy Water Reactors**

Annex 18-2: AERB Safety Guides under Code of Practice on QA

AERB/NPP/SC/QA (Rev.1); 2009	**Quality Assurance in Nuclear Power Plants**
AERB/SG/QA-1; 2001	**Quality Assurance in the Design of Nuclear Power Plants**
AERB/SG/QA-2; 1998	**Quality Assurance in the Procurement of Items and Services for Nuclear Power Plants**
AERB/SG/QA-3; 1998	**Quality Assurance in the Manufacture of Items for Nuclear Power Plants**
AERB/SG/QA-4; 2001	**Quality Assurance During Site-Construction of Nuclear Power Plants**
AERB/SG/QA-5; 1993	**Quality Assurance During Commissioning and Operation of Nuclear Power Plants**
AERB/NPP/SG/QA-6; 2005	**Establishing and Implementing of Quality Assurance Programme for Nuclear Plants**
AERB/NPP/SG/QA-7; 2005	**Assessment of Implementation of Quality Assurance Programme in Nuclear Power Plants**
AERB/NPP/SG/QA-8; 2006	**Non-conformance Control, Corrective and Preventive Actions for Nuclear Power Plants**
AERB/NPP/SG/QA-9; 2006	**Document Control and Records Management for Quality Assurance in Nuclear Power Plants**

Annex 18-3: Typical List of Standards and Codes used in Design

Typical list of standards and codes used in design of civil structures, mechanical equipment & system, electrical equipment and instrumentation

Civil Structures

a) The design of civil containment structures is carried out based on philosophy developed in India by utility in collaboration with AERB based on RCC-G as a reference document since it was considered that RCC-G is the most appropriate for unlined double containment structure, which is adopted in operating Indian PHWRs. For 700 MWe PHWRs and LWRs, in general provision of ASME Section III Division 2 are adopted.
b) For the design of other safety related nuclear structures, India has been following ACI 349, however this has now been replaced by AERB standard AERB/SS/CSE-1 applicable to concrete structures.
c) The design of safety class steel structures is being done by ANSI code, however these are being replaced by AERB/SS/CSE-2.

Mechanical equipment and system

d) ASME section III, Division 1, Subsection NB, NC & ND codes are used for design, fabrication, construction and inspection of piping, pressure vessels, valves, & other pressure bearing components of safety class 1, 2 &3 respectively.
e) ASME section VIII, Division 1 & 2 codes are used for design, fabrication, construction and inspection of non safety related piping, pressure vessels, valves, & other pressure bearing components.
f) ASME section III, Division 1, Subsection NF code is used for design, fabrication, construction and inspection of component supports of safety related equipment & systems.
g) ASME section III, Division 1, Subsection NE code is used for design, fabrication, construction and inspection of core components.
h) ASME section XI code is used for in service inspection of safety related equipment & systems.

Electrical Equipment & Systems

S. No.	IEEE Standard	Description
1.	IEEE 308-2001	Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
2.	IEEE 323-2003	Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
3.	IEEE 383-2003	Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Station
4.	IEEE 384-1992	Standard Criteria for Independence of Class 1E Equipment and Circuits
5.	IEEE 387-1995	Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations
6.	IEEE 484-2002	Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications
7.	IEEE-323	Standard for Quality Class 1E Equipment for Nuclear Power Generating Station
8	IEEE-344	IEEE Recommendation Practice for Seismic Qualification of Class 1E Equipment of Nuclear Power Generating Station
9.	IEEE 485-1997	Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
10.	IEEE 944-1986	Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations

Instrumentation & control systems & equipment

S. No.	Standard/Guide	Title
1.	AERB/NPP-PHWR/SG/D-10; 2005	Safety systems for Pressurized Heavy Water Reactors
2.	AERB/NPP-PHWR/ SG/D-20; 2003	Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants
3.	AERB/NPP-PHWR/SG/D-25; 2010	Computer Based Systems of Pressurised Heavy Water Reactors
4.	IS 2147/13947	Degrees of Protection Provided by Enclosure for Low Voltage Switchgear and Control Gear
5.	IS 9000	Basic Environmental Testing Procedures for Electronic and Electrical Items
6.	ASME PTC-19.2	ASME Performance Test Code- Pressure Measurement
7.	ASME PTC- 19.3	ASME Performance Test Code-Temperature Measurement
8.	ASME PTC-19.5	ASME Performance Test Code-Flow Measurement
9.	IEC-1226	Nuclear Power Plants-Instrumentation and Control Systems Important to Safety Classification
10.	IEEE-323	Standard for Quality Class 1E Equipment for Nuclear Power Generating Station
11.	IEEE-344	IEEE Recommendation Practice for Seismic Qualification of Class 1E Equipment of Nuclear Power Generating Station
12.	IEEE-384	Criterion for Independence of Class 1E Equipment and Circuits.
13.	IEEE-420	IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels and Racks Used in Nuclear Power Generating Stations.
14.	IEEE-946	IEEE Recommended Practice for the Design of Safety Related DC Auxiliary Power System for Nuclear Power Generating Stations.
15.	ISA RB 3.2	Instrument Society of America-Recommended Practice for Flange Mounted Sharp Edged Orifice Plate Assemblies for Flow Measurement

Annex 18-4: Design Safety Provisions in typical 700 MW PHWRs in India

The design of 700 MW units is essentially similar to 540 MW units which are now in operation at Tarapur. This design envisages partial boiling of the coolant (about 2%) at the exit of the coolant channel to extract more power from the core.

The design incorporates multiple barriers to radioactivity release and incorporates established safety design principles like defence in depth, fail safe design, redundancy, diversity etc. Operation of the plant is controlled from the centralised control room. Control panels provide full information regarding the status of the plant so as to enable operating personnel to operate the plant safely and efficiently. In addition to the main control room, a back-up control room located away from the main control room is provided to monitor and ensure safe shutdown of the reactor in case of inaccessibility / inhabitability of the main control room for any reason.

Safety Systems

Shutdown System

The reactor is provided with two diverse, fast-acting and independent shutdown systems. These features provide a high degree of assurance that plant transients, requiring prompt shutdown of the reactor will be terminated safely. Shutdown System # 1 consists of 28 shutoff rods of cadmium sandwiched in stainless steel, which falls in to the reactor in about 2.5 seconds to shutdown the reactor. Fail-safe features like gravity fall and spring assistance have been incorporated in the design of shutoff rods. Shutdown System # 2, injects gadolinium nitrate poison solution directly into the moderator through six perforated injection tubes horizontally oriented inside the calandria.

Containment Systems

The reactor building consists of primary and secondary containments. Primary containment is a pre-stressed concrete structure with steel liners designed to withstand internal pressure of 1.60 kg/cm^2g. Secondary containment is a reinforced concrete structure, completely surrounding the primary containment and having a design pressure of 0.13 kg/cm^2 (g). Ducting for ventilation systems, penetrating the containment, is provided with isolation dampers, which will close on accident signal to box-up the containment. Dry containment is used and containment spray system is provided for long term energy and radionuclide removal.

To mitigate the consequences of design basis accident, containment is provided with engineered safety features like containment spray system, primary containment controlled discharge (PCCD) system and secondary containment clean-up and purge (SCCP) system (figure 18.4.1). Containment spray system helps in cleaning up the containment by removing radioactive Iodine. PCCD system helps in de-pressurising the containment in a controlled manner following accident. SCCP system helps in maintaining negative pressure in the annular space between the two containments, so as to prevent ground level release of radioactivity during post-accident condition.

Emergency Core Cooling System

Emergency Core Cooling System (ECCS), with two trains is provided to cool the core and thereby limit the core damage in the event of postulated Loss of Coolant Accident. Within a train, single failure criteria is used for active components. ECCS involves the following stages:

- High pressure light water injection
- Low pressure long term re-circulation through ECCS sump.

Management of Severe Accidents

The following design features to manage severe accident are provided . These features will be invoked through severe accident management guidelines.

- Inventory addition (light water) in calandria
- Inventory addition in calandria vault
- Injection (light water) in to primary cooling system
- Injection in to end shields.
- Hydrogen management

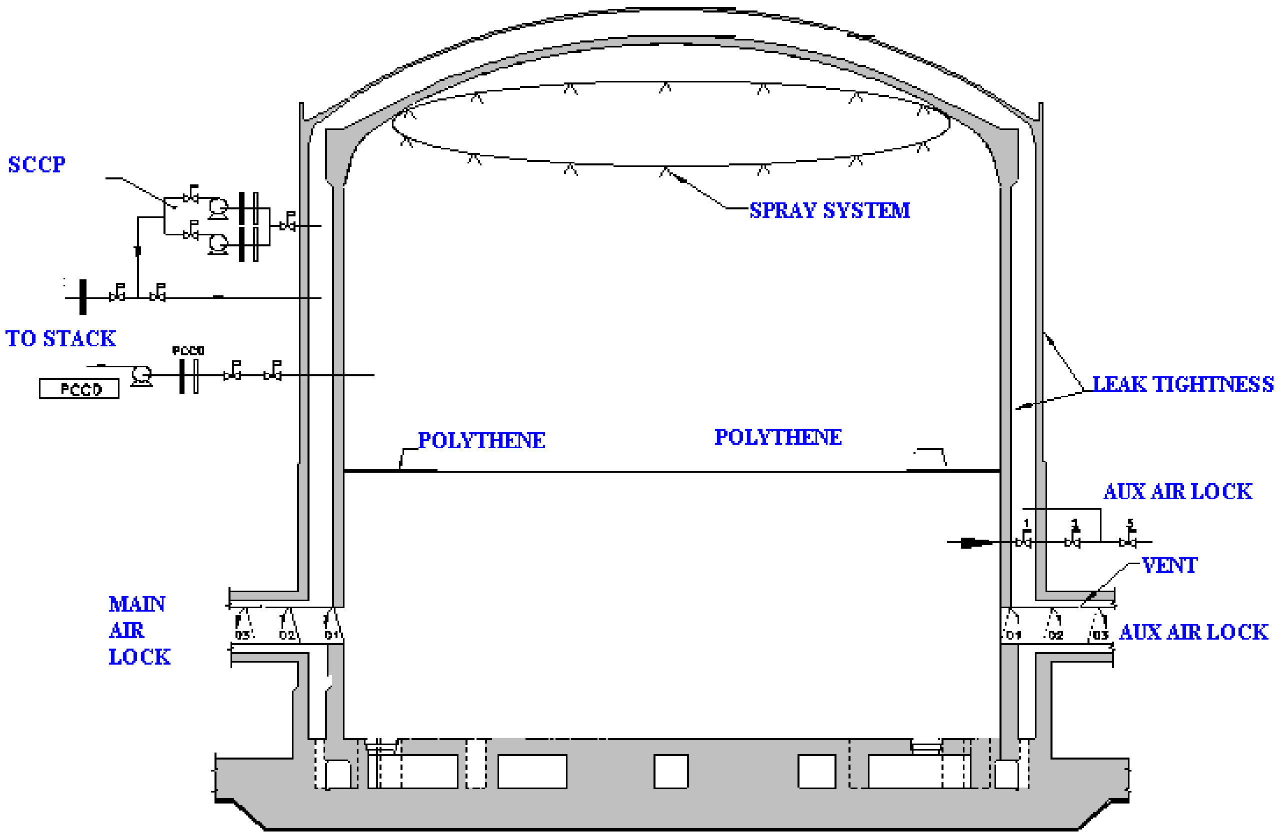


Figure 18.4.1 Containment related Engineered Safety Features

Annex 18-5: Design Safety Provisions in 500 MW PFBR in India

PFBR is a 500 MW unit designed by Indira Gandhi Centre for Atomic Research. PFBR is a sodium cooled, mixed oxide (MOX) fuelled, pool type fast reactor. The core thermal power is about 1250 MW and the gross electrical output is 500 MW.

PFBR Reactor Assembly

The reactor assembly (figure.18.5.1) consists of Grid Plate, Core Support Structure, Inner Vessel, Main Vessel, Thermal Baffles, Safety Vessel, Thermal Insulation, Roof Slab, Rotatable plugs, and Control Plug and absorber rod drive mechanism. PFBR is designed to produce about 1250 MW thermal at full power.

The core support structure supports the grid plate (which has 4 inlet pipes for liquid sodium, 2 from each primary sodium pumps) and inner vessel (which separates hot & cold pool of sodium).

The main vessel has no penetration. Safety vessel is provided to collect the leaking sodium in the remote event of any sodium leakage from the main vessel. 12 Nos. of control rods are used out of which 9 Nos. are used to control the reactor power manually and 3 Nos. for the start-up / shutdown of the reactor. These rods and their drive mechanism are supported by Roof slab.

Main Heat Transport System

The heat transport system (figure.18.5.2) consists of primary sodium circuit & secondary sodium circuit and steam – water system. Primary heat transport from the core is facilitated by two pumps which drive the sodium from the cold pool through the reactor core. The hot sodium flows through IHX, transfers its heat to the secondary sodium and finally returns to the cold pool at the bottom, completing the flow circuit. An intermediate secondary sodium circuit to transfer heat to steam water circuit prevents the possibility of steam/ water leak into the primary system (reactor assembly), in the event of a leak in the steam generator (SG) tube. The function of the steam water system is to utilise the superheated steam from the steam generators to drive the turbine generator to produce electrical output of 500 MW.

Reactor Safety

A defence–in-depth philosophy, consisting of three levels of safety, viz., design with adequate safety margin, early detection of abnormal events to prevent accidents and mitigation of consequences of accidents, if any, is adopted. All safety related systems are designed with adequate redundancy, diversity and independence. Because of the use of sodium coolant, PFBR have several inherent safety features. The most important is the low operating pressures and consequent low release of radioactivity to the environment. The large difference between the operating temperatures and the boiling point gives a large margin for decay heat removal. The excellent heat transport characteristics of liquid sodium facilitate heat removal by natural convection. Because of the low reactivity changes due to burn-up, the reactor control is easy.

The engineered safety features include two diverse reactor shutdown systems, decay heat removal system with passive features of natural circulation of intermediate sodium and of air, and diversity in design of sodium to sodium and sodium to air heat exchangers. Core catcher and the reactor containment building are provided as defence in depth for Beyond Design Basis Events (BDBE). Selection of design features; detailed design analysis and requirements specified for manufacture minimize the risk of sodium leaks from sodium components and piping, and leaks leading to sodium-water reaction in SG. In addition, the design provides for in-service inspection of the main and safety vessels, secondary sodium piping and the steam generators. Nevertheless, provisions have been made for early detection of sodium leaks from sodium circuits and sodium-water reaction in SG and safety actions to minimize the consequences of the leaks.

Reactor Shutdown System

Two independent, fast acting diverse shut down systems are provided. The control and safety rod system (CSR) is used for reactivity compensation, power control and shut down, while diverse safety rod system (DSR) is used only for shut down. The control and safety rod system consists of nine rods and their associated mechanisms. The diverse safety rod system consists of three rods and their associated mechanisms. The minimum total reactivity worth of the CSR and of the DSR is equal to the sum of shutdown margin and maximum excess reactivity to be controlled. Any one of the two systems is capable of bringing the reactor to a cold shutdown state, even with one of the absorber rods in the system failing to drop. The systems are designed to effectively shut down the reactor in less than one second.

Containment Systems

The containment is designed to provide a leak tight boundary that contains the release of radioactive core fission products and fuel, and withstands the pressure resulting from burning of sodium in air through potential leak paths in case of core disruptive accident (CDA) so that dose limits for design basis accident (DBA) are not exceeded. The leak tightness has been specified as 0.1% V/h. The design pressure of the containment following CDA is 25 kPa. Single containment, rectangular, non-vented and reinforced concrete construction are the main design features of the containment. During normal operation, the containment is kept under small negative pressure (735 Pa below atmospheric). All ventilation ducts opening to the containment atmosphere are automatically isolated by dampers closing in 10 s in the event of CDA.

Plant Layout

The plant layout has been developed on the basis of a single unit. The layout has been made taking into consideration safety requirements, distance for flow of energy, constructability, maintainability, security and economics. The reactor containment building (RCB) is rectangular in shape. The RCB, fuel building (FB) and two steam generator buildings (SGB) are connected and laid on a common base raft from safety considerations. In addition, control building, two electrical buildings and radwaste building are also laid on the common raft and connected to form a nuclear island consisting of eight buildings to reduce the magnitude of structural response under seismic loads and length of cables.

Electrical Power System

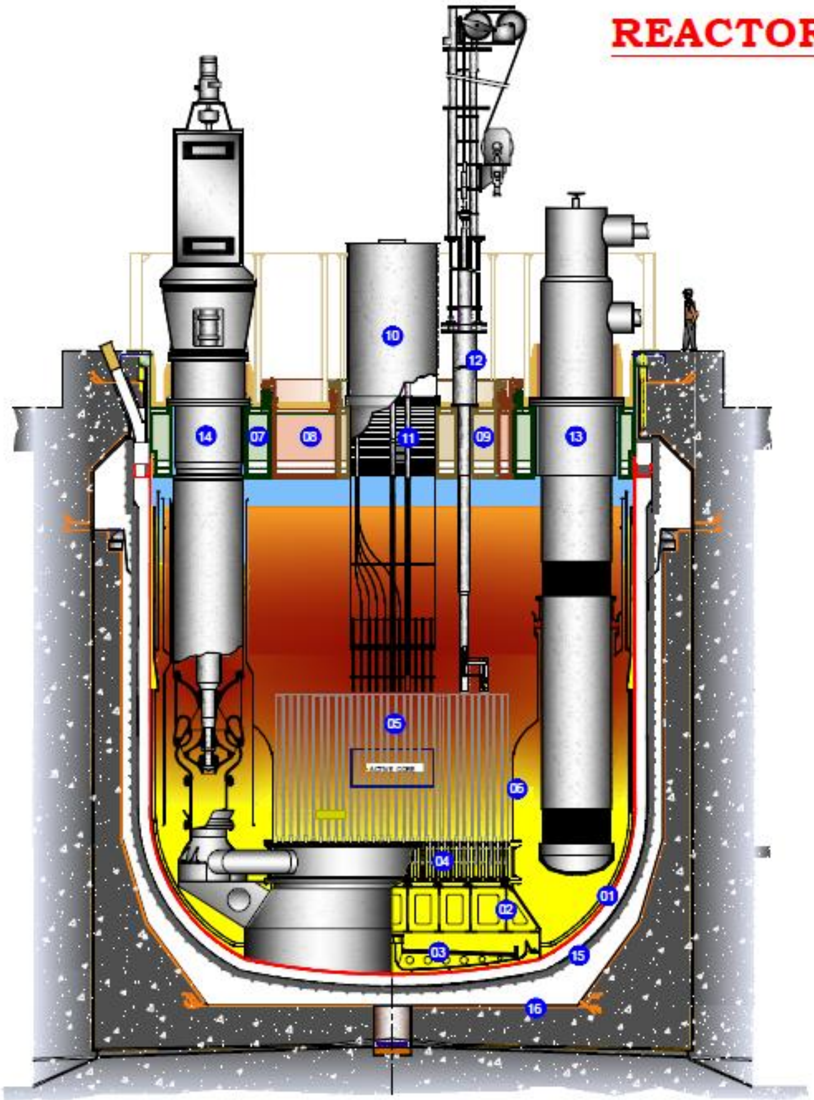
Electrical power system is a source of power for the reactor coolant pumps and other auxiliaries during normal conditions, and for the protection system and engineered safety systems during normal and accident conditions. Both off-site and on-site electrical power supply systems are provided. 220 kV is the transmission voltage.

An indoor GIS switchyard is selected to safe guard and increase the reliability of the electrical equipment against the saline atmosphere. Standby emergency diesel generators are provided to feed the Class III power supply system. 4 diesel generator sets, each rated to supply 50% of the total emergency power supply demand with a rating of 4.5 MVA are provided as on-site sources of AC power. Class I no-break 48V & 220V DC and Class II no-break 240V, 50Hz, 1-phase power supplies are provided for instrumentation and control equipment.

Instrumentation and Control Systems

As the burn-up compensation of reactivity is very small, the reactor power is controlled manually. For neutron monitoring 6 fission chambers are housed inside the control plug axially above the core and six fission chambers under the safety vessel. Cover gas activity and delayed neutrons in the primary sodium are monitored for failed fuel detection. Sodium samples from each fuel subassembly outlet are taken using three selector valves for locating failed subassembly. Two chromel–alumel thermocouples are provided to monitor the temperature of sodium at the outlet of each fuel subassembly. Flow delivered by the sodium pumps are measured using eddy current flow meter and safety action is taken on power to flow ratio. These provisions ensure that there are at least two diverse safety parameters to shut down the reactor safely for each design basis event. Various SCRAM parameters from core monitoring systems and heat transport systems are connected to plant protection system to automatically shutdown the reactor, in case any parameter crosses the limit. Steam generator tube leaks are detected by a leak detector (hydrogen in sodium) provided at the outlet of each steam generator module and an additional detector provided in the common outlet header. Two hydrogen in argon detectors are installed in the cover gas space of surge tank. Acoustic leak detectors are also installed at various locations on the outer shell of steam generator. Crack opening of air heat exchanger dampers and sodium flow monitoring ensures poised condition for safety grade decay heat removal whose operation is automatic. Separate backup control room and fuel handling control rooms are also provided. Instrumentation directly concerned with reactor safety is designed using hardwired systems except core thermocouples, which are processed by real time computers. Non nuclear systems use state of the art distributed digital control system to take advantage of multiplexed signal transmission and reduced cabling leading to cost savings. Safety signals are converted into digital form and are connected to the distributed digital control system for display in control room.

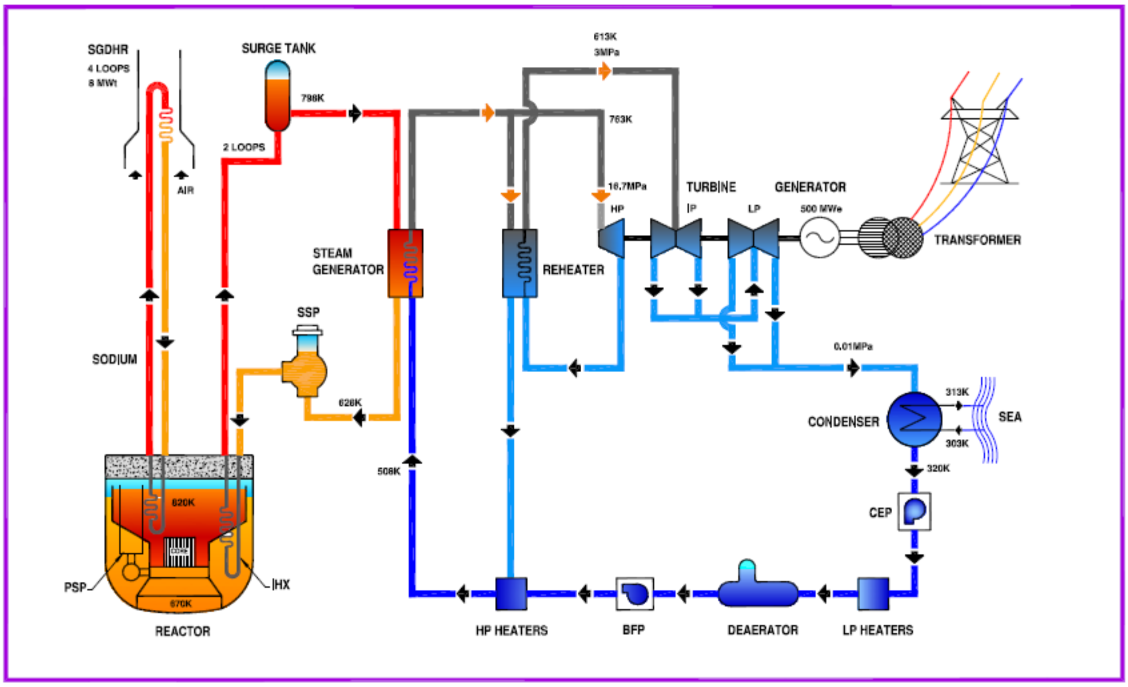
REACTOR ASSEMBLY



01.	MAIN VESSEL
02.	CORE SUPPORT STRUCTURE
03.	CORE CATCHER
04.	GRID PLATE
05.	CORE
06.	INNER VESSEL
07.	ROOF SLAB
08.	LARGE ROTATABLE PLUG
09.	SMALL ROTATABLE PLUG
10.	CONTROL PLUG
11.	CSRDM / DSRDM
12.	TRANSFER ARM
13.	IHX
14.	PRIMARY SODIUM PUMP
15.	SAFETY VESSEL
16.	REACTOR VAULT

Figure 18.5.1

PFBR FLOW SHEET



MAIN DESIGN SPECIFICATION

Electrical Power (gross)	500 MWe	Thermal power	1253 MWt
Core and Fuel		**Plant temperatures :**	
Fuel	PuO_2- UO_2	Primary sodium	
Burn-up (Peak)	100 MWd/kg	Inlet to core	670 K (397°C)
Primary circuit	Pool type	Outlet from core	820 K (547°C)
Coolant	Sodium	Water / Steam	
No. of loops	2	Inlet to SG	508 K (235°C)
No. of primary sodium pumps	2	Steam condition	763 K (490°C) at 16.7 MPa
No. of Intermediate heat exchangers	4		
No. of Steam Generators	8	RCB Shape	Rectangular
No. of Turbo Generator	1	Design life	40 Years

Figure - 18.5.2

ARTICLE 19 : OPERATION

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

- **i.** **the initial authorisation to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme 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 licence to the regulatory body;**
- **vii.** **programmes to collect and analyse 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.**

19.0 SUMMARY OF NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

The requirements for licensing of NPPs for operation emanate from the Atomic Energy Act 1962 and rules framed there under. National laws pertaining to NPP are given in detail in Chapter on Article 7: Legislative and Regulatory Framework. Based on these requirements, the system of licensing, inspection and enforcement has been established. AERB code of practice on regulation of Nuclear and Radiation Facilities, AERB/SC/G and AERB Safety Guide AERB/SG/G-1 on “Consenting Process for Nuclear Power Plant and Research Reactor” establishes the entire licensing process for NPPs. The licensing process is summarised in Chapter on Article 14: Assessment and Verification of Safety. Further, AERB safety code “Nuclear Power Plant Operation”, AERB/NPP/SC/O (Rev. 1) establishes requirements related to operation of NPPs and several safety guides issued under this Code describe and make available methods to implement specific requirements of the Code. The list of safety guides issued under the Code of practice in NPP operation is given as Annex 19-1.

19.1 INITIAL AUTHORIZATION

Prior to issuance of consent for construction, AERB completes the review of Preliminary Safety Analysis Report (PSAR). At this stage, a large part of the review and assessment effort is directed to the safety analysis of design basis events provided by the applicant. The review and assessment process considers whether the applicant’s list of Postulated Initiating Events (PIEs) is complete and acceptable as the basis for the safety analysis. AERB determines that the PIEs, type of analytical considerations and assumptions are in conformance with applicable safety guides. Further, the engineering systems are qualified to meet the functional requirement for which they were designed, under all situations considering environmental conditions, ageing etc. Aspects of review of safety analysis are given in detail in the Chapter on article 18: Design and Construction.

Regulatory clearance for commissioning of NPP is needed at various identified stages. For a typical PHWR, such stages are indicated in the table below.

Phase	Stages of Commissioning	
	No.	Activity
A	i.	Hot conditioning or passivation of the primary system and light water commissioning
	ii.	Fuel loading of the reactor core, and borated heavy water addition to moderator systems for flushing in specified limited quantity
	iii.	Addition of heavy water to primary heat transport system
	iv.	Bulk addition of heavy water to moderator system with minimum specified boron level in heavy water to prevent criticality
B	i.	Initial approach to criticality
	ii.	Low power reactor physics tests and experiments.
C	i	Initial system performance tests at low, medium and rated power levels as determined by the stable operation of the turbine.
	ii	System performance at rated power.

Before start of commissioning activities, NPCIL prepares a comprehensive programme for the commissioning of plant components and submits the same for review and acceptance by AERB.

The commencement of operation of an NPP begins with approach to the first criticality. This is a major step in the licensing process. At this stage NPCIL demonstrates to AERB its preparedness to commence operation of the NPP. This requires completion of all activities with requisite approvals, pertaining to the following.

(a) Preparation of final as built design of the plant components and systems.
(b) Evaluation of safety analyses in view of changes in design, if any.
(c) Quality records (such as construction completion certificate, history dockets etc.) after construction of the plant components and systems, and the program for their operation.
(d) Report on pre-service examination.
(e) Establishment of organization for plant operation, training, qualification & licensing of the operating personnel, as per AERB requirement.
(f) Preparation of Technical Specification specifying operational limits and conditions.
(g) Preparation of operating instructions and procedures for commissioning and operation of the plant including emergency operating procedure.
(h) Establishment of physical protection system.
(i) Radiation protection program.
(j) Emergency Response Plans and demonstration.
(k) Waste management programme.
(l) Security Aspects.

AERB carries out review and assessment of preparedness of NPPs to satisfy itself that the plant has been built in accordance with the accepted design, and meets all the regulatory requirements.

Before licensing regular operation, AERB carries out review and assessment of the results of commissioning tests for their consistency with design information and with the prescribed operational limits and conditions. Any inconsistency at this stage has to be resolved to the satisfaction of AERB. At this stage, the utility revises the PSAR taking into account all the changes that have been carried out and submits Final Safety Analysis Report (FSAR), which forms one of the licensing documents for operation of the unit.

The review and assessment by AERB also includes consideration of the applicant's organization, management, procedures and safety & security culture, which have a bearing on the safety of the operation of the plant. The applicant should demonstrate with the necessary documentation that there is an effective safety management system in place, which gives the highest priority to nuclear safety and security. The typical organisation for plant operation established at an Indian NPP is given in Annex 19-2.

19.2 OPERATIONAL LIMITS AND CONDITIONS

The licensee prepares the Technical specification for operation before approach to first criticality, based on the inputs from the design and safety analysis. AERB safety Guide AERB/SG/O-3: Operational Limits and Conditions for Nuclear Power Plants provide guidelines for preparation of this document, which is submitted to AERB for review and approval. Subsequent to commissioning stage, this document is again reviewed and revised as necessary based on the commissioning results and the final document is approved by AERB.

The Technical Specification document is issued in two parts. Part A contains the technical specifications, bringing out the mandatory requirements to be adhered to during operation. Part-B is explanatory in nature and outlines the bases for arriving at different conditions/requirements in technical specifications for operation.

Technical Specification (Part-A) consists of following sections:

a) Safety Limits
b) Limiting Safety System Settings (LSSS)
c) Limiting Conditions for Operation (LCO)
d) Surveillance Requirements
e) Administrative Requirements

If a change in any section of the Technical Specification becomes necessary, based either on operating experience or new findings consequent to changes in safety analysis, the same is submitted to AERB for review and approval. A general review of the document is carried out once in five years.

19.3 PROCEDURES FOR OPERATION, MAINTENANCE, INSPECTION & TESTING

The safety code on 'Nuclear Power Plant Operation', AERB/NPP/SC/O (Rev 1) requires that all the activities in the NPP be carried out as per the well laid down operating procedures. The procedures should be prepared, tested and approved as per the standard guidelines developed for the same. Based on these guidelines, the plant management prepares various procedures for commissioning and operation of all systems, maintenance, inspection, testing, and surveillance requirements. The procedures also include conditions dealing with plant under normal operation and anticipated operational occurrences as well as appropriate actions for accident conditions including design basis accidents. These documents are normally prepared by plant personnel in co-operation with the designers and suppliers. The Plant Management ensures that the aspects of Quality assurance are duly considered in the preparation, review and approval of these procedures. All the approved procedures are available to the users on plant local area network.

19.4 PROCEDURES FOR RESPONDING TO OPERATIONAL OCCURANCES AND ACCIDENTS

At present, all NPPs have emergency operating procedures for various anticipated operation transients and accident conditions. These procedures are primarily event based and are also used extensively for training of the operating personnel.

NPCIL has completed the development of symptom-based procedures for accident management and these Emergency Operating Procedures (EOPs) have been validated on plant simulator. Development of system for deploying these procedures in NPPs is taken up and will be implemented first in one unit for evaluation. The progress on establishing Severe Accident Management Guidelines is summarised in chapter on summary.

In addition to the above, several plant specific administrative procedures are also prepared, which include shift change over procedure, station work permit procedure, radiation protection procedure, engineering change procedure, jumper control procedure, etc.
All the above procedures are periodically reviewed and revised, as necessary.

19.5 ENGINEERING AND TECHNICAL SUPPORT

NPCIL manages all the presently operating NPPs through the Directorate of Operation set up at its Head Quarters at Mumbai. This Directorate monitors the operational and safety performance of NPPs and provides the necessary engineering and technical support. The Directorate also acts as interface between plant management and AERB. For achieving these objectives, the Directorate of Operation also derives support from other technical groups at Headquarters, which include Directorates of Engineering, Safety, Quality Assurance and Procurement. These groups at headquarters also provide engineering and technical support to units under construction and commissioning. NPCIL also enters into memoranda of understanding with Research and Development and academic institutions so as to avail additional engineering and technical support as and when required.

To initiate in-house Research & Development effort, NPCIL established Directorate of R&D in 2001 with specific focus on enhancement of nuclear safety and reduction in unit energy cost of nuclear power plants. The thrust areas of development effort in NPCIL are nuclear systems and electronic systems. Nuclear systems R&D undertakes application oriented projects to provide quick solutions to the problems emanating from operating stations/project under construction, assessing/extending life of plant systems, structures and components or experiment oriented projects for furthering plant nuclear safety or validating new designs and in-house developed computer models/codes. Electronic systems R&D group concentrates mainly on development of electronics and computer based controls and instrumentation. The laboratory facilities of nuclear system are established at Tarapur and of electronic system at NPCIL headquarters, Mumbai.

At the plant level, the Technical Services Section, which provides support in monitoring and review of operational and safety performance, is also equipped to provide the necessary engineering and technical support. A Corporate Level Safety Review Committee for operation reviews all the issues pertaining to safety in NPPs. This committee reviews all the safety related proposals emanating from stations before being forwarded to AERB. Vendor support is taken for systems like turbine and other conventional systems as and when needed.

19.6 REPORTING OF INCIDENTS SIGNIFICANT TO SAFETY

AERB safety code on 'Regulation of Nuclear and Radiation Facilities', AERB/SC/G specifies the reporting obligations of the Plant Management. The code specifies the events for which the event reports and significant event reports are to be prepared and submitted to the regulatory body. The detailed reporting criteria for these two categories form part of Technical Specifications for Operation. AERB/SG/O-13 on Operational Safety Experience Feedback on Nuclear Power Plants issued under the Code of Operation provides guidance for reporting events to regulatory body.

Events of relatively lower safety significance (limited consequences from safety point of view) are reported as 'Event Report' to AERB in a prescribed format as part of the minutes of the Station Operation Review Committee (SORC). However, Events with relatively higher significance for safety are required to be reported as Significant Event Reports (SER) as per the reporting criteria specified in Technical Specification for Operations. These events are reported to AERB in three stages.

a. Prompt Notification
   Prompt Notification in the prescribed format is sent within 24 hours of the occurrence of the event.
b. Significant Event Report
   A detailed significant event report (SER) in a prescribed format for SER is submitted within a period of 20 days from the date of occurrence of the event.
c. Event Closing Notification Report
   Event Closing Notification Report (ECNR) in a prescribed format is submitted for those significant events for which the root causes could not be established within 20 days (reporting time for significant event report). ECNR indicates completion of all investigations pertaining to the event.

A total of 47 SERs were reported during the years 2008 and 2009.

All the SERs are reviewed by AERB and recommendations arising out of the multi-tier review process are addressed in a time bound manner. A system for reporting of low level and near miss events is established at each NPP. A report on trend analysis and corrective actions taken for such events is submitted periodically to utility headquarters.

19.7 OPERATING EXPERIENCE FEEDBACK SYSTEM

AERB safety code on operation specifies the requirement for establishing operation experience feed back system at NPPs. AERB/SG/O-13 on 'Operational Safety Experience Feedback on Nuclear Power Plants' issued under the code provides guidance and procedure for establishing an Operating Safety Experience Feedback (OSEF) system based on national / international experience on management of safety related operational experience in NPPs. The OSEF system at NPPs and at NPCIL complies with the guidelines given in the safety guide.

NPCIL obtains reports of international events through IAEA-IRS, WANO and COG and sends the event reports (both national and international) to the experts in the relevant fields like operation, design and safety and also to all the NPPs. The expert comments are reviewed by the Corporate Level Safety Committee. NPCIL through its safety management system ensures the dissemination of relevant information amongst all senior management persons in NPPs and projects under construction.

The organizational structure at Plant Level ensures that both national and international events are systematically analyzed and appropriate actions are taken to prevent the occurrence of similar events in Indian NPPs. A committee comprising of members from Technical

Services, Operation, Maintenance, Health Physics, Training and other relevant sections is responsible for the review of these events. The observations of this Committee are further reviewed in Station Operation Review Committee (SORC) for finalization of recommendations.

The system ensures that events taking place at one NPP are communicated to other NPPs in India. The system also ensures that the information on events and corrective actions at one NPP is disseminated to other NPPs. Further, management of various NPPs interacts with each other at different levels. At these meetings, the information on various modifications to equipment and procedures is exchanged. These exchange meetings are held periodically.

At corporate level a 'Flash Report' is issued by Directorate of operations at NPCIL headquarters to all the stations for quick dissemination of information pertaining to the occurrence of an event in any plant. In addition, an 'Operational Experience Feedback Report' is also issued by headquarters on those events which have significant learning points for all the other stations of NPCIL.

In addition, to the reporting of events significant to safety (refer section 19.6), the plant management is also required to submit routine reports such as periodic performance reports, inspection & testing reports, health physics reports, environmental surveillance reports, waste management reports, minutes of Station Operation Review Committee (SORC) and other miscellaneous reports to AERB. The functioning of the operating experience feedback setup at the plant and the corrective actions taken in response to internal and external operating experience is monitored by AERB through the reports received from licensee and during regulatory inspections carried out twice in a year. Actions taken by licensee based on internal and external operating experience are also reviewed during renewal of licence for operation every five years.

AERB reviews operational experience available from Indian NPPs, TSOs and also of external information available from NPPs abroad received through IAEA, IRS and other regulatory forums (like CANDU Senior Regulators Group, VVER Senior Regulators Forum). IAEA-IRS reports are made available to AERB staff who reviews these reports for further discussions in Operating Experience Review Group in AERB. The selected reports are further referred to the utility headquarters and the Licensees for checking applicability of the reports to their NPP and to submit response to AERB on the actions taken or proposed to be taken. Some reports involving specific technical issues are referred to Technical Support Organisations (TSO) also for obtaining their views. The responses received from utility, licensee and TSOs, are reviewed in AERB.

AERB is the national coordinator for all IAEA-IRS activities. Reporting of events to IAEA - IRS is done as per the guidelines of IAEA-IRS.

19.8 MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE ON THE SITE

19.8.1 Spent Fuel Storage

Spent fuel is stored in a water filled storage bay provided at each NPP. These storage bays are designed to accommodate spent fuel accumulated during 10 reactor years of operation. In addition, space is also reserved for storing one full core inventory of fuel in case of exigencies. For storage of spent fuel beyond this capacity, additional facilities in the form of Away From Reactor-Spent Fuel Storage Bay and Dry Storage Facilities are created. All such additional storage facilities are subject to regulatory review and clearance.

19.8.2 Radioactive Waste Management

Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 specifies the requirement for obtaining authorization for safe disposal of radioactive waste arising out of operation of NPP. Further, AERB Safety Code on Management of Radioactive Waste, AERB/NRF/SC establishes the requirements, which need to be fulfilled for safe management of solid, liquid and gaseous radioactive waste disposal. This safety code deals with the requirements for radiation protection aspects in design, construction and operation of waste management facilities and the responsibilities of different agencies involved. In addition, AERB/SG/O-11 on Management of Radioactive Wastes Arising during Operation of NPPs gives guidelines for radioactive waste management.

Based on the requirements as specified, NPCIL has to establish at each NPP site, a facility for storage and disposal of radioactive solid, liquid and gaseous wastes, which is approved by AERB prior to the commencement of operation. NPCIL demonstrates that the facility has necessary engineered systems and administrative procedures to exercise control on release of activity into the environment, as per the regulatory requirements.

The disposal of radioactive waste from NPPs was governed by Technical Specifications and also the authorized limits (lower than technical specification limits) issued under GSR-125. It was observed from the past data that none of the units crossed these limits any time. Hence from ALARA considerations, and addition of new facilities at the same site, it became necessary to review and revise the limits and consequently the dose apportionment of existing plants. In line with these requirements, AERB has issued directives to revise the technical specification/authorized limits for discharge of radioactive effluents from these stations. These limits which are significantly lower than the existing discharge limits have been incorporated in the technical specifications for all the stations.

19.9 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The licensing process in India ensures that the initial authorisation for operation is given after a comprehensive review of the safety analysis and safety management system to ensure that the commissioning and operation of NPP is carried out in a safe and reliable manner. Operation of NPP is carried out within the operating limits and conditions specified in the Technical Specifications for Operations. In addition to the organisational set-up in accordance with the Technical specifications, an effective operating experience feedback mechanism has been set-up both at utility and AERB to ensure that both internal and external operating experience is reviewed and appropriate corrective actions as applicable are taken at Indian NPPs as well as the projects under construction. Therefore, India complies with the obligations of the Article 19 of the Convention.

Annex 19-1: AERB Safety Guides under Code of Practice on Operation

Safety Code / Guide No.	Title
AERB/NPP/SC/O : 2008	Nuclear Power Plant Operation
AERB/SG/O-1: 1999	Staffing, Recruitment, Training, Qualification and Certification of Operating Personnel of Nuclear Power Plants.
AERB/SG/O-2 : 2004	In-service Inspection of Nuclear Power Plants
AERB/SG/O-3 :1999	Operational Limits and Conditions for Nuclear Power Plants
AERB/SG/O-4 : 1998	Commissioning Procedures for Pressurised Heavy Water Reactor Based Nuclear Power Plants
AERB/SG/O-5 : 1998	Radiation Protection During Operation of Nuclear Power Plants
AERB/SG/O-6 : 2000	Preparedness of Operating Organisation for Handling Emergencies at Nuclear Power Plants
AERB/SG/O-7 :1998	Maintenance of Nuclear Power Plants
AERB/SG/O-8 : 1999	Surveillance of Items Important to Safety in Nuclear Power Plants
AERB/SG/O-9 : 1998	Management of Nuclear Power Plants for Safe Operation
AERB/SG/O-10A 1998	Core Management and Fuel Handling in operation of Pressurised Heavy Water Reactors
AERB/SG/O-10B : 1999	Core Management and Fuel Handling in operation of Boiling Water Reactors
AERB/SG/O-11 : 2004	Management of Radioactive Waste Arising from Operation of Pressurised Heavy Water Reactor Based Nuclear Power Plants
AERB/SG/O-12 : 2000	Renewal of Authorisation for Operation of Nuclear Power Plants
AERB/SG/O-13 : 2006	Operational Safety Experience Feedback on Nuclear Power Plants
AERB/NPP/SG/O-14: 2005	Life Management of Nuclear Power Plants
AERB/NPP/SG/O-15 : 2004	Proof and Leakage Rate Testing of Reactor Containments

Annex 19-2: Typical Organisation at NPP

NPCIL has established a well-defined functional organization for each station. A typical organization chart is annexed for reference. The functional responsibilities of various wings of the organization to conduct safe, orderly and efficient operation of the Station are described below.

STATION DIRECTOR (SD) is the Head of station management at site. He has the overall responsibility for the safe operation of the plant and implementation of all relevant policies, statutory requirements and radiation protection rules and other instructions and procedures laid down by the operating organization for plant management. He is also responsible for ensuring that the requirements of Regulatory Body are complied with. He is also responsible for training, qualification and licensing of operating personnel, in accordance with the approved laid down procedures.

The Station Director ensures compliance with that the technical specifications, which detail the operational limits and conditions. In addition to the overall responsibility for ensuring the safety of the Station and the public, his responsibilities also include:

- Prompt notification of deviations from established technical specification limits and conditions in accordance with procedures.
- Maintenance of quality assurance in all activities at the Station including in maintenance, testing, examination and inspection of structures, system and components.
- For ensuring that modifications to plant configuration are carried out only after due approval by AERB as per the laid down procedures.
- Assumes the role of site emergency director in case of an emergency.
- Liaison with HQ, AERB and other statutory bodies.

In discharge of his responsibilities, Station Director is assisted by a team of operations personnel, responsibilities of whom are described in detail in the Technical Specification and Station Policy documents for station operation. Some of these are summarized below:

CHIEF SUPERINTENDENT (CS) is responsible for coordinating the safe and orderly operation and maintenance of the station / systems in accordance with approved procedures. Operation, Maintenance, Technical Services and Quality Assurance Superintendents assist him in this regard.

TECHNICAL SERVICES SUPERINTENDENT (TSS) is responsible for:

(a) Engineering assistance required to efficiently operate the station/systems at optimum performance level.
(b) Performing engineering/technical studies and reviews.
(c) Issuing of work plans for specific jobs during operation and shutdowns.
(d) Reactor Physics and fuel management.
(e) Chemistry control of the systems.
(f) Upkeep and arranging updating of all technical documents including all design manuals and drawings.

OPERATION SUPERINTENDENT (OS) is responsible for:

(a) Safe operation of station / systems as per approved objectives, procedures, policies and within the limits and conditions laid down in the Technical Specifications.
(b) Bringing to notice of **S**tation **O**peration **R**eview **C**ommittee (SORC) members deviations / deficiencies in the operation of the systems.

(c) Ensuring that shifts are manned efficiently by providing adequate trained and licensed manpower.
(d) Bringing to the notice of SD/ CS/ TSS, promptly all deviations of Technical Specifications and all unusual occurrences with full information along with his comments and recommendations.
(e) Arrange to convene SORC meeting at least once in a month and also as and when necessary.
(f) Upkeep and updating of operating manuals.

MAINTENANCE SUPERINTENDENT (MS) is responsible for:

(a) Planned preventive / breakdown maintenance in respect of mechanical, electrical, control and fuel handling equipment / systems.
(b) Maintenance of adequate spares and consumables.
(c) Modifications to systems after approval by concerned authorities.
(d) Civil and Service maintenance.

TRAINING SUPERINTENDENT (TS) is responsible for coordinating arrangements for:

(a) Training of station staff in radiation protection, first aid and emergency procedures, industrial safety & fire protection.
(b) Training / Qualification / Re-qualification of operation staff.
(c) Training / Qualification / Re-qualification of maintenance staff.
(d) Training / Qualification / Re-qualification of fuel handling staff.

SUPERINTENDENT (QA) Heads the Quality Assurance group and is responsible for:

(a) Station Quality Assurance.
(b) Technical Audit.
(c) QA documentation.
(d) Monitoring the implementation status of recommendations of the Regulatory Body.
(e) Pre-Service & In-service inspections.

Radiological Safety Officer (RSO) is responsible for advising station management and staff on radiation protection. This includes advice on personnel exposure, radiation monitoring and surveys and for liaison with Waste Management Plant regarding discharges and management of radioactive wastes, equipment for radiation protection and emergency arrangements and environmental surveys within the boundary of the unit. He is responsible for making measurements and observations during normal operations as well as during abnormal occurrences in the area of radiation safety.

SHIFT CHARGE ENGINEER (SCE) is responsible for authorizing all operation and maintenance activities of the station on shift basis. He is delegated all powers given to the SD / CS to maintain reactor systems under safe condition during operation and shutdown of the reactor. He is responsible for safe start up, operation and shutdown of the reactor, turbo generator and auxiliaries. In the absence of SCE, Assistance Shift Charge Engineer (ASCE) discharges these responsibilities. Both SCE and ASCE hold licence granted by AERB for plant operation, including authorization for control panel operations.

REVIEW MECHANISM

TECHNICAL SERVICES SECTION at each station is entrusted with the responsibility of review of operational and safety performance of all the systems on a routine basis, identify areas for improvement and suggest necessary corrective actions. TSS, the head of the unit maintains liaison with unit safety committee and SARCOP. He also submits all safety related proposals for multi-tier review to SORC, NPC-SRC, unit safety committee and SARCOP for obtaining necessary approvals.

STATION OPERATION REVIEW COMMITTEE (SORC), headed by Station Director / Chief Superintended and having TSS, MS, OS, Superintendent QA and Radiological Safety Officer as members is formed at each station. The committee,

- Reviews the station operations at regular intervals to detect potential safety issues at the station and recommends corrective actions.
- Reviews all proposed special / emergency operation, maintenance and test procedures and recommends revisions thereto as necessary.
- Reviews reactor shut downs initiated by safety system and recommends action to prevent recurrence of unwarranted shutdowns, where applicable.
- Reviews all proposed changes, Engineering Change Notices including modifications to approved procedures for plant systems / equipments and recommends action. The review includes an evaluation of the effect of the proposed change on the relevant technical specifications.
- Reviews all proposed changes to technical specifications / Station Policies and gives recommendation.
- Investigates promptly, all safety related unusual occurrences and instances involving deviations of technical specifications, station policies (as applicable).
- Investigates loss, misplacement or unauthorized use of radiation sources.
- Investigates incidents involving radioactive material during transportation within the controlled area of the station.
- Investigates incidents involving disabling injury preventing the person from working for a period of 24 hours or more. (Injuries of lesser significance are reviewed by Head. Fire & Industrial Safety).

TECHNICAL AUDIT ENGINEER is responsible for auditing and monitoring the compliance with the operating procedures, administrative procedures, surveillance test schedules, SORC recommendations, in-service inspection and Engineering Change Notices of all safety related systems. He also monitors deviations of the technical specifications & station policy, and follows up implementation of the decisions given by SORC / Unit Safety Committee / SARCOP from time to time.

OVER EXPOSURE INVESTIGATION COMMITTEE is constituted at each station to review all cases of radiation exposure above the investigation level, identify root causes and recommend remedial measures to prevent re-occurrence. The functions of the committee are:

- To investigate genuineness of the reported value in case of external exposure and measured value in case of internal exposure.
- To investigate fully, the causes of the over exposure and to prepare a factual report.
- To suggest remedial measures to prevent recurrence of such overexposures.
- To suggest further action in respect of work to be allocated to such over exposed persons.

Investigation by the committee is carried out within specified timeframe and the report is forwarded to Unit Safety Committee / SARCOP.

NPC-SRC is the corporate level safety committee, with representation from design, safety, operation and quality assurance groups at NPCIL head quarter. All safety related proposals, including engineering changes, which require review and concurrence by regulatory body are first reviewed in NPC-SRC. The recommendations made by this committee are incorporated before the proposal is forwarded to unit safety committee / Safety Review Committee for operating plants (SARCOP) at AERB.

Organization Chart of a Typical Indian Nuclear Power Station