Government of India

NATIONAL REPORT

to

THE CONVENTION ON NUCLEAR SAFETY

Fourth Review Meeting of Contracting Parties, April 2008

September 2007

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FOREWORD

The Government of India ratified the Convention on Nuclear Safety on March 31, 2005. This is the first National Report being submitted 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". India continues to believe that this Convention on Nuclear Safety should cover all nuclear power plants, civil and military. Accordingly, all land-based nuclear power plants under the jurisdiction of the Government of India, including such storage, handling and treatment facilities for radioactive materials, as are on the same site and are directly related to the operation of nuclear power plants, as defined in Article 2 of the Convention, are covered in this national report.

The preparation of the National Report was coordinated by a Steering Committee wherein several officers of the Atomic Energy Regulatory Board and the Nuclear Power Corporation of India Limited participated.

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LIST OF ACRONYMS

ACCGD	Advisory Committee on Code, Guides & Associated Manuals for Safety in Design of NPPs
ACCGO	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 for Nuclear Safety
ACRDS	Advisory Committees are 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 Mineral Division
AOO	Anticipated Operational Occurrence
ARA	Application for Renewal of Authorisation
BARC	Bhabha Atomic Research Centre
BHAVINI	Bharatiya Nabhikiya Vidyut Nigam Limited
BRIT	Board of Radiation & Isotope Technology
BRNS	Board of Research for Nuclear Sciences
BWR	Boiling Water Reactor
CCW	Condenser Cooling Water

CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CESC	Civil Engineering Safety Committee
CSED	Civil & Structural Engineering Division
CMG	Crisis Management Group
CSO	Central Statistical Organisation
CSRP	Committee for Safety Research Projects
DAE	Department of Atomic Energy
DBGM	Design Basis Ground Motion
DBR	Design Basis Report
DGSNR	Directorate General of Nuclear Safety and Radiation Protection, France
DRD	Direct Reading Dosimeter
EBGM	Engineering Basis Ground Motion
ECCS	Emergency Core Cooling System
EOP	Emergency Operating Procedure
EPZ	Emergency Planning Zone
ESL	Environmental Survey Laboratory
FAC	Flow Accelerated Corrosion
FBR	Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FSAR	Final Safety Analysis Report
GDP	Gross Domestic Product
HBNI	Homi Bhabha National Institute
HPU	Health Physics Unit
HWB	Heavy Water Board
IAEA	International Atomic Energy Agency
ICRP	International Commission for 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

LBB	Leak Before Break
LCO	Limiting Conditions for Operation
LOCA	Loss of Coolant Accident
LSSS	Limiting settings for Safety Systems
MAPS	Madras Atomic Power Station
MoEF	Ministry of Environment and Forest
NDMA	National Disaster Management Authority
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
OPRD	Over Pressure Relief Device
OPSD	Operating Plants Safety Division
PCB	Pollution Control Board
PDSC	Project Design Safety Committee
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India Limited
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
RSD	Radiological Safety Division
SARCAR	Safety Review Committee for Application of Radiation
SARCOP	Safety Review Committee for Operating Plants
SBO	Station Black Out
SCR	Supplementary Control Room
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

INTRODUCTION

1. GENERAL INFORMATION

1.1 General Overview

India occupies a strategic position in Asia with a distinct geographical identity. Bounded by the Great Himalayas in the north, it stretches southwards and from Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and Arabian Sea on the west. India has seven major physiographic regions: Northern Mountains viz. the Himalayas; The Indo Gangetic Plain; Central Highlands; Peninsular Plateau; East Coast; West Coast; Bordering Seas; and Islands. A major part of the land surface is covered by a plateau landscape.

There are a number of rivers flowing in the country i.e. Himalayan rivers, Peninsular rivers, coastal rivers and rivers of Inland Basin. India gets its rains from the southwest monsoon during the months of June to September, and northeast monsoon during October to December. The rainfall varies in wide degrees in different parts of India. The tropic of cancer passes through the middle part of India. The climate may be broadly described as tropical monsoon type. There are four seasons i.e. (i) Winter (January-February); (ii) Hot weather summer (March-May); (iii) Rainy southwest monsoon (June-September) (iv) Post monsoon also known as northeast monsoon (October-December) in the southern peninsula.

India became an independent nation on the 15th August 1947. It became a Republic on 26th January 1950 and the Constitution of India came into force. India is a Sovereign, Socialist, Secular, Democratic republic with a parliamentary system of Government sustained by a well-developed electoral process. India is a federal polity with a Central Government, 28 State Governments, a National Capital Territory and 6 Union Territories. Ever since its independence, the country has achieved significant progress in various sectors such as agriculture, industry, power, science and technology including atomic energy, space and services.

According to 2001 census, India's population is 1027 million. The estimated annual growth of population from 1991 to 2001 is about 1.87 %

1.2 Economy

The GDP at factor cost in 2005-06 at current prices was about Rs. 32509 billion (722 billion US $). The advance estimates (AE) of gross domestic product (GDP) for 2006-07, released by the Central Statistical Organisation (CSO), places the growth of GDP at factor cost at constant (1999 -2000) prices in the current year at 9.2 per cent. Growth in 2005-06, initially estimated by the CSO at 8.1 per cent, was revised upwards to 9.0 per cent in the quick estimates released by the CSO on January 31, 2007.

1.3 Energy Scenario

The Per capita consumption of energy in India was 520 kg of oil equivalent (kgoe) per person in 2003. The energy resources are unevenly distributed in the country and are mainly used for power generation, transport and industrial, services, agriculture and domestic uses.

The overall energy resource base is:

India's Energy Resource Base

	Amount	Electricity Potential GWe-yr
Coal	53.3 -BT	10,660
Hydrocarbon	12 -BT	5,833
Uranium-Metal - In PHWR - In Fast Breeders	61,000 -T	 328 42,231
Thorium – Metals (In Breeder)	2,25,000 - T	155,502
Hydro	150 -GWe	69 GWe-yr/yr
Non-conv. Ren.	100 -GWe	33 GW-yr/yr

Uranium reserves in the country are estimated to be about 95,000 tonnes (metal) excluding reserves in speculative category. After accounting for various losses in mining, milling and fabrication the net uranium available for power generation is estimated to be about 61,000 tonnes (metal). One of the largest resources of thorium in the world is contained in monazite deposits (about 8 million tonnes) in India mainly along the Indian seacoast. Out of this about 4 million tonnes is considered exploitable of which 70% is considered mineable containing about 2,25,000 tonnes of thorium metal and hence the energy potential of thorium is very significant.

1.4 National Policy Towards Nuclear Activities

The integrated energy policy of the country recognizes that nuclear energy is capable of providing long-term energy security and is based upon judicious utilization of the nuclear resource profile of the country. The major source of electricity generation in the country at present is coal. The installed power generating capacity (Power Utilities) as of 31st March 2007 is about 132 GW (e) with about 66% contributed by fossil thermal power. The role of nuclear power is to supplement the base load generation from coal fired power plants at locations away from the coalmines and in the long term, to utilise the abundant thorium resources to generate electricity.

The national policy towards nuclear activities has been one of full support for all activities. The broad areas of nuclear activities are energy (nuclear power), societal and technology development and human resources development apart from basic research in nuclear sciences. The societal development encompasses food and agriculture (food preservation, development of superior mutant varieties of seed/crops), health (nuclear medicine for diagnostics and radiation therapy), water (nuclear desalination) and environment (sewage and waste management). The development of frontier technologies like nano technologies, microelectronics, robotics and remote handling tools, accelerators, superconductors etc has been taken up for industrial applications.

Safety is accorded overriding priority in all these activities. All nuclear facilities 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. The regulatory framework in the country is robust with the independent Atomic Energy Regulatory Board (AERB) having powers to frame policies; laying down safety standards & requirements and monitoring & enforcing all the safety provisions. AERB exercises the regulatory control through a stage wise system of licensing. As a result, India's safety record has been excellent in over 260 reactor years of operation of power reactors and various other applications.

1.5 Electricity Sector

As per the Constitution of India, electricity is a concurrent subject implying that both the Central Government and State Governments have the authority to legislate on the subject. The structure of the electricity sector derives its character and composition from the Indian constitution.

In 2003, the Electricity Act has been enacted. The act seeks to create a liberal framework of development for the power sector. The objectives of the Act are "to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies." Under the act Central Electricity Authority, Regulatory Commissions and Appellate Tribunal have been constituted to deal with all the related issues.

The Ministry of Power in the Government of India (GOI), is responsible for the administration of the above act and to undertake such amendments to the Act, as may be necessary from time to time, in conformity with the policy objectives of GOI. The Central Electricity Authority (CEA) is the central control authority and the Central Electricity Regulatory Commission (CERC) is the central commercial regulator. Each State also has its own Regulatory Commission.

Nuclear Power generation is governed by a separate legislation, the Atomic Energy Act, 1962. The Atomic Energy Act encompasses all the activities concerned with Atomic Energy including electricity generation. The tariffs and other commercial parameters of nuclear power stations are notified by the Department of Atomic Energy in consultation with the CEA. As per the prevailing Atomic Energy Act, only the Government or Government owned companies are permitted in the field of nuclear power generation.

The generation, transmission and distribution are largely in the public sector. Of the total 132 GWe installed capacity, 115 GWe (70 GWe in State sector and 45 GWe in Central sector) is in the public sector and 17 GWe in the private sector. There are a few industrial units with captive generating capacities supplying excess generation to the grid.

The generation through non-conventional renewable energy sources comes under the administrative control of the Ministry of New and Renewable Energy Sources, GOI.

The Power Finance Corporation (PFC) provides term finance to projects in the power sector. The PTC (Power Trading Corporation) is an entity established to serve as a single point of contact for entering into power purchase agreements with independent power producers on the one hand and the consumers or state utilities on the other.

India is divided into five Electricity Regions; namely, Northern, North- Eastern, Eastern, Western and Southern. For each region, a Regional Electricity Committee is constituted to provide guidelines for operation of the grid and to co-ordinate exchange of power between States and Regions. The Regional Electricity Committee also reviews progress of schemes and plans generation schedule.

The Power Grid Corporation of India Limited (PGCIL) has been established by the Central Government with the mandate to establish and operate Regional and National Power Grids to facilitate transfer of power within and across the Regions with reliability, security and economy on sound commercial principles. All transmission facilities originally under Central Sector organizations were transferred to PGCIL.

The installed capacity by fuel sources is as follows

Table 1: Region wise installed capacity (MW) as on 31.3.2007

Region	Hydro	Thermal				Nuclear	Renew.	Total
		Coal	Gas	Diesel	Total			
Northern	13,000.38	18,027.50	3,323.19	14.99	21,365.68	1,180.00	813.37	36,359.43
Western	6,918.83	22,441.50	5,820.72	17.48	28,279.70	1,840.00	1,874.76	38,913.29
Southern	11,011.71	16,172.50	3,586.30	939.32	20,698.12	880.00	4,971.55	37,561.38
Eastern	2,496.53	14,149.88	190.00	17.20	14,357.08	0.00	46.76	16,900.37
N.Eastern	1,221.07	330.00	771.50	142.74	1,244.24	0.00	48.91	2,514.22
Islands	5.25	0.00	0.00	70.02	70.02	0.00	5.25	80.52
All India	**34,653.77**	**71,121.38**	**13,691.71**	**1,201.75**	**86,014.84**	**3,900.00**	**7,760.60**	**132,329.21**

The nuclear generation in the year 2006-07was 18800 Million Units, constituting about 3% of the total generation in the country.

2. NATIONAL NUCLEAR POWER PROGRAMME

2.1 Historical Development and Nuclear Power Organisational Structure

2.1.1 Overview

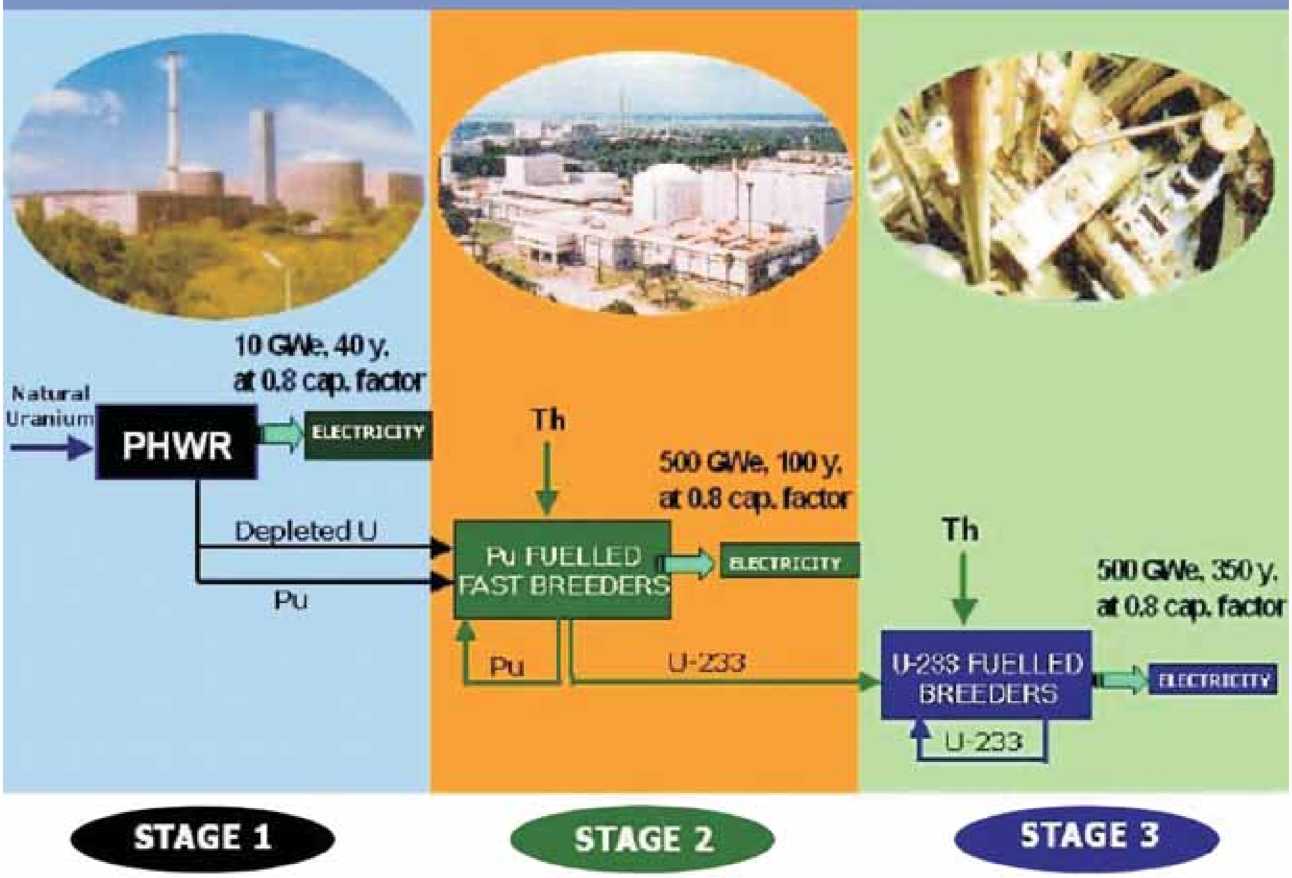
A major step in the formulation of the Atomic Energy Programme in India was the passing of the Atomic Energy Act in 1948 (subsequently replaced by the Atomic Energy Act of 1962).

Under the provisions of the Atomic Energy Act, the Atomic Energy Commission (AEC) was constituted in 1948. Uranium exploration and mining required for the nuclear power programme were some of the initial activities undertaken.

The Department of Atomic Energy (DAE) of the Government of India (GOI) was established in August 1954. The Department is responsible for execution of policies laid down by the AEC. It 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 engineering.

The key policy has been self-reliance. The importance of developing a strong research and development base for the nuclear power programme was recognized early on. Thus, a decision was made, in 1954, to set up a research and development centre, now called Bhabha Atomic Research Centre (BARC) at Trombay. Research reactors APSARA (1956), CIRUS (1960), and DHRUVA (1985) and some critical facilities were set up at the Centre. A number of additional facilities and laboratories were built at the Centre to support the nuclear power programme and

Figure1: Three Stages of Indian Nuclear Power Programme



related nuclear fuel cycle activities. The Centre extends the necessary R&D support to the nuclear power programme and associated fuel cycle activities. Over the years, BARC has developed into a frontline multidisciplinary research centre and a strong technical support organisation for nuclear power programme of the country.

In 1947 when India became independent, its installed electric power capacity was only about 1.5 GW (e), which has grown, as on March 31, 2007, to about 132 GW (e). Considering the population growth, low per capita electricity consumption and need for increasing the share of commercial energy sources, large-scale production of electric power was necessary. By the late 1950's, AEC had worked out the economics of generating electricity from atomic power reactors. Based on this study, the Government decided to set up a series of nuclear power plants at locations away from coalmines and nearer to load centres. The strategy adopted by the Indian nuclear power programme is to use the country's modest uranium and vast thorium resources. In line with this strategy, a three-stage programme, as shown in figure-1, is envisaged. The first stage is based on setting up of pressurized heavy water reactors (PHWRs) using indigenously available natural uranium producing electricity and plutonium and is in commercial domain. This will be followed by the second stage by plutonium fuelled fast breeder reactors (FBRs) producing electricity and additional quantity of plutonium and also uranium 233 from thorium. The third stage of reactors will be based on thorium-uranium233 cycle.

2.1.2 Organisational Structure

The Indian Atomic Energy Organisational Structure is shown in Figure 2. Development of nuclear power and related nuclear fuel cycle and research and development activities are carried out in various units under DAE. The organisation is divided into four major sectors, namely research and development sector, industrial sector, public sector undertakings and services and support sector. The DAE also provides for close interaction needed between the production and R&D units

i. The Atomic Energy Regulatory Board (AERB) is directly under the Atomic Energy Commission as the independent Regulatory Authority. It is totally independent of DAE.

ii. 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 Technologies (RRCAT), Variable Energy Cyclotron Centre (VECC), and fully aided research institutions like Tata Institute of Fundamental Research (TIFR), Institute for Plasma Research (IPR) and others. It also includes Board of Research in Nuclear Sciences (BRNS) and National Board for Higher Mathematics (NBHM) for providing extra-mural funding to universities and other national laboratories. Homi Bhabha National Institute (HBNI) is an institute having the status of a University and the academic programmes being run by research and development centres and grant-in-aid institutions, except TIFR, are affiliated to HBNI.

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

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

- Nuclear Power Corporation of India Limited (NPCIL) engaged in the design, construction, commissioning and operation of the nuclear power plants based on thermal reactors;
- Uranium Corporation of India Limited (UCIL) engaged in mining, milling and processing of uranium ore;
- Indian Rare Earths Limited (IRE) engaged in mining and mineral 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 (ECIL) engaged in design and manufacture of reactor control and instrumentation equipment related to atomic energy and also to other sectors;
- Bhartiya Nabhikiya Vidyut Nigam Limited (BHAVINI) for setting up fast reactor based nuclear power plants.

v. Directorate of Construction Services and Estate Management is responsible for construction and maintenance of residential housing/office buildings and other related facilities; Directorate of Purchase and Stores is responsible for centralised purchases and stores.

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 corporatised 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 give the required degree of operational freedom and to mobilise funds from the Indian capital market to finance new nuclear power projects. NPCIL is responsible for design, construction, commissioning and operation of the nuclear power plants of the first stage nuclear power programme.

Construction of the first 500 MWe Fast Breeder Reactor was started by the recently set up company, BHAVINI.

Design and development of the 300 MWe Advanced Heavy Water Reactor for demonstration of technology towards large-scale utilisation of thorium for electricity generation, is being carried out at BARC.

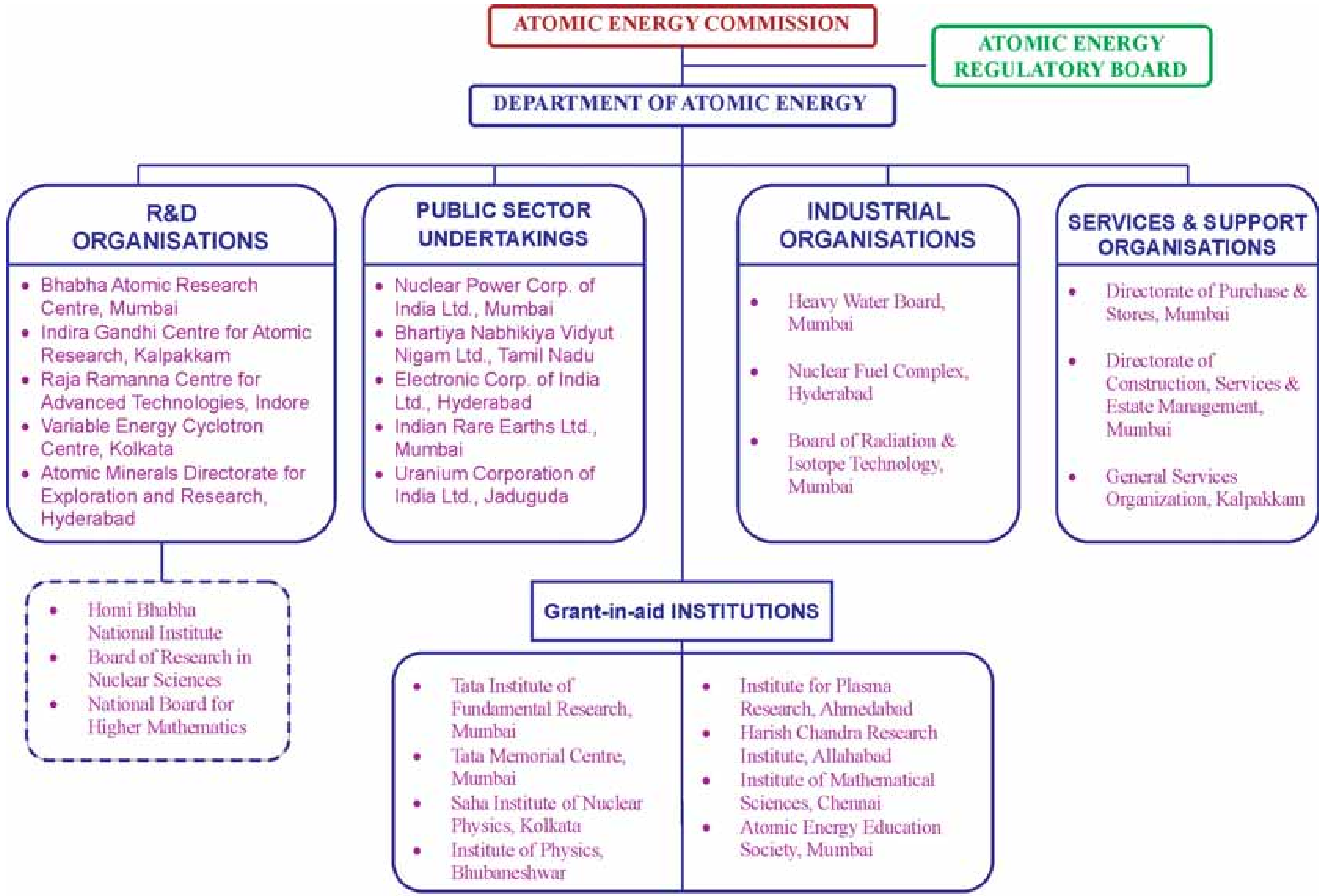


FIG.2. Organisational Structure

2.2 Evolution of Indian Nuclear Power Programme

The construction of India's first nuclear power station at Tarapur consisting of two boiling water reactors (BWRs) by General electric, USA on a turnkey basis, was commenced in the 1960s. This was essentially to establish the technical and economic viability of nuclear power in India and to gain valuable experience nuclear power plant operation. In parallel, the work on construction of PHWRs was also commenced at RAPS 1&2 with technical cooperation of AECL (Canada). Subsequently, in 1980s two 220 MWe PHWRs (MAPS-1&2) were constructed near Madras with indigenous efforts.

After gaining experience in setting up of RAPS and MAPS, a standardised design of 220 MWe reactor was developed. This incorporated major design modifications in terms of two independent fast acting shut down systems, high pressure emergency core cooling system, integral calandria & end shields, water filled calandria vault, elimination of dumping and provision of double containment with modified vapour separation pool. Four such reactors, two each at Narora, Uttar Pradesh and Kakrapar, Gujarat were set up. Four more 220 MW PHWRs, with some more modifications such as locating the steam generators fully inside the primary containment, complete pre stressed concrete construction for primary containment and a compact site layout were set up at Kaiga and Rawatbhata subsequently. These reactors (Kaiga-1&2 and RAPS-3&4) commenced operation in the year 2000. In addition, four similar PHWRs (Kaiga-3&4 and RAPS-5&6) of standard 220 MW design were taken up for construction at same sites in 2002. The first among these, Kaiga-3 has become operational in April 2007and the other three are planned for completion sequentially by end of 2007 or beginning of 2008.

RAPP-5&6 Project

Thus apart from the first two BWR units at Tarapur which are in operation since 1969, twelve PHWR 220 MWe units with two units at each of the four locations Kalpakkam (MAPS), Narora (NAPS), Kakrapar (KAPS) and Kaiga (KGS), and four units at Rawatbhata (RAPS-1&2 and RAPS-3&4) are now in operation.

In parallel, design and development of larger size 500 MWe PHWR unit was taken up in 1990s. The experience of design, construction and operation of 220 MWe units provided significant inputs in the design, which was later, scaled up to 540 MWe capacity. The construction of two 540 MWe units at Tarapur was commenced in the year 2000 and the units became operational 2005 and 2006 respectively.

Presently a 700 MWe PHWR design with limited boiling in the coolant channels has been developed. Two units of this design are planned at Kakrapar in Gujarat.

In order to achieve faster capacity addition, construction work for setting up of 2 × 1000 MW (e) Russian VVERs based NPPs at Kudankulam was taken up in co-operation with Russian Federation. Several advanced safety features have been provided in these reactors. These units are likely to be operational by end of 2008.

Kudankulam -1&2 Project

The work on the second stage of the nuclear power programme is in progress at the Indira Gandhi Centre for Atomic Research (IGCAR). The Fast Breeder Test Reactor (FBTR) 40 MW (th) at Kalpakkam is in operation since 1986. Its unique carbide fuel has achieved a burn-up of 125,000 MWD/Tonne. The technology development for the first 500 MWe fast breeder reactor (FBR) has been completed. The project has been launched with first pour of concrete in October 2004 and is presently under construction.

Towards building up thorium-based reactors, the strides taken by DAE include setting up of 30 kW (th) neutron source reactor KAMINI at Kalpakkam. The reactor has been in operation since 1997. Kamini uses uranium^{233}-based fuel derived from irradiated thorium. BARC has developed the design for the Advanced Heavy Water Reactor (AHWR) of 300 MW(e) capacity. This is a vertical pressure tube reactor utilising heavy water moderator, boiling light water coolant, thorium-plutonium based fuel and incorporates several passive safety systems. It derives about two-third of its power from thorium and DAE/BARC expects to launch its construction in near future after obtaining approval from AERB. The pre-lecensing design review of AHWR has been completed recently by AERB. This reactor will be a technology demonstration project for utilising thorium for electricity generation.

2.3 Safety Management

Utmost attention is given to safety in every stage of realisation of nuclear power plants to ensure safety of operating personnel, public as well as the environment. The principle of safety being the overriding priority encompasses the entire gamut of activities associated with nuclear power plants (NPPs), that is, siting, design, construction, commissioning, operation and decommissioning.

A systematic approach using well-defined principles is followed in the design of the nuclear power plants to provide the required safety features adopting principles of defence-in-depth, diversity and redundancy. Nuclear Power Plants are constructed in accordance with the design intent, and with required quality of workmanship to ensure highest 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 the operation of the plant. Operation of the plant is carried out as per defined and approved procedures defining the operational limits and conditions for various system parameters, in the technical specifications for operation that are thoroughly reviewed and approved by AERB. Further AERB, through formal clearances authorises actions stipulating specific conditions at various stages of the plant. These include site approval, review and approval of design of systems important to safety and authorisations for construction, commissioning and operation and safety review during operational phase. The regulatory framework in India is indeed robust. All these measures are for ensuring safe operation of the plants, safety of occupational workers, members of public and protection of environment.

All nuclear power plant sites in India are self sufficient in the management of radioactive waste 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 based on internationally accepted principles.

2.4 National programme for nuclear fuel cycle

India’s three-stage nuclear power programme is based on a closed fuel cycle. The advantages of the approach are maximum utilisation of the energy potential of fuel and minimisation of high level wastes.

Comprehensive fuel cycle facilities – front end and back-end have been developed and are in operation. Front end facilities including mining of ore, milling and processing and fuel fabrication are taken up by UCIL and NFC, as brought out earlier. The back end facilities for reprocessing of spent fuel and extraction of Plutonium to fuel the second stage reactors and the associated fuel fabrication facilities have been developed and are in operation.

Vitrification technology has been developed for capturing the high level wastes produced during reprocessing in a glass matrix, to be stored in vaults before final disposal in a geological repository. Vitrification plants and vaults for storage of vitrified waste packages are in operation.

2.5 Role of Nuclear power in national industrial infrastructure

In the beginning of the nuclear power programme, the Indian industry needed up-gradation to manufacture/undertake precision jobs to exacting quality standards of the nuclear industry. However, the Indian engineering industry has since developed significantly and today almost all the materials, components and equipment required for nuclear power plants are manufactured indigenously.

India has heavy engineering plants in both public and private sectors, manufacturing large steam generators, turbines, electrical equipment, heat exchangers, pumps, pressure vessels and other industrial equipment. The Indian Nuclear Power Programme has utilised these facilities for manufacture of nuclear and conventional equipment and undertaking large mega-package contracts. 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.

2.6 Human Resources Development

Realising the importance of having adequate number of well trained scientists and engineers in achieving success in the programme, a training school at BARC was established in 1957. Subsequently when the training needs for the operating nuclear power stations arose, the Nuclear Training Centres (NTC) were set up by the Nuclear Power Corporation of India Limited (NPCIL). To meet the expanding needs of Human Resources, Training Schools have also been set up at the Centre for Advanced Technology, Indore (2000), Nuclear Fuel Complex, Hyderabad (2001) and IGCAR, Kalpakkam (2006). These NTCs and training schools are affiliated to the BARC Training School with respect to training of engineers and scientists. To date, nearly, 7500 engineers and scientists have been trained in these training schools.

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.

As a part of operator training, training on simulators for key operation personnel has been introduced. Simulators have been established for each type of reactor at various sites for effective training.

Engineers and scientists from the nuclear industry also participate in several international meetings and training programmes conducted by the International Atomic Energy Agency (IAEA) and other organisations to further enrich their capabilities.

3. CONCLUSION

As a result of long-range planning, extensive research and development infrastructure has been created in the country. This has helped industry to undertake activities involving high technology such as design, construction and operation of nuclear power plants and all the associated facilities. Establishment of legislative and regulatory framework which demands priority to safety in all the activities undertaken in the areas involving radiation and atomic energy has ensured safety of these facilities at all stages.

Annex I-1: Reactors in Operation

Station/ Unit	Type	Gross Capacity (MWe)	Net Capacity (MWe)	Operator & Owner	Reactor Supplier	Construction Start (FPC)	Criticality Date	Grid Connection	Commercial Operation
KGS-1	PHWR	220	202			01-Sep-89	26-Sep-00	12-Oct-00	16-Nov-00
KGS-2	PHWR	220	202			01-Dec-89	24-Sep-99	02-Dec-99	16-Mar-00
KGS-3	PHWR	220	202			30-Mar-02	26-Feb-07	11-Apr-07	6-May-07
KAPS-1	PHWR	220	202			01-Dec-84	03-Sep-92	24-Nov-92	06-May-93
KAPS-2	PHWR	220	202	NPCIL	NPCIL	01-Apr-85	08-Jan-95	04-Mar-95	01-Sep-95
MAPS-1	PHWR	220	202			01-Jan-71	02-Jul-83	23-Jul-83	27-Jan-84
MAPS-2	PHWR	220	202			01-Oct-72	12-Aug-85	20-Sep-85	21-Mar-86
NAPS-1	PHWR	220	202			01-Dec-75	12-Mar-89	29-Jul-89	01-Jan-91
NAPS-2	PHWR	220	202			01-Nov-77	24-Oct-91	05-Jan-92	01-Jul-92
RAPS-1	PHWR	100	90	NPCIL/DAE	AECL, CANADA	01-Aug-65	11-Aug-72	30-Nov-72	16-Dec-73
RAPS-2	PHWR	200	187		AECL/ DAE	01-Apr-68	08-Oct-80	01-Nov-80	01-Apr-81
RAPS-3	PHWR	220	202		NPCIL	01-Feb-90	24-Dec-99	10-Mar-00	01-Jun-00
RAPS-4	PHWR	220	202			01-Oct-90	03-Nov-00	17-Nov-00	23-Dec-00
TAPS-1	BWR	160	150	NPCIL	GE, USA	01-Oct-64	01-Feb-69	01-Apr-69	28-Oct-69
TAPS-2	BWR	160	150			01-Oct-64	28-Feb-69	05-May-69	28-Oct-69
TAPS-3	PHWR	540	490		NPCIL	08-Mar-00	21-May-06	15-Jun-06	18-Aug-06
TAPS-4	PHWR	540	490			12-May-00	06-Mar-05	04-Jun-05	12-Sep-05

Annex I-2: Reactors under Construction

REACTORS UNDER CONSTRUCTION							
Station/ Project	**Type**	**Gross Capacity (MWe)**	**Net Capacity (MWe)**	**Operator & Owner**	**Reactor Supplier**	**Construction Start (FPC)**	**Scheduled Commercial Operation**
KGS-4	PHWR	220	202	NPCIL	NPCIL	10-May-02	2007
KUDANKULAM-1	PWR	1000	905		ASE, RUSSIA	31-Mar-02	2009
KUDANKULAM-2	PWR	1000	905			31-Mar-02	2009
RAPS-5	PHWR	220	202		NPCIL	18-Sept-02	2007
RAPS-6	PHWR	220	202			23-Jan-03	2008
PFBR	FBR	500	470	BHAVINI	BHAVINI	23-Oct 2004	2011

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.

6.1 GENERAL

At present seventeen nuclear power reactors are being operated in India. Nuclear Power was ushered in India in 1969 with commissioning of Tarapur Atomic Power Station (TAPS), comprising two boiling water reactors as a turnkey project by General Electric Company (GE) USA. Subsequently, as per policy decision of Government of India, several Pressurized Heavy Water Reactor (PHWR) based Nuclear Power Plants (NPPs) were set up starting with Rajasthan Atomic Power Station (RAPS unit-1&2). Since the inception of the programme in the country, priority has been given to the adoption and maintenance of high safety standards. As early as in the 1960s, the Department of Atomic Energy (DAE) had set up a Safety Committee to advise on matters of safety and give clearances for criticality & operation for India's first NPP at TAPS-1&2 after exhaustive safety review. Similarly, a Safety Review Committee for RAPS was formed in 1969 for review of RAPS-1, the first PHWR (CANDU Type) built in the country in collaboration with AECL, Canada.

The benefit of the above experience led to the establishment of an Independent Safety Review Committee (DAE-SRC*)* in 1972, to advise the DAE on safety matters related to commissioning and operation of Unit-1 of RAPS. In 1975, this committee was further empowered to oversee the safety in all the constituent units of DAE. With the constitution of Atomic Energy Regulatory Board (AERB) in 1983, various regulatory functions envisaged in Sections 16, 17 & 23 of Atomic Energy Act, 1962 were brought under one umbrella. To ensure greater independence in review, assessment and regulatory decision-making, the reporting obligation of AERB is vested with the high-powered Atomic Energy Commission (AEC), a policy-making body advising the Government of India on matters related to Atomic Energy.

In the beginning, the design, construction and operation of the NPPs were carried out as a departmental activity of DAE. In the year 1967, Power Projects Engineering Division (PPED) was created within the DAE and was entrusted with this responsibility. This was converted into Nuclear Power Board (NPB) in 1984, with increased delegation of powers. In 1987, NPB was converted into the Nuclear Power Corporation of India Limited (NPCIL), as a public sector enterprise wholly owned by Government of India, under the administrative control of the DAE. It was registered as a public limited company under the companies Act 1956, with the objective of undertaking the design, construction and operation & maintenance of nuclear power stations for generation of electricity in pursuance of the schemes and programmes of the Government of India under the provisions of Atomic Energy Act, 1962. The mission of NPCIL is to produce electricity and develop nuclear power technology, as a safe, environmentally benign and economically viable source of electrical energy to meet the increasing energy needs of the country.

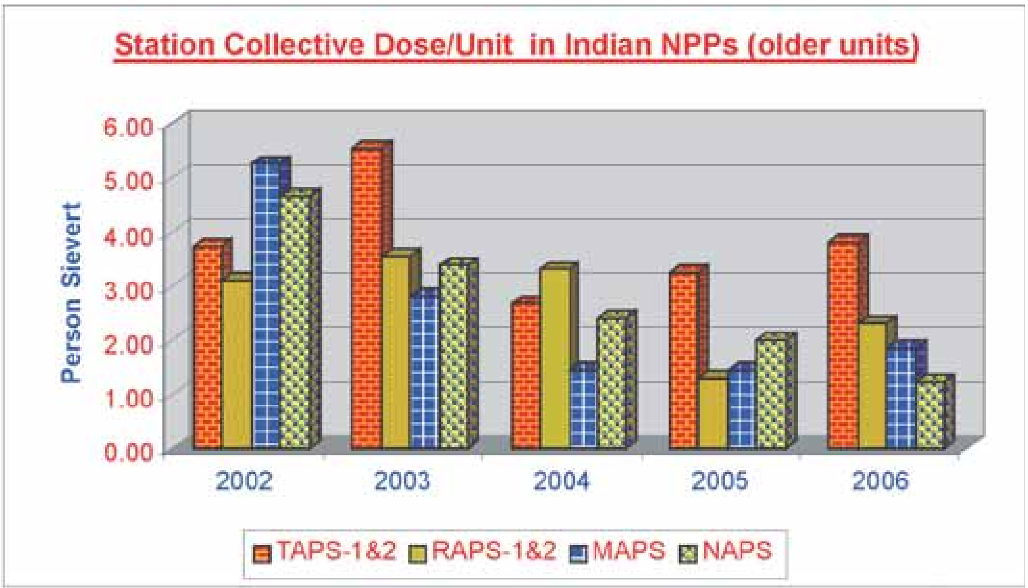
The mechanism for review and assessment of safety has evolved over the years. The concept of third party review and subsequently, that of a formal regulatory review have always been associated with design evolution, construction, commissioning and operation of NPPs. These mechanisms have resulted in 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, aspects related to training and safety culture are further improved. For effecting any changes in the design and procedures important to safety during operation, an elaborate review and approval system has been put in place and this has improved progressively with experience. The inputs from operational experience are utilised for design improvements in the new reactors.

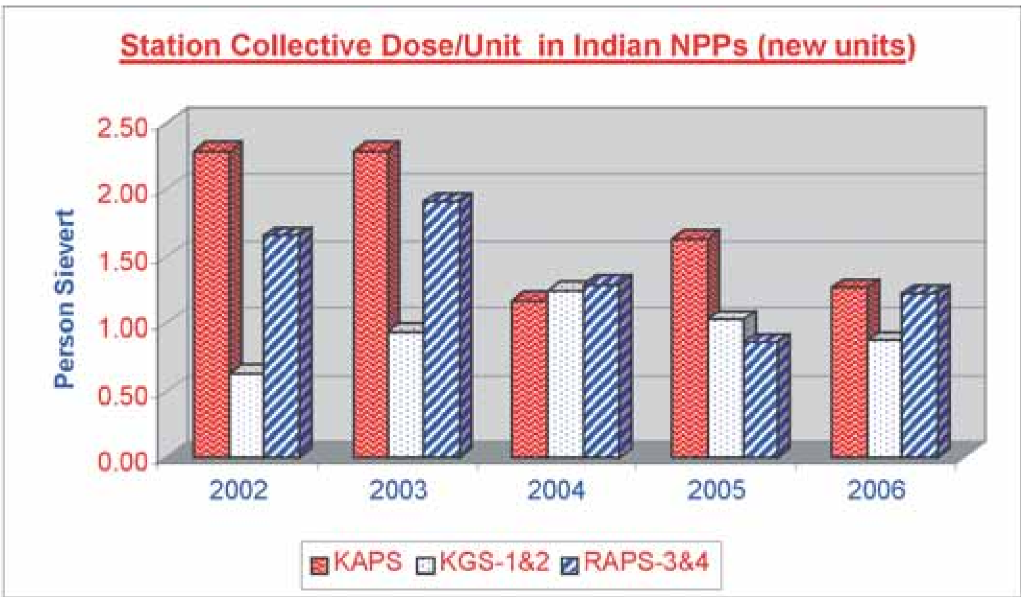
The radiological exposures of all the radiation workers are scrupulously monitored and records are maintained. In line with ICRP recommendation, AERB has prescribed the limit of 20 mSv for a radiation worker averaged over five consecutive years, calculated on a sliding scale of five years (The cumulative effective dose in any consecutive five-year period shall not exceed 100 mSv) and a maximum of 30 mSv in any year. As a precautionary measure, the limit for contract workers has been kept at 15 mSv in a year. To achieve these targets, the nuclear power stations have introduced interim limits for individual dose on a daily, monthly and quarterly basis. An AERB committee carries out an investigation if the annual exposure of any worker exceeds the prescribed limit.

Since the year 1990, AERB has introduced a system under which each station is required to plan and prepare a budget for collective exposure and get it approved by AERB at the beginning of the year. If the collective exposure during the year exceeds the approved budget, the station has to provide adequate justification. Efforts have also been made by way of design modification, procedural improvements, planning, discipline, job briefing, mock up, etc to control the collective dose for the station.

The efforts as above have succeeded in bringing down the annual collective exposures over the years as can be seen from the charts for earlier and later versions of Indian NPPs.

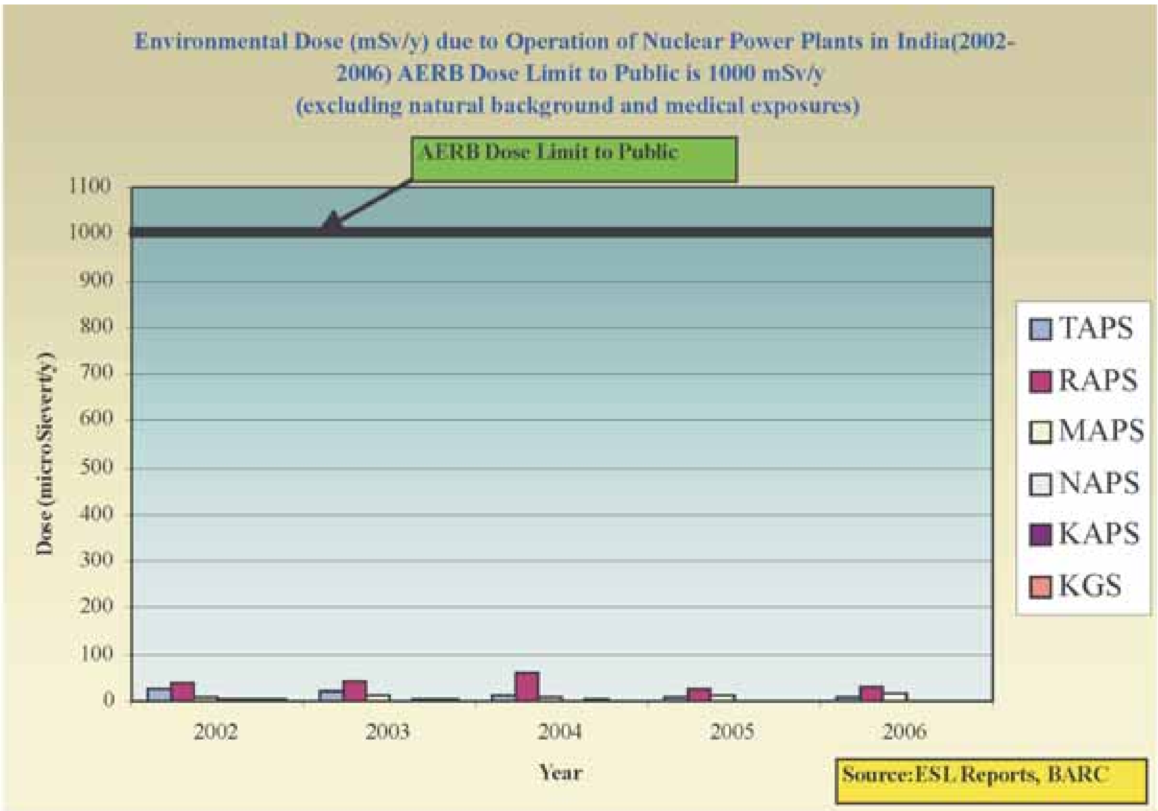
All Indian NPP sites have an extensive programme in place for monitoring environmental impact. For this purpose, BARC establishes an Environmental Survey Laboratory (ESL) at each new site well before commencement of operation of a NPP to facilitate base line data. The aim





of environmental monitoring and surveillance programme is to assess the radiological impact of NPP operation and to demonstrate 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 NPP have been a very small fraction of the AERB dose limit of 1000µSv/Yr, as depicted in the chart.

Right from the inception of the nuclear power programme in the country, BARC provides the entire radiological support at all NPPs. This includes the Health Physics Units (HPUs) and Environmental Survey Laboratories (ESLs), which are independent of NPP management. BARC continues to provide the research and development support to the programme in all its stages viz. siting, design, construction, commissioning, operation and decommissioning. The independent assessments made by BARC experts form a very important input for the regulatory body.



With sound design, trained and experienced operating staff and safety conscious approach to operation, the possibility of any accident is remote. However, to meet any unlikely situation of an accident, well thought out formal emergency preparedness plans are in place. 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.

As part of operating safety experience feedback system, comprehensive safety assessments are also carried out in response to major incidents and operating experience obtained within the country or from abroad. Some of the major reviews that have taken place over the years have been detailed at section 6.3 to illustrate the importance given to safety, ever since the beginning of the nuclear power programme in the country.

6.2 EXISTING NUCLEAR INSTALLATIONS

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

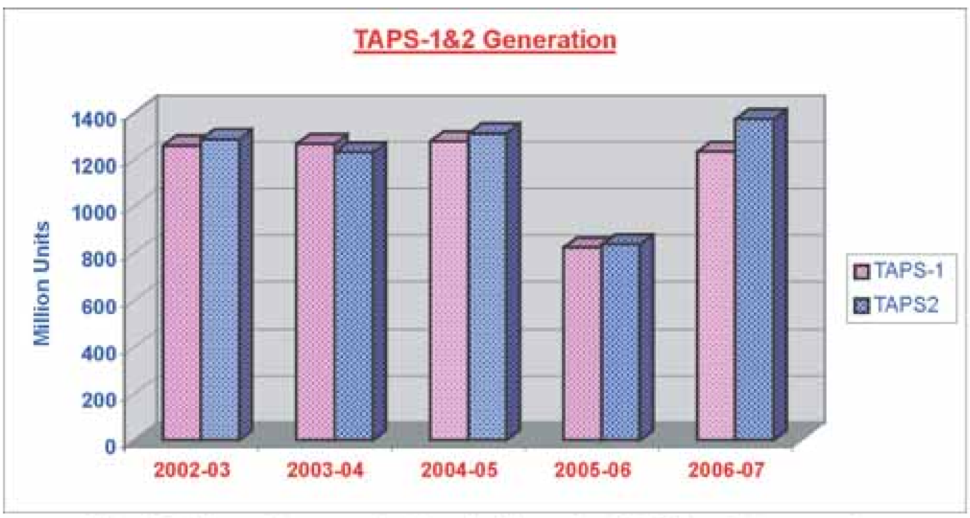
A comprehensive periodic safety review of operational and safety performance of NPPs which includes factors like changes in safety standards, ageing, new information, etc, are carried out at the time of renewal of authorisation or major refurbishment or for plant life extension. Such reviews bring out requirements for major modification and safety up-gradation particularly in older plants, which were built to earlier safety standards.

All the older 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 have been brought out.

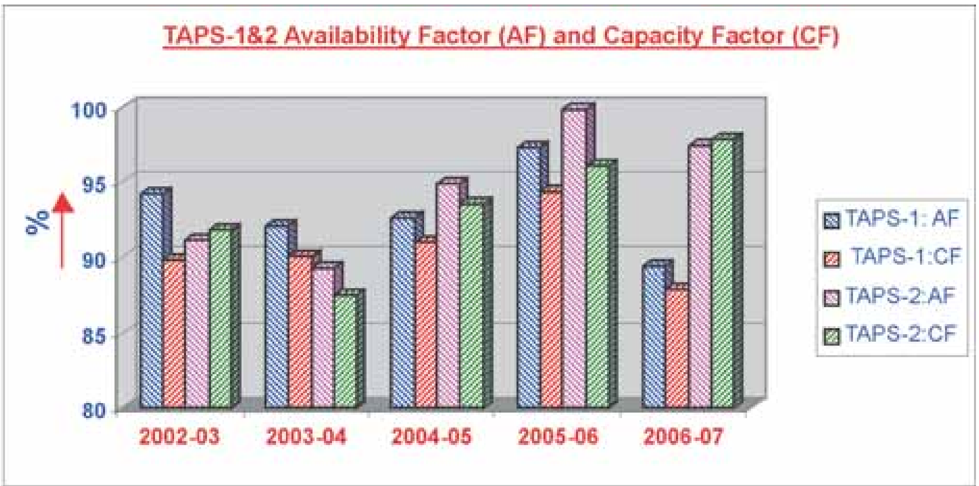
The list of operating NPPs is given in Annex 6-1.

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

TAPS-1&2, the first nuclear power plant in India started operation in the year 1969. This is a two unit BWR based NPP, supplied by GE of USA. Since 1984, the reactors are being operated at 160 MWe, as against the original rating of 210 MWe, owing to problems in the secondary steam generators and their subsequent isolation. The performance of the units has remained steady over the years as can be seen from some of the performance indicators shown below.



Note: Both the units were shutdown in November 2005 for safety upgrades.



Some of the safety related improvements carried out on the units are described in the following paragraph.

Inspection of TAPS Core Shroud

In view of cracks reported in the core shrouds of overseas BWRs and potential risks associated with cracked shroud, their inspection was initiated from 1994/95 onwards in stages, in both the units of TAPS during their respective refuelling outages.

All the accessible welds and the reactor internal structures / components pertaining to core shrouds were identified for inspection. The requirement for inspection of all the accessible weld joints and the reactor internals pertaining to core shrouds has been included in the station ISI manual and as per the specified frequency they are inspected during refuelling outage. As per the inspections carried out so far, all the accessible welds have been found to be in good condition.

Since all the welds were not accessible for inspection, structural integrity analysis for core shroud of TAPS was also carried out with assumed 360º through wall crack/part circumference crack. This indicated that

a) The shroud structural integrity is maintained under conditions of normal operation.

b) Under postulated main steam line break, re-circulation line break and seismic events, the core shroud deflection / displacements are within the permissible limits. Hence, insertion of control rods will not be impaired, core spray lines would be available for cooling and also the liquid poison injection system will remain available.

Comprehensive Safety Review for Continued Operation of TAPS

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, covering the following aspects:

a. Review of design basis of plant systems and Safety analysis, vis-à-vis the current requirements.

b. Seismic Re-evaluation.

c. Review of Ageing Management and residual life of Systems, Structures and Components (SSCs).

d. Review of operational performance.

e. 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) fresh analysis performed and (c) adequacy of coverage.

The new analysis indicated that the existing low pressure emergency core cooling system along with the auto blow-down system are sufficient to keep the fuel sheath temperatures within acceptable levels, under the whole spectrum of postulated LOCA events.

In the review of ageing management, detailed assessment was carried out, addressing present status of the SSCs identified for coverage under ageing management programme, their identified modes of degradation, monitoring methods, etc. The studies also included available margins taking into account results of revised safety analysis, comparison of the current Codal design requirements with the earlier requirements followed for TAPS units. Based on these assessments, action plans for ensuring continued service worthiness of SSCs were established. Wherever the current monitoring methods were found to be inadequate, additional requirements were identified.

For identifying the additional ageing management actions, the SSCs were categorized as per the standard practice, as non-replaceable, replaceable with re-engineering and replaceable. In case of TAPS, which had seen significantly long period of operation, the maximum focus was on addressing the ageing concerns of non-replaceable SSCs, as these would govern the plant life. The review also indicated that the ageing management of replaceable components was being handled satisfactorily. Wherever problems of obsolescence were encountered, steps were taken in time for the development of vendors for alternate equipments and their necessary qualification.

Level-1 PSA for TAPS units with internal events was carried out to develop insight into the existing design weaknesses and impact of proposed design changes. Results of the PSA were used to support the decisions regarding design modifications and upgrades.

For seismic re-evaluation, the design basis ground motion (DBGM) of TAPP 3&4, a newly built PHWR based NPP of 540 MWe capacity at the same site, was used for TAPS 1&2. The DBGM based artificial time history was used for time history analysis of reactor building, service building, turbine building pump house and stack, to generate the floor response spectra. Seismic re-evaluation of structures, systems and equipment were based on these floor response spectra.

The seismic re-evaluation covered the following safety systems and safety support systems.

i) Systems required for shutdown of the plant; control rod drive system.

ii) One chain of decay heat removal including

  (a) Reactor Pressure Vessel

  (b) Reactor re-circulation line

  (c) Emergency Condenser

  (d) Shutdown Cooling System

  (e) Reactor Building Cooling Water System

  (f) Salt Service Water System

iii) Containment, covering the dry well and containment box-up system.

iv) Emergency power supplies including Diesel Generators, Motor Generator sets and battery banks.

v) All control and instrumentation related to the above systems.

The structures, systems and equipment of safety systems and safety related systems have been qualified by seismic margin assessment method, taking into account the ductility and damping factors, as given in IAEA Safety Reports Series No. 28 on “Seismic Evaluation of Existing Nuclear Power Plants”. Systems other than safety and safety support systems were qualified by “Seismic walk-down” by experts, as per the guidelines given in IAEA Safety Reports Series No. 28.

Safety system Upgrades and Modifications

Based on above studies and assessments, several modifications 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, aspects of supplementary control centres/points, strengthening of supporting arrangements at some places for seismic considerations, upgradation of fire protection system, etc were identified. However, the major modifications/backfits were in emergency power supply system, shutdown cooling system and for provision of supplementary control room, which are summarised below.

- Electrical System

  Redundancy in the emergency power supply system was enhanced by replacing existing 3 x 350 KW (50%) DGs with 3 x 800 KW (100%) capacity DGs. The new DGs are housed in dedicated rooms and separated by three-hour fire rated walls. Power and control cables for each DG were segregated as per IEEE 384. All three DGs start automatically under loss of station power and energise the respective emergency bus. Normally, the individual DG and its associated bus operate in isolation. However, automatic logic has been employed for tying of the emergency buses under condition such as failure/non-availability of any DG. PLC based automatic logic system is employed to pick-up the loads under various conditions.

Safety related and non-safety related buses in 415 V AC systems were segregated and made unit-wise. A physical barrier with three hours of fire rating was constructed in cable spreading room to divide the 415 V buses in two separate physical zones. While one zone caters to Unit-1, the other caters to Unit-2.

Cables (control as well as power) were properly separated as per requirement of IEEE 384. Where proper separation clearances are not available, metal enclosed barriers were provided.

The existing scheme of tie formation of the emergency buses was dispensed with and the new scheme was introduced where the buses operate in isolated configuration. The 250 V DC control power supply for the 415 V AC emergency buses were also segregated.

The 120 V AC instrumentation power supply buses in Class II and Class III were also physically separated and one additional 120 V AC Class II power supply bus for each unit was provided for redundancy. 250 V and 48 V DC distribution panels were also segregated and made unit wise.

- Supplementary Control Room

  The Supplementary Control Room (SCR) was retrofitted as part of upgradations for long-term operation of the units. SCR and the identified supplementary control points in different areas together provide the necessary functionality to bring the reactors to safe shutdown state, maintain core cooling and monitor the essential reactor safety parameters, in case the main control room becomes uninhabitable. The SCRs, one for each unit, is located in the present instrument rooms of the respective unit, in the reactor building.

- Shutdown Cooling

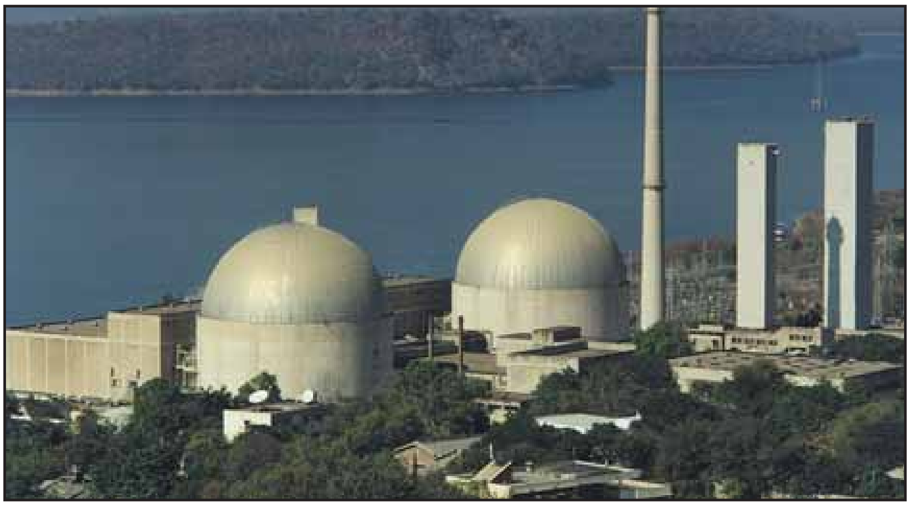
  The existing shared shutdown cooling system was upgraded to make it independent for each unit by installing additional pump and heat exchangers. The fuel pool cooling system has also been made independent of shutdown cooling system.

As per an action plan, approved by AERB, the above modifications were implemented at TAPS, in a long shutdown of both the units during November-2005 to January 2006. Several other modifications and safety upgrades were implemented during the normal refuelling outages of individual units prior to November 2005.

After successful completion of all the identified activities, the units were restarted in February-2006 after obtaining AERB authorisation for operation of the units for next five years.

Further operation of the units will be subject to periodic reviews and assessments as per the AERB reauthorisation procedure.

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



The construction of RAPS-1&2 started at Rawatbhata in Rajasthan during sixties as a collaborative venture with Canada. The station is situated on the bank of the "Rana Pratap Sagar" lake, formed between two dams – the Gandhi Sagar Dam upstream and the Rana Pratap Sagar Dam downstream on the Chambal River. Each unit is 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.

Both RAPS-1 and RAPS-2 were designed for a capacity of 220 MWe each. They were designed as a two-unit station with certain civil structures like turbine building, service building and main control room being common for both the units. The units share the common services like firewater, compressed air, demineralised water etc. RAPS-1&2 are horizontal pressure tube type reactors. There are 306 coolant channel assemblies, consisting of pressure tubes, end fittings and other components. The coolant channel assemblies are supported at the two ends by end shields and pass through a horizontal cylindrical vessel called calandria. Cold and low-pressure heavy water moderator is kept in the calandria vessel. Uranium dioxide fuel bundles are kept in the pressure tubes. The hot and pressurised heavy water is circulated through the pressure tubes to remove heat from the fuel and to transfer it to light water secondary cycle in the steam generators. Reactor power is controlled by a combination of adjuster rods movement and moderator level. The shutdown is achieved by dumping the moderator from the calandria vessel. The reactor is enclosed in a single RCC containment and is provided with an overhead dousing tank containing about 1800 cubic meter of water to limit the peak pressure in the containment in the event of design basis accident.

RAPS-1 has had a chequered history of operation since its commissioning in 1973. Initial teething problems were followed by long outages due to turbine blade failures. South end shield failure in 1980 resulted in a long outage and stable operation could be resumed only in 1989. The unit was shutdown during 1994 to 1997 for repair of calandria over pressure relief device (OPRD). The north end shield developed a leak in October 2000 and the unit remained under shutdown up to July 2001 for necessary repairs. The unit had to be shutdown from 30-04-2002 for coolant channel health assessment and safety upgrades as directed by AERB. Health assessment of all coolant channels was carried out. Certain safety upgrades like installation of supplementary control room, flood diesel generator, high-pressure emergency core cooling system and replacement of a number of heavy water heat exchangers were carried out.

However, unit operation after restart in Feb.2004 was not satisfactory. There were random failures in pipe welds and other equipments, high heavy water escapes and losses and high collective dose consumption during the following nine months of unit operation. The unit was shutdown on 09-10-2004 after multiple light water leaks were detected from boiler blow down lines. It was decided to carry out a comprehensive review of all aspects of RAPS-1 for its operation. NPCIL has carried out an exhaustive review of the performance of RAPS-1 including techno-economic viability and requirement for further operation. The course of action regarding further operation of the unit is under review with the Government. Presently, the unit is under shutdown state and as directed by AERB, all the plant systems are being maintained in accordance with the requirements of Technical Specifications and Station Policies, including the surveillance, monitoring and the inspection requirements.

The performance of RAPS-2 has been satisfactory over the years since its commissioning. As the pressure tube material employed in this reactor was Zircaloy-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 channel replacement (EMCCR) when it completed 8.5 FPYs of operation in 1994. The material of the tube was changed to zirconium alloy having 2.5% niobium by weight (Zr2.5%Nb) and was provided with four tight fit garter springs between the pressure tubes and calandria tubes.

This long shutdown for EMCCR was also utilized for an extensive review including operational performance. Based on these reviews, several safety upgrades and design modifications were incorporated after obtaining the necessary regulatory clearances. Some of the major modifications carried out are listed below.

* RAPS Containment Dousing System

  The original containment dousing system at RAPS incorporated a flow-modulating feature whereby dousing flow varies in proportion to the velocity of steam-air mixture flowing in the vicinity of the dousing curtain. This velocity in turn is expected to depend on the discharge flow rate from a postulated LOCA. This scheme was modified to a simpler optimised one, wherein the modulating feature was done away with, and a fixed dousing flow rate was set which can cater to all break sizes for LOCA.

* Emergency Core Cooling System (ECCS)

  In the original design, emergency core cooling was provided through injection of moderator heavy water to the coolant circuit using the normal moderator circulation pumps at low pressure (6 kg/cm^2 and below). In the modified design, a high-pressure emergency coolant injection system has been incorporated. The safety analysis of the reactor with the upgraded system was carried out using the latest computational tools.

* Supplementary Control Room

  A Supplementary Control Room away from the main control room was added at RAPS. Separate cables and power supplies independent of the main control room have been provided for the instrumentation in this room. The features provided ensure that the supplementary control room along with local panels/controls have the capability to perform essential safety functions (safe shutdown and decay heat removal as well as monitoring of plant safety status) independent of the main control room. It also has instrumentation to monitor the important safety parameters of the plant.

* Minimizing Instrument Air In-Leakage Into Containment

  During postulated LOCA conditions requiring boxing up of containment, the continued in-leakage of instrument air into the containment has the potential for gradual re-pressurisation. To address this, a dedicated instrument air system has been back fitted for providing instrument air to identified essential components during LOCA conditions. This will facilitate isolation of air supply to other non-essential components inside reactor building.

* Segregation and Rerouting of power and control cables for safety related loads

  The review of routing of cables for power and control supplies of safety related loads was carried out and these were segregated as found necessary to achieve the requirement of 'two-group' concept.

* Installation of Flood Diesel Generator

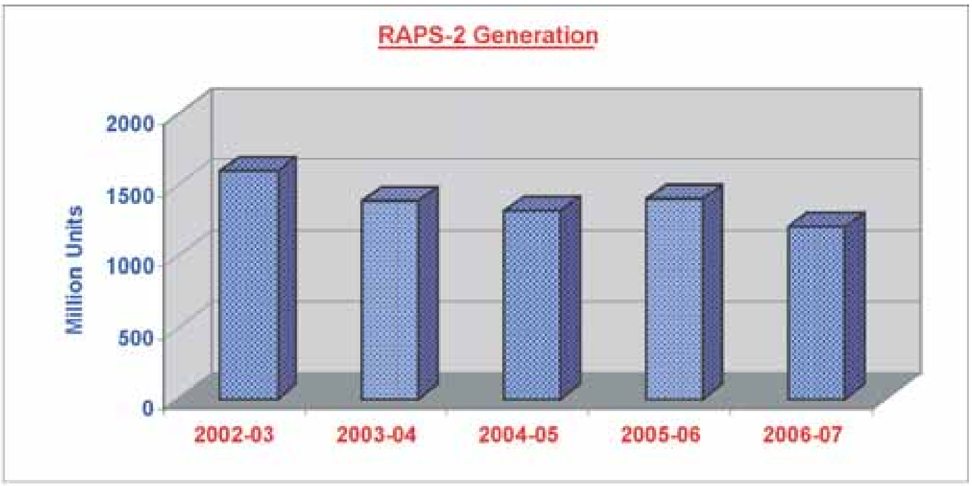
  For catering to the emergency power supply requirement during a flood condition arising from a postulated failure of the upstream dam, a 625 KVA DG set has been installed at a location above the maximum anticipated flood level.

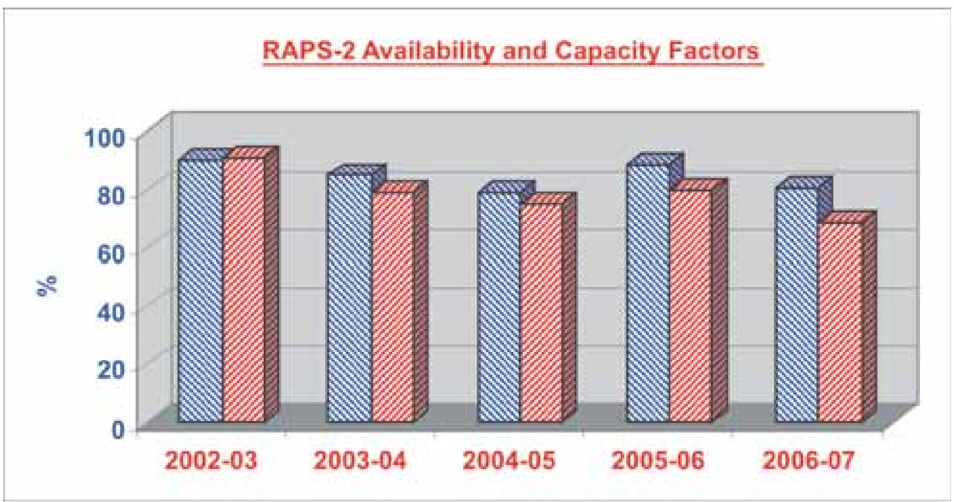
* Upgradation of fire Protection System

  The existing fire protection system at RAPS was reviewed against the requirements specified in AERB safety guide on Fire Protection in Pressurised Heavy Water Reactor Based NPPs, AERB/SG/D-4. Based on this review, additional fire protection measures were introduced. These included introduction of additional fire doors, fire dampers, physical separation of redundant trains of emergency power supplies. A new addressable fire detection system was also installed with enhanced number of detectors

* Calandria Vault Dew point monitoring system

  For assuring 'leak before break' (LBB) of Zr2.5%Nb pressure tubes, a system for monitoring the dew point of calandria Vault air for timely detection of pressure tube leaks was installed. The system employs non-contact type of dew point detectors, which has shown good performance over the years even in the presence of nitrous oxide in the calandria Vault atmosphere. The requirements related to dew point monitoring system for assuring LBB were also incorporated in the technical specifications for operation.





The performance of RAPS-2 after EMCCR and incorporation of safety upgrades has been consistently good. The performance data given since the year 2002-03 reflects the same.

In the year 2001 and 2004, the safety performance of the unit was reviewed as per the requirement of renewal of authorisation and based on this review, the permission for continued operation of the unit was granted.

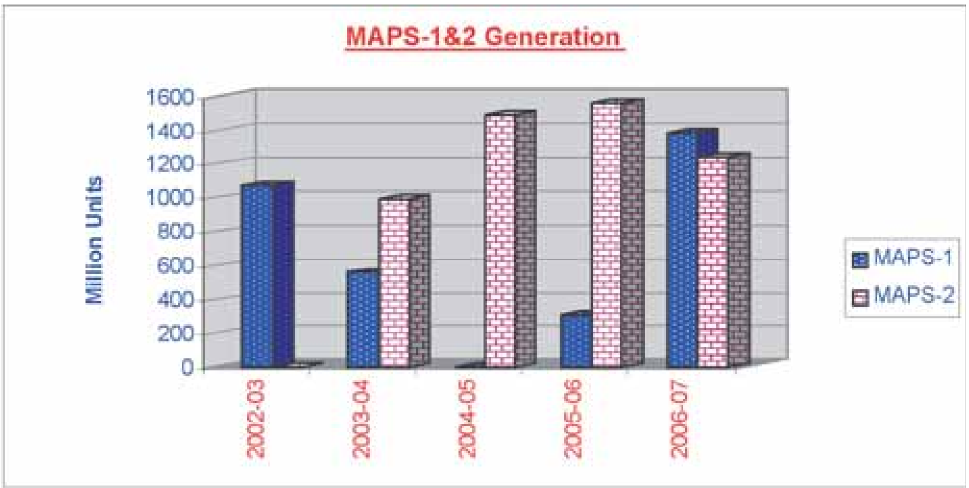
6.2.3 Madras Atomic Power Station (MAPS)

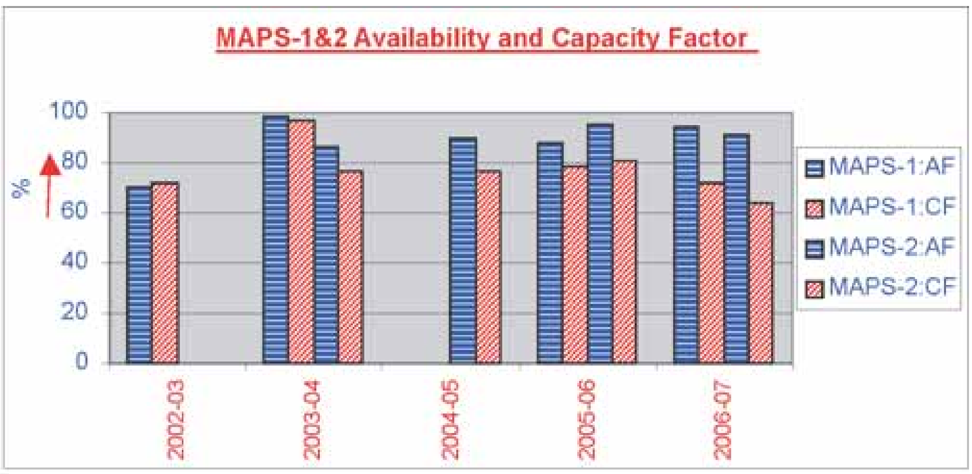
Madras Atomic Power Station (MAPS), a two-unit PHWR plant, each with 220 MWe capacity, is located at Kalpakkam on the East Coast of India about 60 km south of the city of Chennai. The design of MAPS was developed indigenously with several new features compared to RAPS-1&2. Partial double containment and the concept of suppression pool for vapour suppression to limit the containment peak pressure during loss of coolant accident was 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.

In 1988, a failure of the moderator inlet manifold occurred in MAPS-2 and a similar failure took place in MAPS-1 next year. The calandria moderator inlet manifold prevents direct impingement of moderator inlet flow on the calandria tube in front of the inlet line and possible flow induced vibration of the neighbouring coolant channels. It also facilitates proper moderator flow distribution inside the calandria especially for those zones away from the central radial plane and distributes the moderator evenly. Some of the broken pieces of the manifold were recovered from one of the moderator pump casings after a seal leak was observed in the pump.

After a detailed investigation using remote video inspection techniques, it was confirmed that the nelson studs bolted to the manifold and welded to calandria shell had broken. Based on a detailed study of the flow, vibration and jet impingement, velocity and temperature distribution, stress analysis, etc, a modified scheme for operation of the units was evolved. Under this scheme**,** the original inlet pipe was capped and the outlet piping was converted in to inlet piping. The outgoing flow from calandria was routed into dump tank through dump ports and dump tank was connected to moderator pump suction. The reactor was de-rated to 75%FP. Both the reactors were operated satisfactorily. However, subsequently, the flow configuration was restored to original design by installation of spargers for moderator inflow to the calandria. This scheme was implemented at the time of en-masse coolant channel replacement. The performance of MAPS units has been satisfactory. The performance data for the last few years is given.

In MAPS-1, a well-structured assessment and life management program for Zr-2 pressure tubes was put in place for operation of the reactor. 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. It was decided to take up EMCCR in this unit in the year 2002.





As in the case of RAPS-2, a similar review including that of operational performance was undertaken. As per the requirement of renewal of authorisation, the Station was also subjected to periodic safety review as per the requirement of AERB/SG/O-12.

Based on these reviews, following important safety upgrades were implemented.

- Introduction of high pressure emergency core cooling system
- Supplementary control room
- Segregation of power and control cables based on two group concept
- Replacement of MG sets with static UPS in Class II power supply system
- Dedicated instrument air system for identified loads

- Calandria Vault dew point monitoring system
- Augmentation of fire protection system

Apart from the above safety upgrades, certain additional major activities were also performed and these included

a. Replacement of all the boiler hair pin heat exchangers

   Since 1995, there had been five incidents of steam generator tube leaks in MAPS unit-2. Prior to the shutdown in January 2002, MAPS unit-2 was operating with some heat exchangers of the steam generator removed from service due to tube leaks (four out of 11 heat exchangers for steam generator-5 and one heat exchanger for steam generator-7). Metallurgical examinations carried out on some of the leaked tubes indicated that under deposit corrosion and pitting had been the cause of such tube leaks. In view of this, it was decided to replace all the heat exchangers of the Steam Generators.

b. Replacement of all heat transport system feeder elbows in MAPS-2

   In light of feeder thinning experienced in some of the PHWR based NPPs, it was decided to replace all the feeder elbows in MAPS-1. For all other NPPs, a comprehensive health assessment programme has been put in place.

c. Installation of Spargers

   Following failure of calandria moderator inlet manifolds of MAPS 1&2 in 1988-89, the MAPS units were being operated with a modified moderator flow configuration as explained above. During this period, MAPS units operated with their reactor power 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 so as to achieve flow configuration and the temperature profiles similar to the originally designed configuration. After the commissioning of the spargers, 100%FP operation of both the units could be restored.

Additionally, issues like seismic re-evaluation, structured programme of ageing management etc. were also addressed as a result of PSR (ref item 6.5 for details).

After completion of the EMCCR and safety upgradation activities, MAPS Unit-2 and unit-1 were restarted in July 2003 and January 2006 respectively, after obtaining the necessary regulatory clearances.

6.2.4 Narora Atomic Power Station (NAPS)

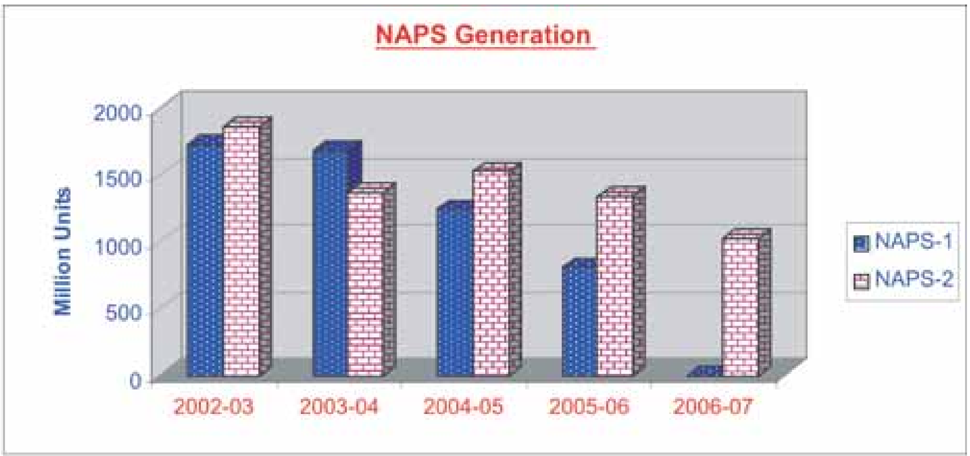
This station located at Narora in District Bulandshahr, Uttar Pradesh has the first two 220 MWe units based on standardized Indian PHWR design. The design incorporates several new features like double containment for reactor building, two independent, redundant and diverse shutdown systems, full tank 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 having incoloy 800 tubes were employed in NAPS.

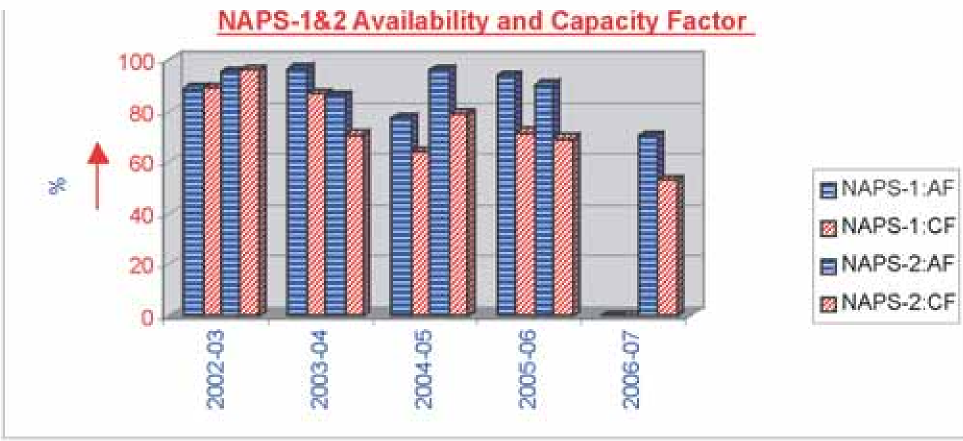
The performance of these units has remained satisfactory over the years.

In the year 2003, a periodic safety review of NAPS was carried out. The report on PSR was reviewed in AERB and following major issues were identified for further actions (for details refer item 6.5).

- Safety Analysis to include additional Postulated Initiating Events (PIEs) in line with current standards
- Ageing Management and Equipment Qualification Programmes
- Revisions in Technical Specifications for Operation
- High collective dose
- In-service inspection programme

The proposed time frame for completion of all the identified activities to resolve these issues was accepted by AERB.





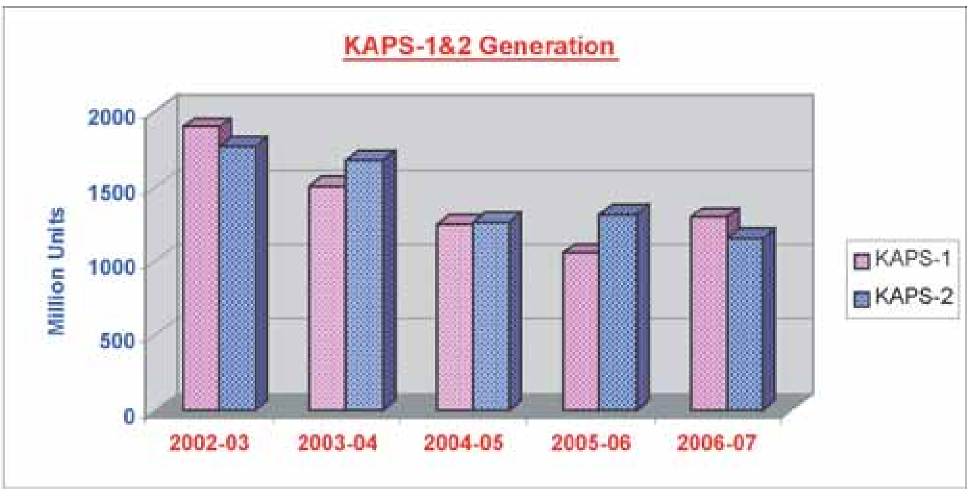
Life management activities for coolant channels were performed periodically at NAPS based on review and advise of the Expert Group on Coolant Channels constituted by AERB. The in service inspection and sliver sampling were extensively carried out to decide on the fitness for service. Based on the results of these assessments, NAPS-1 was shutdown for EMCCR in November 2005. As mentioned earlier, the coolant channels in NAPS units employ bellows to have a closed annulus. This necessitated development of special tools and tackles for removal and installation of the coolant channels. These were developed indigenously with in-house technical and engineering support. AERB identified the different stages of EMCCR for obtaining regulatory clearance and instituted a regular monitoring programme for the related activities. It also reviewed and recommended, as necessary the safety measures in the relevant plans and procedures. During the shutdown for EMCCR, replacement of heat transport system feeder elbows was also carried out. After completion of all the activities, the unit is likely to be restarted in financial year 2007-08. EMCCR for NAPS-2 is also planned during the financial year 2007-08.

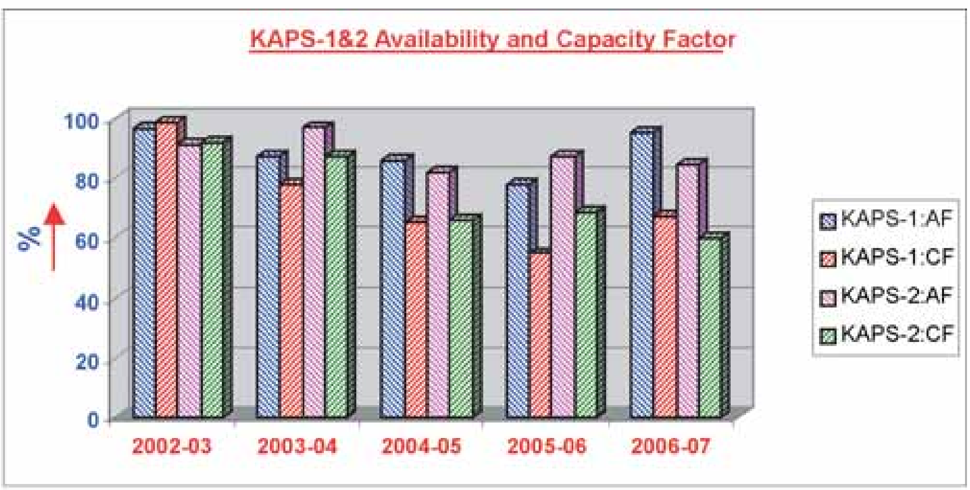
6.2.5 Kakrapar Atomic Power Station (KAPS)

This station located at Kakrapar in District Surat, Gujarat comprises of two 220 Mwe 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 the year 2004, a periodic safety review of KAPS was carried out. The report on PSR was reviewed in AERB and following major issues were identified for further actions (for details refer item 6.5).

- Safety Analysis to include additional PIEs in line with current standards
- Ageing Management and Equipment Qualification Programmes
- In-service inspection programme

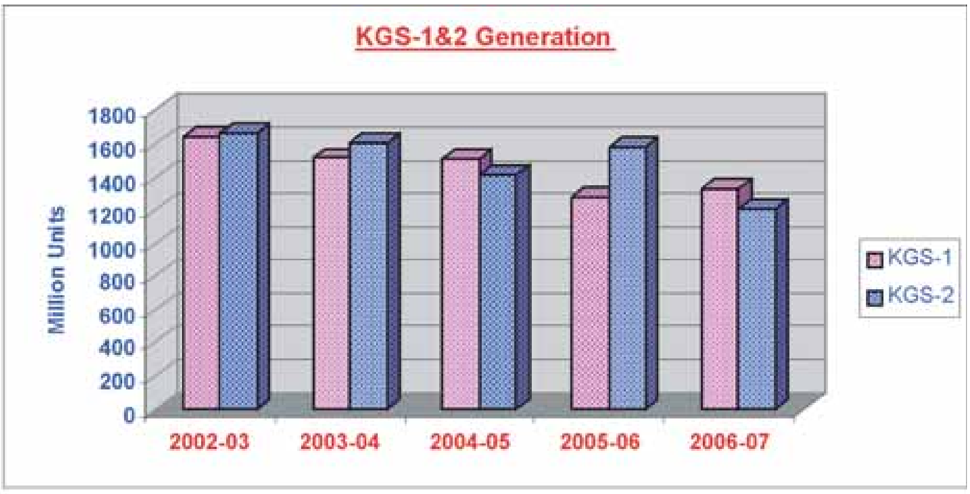
The proposed time frame for completion of all the identified activities to resolve these issues was accepted by AERB.

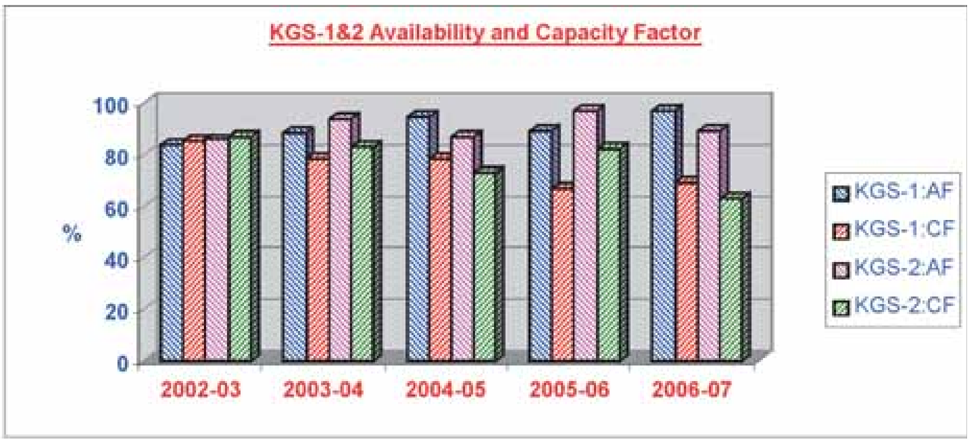
A comprehensive level-1 PSA was conducted for standardised Indian PHWR for the first time for KAPS. Latest methodologies and approaches recommended by IAEA guidelines were adopted for conducting this PSA. The study was done for internal initiating events during full power operation considering reactor core as the main source of radioactivity. After this, PSA level-1 studies have been completed for other standardized Indian PHWRs. A level-2 PSA study for KAPS has also been completed and its review in AERB is in progress.

6.2.6 Kaiga Generating Station (KGS)

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

The performance of the units since commissioning in the year 2000 has been satisfactory.

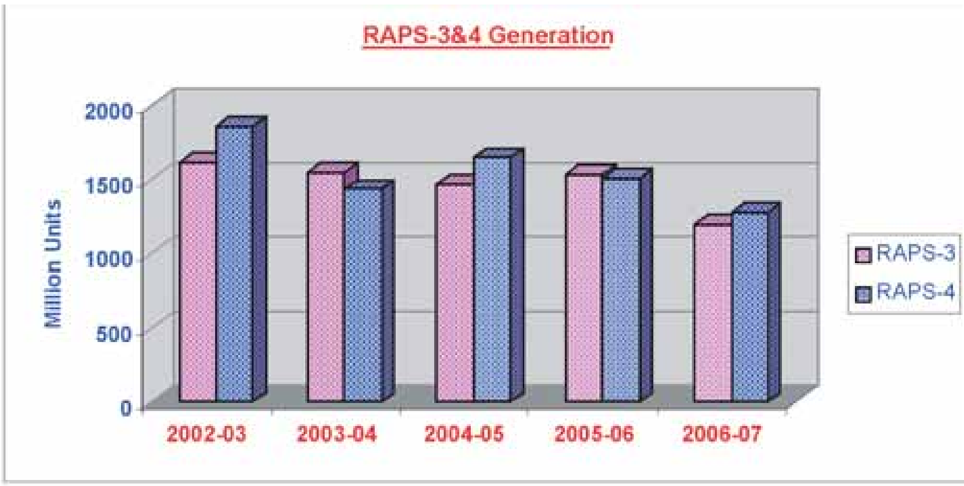


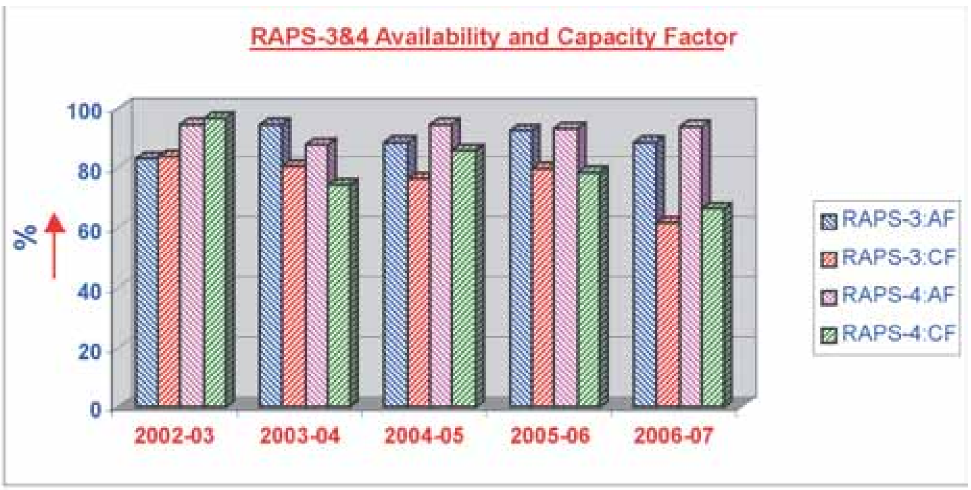


In the year 2004, AERB carried out review of safety performance as per the requirements of the renewal of authorisation and extended the authorisation for operation of the unit until 2007.

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

This station located at Rawatbhata, in District Chittorgarh, Rajasthan comprises of two 220 MWe 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.





In the year 2004, AERB carried out review of safety performance as per the requirements of the renewal of authorisation and extended the authorisation for operation of the unit until 2007.

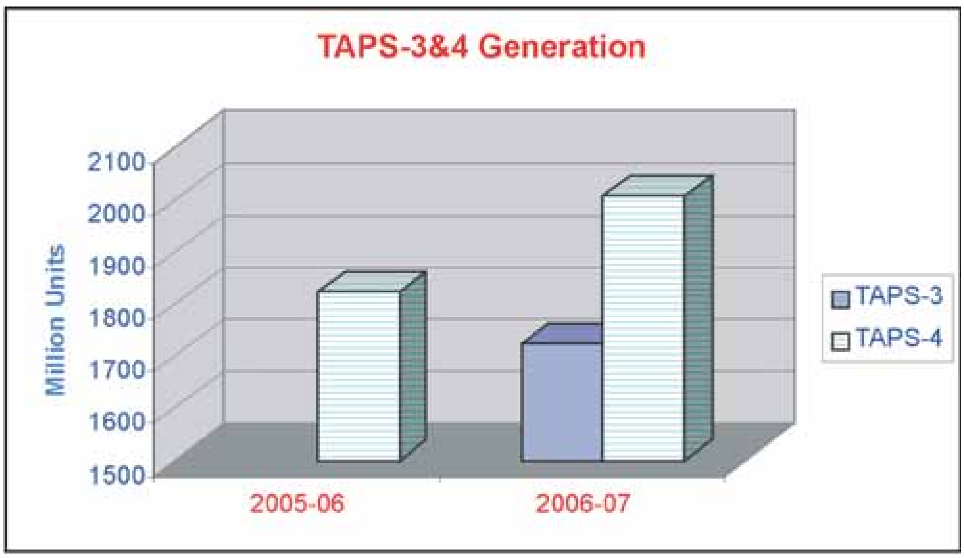
6.2.8 Tarapur Atomic Power Station (TAPS) Unit-3&4

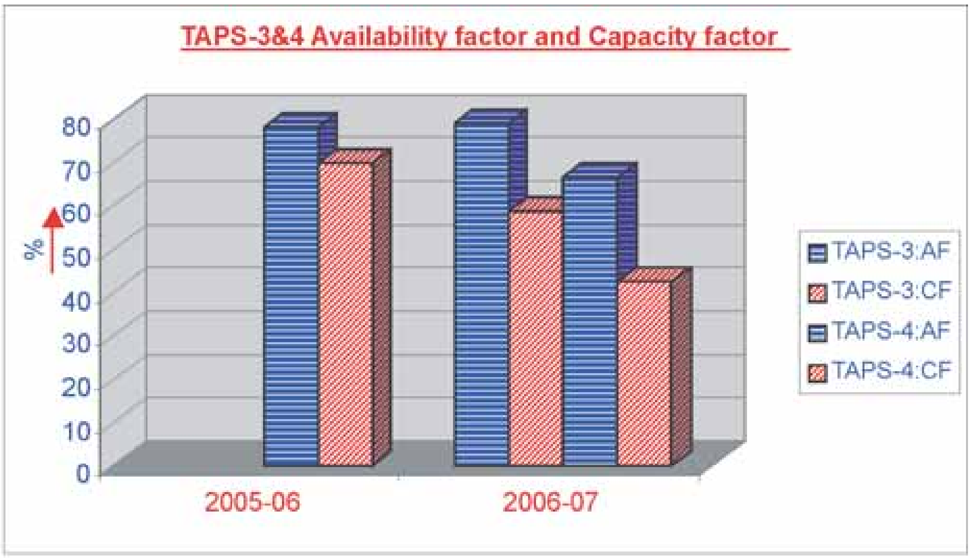
The 540 MWe PHWR units, set up at Tarapur are the first of their kind in the country, based on PHWR technology. The station layout is based on the independent capability for operation of each unit. The safety systems are housed in a seismically qualified building and are also protected from postulated low trajectory missiles originating from turbine generator. The reactor is provided with two independent, diverse, fast acting, physically separated Shutdown Systems (SDS). SDS-1 consists of 28 hollow cadmium rods**,** which drop vertically into the core under gravity to accomplish reactor shutdown. SDS-2 consists of 6 horizontal perforated poison injection

tubes through which gadolinium nitrate solution is injected into the moderator. The primary heat transport system employs two separate loops having common pressuriser and feed & bleed system. The PHT system is split into two halves to limit the reactivity excursion due to voiding during postulated loss of coolant accident. The reactors also have the double containment.

The larger physical dimension of the reactor core has made it susceptible to the phenomenon of spatial Xenon oscillations. In order to take care of this, a more elaborate reactor control system has been adopted. This involves in-core neutron monitors and zone wise reactivity controls.

AERB granted the initial authorisation 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.





6.3 SAFETY ASSESSMENTS PERFORMED FOLLOWING MAJOR 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 effected.

Some of the major safety assessments carried out, their results and details of corrective actions taken thereafter are described below.

6.3.1 Review following the TMI-2 Accident

At the time of TMI-2 accident in March 1979, one 220 MWe PHWR (RAPS-1) & two 200 MW BWR units (TAPS-1, 2) were in operation and five PHWR units were under various stages of construction. Detailed reviews of the systems of these NPPs were carried out in the light of TMI-2 accident. The review resulted in a number of recommended actions requiring modification in the area of design, operating practices, emergency preparedness, quality assurance and training & qualification of operation personnel. Some of these are listed below.

* Enhancement in the reliability of Auxiliary Boiler Feed Water Supply by installing an additional standby auxiliary boiler feed pump; routing a new line for auxiliary feed, independent of the main feed line to the steam generators.
* Augmentation in the feed capacity for inventory control of primary coolant system under off-site power failure conditions. This was achieved by utilizing extra capacity of Fuelling Machine supply pumps, which are fed from emergency power supplies.
* capability for remote isolation of moderator heat exchangers to check spread of radioactivity to cooling water system in the event of leaks in heat exchanger tubes.

* A high-pressure emergency core cooling system was incorporated in the units under construction (NAPS). Back fitting of such system for operating units was also worked out for subsequent implementation. In the mean time, reliability of Emergency Core Cooling System in these operating units was enhanced by provision of local air receivers for each air-operated valve.
* Emergency operating procedures were developed for a large number of postulated initiating events to handle emergency/accident conditions.

6.3.2 Reviews following the Pickering-2 pressure tube failure incident

Following the Pickering-2 pressure tube failure incident in 1983, a major program was launched for Indian PHWRs for ensuring integrity of the pressure tubes by enhancement in design as well as in-service inspection and rehabilitation technologies. BARC provided strong research and development support for life management of coolant channels, which included the study of material properties of irradiated coolant channel components through post irradiation examination in its well-equipped laboratories and development of automated tools for measurement of irradiation-induced deformation. The tool for slivering was developed for collection of samples for measurement of deuterium pick up by the pressure tubes in the reactor environment. Several computer codes were also developed to predict the irradiation enhanced deformations, assessment of deuterium pick up, prediction of time for contact of hot pressure tube with the cold calandria tube, formation of hydride blisters and blister size and evaluation of delayed hydride cracking. The above tools and the prediction models form the backbone of the life management activities for the coolant channels in the country. BARC continues to provide the critical technical support in this area.

The earlier PHWRs employed Zr-2 pressure tubes with loose fitting spacers, called as garter springs, located to provide separation between the pressure tube and the surrounding calandria tube. At RAPS-1&2 and MAPS-1&2, there were two loose fit garter springs while at NAPS-1&2 and KAPS-1, four loose fit garter springs are provided. Current Indian PHWRs from KAPS-2 onwards employ pressure tubes of Zr-2.5% Nb with 4 tight fitting garter springs.

Zr-2 is known to have relatively high hydrogen pick-up rate during operation. The loose spacers can shift from their design location during commissioning/operation, with possibility of pressure tube touching the cold calandria tube. This touching is considered deleterious since hydrogen can migrate to the cold spot and lead to formation of undesirable hydride blister.

For the earlier Indian PHWRs, in which Zr-2 pressure tubes are used along with 2 or 4 loose spacers, a well-structured assessment and life management program was put in place which included in-service inspections, post-irradiation examination as well as replacement of channels as required.

Annex 6-2 summarizes the life management strategies for Zr-2 pressure tubes of Indian PHWRs.

A high-priority element of this program is prevention of formation of unacceptable hydride blisters. Monitoring and repositioning of displaced spacers is therefore an important part of the program.

En-masse replacement of coolant channels with Zr-2.5%Nb pressure tubes has been completed in RAPS-2, MAPS-1&2 and NAPS-1and planned in NAPS-2 and KAPS-1. This activity is taken up at an appropriate stage for each unit (after about 8.5-12 Full-Power-Years (FPY) of operation) based on

i) Predicted time for Pressure Tube/Calandria Tube (PT/CT) contact, and consequent blister growth

ii) Axial elongation exceeding allowances available in the channel bearings, and

iii) Deterioration in fracture toughness due to Hydrogen/Deuterium pickup, which reduces the margins on meeting the leak-before-break (LBB) criteria.

The operating procedure for start up and shutdown of the plants avoids cold pressurization of the pressure tubes. This reduces the probability of delayed hydride cracking (DHC), and also increases the probability of LBB.

For detection of leaks in pressure tubes, from NAPS onwards, an annulus gas system (AGS) is used. In reactors prior to NAPS (i.e. RAPS & MAPS), where the PT/CT annulus is open to the Calandria vault atmosphere, the leak detection system is based on detection of moisture in the Calandria vault atmosphere. The sensitivity of this leak detection method is assessed to be adequate to satisfy the LBB criteria.

For reactors employing pressure tubes of Zr2.5%Nb material, an elaborate in service inspection programme comprising of dimensional measurement, volumetric examination and material surveillance has been put in place in all the PHWR based NPPs.

The pressure tube life management program ensures that the margins available for safe operation of the pressure tubes continue to be adequate at all times.

6.3.3 Review following the Chernobyl accident

The detailed reviews following the Chernobyl Accident (1986) re-emphasized the necessity for adhering to the already established principles of reactor safety design and operation. The feedback from the accident did point to the need for well coordinated plans and organization for on-site & off-site emergencies that may arise from nuclear accidents. It also re-emphasized the need for maintaining 'safety culture' in the conduct of operations at the station, and having disciplined institutionalised procedures. Actions were taken to reinforce these aspects in operating principles and practices. The plans and organization for on-site and off-site emergencies were also strengthened for all the power stations.

6.3.4 Review following the fire incident in NAPS-1

The fire in TG hall of NAPS Unit-1 (220 MWe PHWR) in March 1993 was initiated by sudden failure of two turbine blades, with the resulting vibrations leading to rupturing of hydrogen seals and lube oil lines, culminating in a fire. The fire spread to several cable trays, relay panels etc. in a short duration. The control room operators responded by tripping the reactor by manual actuation of primary shutdown system within 39 seconds from the incident and also initiated the fast cool down of the reactor by opening Atmospheric Steam Discharge Valves (ASDVs) with 2x10% capacity, on the main steam line.

As the fire had spread through the generator bus duct in the Turbine Building (TB) into the Control Equipment Room (CER) where fire barriers had given way, the power cables as well as control cables from the source were damaged. Hence**,** even though the power sources were available, neither the power supply from Grid nor from the Diesel Generators or from the batteries was available. Therefore, a complete loss of power supply in the Unit occurred in about 7 minutes of the incident, which resulted in an extended Station Blackout lasting for a period of 17 hours. During the blackout, the core cooling was maintained by thermo-siphoning in the primary side with steam generators on secondary side fed by firewater as heat sink. There was no radiological impact of the incident either on the plant workers or in the public domain. The major fire was put out in about 90 minutes. Due to the degradation of defence-in-depth of the engineered safety features during the incident, Atomic Energy Regulatory Board (AERB) classified this event as Level-3 event on the International Nuclear Event Scale (INES).

The detailed investigation and reviews following this incident, both by the regulatory body and by the utility, resulted in several modifications and improvements in various areas covering design, operation and administrative & surveillance practices. One study was with regard to the susceptibility of the existing design and layout of NAPS to common cause failure (CCF), mainly due to fire as an initiating event. Consideration was given to formulate preventive measures for avoiding CCFs, as well as to the need for additional mitigating measures for assured core cooling etc. in situations such as station blackout.

The review, initially carried out for NAPS, was subsequently extended to cover all other operating stations. The design provisions of Nuclear Power Plants under construction at that time (RAPP-3, 4 and Kaiga-1, 2) were also checked against the recommendation of this study, and remedial actions were taken, wherever required.

Some of the improvements, which were implemented, are highlighted below.

* Cable Re-routing

    - As an obvious and immediate measure, the control & power cables in Turbine Building for station power supply system covering Class I, Class II & Class III supplies were re-routed through diverse routes for redundant trains.

- The cable routes in the Turbine Building & between Turbine Building and Reactor Building for safety equipment were also reviewed and re-laid where necessary to ensure diverse routes for redundant trains.

* Fire Zones Localization

A detailed review on fire barriers and other protection means for cables etc. was carried out and following remedial actions were identified: -

- Provision of a wall on the mezzanine floor (106M El) of Turbine Building between the fire prone areas of main turbine hall and the corridor adjoining control equipment room, so as to protect the major cable tray routes along the corridor.
- Strengthening of fire barriers at cable penetrations in floors and walls in the Turbine Building as well as at their entry into the control equipment room.
- Enhancement of routine surveillance on fire barriers and fire dampers.

* System wise review to avoid CCF vulnerabilities

A detailed system wise review identified several areas of improvement including the need for relocating and better separation of some of the triplicated instrumentation sensors, viz. containment building high pressure sensors, reactor outlet header pressure transmitters; provision of fire barriers between redundant equipment located side-by-side viz. aux. boiler feed pumps and firewater pumps; provision of double miniature circuit breaker (MCB) with diverse power sources for actuation of valves for backup of firewater injection to process water system.

* Improvement in Control Room Ventilation

Provision to improve control room habitability in the event of a fire in the turbine hall including modifications to the control room ventilation system with provision of relocated/diverse intakes.

* Turbine generator (TG) system related improvements

- Restrictions on operation of TG at grid frequencies beyond specified range.
- Permissible range of TG bearing vibration levels established, for strict adherence.
- Periodic in-service requirements on turbine blades
- Close monitoring of Hydrogen makeup rate to generator; provision of Hydrogen leak detection system around generator.

* Emergency Operating Procedure/Guidelines and provisions for handling Station Black Out (SBO):

The existing guidelines and procedures were reviewed and revised in the light of the incident. Manual valves required for feeding firewater to steam generator during SBO were relocated to a more convenient/accessible location. The reliability and capability of firewater system to inject to Steam Generators, as well as fight fire simultaneously, was established by actual tests. Facility for injecting firewater to end-shields has been incorporated as a part of design.

6.3.5 Review following Tsunami incident at Kalpakkam

On December 26, 2004, tsunami had struck the eastern coastline of India causing severe loss of life and property. MAPS, which is located on the coastline at Kalpakkam near Chennai was affected by this event. Prior to the event, MAPS unit-2 was operating at full power and MAPS unit-1 was under shutdown for EMCCR. Following the event, the fore bay water level had risen causing tripping of Condenser Cooling Water (CCW) pumps in MAPS unit-2. The control room operator initiated safe shutdown of the reactor after identifying the loss of cooling water and brought the reactor to cold shutdown state. Though the offsite power remained available, emergency diesel generators DG-1 and DG-5 were started and kept running as a precautionary measure. An emergency alert was declared at 1025 hrs on December 26, 2004, which was lifted at 2143 hrs on December 27, 2004 after the situation became normal. After rehabilitation of the process water pumps that were submerged during the event, the unit was restarted on January 2, 2005 after obtaining regulatory clearance.

The event was reviewed in detail with respect to operator response, emergency preparedness and AERB requirement for siting and design of the nuclear facilities. The following issues were identified as an outcome of this review.

- Requirement for Augmentation of communication facilities.
- Revision of emergency operating procedures for handling flooding incidents at all coastal sites.
- Need for relocation of some of the process equipment above the maximum flood levels.
- Need for installation of a tsunami warning system.

6.3.6 Review of KAPS-1 Incident of Regulating System Failure

An incident involving failure of reactor regulating system during preventive maintenance on Power UPS-1, leading to a reactor trip on ‘SG delta T high’ took place in KAPS-1on March 10, 2004. Prior to the event, reactor was operating at 73%FP. During the event, the power supply to all the adjusters failed while preventive maintenance on power UPS-1 was being carried out. Consequently, the reactor power started increasing and the reactor tripped on ‘Steam Generator delta T high. AERB rated this incident at level-2 as per INES. The event was also reported to IAEA incident reporting system.

A detailed review of the incident revealed deficiencies in areas of human performance and configuration of power supplies to reactor regulating system. Based on these reviews, following major corrective measures were taken.

- Formal and elaborate retraining and re-licensing of all the frontline operating staff and the station management personnel. The training covered the safety aspects related to operation of the reactor in the peaked flux configuration, the reactor regulating system and safety culture. Similar training was conducted at all the other PHWRs also.

- Establishment of a computerised operating experience feedback sharing system.
- Modification in the automatic liquid poison addition system to prevent manual blocking. This modification was implemented in other standardized PHWRs in India.
- Modification in the configuration of power supplies to reactor regulating system

6.4 GENERIC ISSUES

6.4.1 PHT Feeder Thinning

The thinning of elbows in the feeder pipes in primary heat transport system of PHWR has been observed in several of the Units. The assessment indicates that the rate of thinning in some of the feeders is higher than the initially anticipated rates. Such observations have also been reported from similar reactors abroad. Due to this concern, the scope and coverage of in-service inspection of feeders have been enhanced significantly in the recent years in all the Indian plants. The results of these inspections are utilized for assessment of the fitness for service. These inspections also indicated that the higher than normal thinning is limited only to a small number of feeders.

The reason for the thinning appears to be flow induced erosion-corrosion of the feeder pipe. As a policy decision of NPCIL, it has been decided to change in all new reactors, the material of the feeders with material having higher resistance to FAC. It has also been decided to replace the feeders in the reactors under operation at the time of coolant channels replacement. In line with this, feeders have already been replaced in MAPS-1 and NAPS-1.

6.4.2 Flow Assisted Corrosion in High Energy Secondary Cycle Piping

A surveillance programme for monitoring the health of high-energy secondary cycle piping was in place in all-operating reactors. The programme envisaged thickness measurement at vulnerable locations on a sample basis. The inspection coverage was progressively enhanced in view of the failures experienced at some locations.

Periodic inspection program for all the stations for monitoring the health of high-temperature high-pressure secondary system pipeline was revised after the Mihama incident. Components from all high-energy secondary systems i.e. main steam system, boiler blow down system, feed water system, condensate system, auxiliary feed water system, extraction system, drain system etc were included in this program. The components were selected based on the following criterion.

- Areas where velocity is high
- Areas where local flow disturbances are expected

- Areas where wetness is high
- Where two phase flow is expected
- Locations based on piping configuration
- Industry experience based on failures available from literature

It is also planned to replace the components of the secondary cycle prone to FAC with alloy steel in a phased manner.

6.5 ISSUES ARISING OUT OF PSR

6.5.1 Seismic Re-evaluation of old generation PHWRs

For seismic re-evaluation of RAPS-1&2, the design basis ground motion (DBGM) of RAPS-3&4 was used as Evaluation Basis ground motion (EBGM). Similarly, DGBM of PFBR being built at the same site of MAPS was used as EBGM for MAPS. The DBGM based artificial time history was used for time history analysis of Reactor Building, Service Building, Turbine Building pump house and stack, to generate the floor response spectra. Seismic re-evaluation of structures, systems and equipment were based on these floor response spectra. The approach for selection for various plant structures, systems and equipment and the methodology followed for seismic evaluation were as per the IAEA safety report no. 28 on Seismic Evaluation of Existing NPPs. The safety systems selected for re-evaluation of MAPS and RAPS 1&2 included the following

(a) Reactor shutdown system

(b) One chain of decay heat removal system including PHT system, steam discharge line, shutdown cooling system, process water system and sea water system.

(c) Containment

(d) Spent fuel storage bay

The safety support systems selected for re-evaluation included emergency power supplies Diesel Generators, Class II motor generators, Class I system (Batteries) and the related instrumentation/controls.

The evaluation indicated that in the case of reactor system piping and equipment, the present supporting arrangements are adequate and there would not be any further requirement for seismic upgrades. However, some seismic upgrades are needed for the secondary side piping & equipment and for electrical & instrumentation systems. The necessary seismic upgrades related to electrical and instrumentation systems have already been implemented in MAPS unit-1. Similar modifications are also planned in MAPS unit-2 and RAPS-2.

6.5.2 Revision of Safety Analysis

The Safety analysis of the NAPS and KAPS was reviewed during PSR. A number of design modifications have been carried out during last several years of operation. Also, over the years safety analysis methodology has been refined and new computational tools have become available. The safety analysis in the current reactors such as KGS and RAPS-3&4 cover a larger number of Postulated Initiating Events (PIEs) as compared to NAPS and KAPS. In the PSR, it was brought out that the safety analysis of NAPS & KAPS covers all the bounding cases and the computer codes used were conservative in comparison to the code used for recent NPPs. Though this approach was considered adequate to permit continued operation, it was decided that the Safety analysis reports for the NPPs at NAPS and KAPS should be revised to include the following

i. Analysis with additional PIEs as identified.

ii. Re-evaluation of the analysis with state- of- the- art computer codes.

iii. Changes in the text to reflect plant modifications and applicability of analysis of similar plants.

iv. Editorial changes and presentation of the report in a specified format.

The revision of the safety report will be completed by end of the year 2007.

6.5.3 Ageing Management Programme for SSCs important to safety

During PSR, extensive work was carried out to identify various Systems, Structures and Components (SSCs) requiring Ageing Management. During review it was observed that the NPPs have operated with adequate programmes established for maintenance, in-service inspection and chemistry control, since the beginning. With these programmes in place, there is no concern of any life limiting ageing related degradation of non-replaceable components at this point of time.

For certain non-replaceable components such as Calandria and End Shields, it was observed that they are designed with adequate safety margins. The operational parameters with respect to these components were maintained within the specified limits so as to provide an environment compatible with the material of construction. Also the records of stress cycles seen by these components are maintained to ensure that the number of operational cycles do not exceed the number of permitted stress cycles. This information will be useful for assessment of residual life in future. For the safety related civil structures, the modes of degradation, the monitoring/inspection required and ageing management actions have been identified. From the reviews carried out, there does not appear to be any concern in the short term, with respect to ageing.

During PSR review, the utility has drawn up a comprehensive programme for Ageing Management. Since this is to be followed at other NPPs also for a long period in future, it needs to be reviewed for adequacy of scope as well as specific action plans. The detailed review of the ageing management programme is currently in progress at AERB.

6.5.4 Reduction of Collective Dose

Initially, the collective doses in NPPs were relatively higher compared to prevailing industry standards. Many of the issues affecting collective dose in the older PHWRs were addressed in the new generation reactors. This was either by design improvements and/or improving the working conditions. These improvements have contributed to reduction in collective dose from 4.0 P-Sv/reactor in RAPS/MAPS to around 2.0 P-Sv/reactor in KAPS and less in KGS/RAPS 3&4.

Presently, around 50% of the collective dose is consumed during planned long-duration outage of the reactor for ISI and major maintenance activities. About 20% of the collective dose is consumed during unplanned short shutdowns.

With regard to older units, AERB and NPCIL had a formal dialogue on the issue in December 2003 and a holistic approach covering design changes, improvement in quality assurance procedures, optimisation of deployment of manpower, use of remote tools etc was devised to effectively reduce collective dose in NPP. The changes brought in by this strategy have shown good result.

6.5.5 Revision of Technical Specifications based on the operating experience

During PSR review AERB directed the utility to revise the Technical Specifications for operation of the NPPs based on the operating experience. In the past, some requests for postponement of surveillance requirements pertaining to NPPs were received due to the continued operation of the unit. In this connection AERB asked NPCIL to appropriately revise the Technical Specification for operation of all the stations and if required, incorporate design modifications/ procedural changes, so that there are no deviations of Technical Specifications. Presently, the revised technical specifications are under review at AERB.

6.5.6 Optimisation of In-service Inspection Programme

The shortfalls in the compliance of the in-service inspection were brought out during reviews for renewal of authorisation of NAPS. A comprehensive review attributed the reasons for these shortfalls to overtly conservative requirement initially included to gain experience,

Subsequently, NPCIL had initiated revision of ISI manual with the objective of optimising the ISI requirements in the light of operating experience and the current international practices. The revised manual also enhanced the coverage of inspection in certain areas like primary heat transport feeders, based on operating experience. AERB reviewed the revised manual and accepted it and continues to monitor the coverage of ISI during long shutdowns. Based on NAPS, ISI programme of other units were also revised.

In addition, NPCIL has developed private contractors for carrying out inspection to augment the present infrastructure. NPCIL has also obtained adequate numbers of remotely operated automated tools for inspection of steam generators and heat exchangers.

6.6 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. Every event is promptly reviewed and lessons are learnt. Analysis of international events & their applicability is checked and accordingly the systems, procedures, aspects related to training and safety culture are further improved. A comprehensive Safety review for TAPS-1&2 units was performed and several design modifications were implemented in line with the current safety standards. Such exercises were also performed for old generation PHWR units at RAPS-1&2 and MAPS and large number of safety upgrades were implemented. 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.

Annex 6-1: Existing Nuclear Power Plants

Sl.No.	Unit Name	Location	Type	Gross Capacity MWe	Date of First Criticality	Date of Commercial operation
1.	TAPS-1	Tarapur	BWR	160	1-02-1969	28-10-1969
2.	TAPS-2	Tarapur	BWR	160	27-02-1969	28-10-1969
3.	TAPS-3	Tarapur	PHWR	540	21-05-2006	18-08-2006
4.	TAPS-4	Tarapur	PHWR	540	6-03-2005	12-09-2005
5.	RAPS-1	Rawatbhata	PHWR	100	11-08-1972	16-12-1973
6.	RAPS-2	Rawatbhata	PHWR	200	8-10-1980	1-04-1981
7.	RAPS-3	Rawatbhata	PHWR	220	24-12-1999	1-6-2000
8.	RAPS-4	Rawatbhata	PHWR	220	3-11-2000	23-12-2000
9.	MAPS-1	Kalpakkam	PHWR	220	2-07-1983	27-01-1984
10.	MAPS-2	Kalpakkam	PHWR	220	12-08-1985	21-03-1986
11.	NAPS-1	Narora	PHWR	220	12-03-1989	1-01-1991
12.	NAPS-2	Narora	PHWR	220	24-10-1991	1-07-1992
13.	KAPS-1	Kakrapar	PHWR	220	3-09-1992	6-05-1993
14.	KAPS-2	Kakrapar	PHWR	220	8-01-1995	1-09-1995
15.	KGS-1	Kaiga	PHWR	220	26-09-2000	16-11-2000
16.	KGS-2	Kaiga	PHWR	220	24-09-1999	16-03-2000
17.	KGS-3	Kaiga	PHWR	220	26-02-2007	6-05-2007

Annex 6-2: Life Management Strategies for Pressure Tubes of Indian PHWRs

Sheet 1 of 2

Ageing mechanisms	Potential consequences	Units	Monitoring & Corrective Actions
Irradiation-enhanced deformation (wall thickness, ID, axial creep)	Deformation exceeding design limits	RAPS MAPS NAPS	• Monitor deformation in sample channels during ISI. • Periodic axial repositioning of creep stops to accommodate elongation • En-masse replacement of channels before elongation exceeds allowance provided in channel bearing length.
		KAPS onwards	• Monitor deformation in sample channels during ISI. • Periodic axial repositioning of creep stops to accommodate elongation.
DHC initiating from hydride blister at PT/CT contact	PT rupture or failure of LBB	RAPS MAPS NAPS KAPS-1	• Monitor PT/CT gap or sag profile, and spacer positions in selected channels during ISI. • Identify channels which could have PT/CT contact from combination of vibration diagnostic techniques, calculations based on ISI data on spacer locations and direct inspection of selected channels. • Compute hydrogen pick-up and blister depth at contact location, based on conservative data & assumptions. • Quarantine/replace channel with unacceptable computed blister depth. • Reposition spacers in channels in which inspection has shown shifting and in which blister has not yet exceeded acceptable depth. • En-masse channel replacement based on assessment of hydrogen content and contact time.
		KAPS-2 onwards	• Periodic Inspection (normal) • No special action required : 4 tight fit spacers ensure no PT/CT contact

Life Management Strategies for Pressure Tubes of Indian PHWRs

Ageing mechanisms	Potential consequences	Units	Monitoring & Corrective Actions
DHC initiating from a stress concentration e.g., from service induced flaw	Failure of LBB	All units	• Volumetric/surface examination of sample channels during BLI, ISI. • For any detected flaw exceeding calibration standard, evaluate cause, effect on PT integrity; repair/quarantine/replace channel if required.
Changes of tube properties during operation	Failure of LBB	All units	• Material surveillance: PIE of selected channels from lead units; scrape samples.
Reduction in fracture toughness (CCL) due to hydrogen pickup + irradiation.	Failure of LBB	All units	• Operating procedure for avoidance of cold pressurization • Replacement whenever hydrogen levels is unacceptable.

ID	-	Internal Diameter	LBB	-	Leak Before Break
DHC	-	Delayed Hydride cracking	ISI	-	In Service Inspection
PT	-	Pressure Tube	BLI	-	Base Line Inspection
CT	-	Calandria Tube	PIE	-	Post Irradiation Examination
CCL	-	Critical Crack Length			

ARTICLE 7

LEGISLATIVE AND REGULATORY FRAMEWORK

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.

2. The legislative and regulatory framework shall provide for:

i. the establishment of applicable national safety requirements and regulations;

ii. a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a license:

iii. a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;

iv. the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.

7.1 GENERAL

India is a Union of States. It is a Sovereign Socialist Secular Democratic Republic with a parliamentary system of government. The Republic is governed in terms of the Constitution of India, which came into force on 26th January 1950. 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.

7.2 LEGISLATIVE AND REGULATORY FRAMEWORK

Atomic Energy Act 1962 and rules framed thereunder provide the main legislative and regulatory framework pertaining to atomic energy in the country. It 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. However, for locating and operating Nuclear Power Plants (NPPs), in addition to the provisions of the Atomic Energy Act, the provisions of several other legislations related environment, land use, etc have also to be met. The provisions of these acts are enforced either by Central or State (Provincial) Government, as the case may be. Some of these important legislations that have a bearing on the establishment of NPPs are summarised below.

7.2.1 Atomic Energy Act 1962

The legislative and regulatory framework for the atomic energy in the country was first formulated by the constituent assembly in the year 1948 and was called as Atomic Energy Act 1948. In the same year, the Government of India constituted a high powered Atomic Energy

Commission to implement the Government policy to harness the benefit of atomic energy. In the year 1954, Government of India created Department of Atomic Energy (DAE) for implementing the government policies pertaining to atomic energy. With the creation of DAE, AEC was reconstituted in accordance with the Government resolution dated March 1, 1958, to frame policies and advise the Central Government on matters pertaining to Atomic Energy.

The Atomic Energy Act of 1948 was repealed by the Parliament in the thirteenth year of the republic and Atomic Energy Act 1962 was enacted. The Atomic energy Act 1962 was amended in the year 1986 by the Parliament through the Atomic Energy (amendment) Act, 1986 (No. 59 of 1986). This amendment primarily addressed section 6 of the act, which deals with the disposal of uranium in minerals, concentrates and other materials containing uranium in its natural state. The amendment was brought in to enhance the exercise of monitoring and control of the nuclear material. In the year 1987, the Act was further amended (No. 29 of 1987) to give impetus to the activities related to design, construction and operation of NPP. The following paragraphs briefly describe the salient Provisions of this act.

a. 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 and for taking measures conducive to such production and supply and for all matters incidental thereto; (iii) to provide for control over radioactive substances or radiation generating plant in order to (a) prevent radiation hazards; (b) secure public safety and safety of persons handling radioactive substances or radiation generating plant; 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.

b. 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. The Act is comprehensive about the discovery of uranium or thorium (section 4), control over mining or concentration of substances containing uranium (section 5), disposal of uranium (section 6), power to obtain information regarding materials, plant or processes (section 7), power of entry and inspection (section 8), power to do work for discovering minerals (section 9), compulsory acquisition of rights to work minerals (section 10), compulsory acquisition of prescribed substances, minerals and plants (section 11), compulsory acquisition not sale (section 11-A), compensation in case of compulsory acquisition of a mine (section 12), and novation (contract law or business law) of certain contracts (section 13).

c. 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 license granted by it. This includes control for the acquisition, production, possession, use, disposal, export or import of any of the prescribed substances; or of any minerals or other substances specified in the rules; or of any plant designed or adopted or manufactured for the production, development and use of atomic energy or for research into matters connected therewith; or of any prescribed equipment. Subsection 2 of this section gives the Central Government powers to refuse license or put conditions as it deems fit or revoke the license. 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 control on information, access, measures necessary for protection against radiation and safe disposal of harmful by-products or wastes, the extent of the licensee's liability and 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.

d. 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.

e. 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.

f. 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.

g. 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.

h. 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.

i. 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.

j. 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. Exercising these powers, the Central Government has framed following rules to implement the following provisions of the Act.

i. Atomic Energy (Radiation Protection) Rules 2004: The Atomic Energy (Radiation Protection) Rules, 1971 were framed to establish the requirement of consent for carrying out any activities for nuclear fuel cycle facilities and use of radiations for the purpose of industry, research, medicine, etc. This rule was revised in the year 2004 with Atomic energy (Radiation Protection) Rules 2004.

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

iii. Atomic Energy (Control of Irradiation of Food) Rules, 1996: The Atomic Energy (Control of irradiation of Food) Rules, 1990 were framed to regulate the irradiation of foods in the country. These rules were revised as Atomic Energy (Control of Irradiation of Food) Rules, 1996.

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

v. 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, (63 of 1948), read with sections 23 and 30 of the Atomic Energy Act, 1962, (33 of 1962) had framed the Atomic Energy (Factories) Rules, 1984 to administer the requirement of Factories Act in the nuclear establishment of the country to ensure industrial safety. These rules were revised by Atomic Energy (Factories) Rules, 1996.

vi. Atomic Energy (Arbitration Procedure) Rules, 1983: In exercise of the powers conferred by Section 21 of the Atomic Energy Act, 1962, Central Government framed Atomic energy (Arbitration Procedure) Rules, 1983 to regulate arbitration procedure for determining compensation.

7.2.2 *Indian Electricity Act 2003*

The Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998 was replaced in the year 2003 with Indian Electricity Act 2003. The new act consolidates the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalisation of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto. 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.

7.2.3 *Environment (Protection) Act 1986*

The Environment Protection Act, 1986 and Environment (Protection) Rules, 1986 provide for the protection and improvement of environment and matter connected therewith. The Act empowers the Central Government to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution.

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).

7.2.4 *Other Applicable Legislation*

There are some other applicable legislation whose provisions have to be met for locating and operating NPPs in the country. These legislations include

- 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
- The Hazardous Waste (Management & Handling), Rules 1989
- Indian Explosive Act 1884 and Indian Explosive Rule 1983
- Disaster Management Act 2005

7.3 NATIONAL SAFETY REQUIREMENTS AND REGULATION

7.3.1 Safety Requirements under the Atomic Energy Act 1962

The National Safety Requirement & Regulation 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 and the rules issued there under. For NPP, the applicable rules are Atomic Energy (Radiation Protection) Rules 2004 and Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987.

In the year 1983, the Central Government using the provision of Section 27 of the Act on delegation of power, constituted an independent regulatory body, Atomic Energy Regulatory Board (AERB), through a gazette notification, to carry out the regulatory functions envisaged in sections 16, 17 and 23 (refer chapter on article 8: 'Regulatory Body' for further details). Chairman, Atomic Energy Regulatory Board (AERB) is the `Competent Authority` to exercise the powers conferred on it as per the rules framed under the Act for safety provisions.

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. These safety documents lay down requirement for safety in siting, design, construction, commissioning and operation of the NPPs in India. 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. For NPPs designed abroad, AERB takes in to account the differences in safety standards and requirements between the two countries for locating these in India. After satisfying itself with the provisions of the safety standards & requirements, AERB through appropriate notification/ directives may accept them applicable for this country.

AERB issues safety directives to implement the recommendation of the International Commission on Radiological Protection (ICRP) on dose limits for radiation workers and members of public.

7.3.2 Safety Requirements and Regulations arising from Other Legislations

In addition to above, the safety requirement 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.

Environment Protection Act, 1986 and Environment (Protection) Rules, 1986 provides safety requirement and regulation for the protection of environment. Nuclear Power Plants is included in the Category ‘A’ in the schedule and hence requires prior environmental clearance from Central Ministry of Environment and Forest (MoEF). The applicant is also required to conduct a public hearing to explain the safety, environmental, social and economic impacts of the nuclear power stations and allow the public to express its views and receive answers to its questions.

The Central or State Pollution Control Board (PCB), as the case may be, depending on the location of NPP site, acts as the regulatory authority for conventional pollutants from NPP and regulate the safety provisions of the following legislations related to the protection of the environment in the country.

- 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
- The Hazardous Waste (Management & Handling), Rules 1989.

The Indian Electricity Act, 2003 and Indian Electricity Rules, 2005 covering various aspects of electrical safety also applies 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.

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

Indian Explosive Act 1884 and Indian Explosive Rule 1983 provides the Central government power to prohibit manufacture, possess, use, sell, transport of explosives except under a license granted by it. The Directorate of Explosives regulates the provision of the Act and rules for use and storage of materials such as Diesel, Chlorine, compressed air, fuel oil etc.

Annex 7-1 gives safety requirements arising from some of the important legislation and the agencies identified to regulate them.

7.4 REQUIREMENT OF LICENSING UNDER THE ATOMIC ENERGY ACT

Section 14 of the Act specifies the requirement of obtaining license 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 of safety and waste management. The Atomic Energy (Radiation Protection) Rules 2004 and Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 issued under the Act further elaborate the requirement of obtaining license, the responsibility of license holder, the power of the Central government for licensing, inspection and enforcement. Atomic Energy (Factories) Rules, 1996 issued under section 23 of the Act sets requirement for the industrial safety in the facilities owned by the Central government and puts the requirement of license, monitoring, inspection and enforcement. AERB issues the license to an NPP and carries out safety monitoring, inspection and enforcement activities under the provisions of above rules. AERB Code of practice in Safety on Regulation of nuclear and radiation facilities (AERB/SC/G) specifies the minimum safety related requirements/obligations to be met by a nuclear or radiation facility to qualify for the issue of regulatory consent 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 authorisations are issued for the major stages of Siting, Construction, Commissioning, Operation and Decommissioning. After the issuance of initial authorisation for operation, AERB establishes the system of regulatory review and assessment by way of reporting obligations, regulatory inspections and enforcements. Annex 7-2 typically indicates various requirements for locating and operating NPPs in India.

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

7.5 REGULATORY INSPECTION AND ENFORCEMENTS

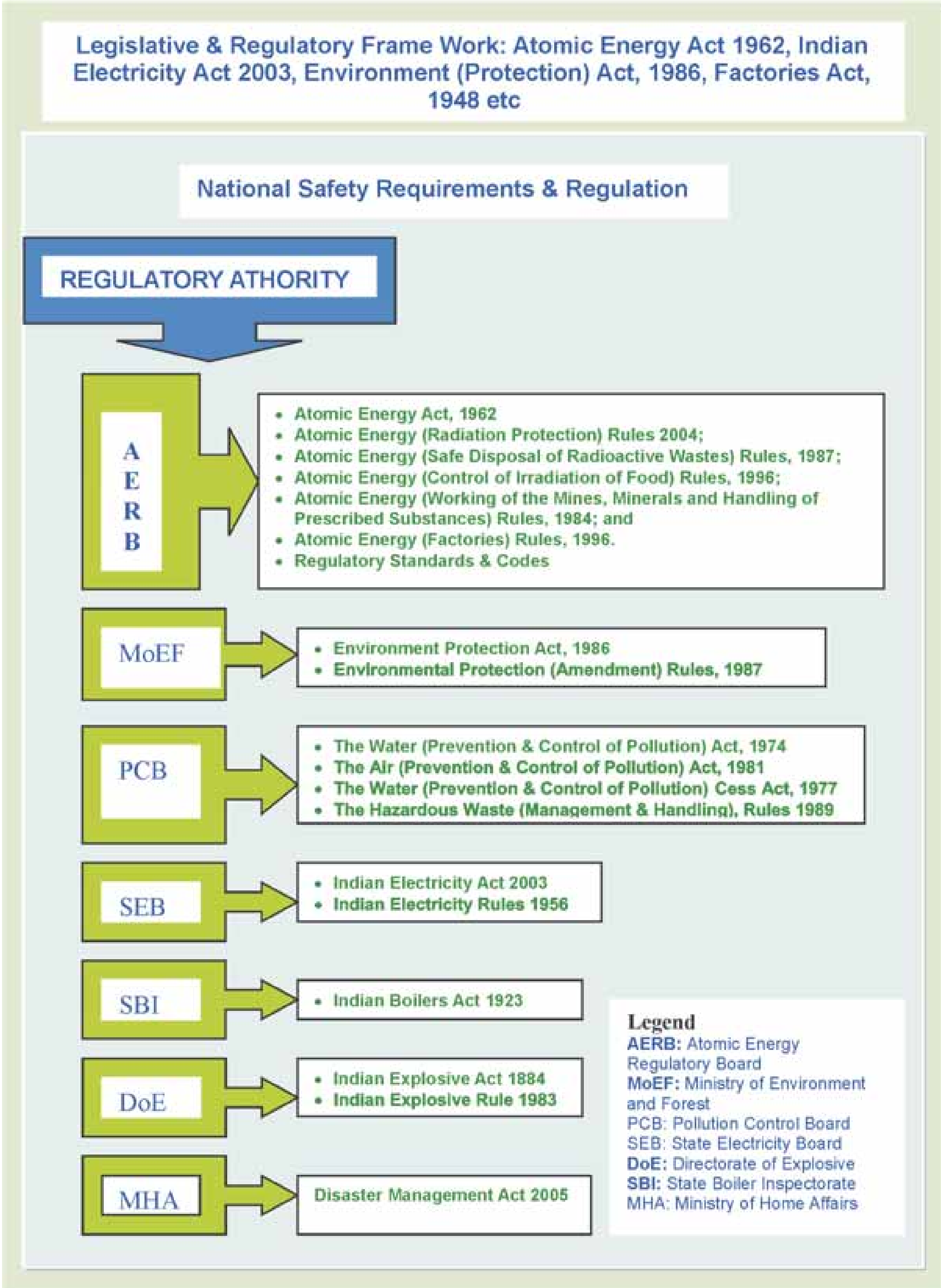
Section 8 (powers to entry and inspection) of the Act gives the Central Government powers for enter and inspect any mine, premises and land for the purpose of the Act. For the purpose of safety, subsections 4 and 5 of Section 17 (Special provisions as to safety) of the Act gives the Central Government 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. Atomic Energy (Radiation Protection) Rules 2004 and Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987, framed under the Act, are applicable for safety of NPPs. AERB enforces the safety provisions of these rules and has established the system of regulatory inspection and enforcement. AERB also enforces the provisions of Atomic Energy (Factories) Rules, 1996 for industrial safety of the plant. 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 radiation facilities (AERB/SC/G) and Safety guides and manuals issued under it provides the details regarding the system of regulatory inspection and enforcement.

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

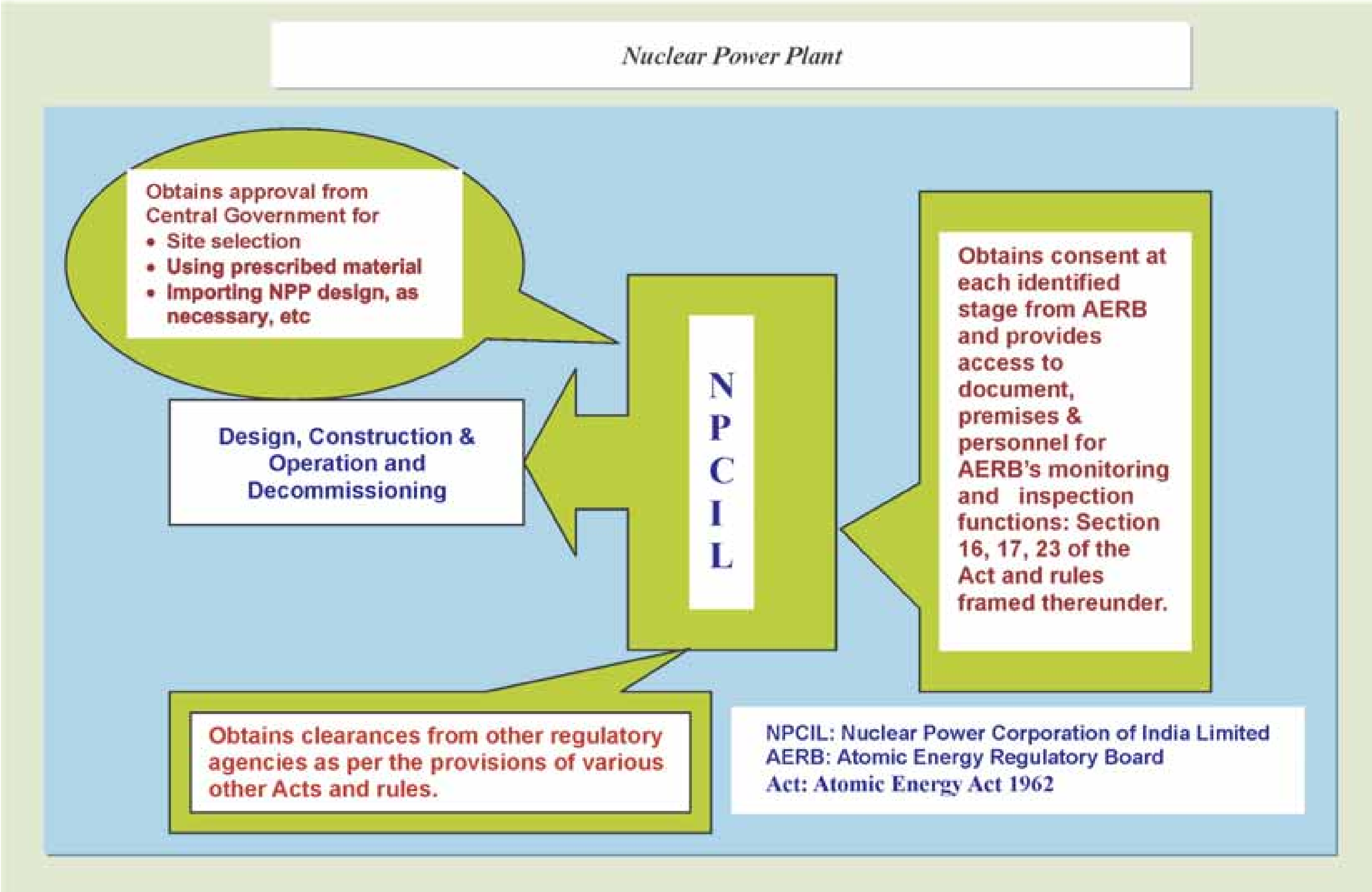
7.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

Since the inception of the atomic energy programme in the country, an elaborate legislative and regulatory framework was established. The national safety requirements pertaining to atomic energy emanate from the Atomic Energy Act 1962 & rules issued there under. This Acts and rules explicitly bring out the requirement of licensing, inspection & enforcement for the purposes of the Act. 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 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



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.

8.1 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 regards 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. For the plants and facilities managed by the constituents of Department of Atomic Energy (DAE), AERB also regulates industrial safety as per the provision of Factories Act 1948 and the Atomic Energy (Factories) Rules 1996.

8.2 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. Article 7 of this report describes provisions of these sections of the Act in detail. 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.

Deriving powers and functions specified in the gazette notification, AERB Safety Code, AERB/SC/G on “Regulation of Nuclear and Radiation Facilities” establishes the regulatory practices in the country. List of AERB guides issues under this code is given in annex 8-1. The functions & responsibilities of AERB are summarized below.

a) Develop safety policies in nuclear, radiological and industrial safety areas.

b) Develop Safety Codes, Guides and Standards for siting, design, construction, commissioning, operation and decommissioning of different types of nuclear and radiation facilities.

c) Grant consents for siting, construction commissioning, operation and decommissioning, after an appropriate safety review and assessment, for establishment of nuclear and radiation facilities.

d) 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.

e) 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.

f) Review the emergency preparedness plans for nuclear and radiation facilities and during transport of large radioactive sources, irradiated fuel and fissile material.

g) 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.

h) Take such steps as necessary to keep the public informed on major issues of radiological safety significance.

i) Promote research and development efforts in the areas of safety.

j) Maintain liaison with statutory bodies in the country as well as abroad regarding safety matters.

8.3 STRUCTURE OF REGULATORY BODY

8.3.1 The Board

The governing Board of AERB consists of a Chairman, four Members and a Secretary. While the chairman, vice-chairman and secretary are employees of AERB, the other members are part time members. 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), the apex body of the Central Government for atomic energy. The officials in the AEC include among others, some of the senior most officials from the office of the Prime Minister, the government machinery as well as eminent scientists and technocrats. The AEC in turn 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. The organisation of AERB is given in Annex 8-2 and the position of AERB in the government set up is given in Annex 8-3.

8.3.2 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 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.

8.3.3 AERB Staff

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 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
- ❖ 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 NPP
- ❖ Review of Emergency Preparedness at NPP
- ❖ Renewal of Authorisation for operation of NPP
- ❖ 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 Engineering and Structural Safety 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.

8.3.4 Technical Support

AERB constitutes advisory committee for project safety review for review and 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 Heavy Water Reactors/Prototype Fast Breeder Reactor (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), and
- 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 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 (ACCGO),
- 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. Another important resource for AERB's safety review and safety documents development work is the large cadre of retired senior experts.

8.4 HUMAN RESOURCES

The staffs of AERB mainly consist of technical & scientific experts in different aspects of nuclear and radiation technology. The fresh recruitments for technical & scientific staff are taken from Homi Bhabha National Institute (HBNI) as well as from Indian Institutes of Technology. Direct recruitment of experienced professionals is also done through open advertisement. The recruited staffs are given orientation training in AERB activities at Mumbai and on the job training in various nuclear training centres. AERB also conducts several retraining programme for its staff on a regular basis. AERB staffs participate in various courses, workshops and seminars conducted by Indian Nuclear Society and other renowned institutions for development of their expertise in their professional fields.

8.5 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 2006/07 is about 130 million rupees. This budget does not include the cost of Technical Support provided by different organizations.

8.6 SAFETY RESEARCH

A large number of safety research important to regulatory activities are carried out by BARC, the main technical support organisation. 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.

AERB also has its own Safety Research Institute (SRI) at Kalpakkam near the city of Chennai, which conducts research in the areas of nuclear, radiation, environmental, industrial and fire safety. It also organizes workshops and seminars on specific safety topics.

8.7 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 9001:2000 certifications for its activities pertaining to consenting, inspection and development of regulatory documents.

8.8 CO-OPERATION WITH INTERNATIONAL BODIES

8.8.1 International Atomic Energy Agency (IAEA)

The Atomic Energy Regulatory Board (AERB) of India has been actively participating in the activities of IAEA. The staffs of AERB participate 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. Chairman AERB also attends meetings of Commission on Safety Standards (CSS). AERB has been participating in IAEA

Coordinated Research Programme (IAEA-CRP) on topics such as Methodologies for Event Analysis and Safety Significance of Near field earthquakes.

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 and further development of INES and IRS. AERB participates in the biennial meeting of the INES national coordinators, annual meeting of IRS coordinators and IAEA-IRS advisory committee meetings.

These interactions help AERB in keeping abreast of the developments in the related fields, safety issues and the evolving safety standards. These are taken into account while developing national standards and guidelines for their implementation.

8.8.2 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. Besides India, the other countries participating in this forum are Argentina, Canada, China, Pakistan, Romania and South Korea. AERB's participation in this forum helps in understanding events and generic safety issues in CANDU reactors world over, based on which corrective actions as may be necessary are implemented in Indian NPPs.

8.8.3 United States Nuclear Regulatory Commission (USNRC)

Cooperation in nuclear safety between AERB and USNRC was resumed in February 2003. Since then eight 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 License 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.

The USNRC teams have visited some of the NPPs in India. The Indian delegation, which visited USA, also had the opportunity to visit some of the NPPs. Two officers of AERB have undergone familiarisation on risk informed decision making at USNRC.

8.8.4 Directorate General for Nuclear Safety and Radiation Protection, France

A formal cooperation between AERB and Directorate General of Nuclear Safety and Radiation Protection (DGSNR), France (erstwhile Nuclear Installation Safety Directorate (DSIN)), for exchange of information and cooperation entered in force on July 29, 1999 for a period of five years. This arrangement has been extended for further period of five years from July 29, 2004. The new arrangement also covers the cooperation in the fields of radiation protection and safety of transport of radioactive sources and materials in addition to the previously covered areas.

8.8.5 Radiation Safety Authority, Russia

AERB and the Federal Nuclear and Radiation Safety Authority of Russia entered into an agreement for cooperation in the field of safety regulation in the process of use of nuclear energy for peaceful purposes. This agreement came into force on February 15, 2003 and is valid till Kudankulam NPP begins regular operation.

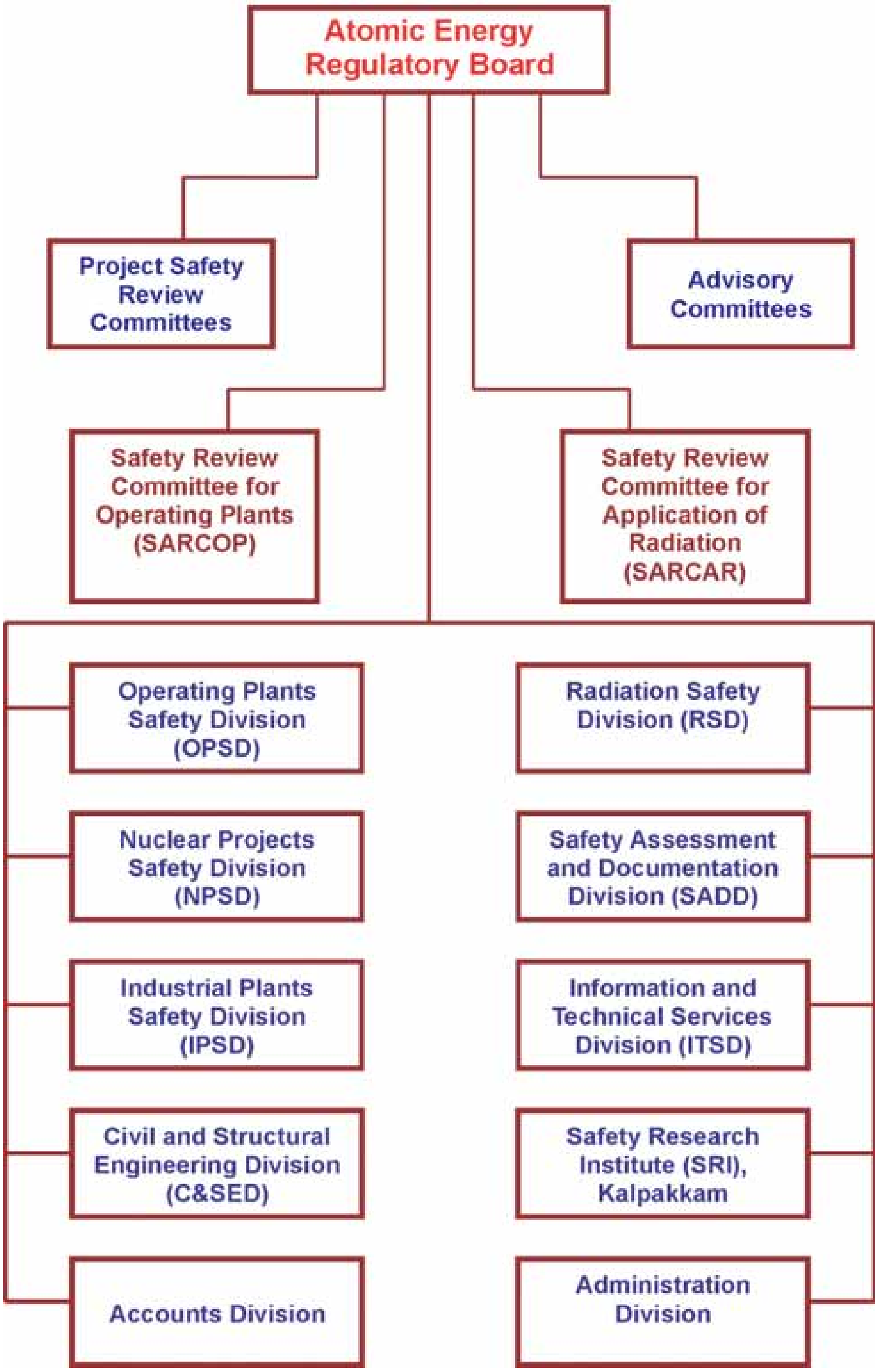
8.9 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

As atomic energy programme in India is expanding, the regulatory body also has to keep pace with this progress. 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. From the description above, it can be seen that statutory and legal provision of the Act & various rules framed thereunder 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.

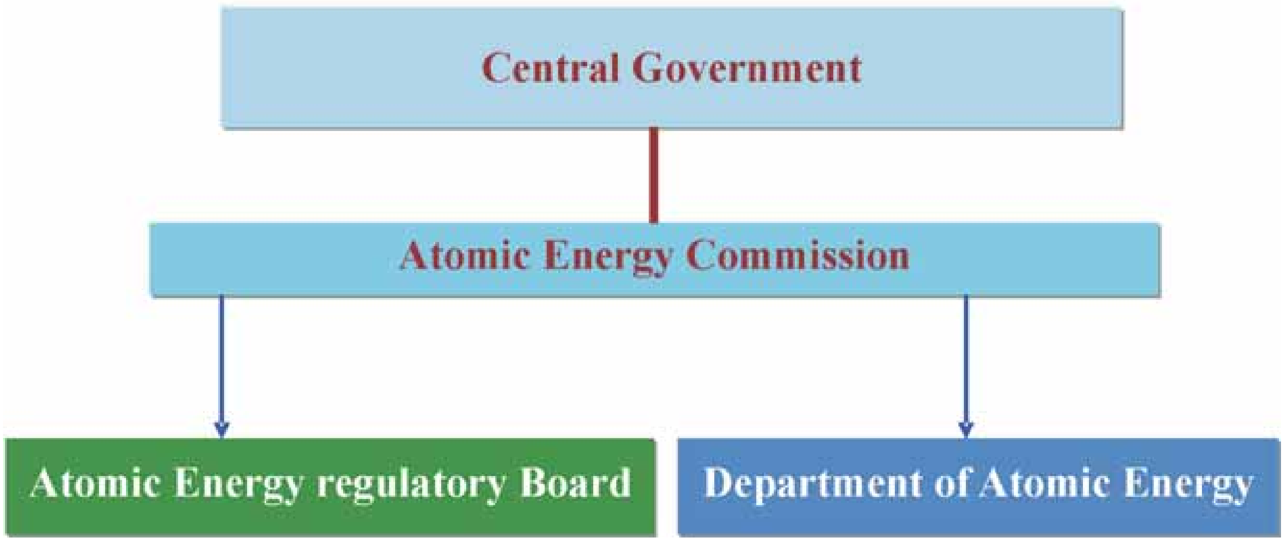
Annex 8-1: AERB Safety Guides under the Code On Regulation

Safety Series No.	Title
AERB/SC/G	Code of Practice on Regulation of nuclear and radiation facilities.
AERB/SG/G-1	Consenting Process for Nuclear Power Plants and Research Reactors: Documents Submission, Regulatory Review and Assessment of Consent Applications.
AERB/SG/G-2	Consenting Process for Nuclear Fuel Cycle and Related Industrial Facilities: Documents Submission, Regulatory Review and Assessment of Consent Applications.
AERB/SG/G-3	Consenting Process for Radiation Facilities: Documents Submission, Regulatory Review and Assessment Of Consent Applications.
AERB/SG/G-4	Regulatory Inspection and Enforcement in Nuclear and Radiation Facilities.
AERB/SG/G-5	Role of Regulatory Body with respect to Emergency Response and Preparedness at Nuclear and Radiation Facilities.
AERB/SG/G-6	Codes, Standards and Guides to be Prepared by the Regulatory Body for Nuclear and Radiation Facilities.
AERB/SG/G-7	Regulatory Consents for Nuclear and Radiation Facilities: Contents & Format
AERB/SG/G-8	Criteria for Regulation of Health and Safety of Nuclear Power Plant Personnel, the Public and the Environment

Annex 8-2: Organisation Structure of AERB



Annex 8-3: Position of Regulatory Body in Government Set up



ARTICLE-9

RESPONSIBILITY OF THE LICENSE HOLDER

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

9.1 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, 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 Central Government which 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.

NPCIL, as the responsible organisation for design, construction, operation and maintenance of NPPs, has the primary responsibility of safety. It is the responsibility of NPCIL and its constituent units to perform the assigned task as per the regulatory requirements and demonstrate to the regulatory body that the NPP operations meet all the established safety norms throughout the design life.

The Central Government established another company Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) in 2003, fully owned by it, with the objective of constructing and commissioning the first 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam in Tamilnadu and also to pursue construction, commissioning, operation and maintenance of subsequent Fast Breeder Reactors for the generation of electricity.

9.2 MAIN RESPONSIBILITIES OF THE LICENSE HOLDER

As mentioned above, the AERB/SC/G, Safety Code, on "Regulation of Nuclear and Radiation Facilities" and Safety Guides and Manuals issued under it, spell out in detail the obligations of the licensee towards safety. The major obligations and responsibilities of the license holder are summarised below.

9.2.1 The licensee is solely responsible for ensuring the safety in siting, design, construction, commissioning, operation and decommissioning of a Nuclear Power Plant (NPP)/ Research Reactor (RR) and shall demonstrate to the Regulatory body that safety is ensured at all times. For this purpose, the licensee shall establish necessary systems, procedures and organizational arrangements.

The applicant seeking a license 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 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 material false statement in the application for consent or in the supplemental or other statement of facts required of the applicant.

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

i) The licensee shall make sure that the operation of NPP is carried out according to relevant laws, regulations and condition of the license 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 thereunder and the license, 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 with full access to personnel, facilities and records that are under the control of licensee.

iv) The licensee shall keep the regulatory body fully and currently informed with respect to any significant or potentially significant events or changes in the considerations, information, assumptions, or expectations based on which the authorisation was issued.

v) The licensee shall take such corrective actions or measures as required by the Regulatory body in the interest of safety.

vi) The licensee shall not undertake any activity beyond those authorised in the license, without the prior approval of the Regulatory Body.

vii) The licensee shall report all accidents, incidents 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 important 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 properly followed.

xiii) The licensee shall make sure that radiation protection of the public and the plant personnel is according to the radiation protection regulation. Radioactive 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.

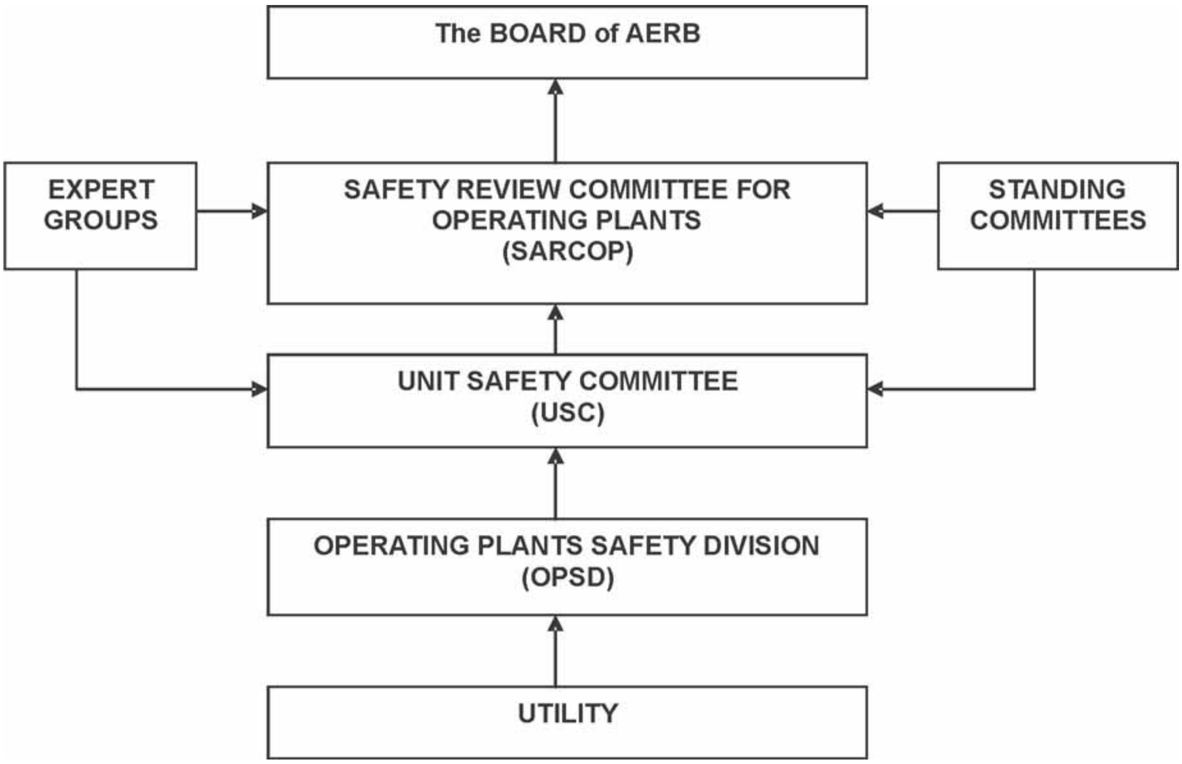
xv) The licensee shall make sure that the conditions for renewal of authorisation as prescribed by the Regulatory Body are met.

9.2.3 The NPCIL 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. 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 MECHANISM OF REGULATORY BODY FOR IMPLEMENTATION

As mentioned above, the primary responsibility for safety of NPPs rests with the licensee. The regulatory control for assurance of safety during all stages of NPPs is exercised through a system of licensing, which permits 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. For NPPs under construction as well as during operation, the AERB monitors safety and ensures compliance to 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.

AERB follows a multi tier review system of safety committees to carry out review and assessment for different stages of licensing. For operating NPPs, 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. The USC constituted for every station or a group of stations having NPPs built to the same safety standards, assists SARCOP in the review and assessment function to ensure comprehensive safety review on a regular basis. 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. 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. The Operating Plants Safety Division (OPSD) is the nodal agency within AERB for coordinating the functioning of various safety committees and synthesising their decisions. This system of safety committees function on the principle of "regulation by exception" following a graded approach and are based on safety goals, principles and requirements laid down by AERB. 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 authorisations require endorsement of the governing Board of AERB. The multi-tier review mechanism followed for an operating NPP is shown.

The membership of above committees is drawn from AERB, various national laboratories and academic institutions. In addition to above, all the committees have the representation from the licensee.

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 license 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 and assessment and regulatory inspections and enforcements are described in Section 14.3.3 of Chapter on Article 14. Similar mechanism is also established for NPP projects for exercising regulatory control.

9.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

At present, the responsibility of design, construction, operation and maintenance of NPP for producing electrical energy in a safe manner has been assigned only to Government Companies. The Safety Code, AERB/SC/G, on "Regulation of Nuclear and Radiation Facilities" clearly assigns the primary responsibility of safety to the license 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.

10.1 GENERAL

The Atomic Energy Regulatory Board (AERB), the regulatory body and the utility, Nuclear Power Corporation of India Ltd (NPCIL) have a stated formal policy, which emphasises priority to safety in all their activities. Adherence to this policy nurtures and maintains the safety culture developed over years of experience.

10.2 PRINCIPLES EMPHASIZING THE OVERRIDING PRIORITY

AERB, the licensing authority for all NPPs in India, carries out a multi-tier review for the new and operating NPPs through safety committees. The activities of siting, design, construction, commissioning and related regulatory authorisations follow procedures and policies prioritising safety. In addition, the operation of all NPPs is subjected to periodic regulatory inspections by AERB.

Nuclear Power Corporation of India Limited, the utility responsible for design, procurement of manufactured equipment and components, construction, commissioning and operation of NPPs in India, carries out its function with a commitment to safety and regulatory requirements. Well-established safety principles and procedures are adhered to by NPCIL to give priority to safety in all its activities. Priority to safety is embedded in the corporate mission statement of NPCIL and each NPP site 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 NPCIL too follow the safety and QA norms of NPCIL. NPCIL has management systems in place to ensure that safety is accorded priority in its activities.

10.3 SAFETY POLICIES

The NPPs in India are designed, constructed, operated and maintained by Nuclear Power Corporation of India Limited (NPCIL). It has issued its safety policy in October 1996 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, HQI-7003. Each NPP ensures that their work place is safe and their employees (departmental and contractors) adopt safe working procedures. Individual unit also ensures that they have effective on-site and off-site emergency plans, which are implemented and rehearsed so that in the unlikely event of any accident, the impact on the public and environment is minimized. Some of the important activities of implementation of safety policies are –

- Setting up of targets of 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 been awarded with ISO-14001 and ISO18001 for their Environment Management System. Similarly, the Quality Assurance (QA) Directorate and Engineering Directorate of NPCIL have been awarded with ISO-9001 for Quality Assurance and Design respectively. As a part of this International Standardisation, both these Directorates have issued policies, which have a strong bearing on safety of NPPs.

10.4 PRINCIPLES DIRECTLY RELATED TO SAFETY

10.4.1 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 referred as the primary bases for NPCIL to derive the details of principles, practices and policies for design and operation of Nuclear Power Plants. These Codes, Guides and Standards have evolved over years based on similar documents issued by IAEA, other regulatory body and Indian experience.

The broad concepts of

- Defence-in-Depth in design and operation and
- ALARA with respect to Radiation exposure during normal plant operation

are the main guiding principles followed in design and operation of plants.

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

10.4.2 Design Safety Principles

In general the following safety principles are adhered to:

(i) Defence in Depth Principle

- The defence in depth is implemented to provide a graded protection against a large variety of transients, incidents and accidents, including equipment failures and human error within the plant and events initiated outside the plant.
- AERB Guides are used for the detailed design. Various National and International codes and guides are also referred. The emphasis throughout is to produce a robust design having sufficient safety margins so as to perform safely under all normal operating conditions throughout the design life. Strict control is exercised during the manufacturing and commissioning processes to assure the reproduction of intended design.
- Systems e.g. the control, setback and step back and procedures are in place to detect abnormal conditions and controlling them so as to minimize deviation from normal operation.
- Safety systems and Engineered Safety Features are provided to mitigate the consequences of accidents within design basis e.g. Shutdown systems, ECCS, Containment and associated engineered safety features etc.
- Procedures to implement counter measures in public domain in case of offsite release of radioactivity are available, refer Article 16 for details.

(ii) Safety systems are designed with adequate redundancy and diversity to achieve specified reliability target. The equipment which is required to operate during the accidents is environmentally qualified.

(iii) Fail-safe design is adopted for system important to safety. These systems are routinely tested and safety systems have provisions to test them on power.

(iv) Physical and functional separation is provided to avoid failure due to common cause.

(v) Systems are seismically designed in accordance with their safety requirements.

(vi) The system design incorporates feedback from the operating stations

(vii) Safety Systems are subjected to a number of commissioning tests to check and confirm design robustness.

Safety Analysis

A comprehensive safety analysis by rigorous deterministic and complementary probabilistic methods is carried out. The objective is to identify and evaluate all possible sources of radiation exposure for workers and the public through

- Normal operational modes of plant
- During anticipated operational occurrences

- During design bases accidents
- During combination of events leading to beyond design base scenarios

The analysis while establishing adequacy of the design of safety systems, also provides an independent means of checking that all features mentioned above are provided as required. The safety analysis also, at times, provides input to iterate the design and make further improvements.

10.4.3 Design Procedure

All through the process of design, manufacturing, construction and commissioning the QA systems (refer Article 13 for details) 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 certified. A thorough systematic approach and culture is followed in the design, review and approval.

(ii) Design criteria defined in the different design documents are reviewed and approved by AERB. The design criteria also take into account feedback from the operating experience. The design is based on National and International Codes and Guides.

(iii) The detail 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 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.

10.4.5 Operational Safety Principles

The requirements for safety in operation of the Nuclear power plants are covered in Article 19. They ensure that the safety margins are not exceeded during any disturbance in the plant. The safety policies, the safety culture and the operating good practices followed 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 and approved by AERB for normal operation and special maintenance campaigns.

(v) Equipments, 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 Safety Committee 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 independent periodic report to AERB. (refer Article 15 for details).

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 condition in Technical Specification is not met.

The QA groups at station and the Audit Engineer are two independent channels available to the station management to obtain feedback on maintenance and operation 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.

10.4.6 Operation Safety Procedures

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

(i) The normal plant operation is governed by Technical Specifications for operation, which is approved by AERB. In addition, protection system actuation set points are defined through Limiting Safety System Settings (LSSS). The set points for protection system actuation are tested as per frequency defined in Technical Specification of Operation. The safety limits, Limiting Condition of Operation (LCOs) 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 drills as part of preparedness and also include provisions for implementing counter measures in public domain.

10.5 SAFETY PRINCIPLES OF THE REGULATORY BODY

AERB is entrusted with the responsibility for regulating activities related to safety in nuclear power generation, nuclear fuel cycle facilities and industrial & medical uses of radiation according to the Atomic Energy Act 1962 and rules promulgated under it 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.. For the plants and facilities managed by the constituents of Department of Atomic Energy (DAE), AERB also regulates industrial safety as per the provision of Factories Act 1948 and the Atomic Energy (Factories) Rules 2000.

The safety principles followed by the Regulatory Body are as follows:

i. AERB permits activities according to the mandate given to it, through a system of licensing and stipulates and enforces the conditions of license.

ii. While AERB considers standards and recommendations of international organisations and the best practices of other countries, it takes into account the Indian conditions for developing safety standards and requirements for the country.

iii. AERB encourages compliance to safety guides but accepts other approaches if safety objectives and requirements can be met.

iv. AERB 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. AERB encourages self-regulation by the licensee.

vi. AERB considers licensee as a partner in safety and extends all necessary assistance in the interest of safety, where appropriate, through concurrent regulation.

vii. AERB encourages participation of licensee in the regulatory process.

viii. AERB conducts periodic inspections and channels its resources according to the safety performance of the licensee.

ix. AERB encourages licensee to achieve high level of safety culture.

x. AERB learns from the experience feedback and adapts to improve its functioning and effectiveness.

xi. AERB conducts its activities in a transparent manner.

10.6 SAFETY CULTURE AND ITS DEVELOPMENT

Based on guidelines of IAEA, a considerable amount of work has been carried out at Indian NPPs on assessment and enhancement of safety culture. The programmes included organisation of ASCOT (Assessment of Safety Culture Organisation Team) seminar in 1994 and an Executive Workshop on 'QA Implementation & Safety Culture' in 1996, with the help of IAEA. Many such similar programmes were subsequently organised by the participants of these workshops from safety culture point of view using guidelines provided during IAEA's ASCOT seminar.

In order to develop a strong safety culture in a systematic way an internal document called Head Quarter Instruction (HQI-7006) entitled 'Guidelines for developing strong safety culture' was issued by NPCIL in 1997. 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.

<u>Voluntary Activities and Good Practices</u>: Various methodologies are being used for enhancement of safety culture and these include –

- Brain storming sessions for identifying areas requiring attention to enhance safety culture.
- Conducting training programmes on Human Resource Development (HRD) like –
  - Team Building Workshops
  - Leadership Development
  - Improving Inter Personnel Relationship

  - Arranging programmes for inculcating Indian yogic and meditation approaches like Vipasana, Siddha-Samadhi-Yoga
  - Introducing system on Behaviour Based Safety Management
- WANO peer reviews have already been conducted at all Indian plants. Participation in many training courses and meetings conducted by WANO help inculcate good practices.

10.7 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 the Utility have stated safety policies that give utmost priority to nuclear safety. 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.**

11.1 GENERAL

11.1.1 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 incorporated in September 1987 by converting the erstwhile Nuclear Power Board, a Central Government department, which was responsible for setting up Nuclear Power Plants (NPPs) within India 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 Governmental unit, being operated by NPCIL on behalf of the Government. The main objective of the company has been to produce electricity using nuclear fuel resources.

Prior to the formation of NPCIL, NPPs under construction and operation were fully funded by Government of India. The formation of NPCIL was necessitated by the need to ensure 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 $ 2254 Million (Rs. 101450 Million). The company has reserves in excess of about US $ 2222 Million (Rs.100000 Million). The gross block of the Company at its inception [comprising TAPS 1&2, RAPS – 2 and MAPS 1&2, totalling 960 MWe] was only US $ 99. 6 Million (Rs. 4480 Million) which has now grown to [3360 MWe] about US $ 2814 Million (Rs. 126620 Million) as on end March 2006. 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. Adequate financial discipline and prudence are exercised in borrowing money from the market apart from implementing steps to reduce the gestation periods of the projects 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 any 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.

11.1.2 In the Indian context, availability of qualified and trained manpower for the nuclear power programme has been one of the greatest strengths. 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 (NTC) 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 formed the basic educational infrastructure from which engineering/science graduate, technicians and skilled tradesmen were recruited and subsequently trained to suit the job needs. When erstwhile Nuclear Power Board was converted to NPCIL, it had the advantage of having the qualified, trained and experienced manpower in its different units and also autonomy for subsequent augmentation of manpower/ training infrastructure and reorientation of the training and qualification programmes. The number of Nuclear Training centres increased to six and started working as affiliates to the BARC Training School. Networking with the Indian Institutes of technology was strengthened and post-graduate courses in nuclear engineering started at IIT-Kanpur and Mumbai. Sponsored post-graduate programs called 'DAE Graduate Fellowship Scheme' was started at all the IITs. A deemed university 'Homi Bhabha National Institute' has been established under DAE for pursuing post-graduation and Ph.D 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 of NPCIL have participated in several international training programmes conducted by the International Atomic Energy Agency (IAEA) and other organisation to further enrich their capabilities.

11.2 FINANCIAL RESOURCES

11.2.1 Operation and Maintenance

NPCIL, as the owner of nuclear power plants 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) throughout the life of plant. As already mentioned, it also ensures the financial closure of the projects under construction

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, given below:

i) Return on Equity

ii) Interest on debt capital

iii) Depreciation

iv) Fuel consumption charges

v) Heavy Water lease charge

vi) Provision for decommissioning

vii) Operation and maintenance cost

NPCIL sells its electricity to 21 State Electricity Boards/ distribution companies primarily located in Northern, Western, 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 97% of the payments are received during the subsequent billing month.

The Operation and Maintenance (O&M) expenditure for each station is budgeted every year and is being funded by internal resources generated by the NPCIL every year. In addition, whenever it is necessary to finance any major works in the NPPs in operation, the resources through borrowings or budgetary support as appropriate are deployed. Since the tariff is similar to the principle of cost plus basis, O&M expenditures are covered through tariff in addition to 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 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.

11.2.2 Renovation and Modernization (R & M)

These activities about NPPs in operation are of two types. The first is involving 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. This is covered by the tariff as part of O&M expenditure. The second type is of a major nature. This 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. The details in this regard are described in 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 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 the committed reserve account with the objective that this would be used for undertaking the R&M activities only. This in combination with other financial resources was deployed for carrying out these activities. 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.

Since a number of NPPs are being operated and owned by NPCIL, apart from financial control exercised by individual NPP Management, a holistic analysis on expenditure and resource mobilization in regard to all the units in operation takes place at the NPCIL Corporate Office by proper financial planning, monitoring and resource mobilization.

11.2.3 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, assessment and regulatory review, better materials and equipment, the reactors can now operate safely for much longer periods of 40 to 60 years.

Out of the 17 operating nuclear power reactors, the two boiling water reactors at Tarapur are the oldest. They were commissioned in the year 1969. As already explained in Article-6, these reactors have been progressively retrofitted with the evolving international safety requirements and have recently been authorized, after suitable life extension measures by AERB to operate for another five years. After future regulatory reviews, further extensions are foreseen for extended periods considering the performance and health of this station.

Similarly, the older generation Pressurised Heavy Water Reactors have been undergoing renovation and modernization programmes. In this connection, En-masse Coolant Channel Replacement (EMCCR) and necessary safety up-gradations of RAPS-2, MAPS-1&2 have been completed. With the reactors now employing pressure tubes made of zirconium niobium alloy, it is expected that these reactors would give a further service life of about 25 years.

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.

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.

11.3 HUMAN RESOURCES

11.3.1 Sources and Induction

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 December 2006 was 11987 out of which 8911 belong to technical and scientific cadre. NPCIL recruits technical manpower through Bhabha Atomic Research Centre, a premier institute for training in nuclear science and technology. NPCIL's technical manpower includes engineering graduates from various Indian Institutes of Technology and other 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 have to undergo licensing/ qualification examination before they are actually assigned the higher responsibility. The licensing scheme of the operating staff is as per AERB requirement. NPCIL also carry out recruitment for specialized vacancies through open market. 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 2 year Industrial Training after High School conducted by Industrial Trade Institutes are other levels of recruitment.

NPCIL has six Nuclear Training Centres and two Station Training Centres, where engineers and workmen are trained. NPCIL has also full-scope training simulators at RAPS, Kaiga and Tarapur. Soft panel based Fuel Handling Training simulators are under development at NTC-RAPS and NTC-TAPS-3&4. These training simulators provide valuable training to the operating personnel at different types and levels. NPCIL has regular training at three levels i.e. Induction training, re-training and refresher training. The details in this regard are explained in greater detail in subsequent section "Qualification, training and re-training of personnel" of this Article.

DAE/NPCIL follows merit promotion policy for its technical personnel that provide excellent career growth opportunities to the deserving candidates. 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 the independent NPP based on requirement.

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 is in position prior to start-up of the unit.

AERB Safety manual on decommissioning of Nuclear Facilities (AERB/SM/DECOM-1) has specified requirements of safety provisions during the entire sequence of de-commissioning. Depending upon the sequence of activities, the manpower requirement for the de-commissioning activities would be finalized. While the core human resource for decommissioning would come from the experienced manpower available at the plant itself, this would be supplemented by human resources generated through fresh recruitment of experienced persons as well as by out sourcing through experienced contracting companies. NPCIL has a full-fledged Research & Development Directorate, which is working on these aspects and is expected to provide, with the help of Indian industry, the necessary technologies and tools needed for de-commissioning.

11.3.2 Qualification, training and re-training of personnel

(A) Regulatory Code/Guide

AERB safety Code, AERB/SC/O, on 'Safety in Nuclear Power Plant in Operation' and AERB Safety Guide, AERB/SG/O-1 on 'Staffing Recruitment, Training, Qualification & Certification of Operating Personnel of NPPs' bring out the necessary regulatory requirements.

(B) Licensing and qualification

B.1 Levels

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 as shown in Figure 11.2. Positions requiring certification for licensing are control room operations personnel (levels I, II, III) and those operations personnel normally working in field (levels IV, V). These are depicted in Figure 11.2 as applicable for main plant operation as well as fuel handling operation.

B.2 Certification for licensing / qualification

It involves verification of knowledge in two stages, i.e. entry-level stage and certification / licensing stage

B.2.1 Entry Level Stage

This involves verification of completion of entry-level competency requirement to enter certification stage of licensing / qualification. The following entry-level requirements are to be fulfilled by the candidates for acquiring license/qualification at appropriate levels:

(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 PHWR fundamentals, a typical station specific equipment and system knowledge, and training towards 'nuclear and industrial' safety, radiation protection, radiation emergency preparedness and work controls.

(iii) Authorisation based Training:-

A candidate for acquiring license at level III and qualification at level IV is required to complete the authorisation based training programs such as Radiation Protection Training -Green Dot qualification, Standard Protection Code (SPC) and Electrical Authorisation (as applicable) before taking up final certification examinations.

(iv) Management Training:-

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 related to 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.

(v) On Job Training (OJT):-

Experience and Checklist Programmes are structured and guided with the help of task-based checklists. 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 license at level-III should have acquired minimum of three months of Control Room Experience under supervision after completion of eighteen month OJT and participated in at least one Start Up / Shut Down activity at the plant.

(vi) Simulator Training: -

Simulator training mainly provide experiential learning of Control Room Operation knowledge, skills and attitude in a structured way as per the lesson plans based on the approved guidelines for 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 In the absence of plant simulator for the plant under consideration, the requirement of simulator training is met by providing training at a simulator (referred as 'non plant reference' (NPR) simulator), located at a plant having similar design.

B.2.2 Licensing / Certification Stage

This calls for verification through conduct of centralized licensing examinations under NPCIL Corporate Office control for Level-III and II for Main plant / Fuel Handling (FH) operation personnel and walkthrough 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. The details of certification requirements are as given under:

(i) First License/Qualification applicable for a position

- Written Examination Procedure: -

  A candidate has to satisfy all the entry-level requirements as detailed above The Directorate of Operation, in the NPCIL Corporate Office conducts the written examination for levels III & II.

- Walkthrough:-

  The walkthrough test is to be conducted when a candidate has qualified in all the applicable written examinations and is applicable for Level-II, III, IV and V only. 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. The passing marks for the walkthrough test are minimum of 70%.

- Medical Fitness: -

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

- 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.

(ii) Re-Qualification Process

A license/ qualification is valid for three years. A candidate needs to be re-licensed/ re-qualified before the last date of validity of the license/ qualification. A person licensed for a particular position can be re-licensed to the same position provided he meets the pre-requisites 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.

(iv) 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 license. 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.

B.2.3. Senior Management Certification

Senior Management Certification is covered under specific instructions issued by NPCIL for meeting the regulatory requirements.

The aim of this certification is to assess candidates through written examinations and interviews for their technical knowledge and overview of safety management. AERB certifies the successful candidate after a final assessment interview conducted by its committee.

B.2.4. Quality Management:

The procedure incorporates various good practices and is subjected to audit by NPCIL Corporate Office as well as by AERB appointed licensing committee for verification of adherence to the procedures. For each training & qualification related activity, NPCIL has developed standards / guidelines so as to enable evaluation of the achievements against the required standards. 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 Tradesmen, 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 are equipped with necessary infrastructures for implementing the courses as per approved syllabi. Based on Job-Task-Analysis, tasks for each position have been defined and a performance-focused checklist against each task developed for effective assessment of On-Job-training. Plant managers also have to acquire Management Certification based on AERB approved guidelines. The licensing procedure which is governing documents provides various standards including the methodology to deal with the exceptions, assumptions etc. The checklists are always kept current through periodic revision.

The Corporate Training group is responsible for ensuring uniform standards of training at each training centre by developing guidelines for orientation training programme. It also develops authorisation-based documents such as SPC and Electrical Authorisation. For ensuring uniform standards of assessment, licensing examinations are coordinated by Corporate Training group.

C. Training Infrastructure

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 standardized 220 MWe reactors and cater to the requirements of all the other 220 MWe PHWRs. The fourth located at Tarapur, is based on the design of 540 MWe PHWR TAPP-3&4. With these four simulators, NPCIL is able to provide simulator training to all the operating personnel working in PHWR 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.

D. Use of Training Infrastructures for qualification, training & re-training

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

E. Simulator based training

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

F. Other standard and special training programme

NPCIL have hosted special training programme for experienced operation engineers conducted by international organizations 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.

G. Human resources for training deployed through experienced hands

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

H. Policy of rotation

By ensuring the maintenance of license and qualification of personnel deployed in Technical Services, Training and Quality Assurance sections their rotations have become feasible.

11.4 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

From the foregoing sections presented 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 has 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 GENERAL

AERB Code of Practice on Design for Safety in PHWR based NPPs, AERB/SC/D 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 Safety Guides issued under the Code namely AERB /SG/D-20 on Safety Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants, AERB/SG/D-12 on Radiation Protection in Design and AERB/SG/D-17 on Design for In-Service Inspection, provide guidance for designing for optimum human performance.

Principles of defence-in-depth, redundancy, diversity are the underlying considerations for design of nuclear power plants. It is well recognized that organizational factors have a major impact on the behaviour of individuals and therefore are an indicator of performance in safety issues. Overall Human error free performance is an indicator of the prevailing safety culture of an organization. Globally the nuclear industry has made continued efforts in minimizing events due to human factors to ensure safe and reliable operation of its Nuclear Power Plants (NPPs). It has formulated various methods to detect, correct and prevent human errors in all stages of NPP activities.

12.2 METHODS TO PREVENT, DETECT AND CORRECT HUMAN ERRORS

Design

The design of systems, structures and components and the plant layout is carried out with applicable codes and guides as stipulated by regulatory body and prevalent international practices and 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. Interlocks and automatic actions are so designed that only those actions are required to be taken by the operator where adequate time is available for taking necessary action. The control panels are ergonomically designed and the working areas and working environment of the site are designed with due consideration being given providing personnel comfort.

Actions requiring early response following an event are automated. PSA insights are used to identify situations where human error could have significant contribution to CDF.

Role of Full Scope Simulators and 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, control room team building, to minimize probable errors due to human factors. In house test facilities are set up to test equipment off line prior to their use in live systems. Additionally, performance based training, need based training, manufacturers training etc are imparted to reinforce error free maintenance. Training sessions relevant to human performance are also organized at different plants in coordination with international organisations like WANO.

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 operation persons are qualified 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.

Event Analysis

An Event reporting system is adopted and maintained to report events of varied significance to bring out underlying weaknesses in the system arising out of latent contributing factors. All the events including low-level events are reported and analysed at various levels in NPCIL. The Significant Event Reports are also reviewed in AERB. All these reviews involve analysis of human performance during the event. The lessons learnt and corrective actions taken are disseminated through an operating experience feedback system. The low level events, which are large in numbers, are monitored and trended at corporate level for identifying latent weaknesses. The remedial measures are implemented by way of design modifications, procedural changes or through specific training modules to avoid the recurrence of such events.

Maintenance Performance

Performance monitoring of maintenance activities with respect to the human factors are 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. 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 MANAGERIAL AND ORGANISATIONAL ISSUES

NPPs in India are generally located in the remote areas, away from big population centres. NPCIL has developed infrastructure facilities at all NPP sites, which include residential accommodation, educational institutions, hospitals and recreation centres for its employees.

A system of six crews operating personnel has been established. Out of these, four crews rotate in eight hours shift, one crew remains under training and re-qualification and remaining one crew supports the shift operation for relieving purposes.

The above measures provide the operating personnel a stress free work environment leading to improved human performance.

12.4 ROLE OF REGULATORS

AERB has specified the requirement for addressing aspects relating to human performance in the design of NPPs. During the consenting stage of construction and commissioning, 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. Review of events, design modifications for systems important to safety, operational performance, radiological performance, waste discharges and impact on environment are some of the important areas of safety monitoring. The regulatory body considers human factor contribution in these areas as one of the indicators for safety culture at the NPPs.

12.5 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 GENERAL

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 for Safety in Nuclear Power Plants (NPPs)' establishes 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 this Code provides 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.

A formalised system of Quality Assurance was established and implemented in the Nuclear Power Corporation of India Limited (NPCIL), the utility organisation, with the formulation and issue of the "Topical Quality Assurance Document" at the corporate level in 1993 in line with the requirements specified in the AERB documents. This document detailed the quality assurance measures to be implemented at NPPs covering areas of quality, safety and reliability during design, construction, commissioning and operation of NPPs.

In the year 2006, the NPCIL in consultation of the AERB, revised the Topical Quality Assurance document in line with IAEA Safety Standard GS-G-3.1 on "Application of Management System for Facilities and Activities". The revised document on "Corporate Management System - Quality Management System Requirements" has emphasis on integrated approach for the management system for Safety, Health, Environment, Security, Quality and Economic requirements.

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

13.2 QUALITY ASSURANCE POLICIES

13.2.1 Organisational Policies

The Head of the Utility has defined the "Statement of Policy and Authority" for the Organisation. In the said statement, it has directed 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 fully 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 Quality Management System elaborated in the "Corporate Management System Document-Quality Management System Requirements" of the Utility ensures implementation of the applicable AERB and IAEA Codes of Practices, Standards and guidelines on QA for safety in NPPs. 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.

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 with clarity the characteristics of the processes and activities, their complexity and interactions.

The documentation is categorised into three levels based on priorities and sequenced networking of processes.

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 involved in various phases of NPPs, activities of those managing, performing and assessing the work with the processes, individuals, technology and the organisation aiming at successful product and realisation of the objective.

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.

   Quality Management/Assurance System Manuals, Procedures, Instructions and Practices, to the extent, they are relevant in meeting the Utility Corporate Management System Programme.

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, enabling them to base their inputs and decisions. 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 and 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, stakeholder's 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 levels.

13.3.2 Quality Assurance in Design

Engineering Directorate is responsible for design, development and engineering activities undertaken in the Utility. Designs 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 "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 NPP Construction site Head 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 only 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 station 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 QA 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.

A system of planned and documented audit 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 organizations of suppliers and sub-suppliers.

The Utility has also obtained ISO-14001, ISO-18000 certification for some operating stations and ISO 9001 certification for its various wings.

13.5 REGULATORY 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.

13.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The comprehensive Quality Management System (QMS) in the NPCIL organizations 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.

14.1 GENERAL

The assessment and verification of safety is an integral part of the regulatory review system. AERB Safety Code, AERB/SC/G, on "Regulation of Nuclear and Radiation Facilities" spells out in detail the obligations of the licensee and the responsibilities of the Regulatory body. In India, a multi tier review by system of safety committees is followed for carrying out regulatory review and assessment during all the stages of consenting.

The prime responsibility for safety rests with the licensee, NPCIL, which as the utility organisation gives the utmost importance to its own assessment and verification functions. NPCIL carries out the assessment and verification functions during design, manufacturing, construction, commissioning and operation with several of its agencies such as Directorates of Engineering, Safety, Projects and Operation. A separate corporate level safety review committee reviews all issues including the results of assessment and verification of safety. All the information generated during the entire design, construction and commissioning phases are documented and handed over to the Plant management before the commencement of reactor operation.

During reactor operations, AERB establishes its programme of regular safety monitoring and periodic assessment to ensure that NPP continues to be capable of safe operation at the power levels authorised for the plant within the operational limits and conditions and that the utility programmes are adequate for the verification of the same.

14.2 NPP PROJECTS

14.2.1 Licensing process

AERB Safety Guide AERB/SG/G-1 on "Consenting Process for Nuclear Power Plant and Research Reactor: Document Submissions, Regulatory Review and Assessment of Consent Applications" explains the entire licensing process followed in India. Assurance of safety during various stages of NPP is derived primarily through regulatory actions, which include granting of license for a given activity. The license is an official document issued in response to an application submitted by the utility in a prescribed format, which (a) permits a specified activity or set of activities dealing with the siting, construction, commissioning, operation or decommissioning of a nuclear power plant and (b) prescribes requirements and conditions governing the performance of these activities.

These licenses are issued by AERB on the basis of its review and assessment. Compliance to the regulatory requirements is monitored by conducting periodic regulatory inspections. The regulatory inspections of NPPs are carried out as necessary during all stages of licensing to verify and ensure compliance to the regulatory requirements. Typically, these inspections are carried out at a frequency of four inspections in a year during construction and commissioning stages.

Major stages identified for authorisation for an NPP are Siting, Construction, Commissioning and Operation. The following sections briefly describe the safety review process and review and assessment, during different stages of licensing.

14.2.2 Safety Review Mechanism

As mentioned earlier, the AERB adopts a multi-tier review process for safety review and assessment of NPP. The first level of review and assessment is performed by Site evaluation Committee (SEC), Project Design Safety Committee (PDSC)/Specialist Groups OR Civil Engineering Safety Committee (CESC), as appropriate. These Committees as a body 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. This advisory committee reviews the application for authorisation together with the recommendations of first level committees on the related authorisation and offers its own recommendations to the AERB. After considering the recommendations of ACPSR and the first level committee, the Board of AERB decides on the authorisation. Annexes 14-1 to 14-4 explain the review process followed during siting, construction, commissioning and operation stages.

14.2.3 Safety Review for Siting

The authorisation at the first major stage namely Siting, involves the review of the various site related safety aspects considering the conceptual design and issuance of an authorisation for the site for locating the project. This requires on the part of the applicant, submission of a Site Evaluation Report (SER), which should include the salient features of the proposed site, site characteristics affecting safety and Basic Design Information of the proposed NPP. The SER 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 suitable 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 external events (natural and man 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.

14.2.4 Safety Review for Construction

The authorisation at the second major stage namely Construction, involves the review of the design safety aspects and issuance of a construction authorisation. 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, the construction schedule and the construction methodology document for the proposed NPP. As a supplement to PSAR, separate design basis reports (DBR) and design reports (DR) of items important to safety, having relevance to construction authorisation, should be progressively made available for review before authorisation for construction is issued. AERB also reviews various 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 authorisation for construction as an 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 authorisation for construction is issued in these clearance stages, PSAR reviews are organized according to the specified requirement for these clearance stages.

For construction authorisation, the plant design is reviewed to assess whether the plant can be built to operate safely. This includes assessment of compatibility of the design with the site. The Quality Assurance (QA) program and QA organization of the utility are reviewed against the requirements of AERB Code of Practice for Quality Assurance.

14.2.5 Safety Review for Commissioning

Commissioning activities in NPP are initiated in parallel to 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 authorisation 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. 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. The authorisation for Commissioning is given in several interim stages as deemed necessary by the Regulatory body. 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 regulatory body, as per the conditions of license.

For commissioning authorisation, 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 the Regulatory body 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 and Equipment Qualification

(d) Re-training program for operating personnel

14.2.6 Review for initial authorisation for operation

The authorisation for the fourth major stage, "Authorisation for Operation", is needed for regular operations at power levels up to rated power. The authorisation is granted after review of NPP performance at rated power within the commissioning authorisation. The period for power operation within the commissioning authorisation is normally limited to 100 days. During this period, specified tests are conducted to confirm behaviour of the plant as per design. To obtain, the authorisation 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 authorisation for routine 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.

14.3 OPERATING NPPs

"Code of practice on safety in nuclear power plant operation", AERB/SC/O 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. According to these requirements, an elaborate verification programme is established at NPPs and the adequacy of the programme is periodically monitored. AERB exercises regulatory control over the nuclear power plants following a system of safety monitoring, inspection and enforcement and periodic assessment for renewal of authorisation. The following sections briefly describe the review process, verification programme at NPPs, regulatory control during operation and periodic renewal of authorisation for operation.

14.3.1 Review Process

In general, a multi-tier approach involving review at three levels Unit Safety Committee (USC), Safety Review Committee for Operating Plants (SARCOP) and Board of AERB is adopted. The system of safety committees function on the principle of "management by exception" following a graded approach. Safety issues of greater significance are given consideration in higher-level safety committees for resolution. The decisions 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.

The first tier of safety review is carried out by the 'Unit Safety Committee' consisting of representatives from AERB & NPP under review and the experts in various aspects of nuclear technology drawn from different institutions. The second-tier of safety review of Indian NPPs is by SARCOP, which is the apex body to decide on the matters of nuclear safety pertaining to NPPs. The third-tier is the Board of AERB, which based on the recommendations of SARCOP, considers the major safety issues pertaining to NPPs. Chairman, SARCOP is also the ex-offcio member of the Board of AERB. Annex 14-5 gives the aspects of safety review during operation of NPP.

14.3.2 Safety Verification Programmes

As per the regulatory requirements, the operating organisation is required to put in place several programmes with respect to plant life management, before authorisation is issued to a Nuclear Power Plant. These include:

a) <u>Maintenance Programme</u> - The maintenance programme is put in place to ensure that (i) Safety Status of the Plant is not adversely affected due to aging, 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. This schedule is modified based on operating experience. In addition, a computer based system for trend monitoring the important parameters of rotary equipment is used for predictive maintenance. The preventive maintenance includes daily surveillance and verification, periodic preventive maintenance and predictive maintenance.

b) <u>Surveillance Programme</u> - 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).

c) <u>In-service Inspection Programme</u> - 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) <u>Performance Review Programme</u> - 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 incidences 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) <u>Establishment of programme related to life management</u> - This programme is used to obtain information on behaviour of the components, as identified for ageing management purpose, under reactor environment and to undertake necessary studies/ experiments with respect to their residual life assessment. The utility has to demonstrate that the required resources and infrastructure for this activity is being provided.

f) <u>Programme to update Probabilistic Safety Assessment-</u> 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.

14.3.3 Regulatory Control

14.3.3.1 Review and Assessment

Authorisation for operation is issued by AERB for a specified period. During this period, the operational NPPs undergo routine and special safety reviews. In general, the following elements are covered for reviews and assessment for appraisal of safety in NPPs, within the authorisation period.

a. Review of periodic reports submitted by the plant as per reporting criteria specified in the authorisation for operation.

b. Review of off-normal occurrences of safety significance

c. Training and qualification of operating staff

d. Radiological safety status

e. Management of radioactive waste

f. Review of proposals for modification in hardware, control logics, plant configuration and procedures

g. Report of planned long outages for carrying out surveillance, in-service inspection and major maintenance.

h. Reports of Special Investigation Committees and/or special regulatory inspections following an event of major safety significance

In addition to the above, special reviews are also 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.

Radiation and environment safety

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.

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.

Emergency Preparedness

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

Reports to AERB

The technical specification for operation identifies various types of events, which are reportable to AERB as Significant Event Report (SER). Such events are reported to AERB within the 24 hours of occurrence and a detailed report in the prescribed format is submitted within 20 days time. AERB also obtains various reports from the Nuclear Power Stations such as Station Monthly Performance Report, Station Annual Report, ISI report, etc.

Design modification

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.

Licensing of operating personnel

The Technical Specification identifies the qualification levels for operating staff and the management. The curricula of different licensing staff 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. The license is generally valid for three years after which the candidate undergoes a retraining exercise and again appears before the appropriate AERB Committees.

14.3.3.2 Regulatory Inspection and Enforcement

Depending upon the requirements, AERB staffs carry out periodic regulatory inspections as well as special unannounced inspection. These inspections are carried out periodically by a group of experts from within AERB and/or through consultants.

Generally, these inspections are carried out twice a year. During regulatory inspection, documented evidences for compliance to the regulatory requirements are inspected. Besides routine regulatory inspections, AERB also organizes special regulatory inspections with specific objectives as deemed necessary. Such inspections are carried out subsequent to an event, depending on the safety significance or after major modifications in the plant and forms the basis for considering clearance for restart of the unit. In addition to these, unannounced inspections are also 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 above inspection, a detailed inspection report is prepared and the utility is briefed about the findings in an exit meeting. 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.

Enforcement

If, in the opinion of the Regulatory Body, the licensee has violated the conditions of the license wilfully or otherwise or misinformed or did not divulge the information having bearing on safety, the Regulatory Body can initiate enforcement actions 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 license; and

v) Initiate legal proceedings under provisions of the Act.

14.3.3.3 Renewal of Authorisation for Operating Plants

Under the existing legal framework, AERB issues authorisation for operation of NPPs for a period of five years. The renewal of authorisation is issued by AERB based on safety reviews as specified. These are (a) limited safety review of Application for Renewal of Authorisation (ARA) submitted in the prescribed format prior to completion of five years of operation and (b) Comprehensive review of Report on Periodic Safety Review (PSR) submitted prior to completion of ten years of operation.

Based on review of ARA, AERB decides on renewal of authorisation for further period of five years after it is satisfied that the NPP as a whole continues to be capable of safe operation 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.

AERB safety guide AERB/SG/O-12 on “Renewal of Authorisation for operation of NPPs” provides guidelines for carrying out a comprehensive Periodic Safety Review (PSR). Safety assessment performed during PSR takes into account improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feed back of operating experience 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.

Various recommendations emerge from these elaborate reviews, which form the condition for authorisation to be implemented by the utility in a mutually agreed time frame. These recommendations are categorized as follows:-

i. Recommendations that need to be implemented immediately:

   These are generally based on review of anomalies in operation, deviation from specified values of parameters and incidents having safety significance. Implementation of these recommendations, in most cases, is directly linked to permission for continuation of plant operation or restrictions on specific activities in the plant.

ii. Recommendations, which will bring about safety improvements:

   These recommendations arise from review of operating experience of Indian NPPs as well as other NPPs elsewhere in the world. Many of these recommendations would take considerable time for implementation as they involve activities like working out detailed designs, civil construction, procurement of components and integrating them with the existing plant. Further, some of these recommendations require theoretical analysis or design reviews to be carried out for better understanding. In certain cases time would also be required due to the need for developing necessary tools for analysis, their validation, etc.

iii. Recommendations that require considerable Research & Development Work:

These recommendations are generally based on acquisition of new knowledge from experience or research or both. These require extensive support by way of R&D and are also of a long-term nature.

Based on the in-depth regulatory review of PSR, AERB decides on the renewal of authorisation.

14.4 Summary of Continued Monitoring and Periodic Safety Assessments

Continued monitoring and periodic safety assessment of Indian nuclear power stations are performed by utility organisation as well as by the Regulatory body. A variety of safety reviews and assessments are carried out as per the established requirement, which include the following:

a) Routine reviews inclusive of review of Significant Event Reports

b) Reviews of proposed modifications in design / operating procedures to assess their impact on plant safety

c) Safety assessments for renewal of authorisation

d) Safety assessments in response to major incidents and operating experience both nationally and internationally

e) Safety assessment related to major refurbishment

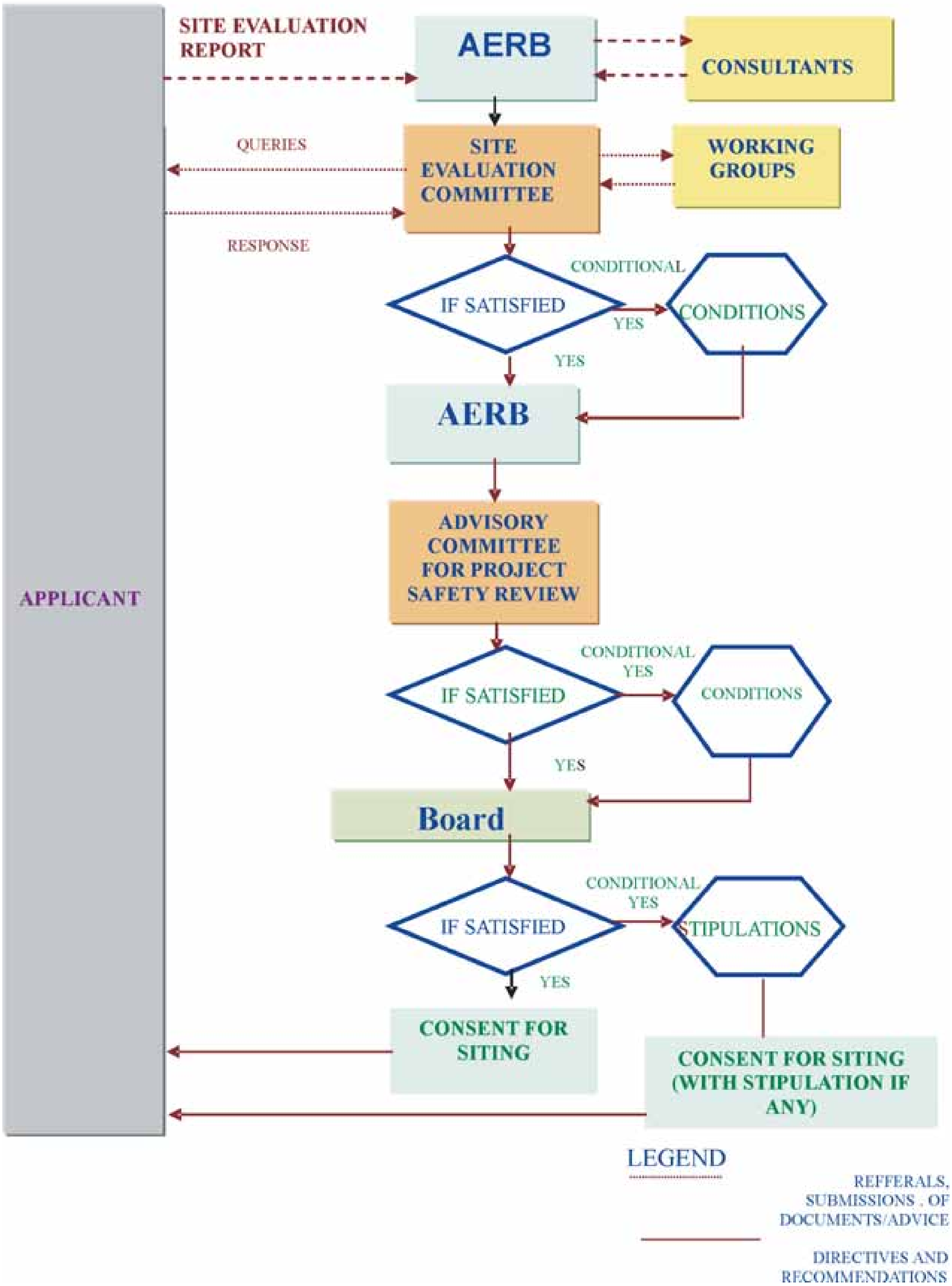
f) Safety assessment for Plant life extension

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

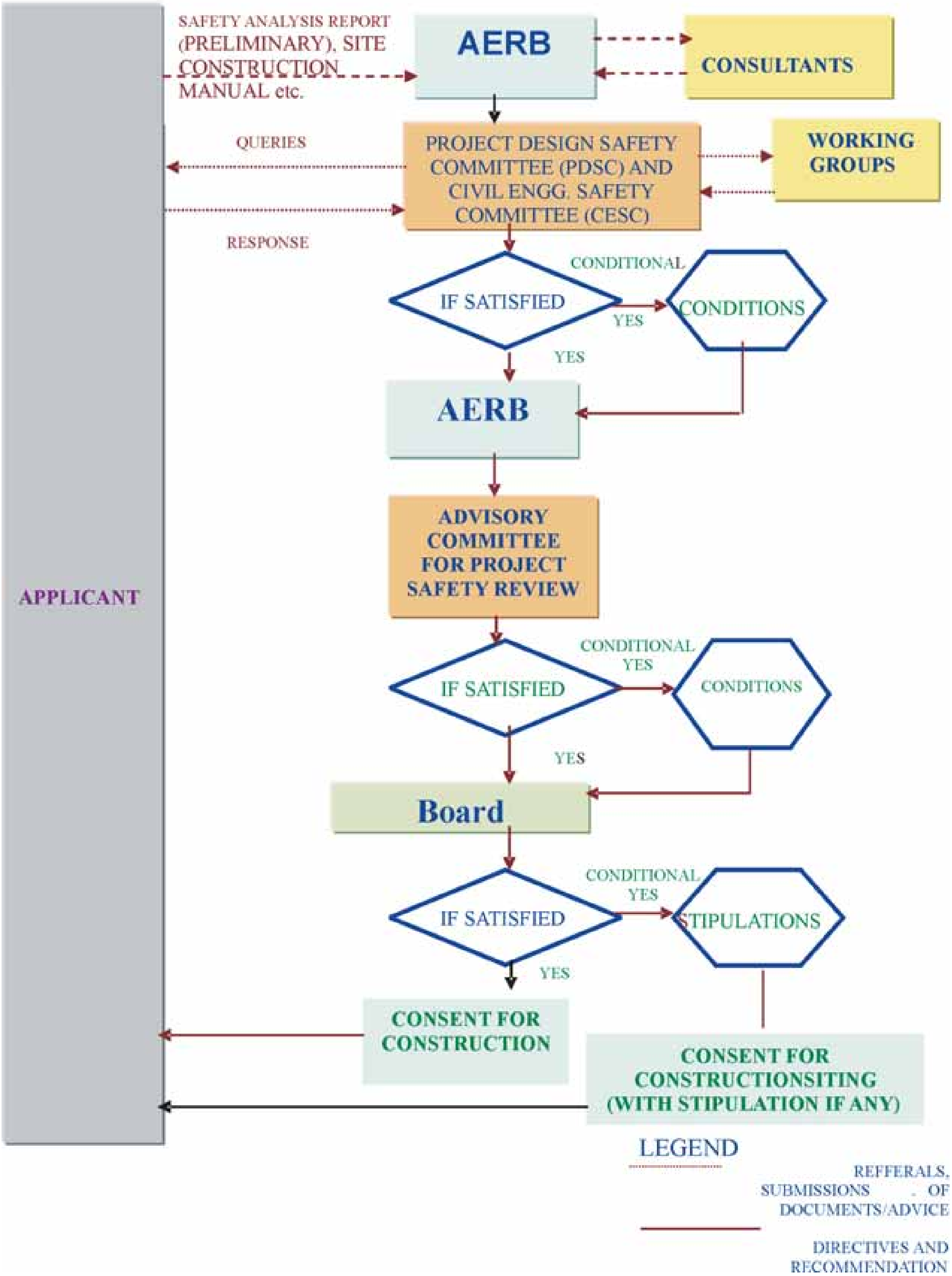
14.5 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

As per the licensing process establish in the country, the license is issued for various stages of siting, construction, commissioning and operation, as described above. During all stages, a comprehensive and systematic safety assessments are carried out. All the changes that have taken place in the design during construction and commissioning are reflected in the FSAR, which forms one of licensing documents. All the relevant documents are formally transferred to the operating organisation 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. During the operation stage, the AERB ensures through its system of regulatory control that the verification programmes established at NPPs are adequate and it is possible 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.

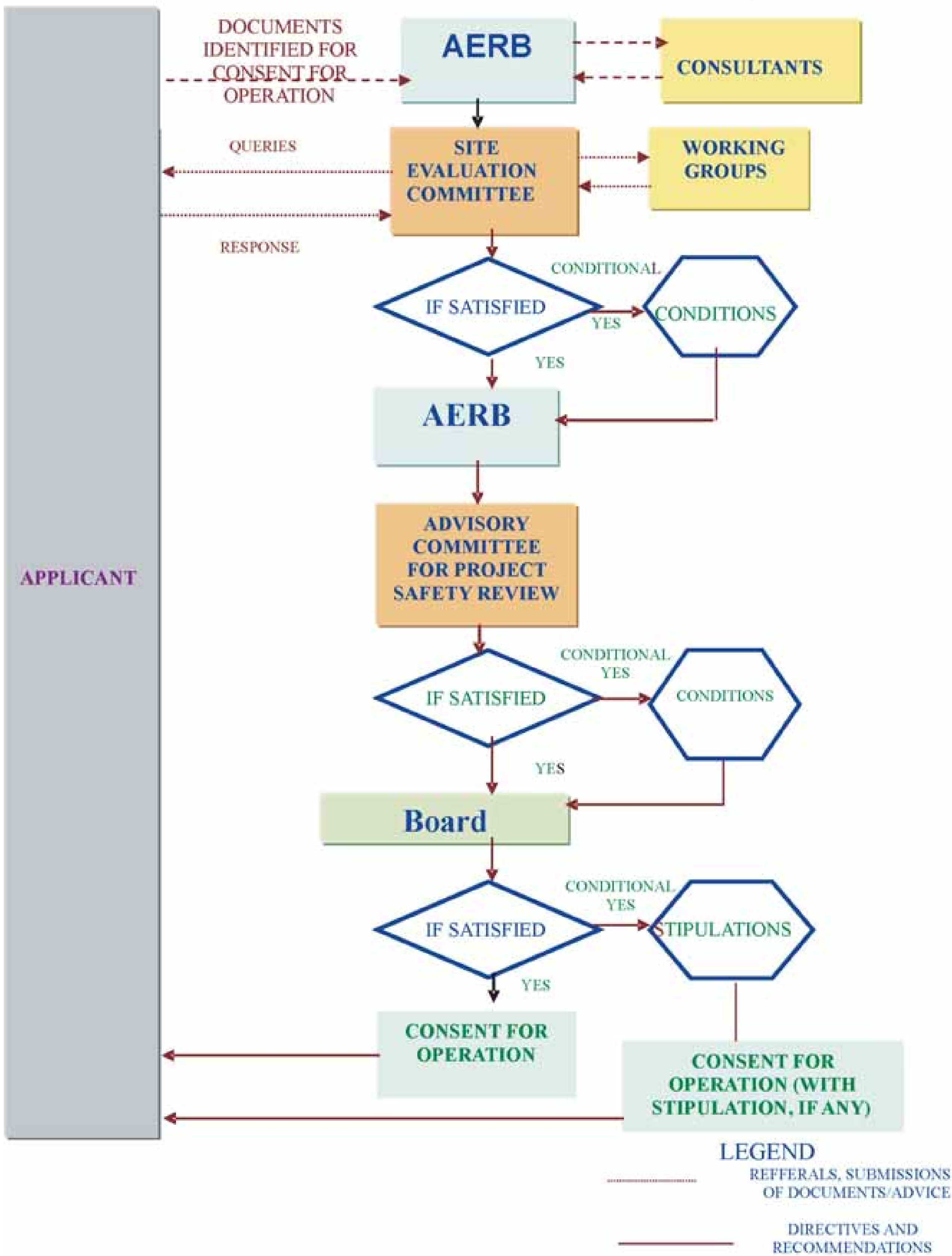
Annex 14-1: Scheme for Licensing for Siting



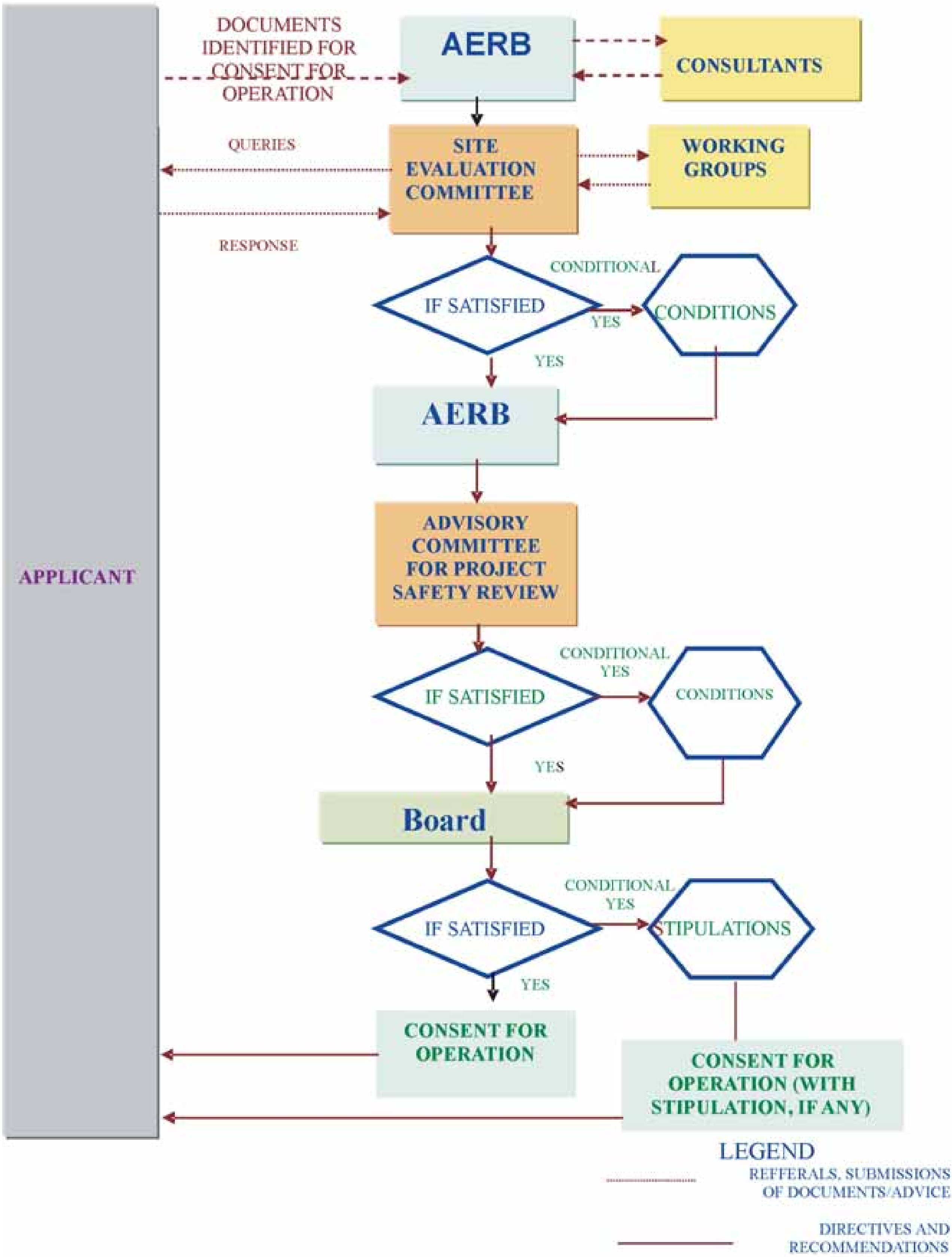
Annex 14-2: Scheme for License for Construction



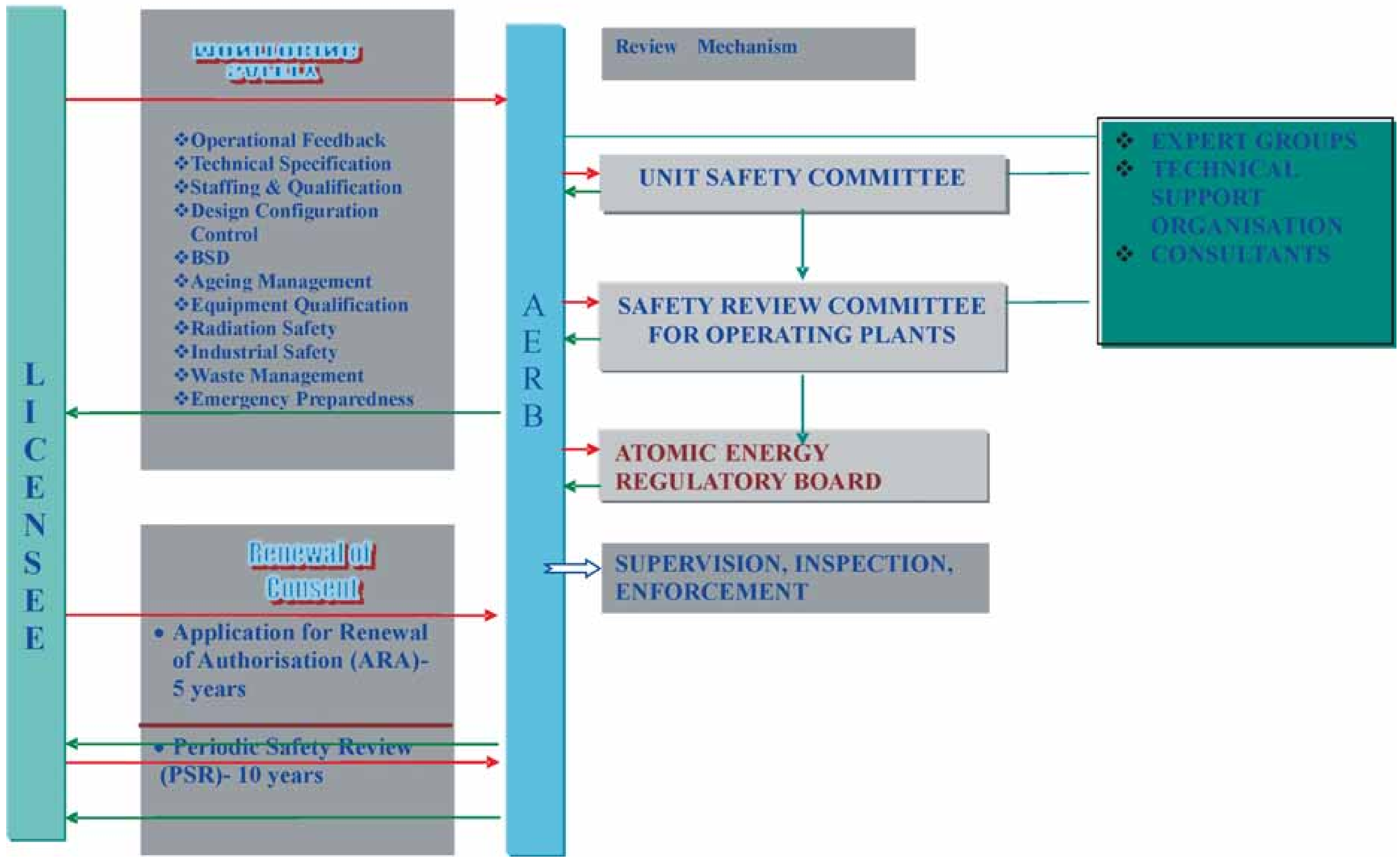
Annex 14-3: Scheme for License for Commissioning



Annex 14-4: Scheme for License for Operation



Annex 14-5: Safety Review during Operation of NPP



ARTICLE 15
RADIATION PROTECTION

Each Contracting Party shall take the 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 prescribed national dose limits.

15.1 NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

15.1.1 General

The regulatory authority of Atomic Energy Regulatory Board (AERB) is derived from the rules and notifications promulgated under the Atomic Energy Act, 1962 and the Environment (Protection) Act, 1986. Atomic Energy (Radiation Protection) Rules 2004 inter alia cover the requirements of licensing or authorisations, power to revoke/ modify/ withdraw the licences, radiation surveillance, the duties and responsibilities of Radiological Safety Officers, radiation surveillance procedures, powers of inspection of radiation installation, sealing and seizure of radioactive materials. In addition, the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987 specify the requirements for safe disposal of radioactive wastes. AERB ensures compliance of the requirements under the above rules by all the nuclear and radiation facilities. Chairman, AERB is designated as the Competent Authority under these Rules.

15.1.2 Requirements Related to Radiation Protection

AERB has laid down the requirements for radiation protection for NPPs in various Codes and Guides as detailed below.

i) The Code of Practice on Design for Safety in Nuclear Power Plants (AERB/SC/D, 1989) lays down the minimum requirements for ensuring adequate safety in plant design including radiation protection for NPPs.

ii) The guidelines for the implementation of radiation protection in the design of the nuclear power plants consistent with the requirements of the Code of Practice on Design are provided in the Safety Guide on Radiation Protection Aspects in Design for Nuclear Power Plants (AERB/SG/D-12, 2005). It covers the design measures and provisions for radiological protection of plant personnel, members of the public and the environment.

iii) 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. SC/O, 1989). It defines the functions and responsibilities of the regulatory body, the operating organisation and the plant management, for assurance of safety in operation.

iv) The guidelines for establishing Radiation Protection Programme to be carried out efficiently and effectively to achieve protection of the occupational workers, members of the public and the environment from adverse effects of radiation are provided in the Safety Guide on Radiation Protection during Operation of NPPs (AERB/SG/O-5, 1999). It focuses on the need for a high degree of commitment on the part of all levels of the management of the Operating Organisation and the plant personnel, to follow the exposure control measures during all operational states and accident conditions at the plant site.

v) The technical and organizational aspects of occupational radiation exposure controls under situations of both normal and potential exposure conditions have been given in the Safety Manual on Radiation Protection for Nuclear Facilities (AERB/SM/O-2 Rev.4, 2005). This Manual on Radiation Protection for Nuclear Facilities of DAE is an updated document which takes into consideration the current radiation protection philosophy, ICRP recommendations, IAEA guidelines, AERB Safety Directives and also the operational experience in radiation exposure management at DAE installations. On the basis of this Manual, each plant prepares its own “Radiation Protection Procedures” relevant to its design and functioning.

15.2 RADIOLOGICAL PROTECTION OF WORKERS

Radiological protection of the workers is ensured by the following measures:

15.2.1 Design Aspects

The design considerations that have bearing on radiation protection in NPPs include:

- Proper design, plant lay out and adequate shielding

  Design values are prescribed for radiation level at a specified distance from equipment/ components as well as for the general radiation fields in different areas of the plant. The plant layout should be such that the areas are segregated according to their radiation levels and contamination potential. The design, layout of areas and equipment, maintenance approach and shielding, etc., are made such that the collective dose to the station personnel would be as low as reasonably achievable and meet the specified regulation on collective dose.

- Limits of air contamination levels in different zones of the plant.

  Provision of ventilation is made such that in full time occupancy areas of the plant, the airborne contamination be maintained below 1/10 DAC.

- Source control by proper selection of materials/ components.

  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.

- Design limit for collective dose

A limit on collective dose is specified at the design stage of each NPP so that adequate provisions for radiation protection are made in the design of the plant to keep radiation levels in different areas below design levels.

15.2.2 Dose Limits

AERB has prescribed the following dose limits for exposures to ionising radiations for occupational workers.

a) Effective dose[1] (whole body)

i) 20 mSv averaged over five consecutive years, calculated on a sliding scale of five years[2]; (The cumulative effective dose in the same five year period shall not exceed 100 mSv)

ii) a maximum of 30 mSv in any year.

b) Equivalent dose (Individual Organs)

i)	Eye lens	150 mSv per year and
ii)	Skin[3]	500 mSv per year
iii)	Extremities (hands and feet)	500 mSv per year

c) Pregnant woman

i)	Equivalent dose limit to the surface of the woman's lower abdomen (for the remaining period of pregnancy)	2 mSv
ii)	Annual Limit on Intake (ALI) for radionuclides (for the remaining period of pregnancy)	0.05 ALI

d) Apprentices and students (above the age of 16 years)

	Effective dose ((whole body):	6 mSv per year
	Equivalent dose (Individual Organs)	
i)	Eye lens	15 mSv per year
ii)	Skin	50 mSv per year
iii)	Extremities (hands and feet)	50 mSv per year

In addition, investigation limits are also prescribed by AERB at which investigation of exposure cases exceeding these limits are carried out by an AERB committee.

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[1] Effective dose means summation of the tissue equivalent doses, each multiplied by the appropriate tissue- weighting factor.
[2]Sliding scale of five years means current year and previous four years.
[3] Average dose over 1cm^2 of the most highly irradiated area of the skin.

For temporary workers, separate control limits on dose and investigations are prescribed which are lower than that for regular workers.

The external and internal exposures of all the plant personnel are assessed on a monthly basis. For assessing internal dose in PHWRs, bioassay programme on weekly basis and dose estimation software are used. A computerised dose data management system is used which helps in updating the data for effective dose control.

15.2.3 Organisation in Radiation Protection

Each NPP has a Health Physics Unit (HPU), comprising of a group of trained and experienced radiation protection professionals, who in co-ordination with plant management implement the radiation protection programme in the plant. The HPUs in all NPPs in the country are entrusted with the responsibility for providing radiological surveillance and safety support functions. These include monitoring of areas, personnel, systems, effluents, exposure control and exposure investigations. The HPUs are part of BARC and are independent of NPP organisation and have direct channels of communication with the top plant management in enforcing the radiation protection programme.

Individual and collective dose consumed in the plant is reviewed in detail and measures for reduction are devised at plant level. These measures include engineering and administrative solutions such as shielding, ventilation, use of protective equipment, procedure adherence, work permit system, access control, display of placards, job planning, mock-up, training, supervision, etc. In addition, a three-tier arrangement is in place to review, and monitor implementation of recommendations pertaining to radiological safety. The first level review is done at plant and the regulatory body does second and third levels reviews.

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 in all the NPPs.

15.2.4 Steps for ALARA Exposures

In order to meet the objectives of ALARA, working procedures and methods are examined with regard to the possibility of reducing doses resulting from radiation jobs. During the operational stage of the NPP, the exposures are kept ALARA by implementation of the following operational aspects.

- Implementation of radiation protection and contamination control procedures
- Use of proper protective equipment
- Adherence to approved operating and maintenance procedures
- Implementation of radiation protection training and qualification programmes and conduct of refresher courses to impart ALARA concept and awareness

- Proper work planning and its practical implementation through the issuance of Radiation Work Permit and dose budgeting for each operation
- Constitution of ALARA Committee at Plant Level
- Planning and preparedness for unusual events

15.2.5 Radiation Protection Review by AERB

The Atomic Energy (Radiation protection) Rules, 2004 form the basis of regulatory control activities related to radiation protection. These rules are implemented by the utilities through various procedures. In addition, AERB practices other measures to have control on radiation protection aspects for NPPs, which among others, include the following:

a) Collective Dose Budget

AERB approves the annual collective dose budget for each NPP. The stations are required to propose the budget along with planned activities. AERB committees review the collective dose expenditure and the proposed budget, and based on the review, formally approve the annual budget within which all the operation and maintenance activities have to be managed.

b) Review of Excess Exposure Cases

Exposure cases exceeding the investigation limits are investigated and reported by Exposure Investigation Committee set up at each NPP. Such reports are reviewed by AERB Safety Committees and SARCOP. The root causes of such exposures are established and corrective measures are recommended.

c) Regulatory Inspection

The adequacy of radiation protection programme and its implementation in the operating NPP are inspected twice a year. The deficiencies are reported and corrective measures are recommended and followed up through enforcement procedures.

d) Review of Radiological Safety Aspects

Regulatory Body reviews the report on radiological safety aspects of the plant on a quarterly and annual basis.

15.3 RADIOLOGICAL PROTECTION OF PUBLIC

The following measures ensure the radiological protection of the public due to operation of a NPP.

15.3.1 Design Aspects

- Dose limits for members of the public

The sources contributing to generation of radioactive solid, liquid and gaseous wastes and their release to the environment are examined with respect to minimisation of waste at the source at the design stage itself. The dose to public resulting from these releases are assessed and if necessary, appropriate design measures to reduce these releases are introduced.

- Exposure criteria for accident analysis

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

15.3.2 Dose Limit

AERB has prescribed the following limits to a member of public at exclusion distance due to releases of radioactive effluents from nuclear facilities at a site.

Effective dose (whole body):	1 mSv per year
Equivalent dose (Individual Organs):	
i) Eye lens	15 mSv per year; and
ii) Skin	50 mSv per year

15.3.3 Radioactive Waste Management

i. Method of Disposal and Monitoring

Gaseous wastes from reactor building are filtered using pre-filters and HEPA filters and released after monitoring through a stack of 100 m height. The release rate and integrated releases of different radionuclides are monitored and accounted for, to demonstrate that the releases are within the prescribed limits.

The radioactive liquid wastes generated in a NPP are segregated, filtered and conditioned as per procedure and after adequate dilution to comply with the limits of discharges disposed to the environment water body. 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 from each NPP, which are site specific.

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

ii. Authorised Limits of Discharge

The discharge of radioactive waste from a NPP is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987 which is issued under the Atomic Energy Act, 1962. It is mandatory for a NPP to obtain authorisation under the above rules from Competent Authority for disposal of radioactive wastes.

The regulatory limits (authorised limits) of radioactive effluents are based on the apportionment of effective dose limit of 1 mSv per year to public arising from nuclear facilities at a site considering all the routes of discharges and significant radionuclides in each route of discharge. Derived limits corresponding to the dose apportioned for different radionuclides are established taking into account the site specific parameters. Authorised limits are set at a much lower value than derived limits to achieve effluent releases ALARA. The releases from NPPs have been only a fraction of release limits specified.

15.3.4 Environmental Radiological Surveillance

As mentioned earlier, the elaborate environmental survey programme around each NPP site is carried out by the Health Physics Units (HPUs) and 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 HPUs and ESLs are part of BARC and are independent of the utilities. They provide the regulatory body with periodic reports on radiological conditions of the NPPs and the results of environmental surveillance.

The Environmental Survey Laboratory (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. 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 micro-meteorological data such as wind speed and wind direction, temperature and rain fall are collected for a few years to identify the worst sector and 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. The programme undergoes modification based on experience. Generally, more samples are collected near the vicinity of the plant and from locations where population clusters exist and the sampling frequency reduces with the distance. Areas up to a distance of 30 km distance are covered under the environmental survey programme. Although the main emphasis is on samples that are relevant directly to the estimation of the dose such as drinking water, edible food items, air etc., a number of other samples are also assayed for radioactivity and used as trend indicators.

From the radioactivity level in the environmental matrices, intake parameters and dose conversion factors, the population dose is estimated. The annual effective dose to members of the public in the vicinity of the NPPs have been estimated by ESLs and found to be only a few μSv.

ESLs are accredited laboratories and they take part in inter comparison studies conducted by IAEA.

15.4 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 their respective systems, and organisations, dose limits, limits on release of radioactive effluents, minimising radiation exposure to ALARA and environmental surveillance. 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 on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency.

For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.

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

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

16.1 GENERAL

Nuclear power plants (NPPs) are designed, constructed, commissioned and operated in conformity with existing stringent nuclear safety standards. These standards 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 safety standards, it is necessary to develop, as a measure of abundant caution and in conformity with international practices, emergency response plans so that under any eventuality with a potential to result in undue radiological risk to plant personnel and public, is handled effectively.

The preparedness and response to emergencies are important responsibilities of the Operating Organisation. It has to establish and maintain the necessary emergency procedures by having an on-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.

16.2 NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

The Government of India has 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 at the national level whose Chairperson is the Prime Minister. 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, a National Plan, State Plans and District Plans are drawn up by the respective authorities constituted for the purpose.

These respective plans include measures to be taken by the concerned responsible agencies for prevention of disasters, or for the mitigation of their effects.

The AERB enforces safety and regulatory functions under the Atomic Energy Act 1962. One of the important functions of AERB is to review the emergency preparedness plans prepared by nuclear and radiation facilities.

Specific requirements with respect to emergency preparedness in NPPs have been formulated by AERB in the following regulations.

i) Safety Code “Regulation of Nuclear and Radiation Facilities” (AERB/SC/G, 2000)

    This Safety Code 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 leading to eventual operation. The Code also elaborates on the regulatory inspection and enforcement to be carried out by the Regulatory Body on such facilities. Prior to issuance of consent for operation of a NPP, AERB ensures that the approved emergency preparedness plans are in place.

ii) Safety Guide “Role of the Regulatory Body with Respect to Emergency Response and Preparedness at Nuclear and Radiation Facilities” (AERB/SG/G-5, 2000)

    This Safety Guide provides guidance for the Regulatory Body on its role 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.

iii) Safety Code “Code of Practice on Safety in Nuclear Power Plant Operation” (AERB/SC/O, 1989)

    The Safety Code set forth the minimum requirements including the development of an emergency preparedness plan, which shall be met in order to achieve safe operation of a NPP. It also defines the requirements to be met for maintaining a high degree of emergency preparedness on the part of the Operating Organisation.

iv) Safety Guide “Intervention Levels and Derived Intervention levels for Off-Site Radiation Emergency” (AERB/SG/HS-1, 1993)

    This safety guide presents the intervention levels (ILs) and derived intervention levels (DILs) for initiating countermeasures in the public domain following a nuclear accident or radiological emergency. The ILs are formulated such that exposure to individuals from all pathways is well below the thresholds for deterministic effects, the risk of stochastic effects to individuals is limited and the overall incidence of stochastic effects in the exposed population is also limited.

v) Safety Guide "Preparedness of the Operating Organisation for Handling Emergencies at NPPs" (AERB/SG/O-6, 2000)

This Safety Guide 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 Operating Organisation.

vi) Safety Guidelines "Preparation of Site Emergency Plans for Nuclear Installation" (AERB/SG/EP-1, 1999)

This document lays down the requirements of the regulatory body to the Operating Organisation for preparing and maintaining an emergency response plan for the site emergency.

vii) Safety Guidelines "Preparation of Off-Site Emergency Plans for Nuclear Installation" (AERB/SG/EP-2, 1999)

This document lays down the requirements of the regulatory body to the Operating Organisation and public authorities for preparing an emergency response plan for an off-site emergency. These safety guidelines cover all aspects of off-site emergency response plans, which the Operating Organisation and public authorities shall prepare and maintain for implementation in the event of an off-site emergency.

viii) Safety Manual "Radiation Protection for Nuclear Facilities" (AERB/NF/SM/O-2, Rev. 4, 2005)

This safety manual on 'Radiation Protection in Nuclear Facilities' (Rev. 4), issued under the Code of Practice on Safety in Nuclear Power Plant Operation, provides the necessary information intended to assist the facilities to fulfil the requirements stipulated in the Code including the requirements for emergency preparedness. This manual is an updated document, which takes into consideration the current ICRP recommendations, international developments in the field of radiation protection and AERB safety directives. Reference dose levels for workers undertaking intervention under severe accident conditions and the situations envisaged for such intervention are given in the above document.

16.3 IMPLEMENTATION OF EMERGENCY PREPAREDNESS MEASURES

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

(i) The emergency preparedness and response plans for NPP are drawn up and approval from the AERB is obtained.

(ii) Necessary training is imparted to the personnel to be deployed in implementing the action plans.

(iii) The implementability of the plans is confirmed by conducting exercises.

The Operating Organisation 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 ensure that the NPP and off-site authorities develop and maintain compatible emergency plans. AERB approves Site Emergency Plans and the concerned State Government (Province) 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 and, in the event of an emergency with potential radiological consequences in the public domain, the public functionaries such as District and Central Government Authorities. The responsibility for the overall co-ordination in the case of site emergencies rests with the Operating Organisation (licensee) whereas in the case of off-site emergencies it rests with the public functionaries. The responsibilities of various response agencies, their sub-units and also the concerned officials are clearly indicated in the emergency response plans.

The nature and magnitude of the preparedness and response measures would depend on the specific category or extent of the emergency. Though the safety evaluation of an NPP relates to design basis events, the emergency response plans are based not only on the design basis events but also on accident conditions due to more severe events, even if they have a very low probability of occurrence. An analysis of such events and the projected radiological consequences specific to the NPP, form the basis of the response plans, so that appropriate response actions could be drawn up.

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 public domain. For this purpose, a Crisis Management Group (CMG) has been set up. This group is chaired by Additional Secretary, DAE and has members from various arms of DAE and AERB. The CMG has access to resource agencies to provide advice and 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 NPP to handle the emergency.

16.4 EMERGENCY PREPAREDNESS PLAN

As a mandatory requirement, each NPP prepares an emergency preparedness and response plan. Some of the important considerations which go into the preparation of this plan are:

(i) Counter measures, intervention levels and derived intervention levels

(ii) Identification of response persons and specific action plans for each response person

(iii) Communication channels to be activated in an emergency

16.5 ZONING CONCEPT AND EMERGENCY PLANNING

In India, a NPP is generally sited in a relatively low population zone with the basic objective of limiting the dose received members of the public and population as a whole under normal and accident conditions to ALARA levels. In order to achieve the above objective, the area around the NPP is divided into the following zones:

i) Exclusion Zone

An exclusion zone of 1.5 km radius around the plant is established which is under the exclusive control of the Operating Organisation and no public habitation is permitted in the area. The dose limits to a member of the public under normal operating conditions and under Design Basis Accident conditions specified are applied at the boundary of this exclusion zone.

ii) Sterilised Zone

With the help of administrative measures, efforts are made to establish a sterilised zone upto 5 km radius around the plant. This is the annulus around the exclusion zone which has the potential for extensive contamination in case of a severe accident. Development activities within this area are controlled so as to check on uncontrolled increase in the population. In this area, only natural growth of population is permitted.

iii) Emergency Planning Zone (EPZ)

This is the zone defined around the plant upto 16 km radius and provides for the basic geographic framework for decision making on implementing measures as part of a graded response in the event of an off-site emergency. The EPZ is examined in great detail while drawing up an offsite emergency plan and arranging logistics for the same.

The entire EPZ is divided into 16 equal sectors. The objective is to optimise the emergency response mechanism and to provide the maximum attention and relief to the regions most affected during an offsite emergency.

16.6 CLASSIFICATION OF EMERGENCIES

The Emergency Preparedness and Response Manual describes classifications of emergencies based on severity and magnitude of the condition in the affected zones. Each category is associated with an intervention level for which appropriate countermeasures are specified. In accordance with different degrees of severity of the potential consequences, emergency situations are graded as:

(i) Site emergency; and

(ii) Off-site emergency.

The Operating Organisation is responsible for carrying out remedial measures during site emergency while the District Authority is responsible for taking actions to responds to an offsite emergency.

i) 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 exclusion zone only.

The 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 from the affected parts of the site and radiological monitoring of the environment in the emergency planning zone (EPZ). After being alerted, the OED takes the necessary steps to cater to a potential off-site emergency.

ii) 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 (EPZ) up to 16 km radius is specified. The emergency response manual specifies the criteria to determine an off-site emergency.

The protective measures in public domain are also specified in the Emergency Response Manual. These measures would have to be implemented by the District Officials under the direction of the District Authority, who is designated as the Off- Site Emergency Director (OED).

16.7 ORGANISATION FOR EMERGENCY RESPONSE

16.7.1 Site Emergency Organisation

i) Declaration of Site Emergency

The declaration and termination of a site emergency are made by the Site Emergency Director (SED). The format of message of the declaration of a site emergency are specified in the emergency response manual and adhered to by SED while declaring the emergency.

ii) Site Emergency Director (SED)

SED, as the Chairman of the Site Emergency Committee (SEC) is responsible for convening the SEC when the first report of the initiation of an emergency is received. SEC obtains technical inputs, such as particulars of the accident, radiological monitoring data, wind direction, wind speed etc. The decisions for declaration/ termination of an emergency are based on inputs so obtained. The Station Director (SD) of the NPP is usually identified as SED. The chain of command drawn up in the emergency response manual also indicates who would take over as SED in the absence of the Station Director.

16.7.2 Off-Site Emergency Organisation

i) Declaration of Off-Site Emergency

The declaration/ termination of an off-site emergency is recognised as the responsibility of the Off-Site Emergency Director (OED) in consultation with SED. The SED assesses the effect of any abnormal release of radioactive material extending beyond the site boundary and will instruct 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.

ii) Off-Site Emergency Director (OED)

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 and elaborately planned unit in an emergency management organisation. It is directly responsible for all off-site emergency actions. It is headed by the District authority, who is also designated as the Off-Site Emergency Director (OED). Its membership includes the Chiefs of all Public Services relevant to management of any emergency in the public domain.

iii) Co-ordination with Regulatory Body

The Regulatory Body prescribes the intervention levels to be incorporated in the Emergency Manuals for determining when a specified countermeasure such as administration of prophylactics or evacuation has to be initiated and the duration in which such actions are to be completed. As stipulated by the Regulatory Body, the NPP shall have an approved Off-Site Emergency Preparedness and Response Manual issued by the concerned State Government. Exercises will also be conducted by the Operating Organisation as prescribed in the manual in association with Public Authorities. For monitoring the exercises, the Regulatory Body nominates its representatives.

The Emergency Preparedness and Response Plans are updated, reviewed and after approval of Competent Authority is duly obtained by the Operating Organisation.

16.8 INFRASTRUCTURE FOR EMERGENCY RESPONSE

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

i) Plant Control Room

In the initial stages of an emergency, the plant control room is used by the Site Emergency Committee (SEC) to get first hand information about the emergency situation and to direct actions, as may be necessary. If for the same reason, the main control room is not available, the status of plant can be monitored from the supplementary 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 co-ordination with off-site emergency response, so that control room staff is not distracted from performing control room operations. It is established with due consideration of shielding requirements, so that it is habitable throughout the emergency period. This building houses emergency equipment centre, treatment area, personnel decontamination area and have sufficient space to accommodate SED, SEC members, rescue teams, health physics staff, emergency maintenance unit staff, stores and industrial safety group. It is equipped with communication system, public address (PA) system, emergency equipment/instruments, stationery, standard operating and emergency procedures, design basis reports. P&I diagrams, maps of emergency power supplies, potassium iodate (KIO_3) 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 efficient communication systems such as subscriber's trunk dialling (STD), hot line, satellite, telex, radio, voice-mail, e-mail and fax communication facilities besides power line carrier communications. These are utilized to communicate with Headquarters, DAE Emergency Control Room and other concerned authorities/agencies. These systems are available for use at all times. Appropriate channels are also established to ensure communication to the Regulatory Body.

iv) Assessment Facilities

The Operating Organisation has suitable 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, meteorological data, isodose curves, air samplers, counters, maps etc.

v) Protective Facilities

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

16.9 EMERGENCY MEASURES

The emergency measures consist of emergency actions in respect of notification, alerting personnel, assessment of situation, corrective actions, mitigation, protection 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.

ii) 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 assessment actions enable planning timely corrective and protective actions.

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) Protective Measures (countermeasures)

These actions are 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 finally 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 a very effective countermeasure but is very carefully considered before a decision to implement is taken. The benefits and risks of this countermeasure are carefully assessed in terms of averted dose. If radiation levels in the affected zone continue to exist beyond acceptable levels, then relocating the affected population is resorted to.

v) Contamination Control Measures

Contamination control measures are meant to check the spread of radioactive contamination. These actions include segregation of highly contaminated persons and decontaminating them, decontamination of vehicles, regulating the traffic, access control to prevent unauthorized entry to keep traffic routes open solely from the emergency response point of view, confiscation of contaminated food stuff and substituting fresh uncontaminated food in its place, banning fishing in contaminated sea/river water, banning the consumption of contaminated water and its replacement with contamination-free 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.

16.10 ASSISTANCE TO AFFECTED PERSONNEL

In the event of a nuclear emergency, the plant management is responsible for the affected personnel with all necessary assistance in respect of their rehabilitation and treatment, sheltering and evacuation as necessary. The similar responsibility for providing assistance to persons in the public domain is that of 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/affected 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 Operating Organisation. It is also responsible for setting up fixed and mobile facilities for carrying out decontamination with adequate supply of water. While setting up and maintaining such facilities in the public domain are the responsibility of the District Authorities, the actual operations are carried out under the guidance of operating Organisation.

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 and control of a common authority. Adequate stock of diesel oil and petrol is maintained at all times to face such an eventuality. Arranging 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 fully equipped with necessary instruments, medicines, operating theatres, beds, decontamination centres etc. These 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.

16.11 MAINTAINING EMERGENCY PREPAREDNESS

A viable mechanism has been put in place to assess the overall emergency preparedness of an NPP. The required emergency preparedness is maintained by organizing various training courses for site and off-site personnel at regular intervals. This 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 round the year 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 of each exercise are discussed immediately in the Station Operation Review Committee (SORC) meeting and deficiencies are promptly corrected.

iii) Review and Updating of Plans and Procedures

All plans and procedures are reviewed in their totality at regular intervals and the necessary corrections/ changes are carried out to keep them up to date.

iv) Emergency Equipment and Supplies

Various facilities and equipment such as - the emergency equipment centre, personnel decontamination centre, emergency survey vehicle, radio equipment, contaminated casualty 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, DRDs, 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.

v) Internal and External Auditing

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.

16.12 PUBLIC AWARENESS ABOUT EMERGENCY PREPAREDNESS

Regular training courses are arranged by each NPP for the general public in that area by inviting them in batches 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 nuclear emergency is distributed to the general public.

16.13 TRANS BOUNDARY IMPLICATIONS

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 population in this zone are kept informed on emergency planning and response. The neighbouring states are at very large distances from the location of operating NPPs and those under construction. Hence there are no transboundary implications.

16.14 INTERNATIONAL ARRANGEMENTS

India is a signatory for convention on early notification and convention on mutual assistance. The Crisis Management Group (CMG) has been identified as the nodal agency under both these conventions for keeping in contact with the IAEA during any off-site emergency scenario. Joint International Nuclear Emergency Exercises are conducted jointly by IAEA and several international organizations. As the nodal agency, the CMG receives and acknowledges the messages in connection with these exercises.

16.15 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, 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.**

17.1 GENERAL

The present statutory provisions permit the Central Government or a company established by the Central Government to set up a nuclear power plant in India. To enable the selection of a suitable site, the Central Government has constituted a Site Selection Committee (SSC). The SSC evaluates the suitability of the various sites proposed by concerned states governments, taking into account site related factors such as socio economic scenario, available infrastructure, population distribution, land use, etc. Based on the recommendation of the SSC, the Central Government takes the decision on the selection of sites. The utility then approaches various central and state level regulatory authorities for obtaining the necessary clearances for setting up a NPP at that site.

Safety is an important factor considered in the engineering of all nuclear power plants. It includes radiological safety of the personnel, public and the environment both during normal operation of the plant as well as during and following accident conditions. This calls for detailed analysis of all site related parameters, which have a direct or indirect bearing on the safety of the plant and environment.

17.2 NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

The Atomic Energy Act 1962 and rules framed there under provide the main legislative and regulatory framework for locating an NPP in India. There are other applicable legislation such as the Environment (Protection) Act 1986, the Water (Prevention & Control of Pollution) Act, 1974, the Air (Prevention & Control of Pollution) Act 1981, etc which also establish requirements of necessary clearances. National laws and regulation pertaining to location of an NPP in India is summarised in Chapter on Article 7: Legislative and Regulatory Framework.

All Nuclear Power Projects, prior to submission of the Detailed Project Report to the Government for approval, need clearance mainly from the Atomic Energy Regulatory Board (AERB) from nuclear safety considerations and the Ministry of Environment and Forests (MoEF) of the Central Government from the environmental considerations.

In addition, clearances also need to be obtained from other central and state level agencies, as per applicable requirements, from National Airport Authority, State Maritime Boards, Ministry of defence and Ministry of external affairs, as appropriate.

AERB Safety Code on Regulation of NPPs and Radiation Facilities, AERB/SC/G establishes the requirements for obtaining license from AERB at all stages such as Siting, Construction, Commissioning, Operation and Decommissioning. The licensing process is described in detail in AERB/SG/G-1, including the requirements for documents, areas of review and assessment, etc. The license 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 this code provide guidance for meeting these requirements. The list of guides is given in annex 17-1. A site is considered acceptable, when all the site related issues have been addressed, 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.

The prior environmental clearance for a NPP is obtained from Ministry of Environment & Forests (MoEF), as per the requirement of Environmental Protection Act 1986. For this, the utility prepares an Environmental Impact Assessment (EIA) Report in a prescribed format in respect of the project or activity for which the clearance is being sought.

17.3 CRITERIA FOR EVALUATING FACTORS AFFECTING SAFETY

17.3.1 License for Siting from AERB

Based on the requirements specified in AERB/SC/S, utility prepares a Site Evaluation Report (SER). The contents of the SER should cover various items under following broad category:

a. Salient features of the proposed site

b. Site characteristics affecting safety

c. Interactions of NPP with its environment

In addition, the SER should contain brief design information on the proposed project. It should provide concise information giving an overview of the proposed power plant. The information should assist in evaluating the given site in relation to the type, capacity, number of units etc. It should include following information.

* proposed type of plant including capacity of plant, number of units etc.
* overall safety approach
* dose limits, bases for emergency preparedness
* offsite power supplies

The regulatory review and assessment of SER 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.

The significant areas of review and assessment under this include:

(a) Those related to environmental conditions and aspects which will influence the design basis of the plant, namely:

i. Geology and soil mechanics

ii. Topography

iii. Hydrology and hydro-geology

iv. Meteorology

v. Natural phenomena such as earthquakes, floods 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 requirement of 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. If, after thorough evaluation, no engineering solution can be found to provide adequate protection against design basis external events, the site shall be deemed unsuitable for the location of the nuclear power plant of the type and size proposed.

(b) Those related to the effects of the plant on the environment that could warrant specific design or operational requirements, namely:

i. Dispersion of radioactive liquid effluents

ii. Dispersion of radioactive gaseous effluents

iii. Radiation exposure of the public arising from liquid and gaseous radioactive effluents released during 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.

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, biological and socio-economic environment, etc. These include physio-chemical, biological characteristics & activity of ground water and surface water, soil characteristics, composition of vegetation cover, meteorological parameters etc. The Environmental Survey Laboratory is established for conducting the pre-operational studies and continued meteorological surveillance.

It is mandatory that an exclusion zone of at least 1.5 km in radius around the plant is established and this area is kept under the exclusive control of the authority of power station, wherein public habitation is prohibited. Further, a sterilized area around the exclusion zone covering up to 5km radius around the site is established. While only the natural growth of population is allowed in this area, the planned expansion of activities are regulated by the administrative or legislative measures.

The site is required to have good atmospheric dispersion characteristics. An emergency planning zone area is established within 16km 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) Availability of roads and access features for emergency response purposes.

(d) Aspects on security measures with reference to site characteristics.

17.3.2 Environmental clearance from Ministry of Environment and Forests

Environmental clearance from MoEF is a precondition for issue of siting clearance by AERB. For the prior environmental clearance for a NPP from Ministry of Environment & Forests (MoEF), Environment Impact Assessment (EIA) Report in a prescribed format is prepared. 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 in the prescribed application form, 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. The State Pollution Control Committee, in pre specified manner, conducts the public hearing.

After completion of the Public Consultation, the project proponent addresses the material environmental concerns expressed during this process and make appropriate changes in the draft Environment Impact Assessment 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 has to be 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.

17.4 CONTINUED SAFETY ACCEPTABILITY OF NPP

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) continue to implement 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 diet 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 are regulated by legislative measures or administrative measures by the state government/local authorities etc.

At the time of renewal of authorisation for operation based on 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.

a. Changes in use of land areas around the site

b. Local population distribution,

c. Off-site population distribution.

d. Site characteristics, particularly flood and seismic, which may pose a hazard, and

e. Local meteorological conditions.

17.5 INTERNATIONAL ARRANGEMENTS

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 population in this zone are kept informed on emergency planning and response. The neighbouring states are at very large distances from the location of operating NPPs and those under construction. Hence there are no transboundary 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 their obligations.

17.6 COMPLIANCE WITH OBLIGATIONS OF THE CONVENTION

The Site Selection for locating an NPP is carried out by the Central Government in consultation with concerned state governments. 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

Safety Series	Title
AERB/SG/S-1	Meteorological Dispersion Modelling
AERB/SG/S-2	Hydrological dispersion of Radioactive Materials in relation to Nuclear Power Plant Siting
AERB/SG/S-3	Extreme value Analysis for Meteorological Parameters
AERB/SG/S-4	Hydrogeological Aspects related to NPP Siting
AERB/SG/S-5	Calculational Models for Dose from Concentrations
AERB/SG/S-6A	Design Basis Flood for Inland Sites
AERB/SG/S-6B	Design Basis Flood for Coastal Sites
AERB/SG/S-7	Man induced events and establishment of DBs
AERB/SG/S-8	Influence of Site Parameters on Emergency Preparedness
AERB/SG/S-9	Population Distribution and its Analysis
AERB/SG/S-10	Quality Assurance in Siting
AERB/SG/S-11	Design Basis Ground Motion for Nuclear Power Plant Sites

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.

18.1 NATIONAL LAWS, REGULATIONS AND REQUIREMENTS

National laws, regulations and requirements for setting up a NPP are summarised in chapter on Article 7: Legislative and Regulatory Framework. AERB code on regulation AERB/C/G and Safety Guide AERB/SG/G-1 on Consenting Process for Nuclear Power Plant and Research Reactor, identifies various authorisation stages, which includes requirements of license for construction and areas of review and assessment for safety in design and construction. The licensing process for locating and operating NPP in India is summarised in the chapter on Article 14: Assessment and Verification of Safety. The AERB Code of practice on Design for safety, AERB/SC/D 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 of the design, 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. For NPPs designed abroad, AERB takes in to account the differences in safety standards and requirements between the two countries and may accept them as the applicable safety standards & requirements.

AERB Code of practice on quality assurance for safety in NPP, AERB/SC/QA 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 and decommissioning of NPPs in the country. Various safety guides issued under these Codes of practice provide guidance for achieving the requirements specified in them. Annex 18-2 gives the list of AERB Guides on Quality Assurance.

18.2 REVIEW OF DESIGN AND CONSTRUCTION

The prerequisite for issue of license 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 influences 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 license 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 Basis Reports (DBR) and 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

18.3 DESIGN

The review and assessment areas of particular significance for design include the following topics

- 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
- Safety classification of systems, structures and components
- Compatibility of the design with the site
- Design basis, ground motion, geo-technical investigations and foundation parameter, meteorological parameter (Hydrology and Hydro-geology)
- 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, plane crashes, fire and other natural and man-induced events.
- Nuclear Security giving emphasis on Physical Protection System Design.

In carrying out its review and assessment of design prior to issue of license for construction, the Regulatory Body determines that the proposed design of NPP meets the following safety objectives and requirements.

- Implementation of defence in depth principle
- Emphasis on prevention of DBEs rather than on mitigation of their consequences
- Technologies incorporated in the design and construction of a nuclear installation have been proven by experience or qualified by testing or analysis
- Implementation of criteria related to human factors and human machine interface

The following paragraphs describe how these safety objectives and requirements are implemented in the design of NPP. The enclosed Annex 18-4 describes briefly how these principles are translated typically in the design of 2 X 540 MWe PHWRs, which were recently constructed at Tarapur.

18.3.1 Implementation of defence in depth principle

The safety in design is primarily based on the concept of defence-in-depth. The 'defence-in-depth' concept is implemented in the reactor design by means of a series of layers of physical barriers and levels of protection. Each layer is designed to act as an independent barrier against breach of safety. Safety systems are also provided with redundancy so as to meet 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 their release to the environment.

The confinement of radioactivity in fuel is achieved by a series of five independent barriers, namely, Ceramic fuel pellet of UO2, Fuel cladding of Zircalloy-2, 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 1.6 Km and a sterilised zone of 5 km from the plant are further layers of defence-in-depth. The area in exclusion zone is fully acquired and cordoned off from public. In sterilised zone, no new organized habitation/industry is permitted through administrative or legislative measures.

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 setback (reactor power rundown), step-back (power drop down) and trips on safety parameters are provided whenever deviations from normal operating conditions are detected. Control and instrumentation systems incorporate appropriate redundancy measures so that single failure criterion is met.

It is ensured that the systems, structures 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 design principles:

- The quality requirements for design, fabrication, construction and inspection for these system is of high order, commensurate with their importance to safety, meaning that they are designed to conform to codes and standards which demand highest quality in material and workmanship.
- 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. As far as practicable this separation is also provided between different safety systems, as well as between redundant components within 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 criterion' 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'. The reactor control and protection systems have triplicated instrument channels operating on two out of three coincidence principle. Each channel 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.

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 aircraft crashes, hazards from toxic and explosive materials, blasting etc, are also considered. 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.

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 plant is designed for a design basis flood resulting from probable maximum precipitation with a mean recurrence interval of 1000 years. Flooding due to failures is also considered for the dam(s) located upstream. Failures of dams located downstream also have safety implications, in that it may 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.

It is the combination of sound design and operating practices that makes a safe reactor. Recognising this, the operation of nuclear power plants are characterised by:

- Strict adherence to technical specification for plant operation, which sets safety limits on various parameters and lay down requirements regarding operability, surveillance and testing of key equipment.
- Content selection training, qualification & re-qualification of operation personnel.
- A well planned in-service inspection programme.
- Regular preventive maintenance.
- Rigorous and multi-tier review of operation as a part of plant procedures, as well as part of the regulatory process during operation.

18.3.2 Prevention of accident and their mitigation

Emphasis on accident prevention is required to be the objective rather than on mitigation of their consequences. This is achieved by a conservative design and manufacturing, proper commissioning and operation within the specified limiting conditions.

The accident prevention measures include:

- Conservative design and maintaining high quality in construction and operation in line with the first level of defence-in-depth
- Redundancy being provided in safety and process sytems. Safety systems are targetted to achieve an unavailability target of 10^{-3}.
- Diversity being provided in design for protection against common mode failures. The design envisages independent and diverse means to achieve core cooling.
- A complete separation between safety and process system being ensured. Separation as well as diversity among components is provided within the system.

Following an accident, the focus shifts to mitigate the consequences, which is achieved by

- Having safety systems to ensure basic safety functions of reactivity control, core cooling and containment of radioactivity

- Operating engineered safety features to reduce/minimize release of radioactivity
- Following emergency operating procedures to handle the event and to bring the plant to safe state.

18.3.3 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 strictly complied with. If the design, construction, manufacture, inspection and maintenance of civil structures, mechanical, electrical, Instrumentation & control equipment and systems is 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.

The equipment which be exposed to radiation and which could experience LOCA environmental conditions are tested after thermal and radiation exposure under LOCA environment for their normal performance. All mechanical, electrical and 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 (SL1)/ & SSE (SL2) 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 at regular intervals during their usage with both benchmark classical problems and experimental tests and results.

Codes which deal with safety analysis such as those for calculating pressure, temperature in the containment under loss of coolant accident, hydrogen concentration in air in containment under accident condition involving LOCA plus loss of ECCS, codes for calculating the temperature of fuel and cladding and temperature and pressure of coolant and fission gases in the fuel element, are developed in house and are benchmarked with results of experiments conducted at national and international laboratories and by participating in blind problem exercises of IAEA. Similarly, the codes simulating the loss of coolant accident (LOCA) have been developed in house and are benchmarked with the results from international experiments.

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

18.3.4 Implementation of Criteria Related to Human Factors

AERB Code of Practice on Design for Safety in PHWR based NPPs, AERB/SC/D establishes the requirement for design for optimised operator performance. The detail on requirement for human factors and human machine interface is given in chapter on article 12: Human Factors. 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. Operator actions are permitted only where adequate time is available for taking the necessary action.
- Ergonomically designed control panels
- Layout to facilitate operability and maintainability
- Working areas and working environment are given due consideration to personnel comfort.

18.4 CONSTRUCTION

Even a good design plant may not achieve the required level of safety if it is not constructed well. Therefore 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. The details on the utility's safety management system are brought out in chapter on Article 13: Quality Assurance.

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 license 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 license 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 Code of Practice on Design

AERB/SC/D	Code of Practice on Design for Safety in PHWR Based Nuclear Power Plant
AERB/CSE-1	Design of Concrete Structures important to safety of Nuclear facilities
AERB/CSE-2	Design, Fabrication and Erection of Steel Structures important to safety of Nuclear facilities
AERB/SC/D-1	Safety classification and Seismic Categorization
AERB/SC/D-2	Single Failure Criteria
AERB/SC/D-3	Protection against Internally Generated Missiles and Associated Environmental Effects
AERB/SC/D-4	Fire Protection
AERB/SC/D-5	Design Basis Events
AERB/SC/D-6	Fuel Design
AERB/SC/D-7	Core Reactivity Control
AERB/SC/D-8	Primary Heat Transport System
AERB/SC/D-9	Process Design
AERB/SC/D-10	Safety Critical Systems
AERB/SC/D-11	Emergency Electrical Power Supply Systems
AERB/SC/D-12	Radiation Protection in Design
AERB/SC/D-13	Liquid and Solid Radwaste Management
AERB/SC/D-14	Control of Air-borne Radioactive Materials
AERB/SC/D-15	Ultimate Heat Sink & Associated Systems
AERB/SC/D-16	Materials Selection and Properties
AERB/SC/D-17	Design for In-Service Inspection
AERB/SC/D-18	LOCA Analysis
AERB/SC/D-19	Hydrogen Release and Mitigation Measures under Accident Condition
AERB/SC/D-20	Safety Related Instrumentation and Control
AERB/SC/D-21	Containment Systems Design
AERB/SC/D-22	Vapour Suppression System
AERB/SC/D-23	Seismic Qualification
AERB/SC/D-24	Design of Fuel Handling and Storage Systems
AERB/SC/D-25	Computer Based Safety Systems
AERB/SM/D-1	Decay Heat Load Calculation
AERB/SM/D-2	Hydrogen release and Nitrogen measures under accident condition

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

AERB/SC/QA	Code of Practice on QA for Safety in NPPs
AERB/SG/QA-1	Quality assurance in the design of nuclear power plants
AERB/SG/QA-2	Quality assurance in procurement of items and services for nuclear power plants
AERB/SG/QA-3	Quality assurance in the manufacture of items for nuclear power plants
AERB/SG/QA-4	Quality assurance during site construction of nuclear power plants
AERB/SG/QA-6	Establishing and implementing a quality assurance programme for NPPs
AERB/SG/QA-7	Assessment of implementation of quality assurance in NPPs
AERB/SG/QA-8	Non-conformance control, Corrective Actions and preventive action for NPPs
AERB/SG/QA-9	Document control and Records for quality assurance in NPPs

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 being adopted in Indian PHWR. For LWR, 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

Sl. 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

Sr. No.	Standard/Guide	Number Title
1.	AERB/SG/D-10	AERB Safety Guide on 'Safety Critical Systems'
2.	AERB/SG/D-20	AERB Safety Guide on 'Safety-Related Instrumentation and Control for Pressurised Heavy Water Reactor Based Nuclear Power Plants'
3.	AERB/SG/D-25	AERB Safety Guide on "Computer-based Systems'
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 Provisions in Typical 540 MWe PHWRs in India

Provisions in the design of 540 MWe PHWR based NPPs to meet the safety objectives and requirements:

Operation of the plant is controlled from the centralised control room. Control panels provide full information to the engineer regarding the status of the plant so as to enable them to operate the plant safely and efficiently. In addition to the Main Control Room, a Supplementary Control Room located away from the Main Control Room, is provided to monitor and ensure safe shutdown of the reactor in case of inaccessibility / uninhabitability of the Main Control Room for any reason. Reactor control systems are provided to take care of reactivity changes in the reactor core and to control the reactor power at the desired power level. These devices are also used for reactor set-back and step-back. Due to the large size of the reactor core, capability for zone control has been provided to take care of xenon-induced flux tilts. A new system viz. Liquid Zone Control System has been designed and engineered for this function.

Safety Systems

Shutdown System

In TAPS-3&4 (2 X 540 MWe PHWRs), the reactor has been 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 fall 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. Shut Down System # 2, which is a new system, injects gadolinium nitrate poison solution directly into the moderator through six perforated injection tubes horizontally oriented inside the calandria.

Containment

The Reactor Building consists of Primary and Secondary containment building. Primary containment is a pre-stressed concrete structure designed to withstand internal pressure of 1.44 kg/cm2g. It is designed to withstand over-pressure and high temperature caused by release of hot fluid from Primary Heat Transport System under Loss of Coolant Accident (LOCA). Secondary containment is a reinforced concrete structure, completely surrounding the primary containment and having a design pressure of 0.13 kg/cm2g. Ducting for ventilation systems, penetrating the containment, are provided with isolation dampers, which will close on accident signal to box-up the containment. A pressure suppression system, incorporating suppression pool, is used for limiting peak pressure in the containment following a Loss of Coolant Accident.

Emergency Core Cooling System

Emergency Core Cooling System (ECCS), incorporated in TAPS-3&4, is provided as an important safety system to cool the core and thereby limit the core damage in the event of postulated Loss of Coolant Accident (Refer Figure-3). ECCS involves the following stages:

- High pressure light water injection
- Low pressure long term re-circulation through suppression pool

All the motorised valves in the system are duplicated to satisfy the single failure criterion. For low pressure long term re-circulation, 4 X 50% pumps are provided for redundancy. They are powered from Class-III electrical power supply (supply backed up by diesel generators). The system is seismically qualified for Safe Shutdown Earthquake conditions.

Multiple Barriers

Safety has been of paramount importance in the design, construction and operation of nuclear power stations. To ensure safety of the reactor, defence in depth philosophy is followed, which provides for multiple barriers to release of radioactivity. A series of five successive barriers are provided to prevent the release of radioactivity to the atmosphere. These safety barriers are depicted in Figure-1.

Redundancy & Diversity

Important reactor systems are designed with redundancy so that if one component fails, another is available to take over. For example, two or three pumps are provided where only one is required with other as a standby and to cater for maintenance requirements. Diversity is provided by use of more than one way on different principles for doing a job. For example, separate systems, having different concepts of operation, are provided to shutdown the reactor. Failure of a component or system, automatically causes that component or system to move to a safe condition. For example, power is required to hold the Shutoff Rods outside the reactor core. If power fails, the rods drop into the core by gravitational force, thereby shutting it down.

Mitigation of Accidents

To mitigate the consequences of Design Basis Accident, containment is provided with Engineered Safety Features like Primary containment clean-up (PCC) system, primary containment controlled discharge (PCCD) system, secondary containment clean-up and purge (SCCP) system and RB cooling system (Refer Figure-2). Primary containment clean-up 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.

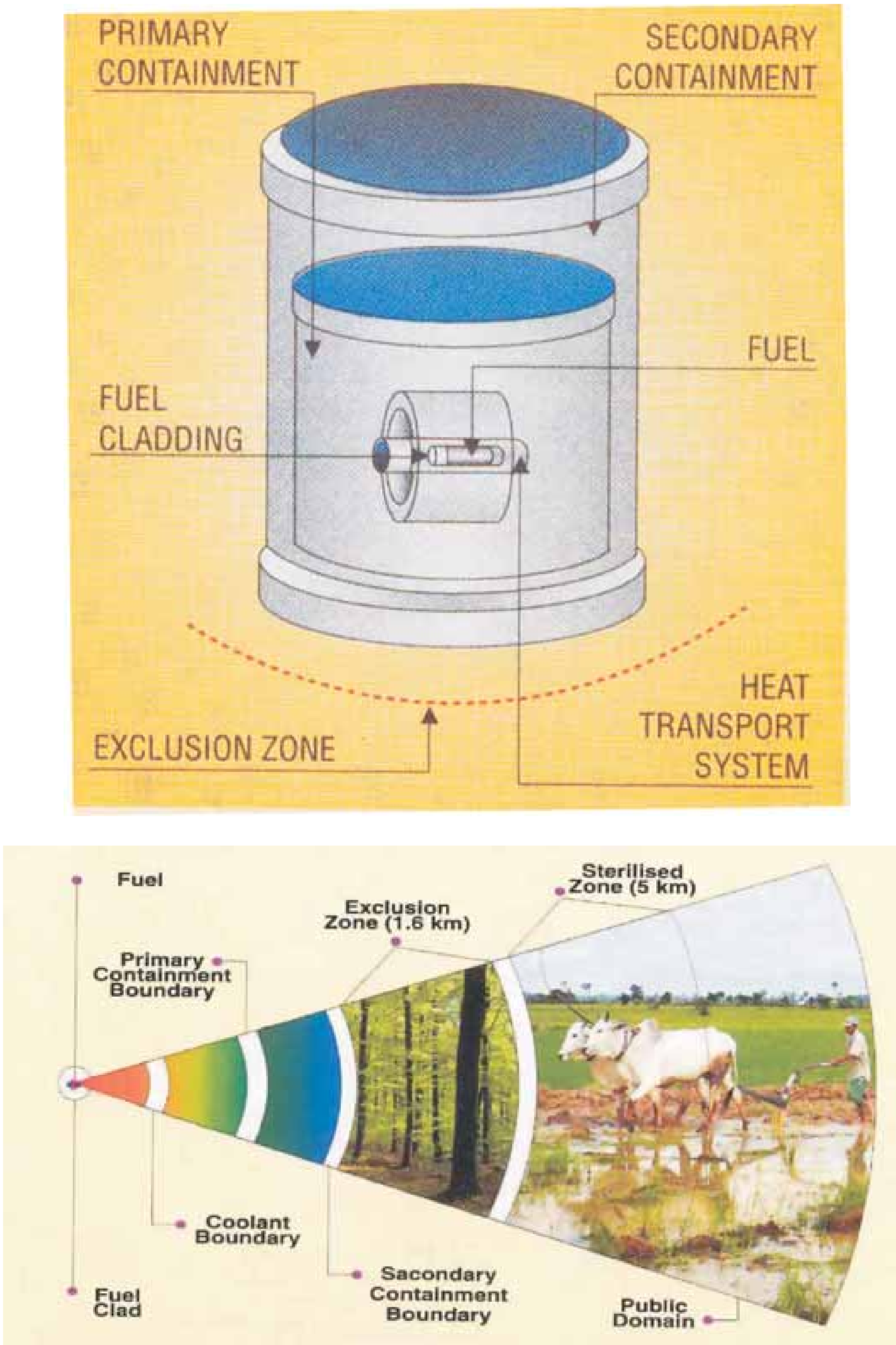


Figure-1: Safety Barriers

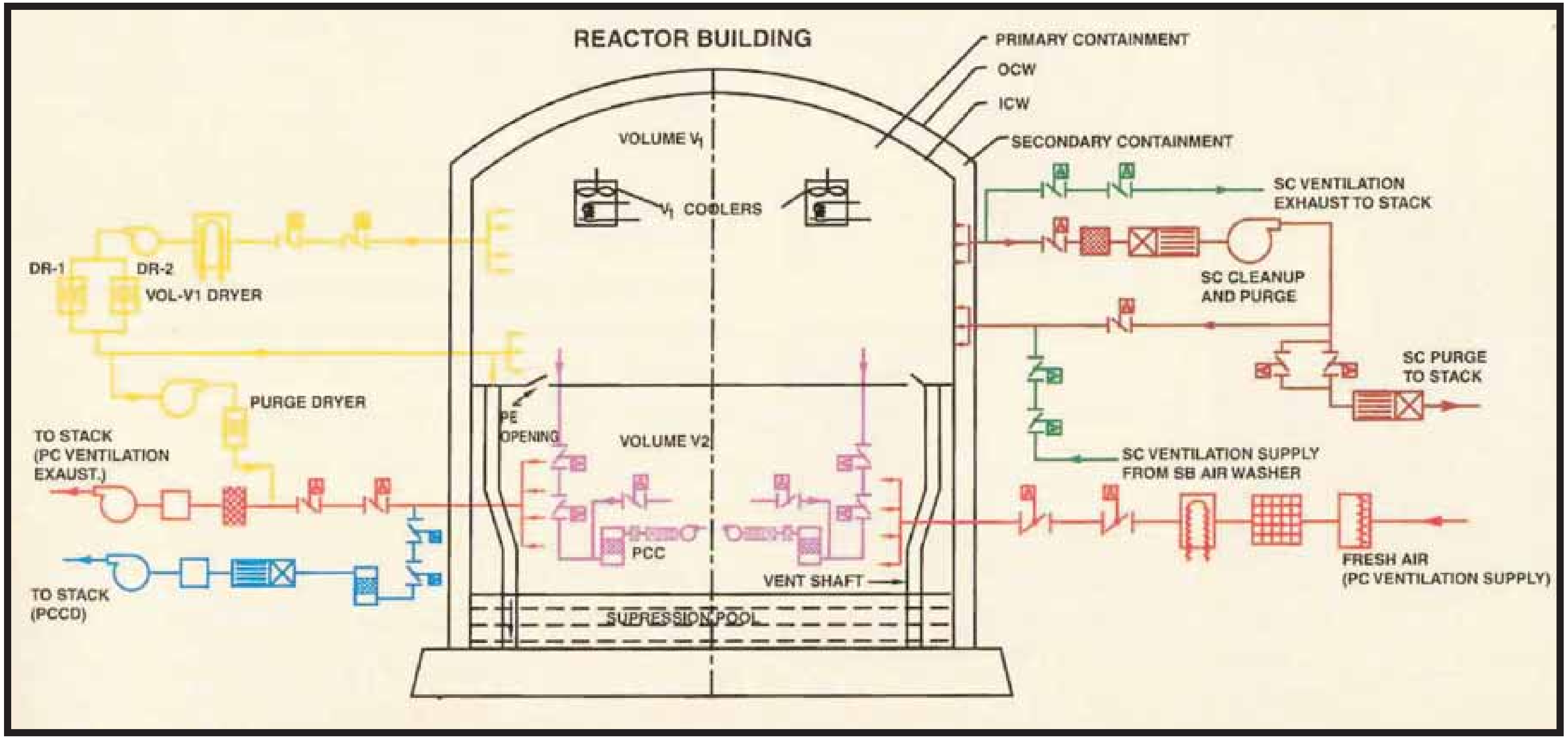


Figure – 2 : Containment related Engineered Safety Features

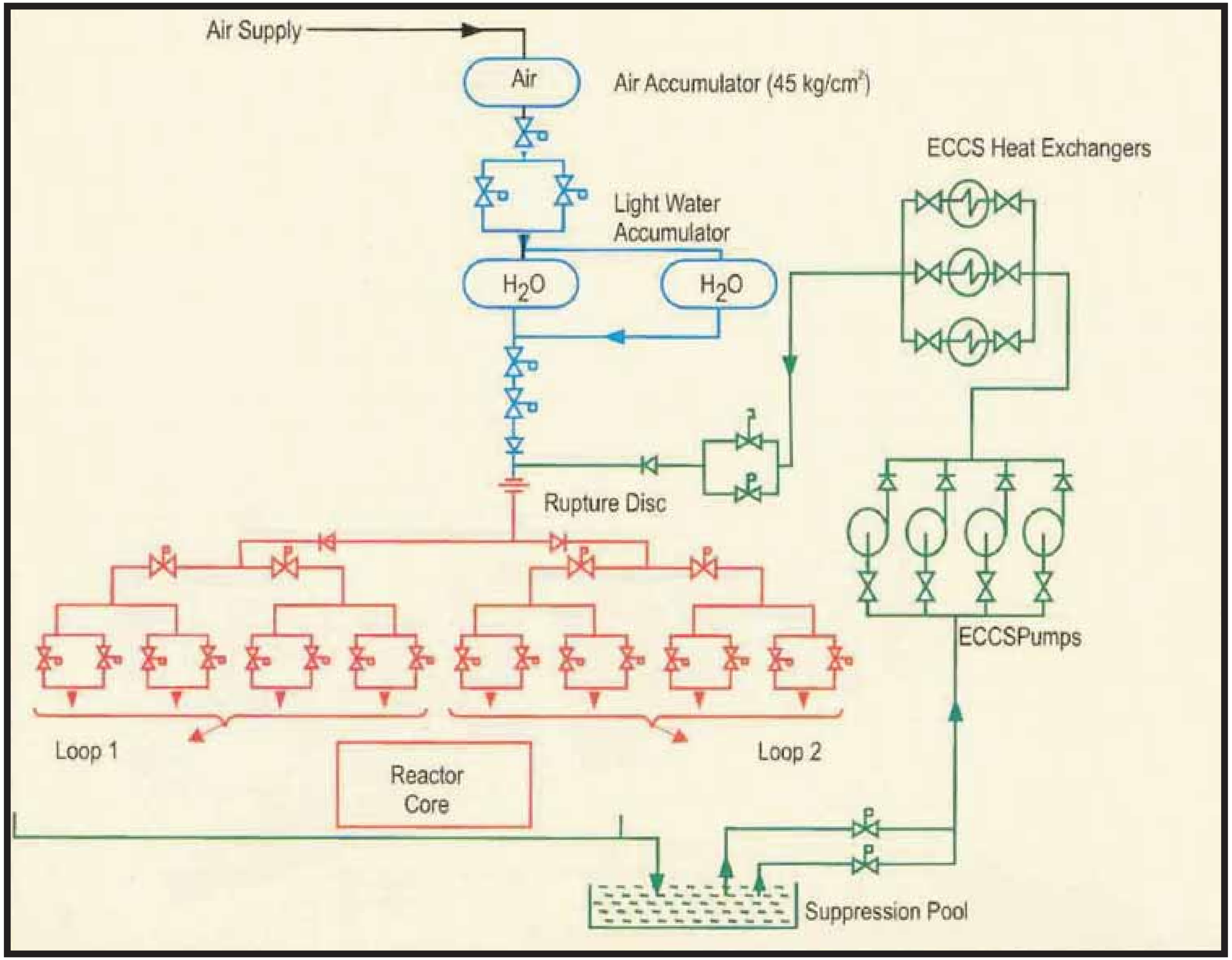


Figure – 3 : Emergency Core Cooling System

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.

19.1 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 is 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/C/G and AERB Safety Guide AERB/SG/G-1 on “Consenting Process for Nuclear Power Plant and Research Reactor: Document Submissions, Regulatory Review and Assessment of Consent Applications” establishes the entire licensing process for NPPs. The licensing process is summarised in Chapter on Article 14: Assessment and Verification of Safety. Further, “Code of practice on safety in nuclear power plant operation”, AERB/SC/O 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 Annexure 19-1.

19.2 INITIAL AUTHORISATION TO OPERATE A NUCLEAR POWER PLANT

Prior to issuance of authorisation 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 (DBEs) provided by the applicant. The review and assessment process considers whether the applicant's list of Postulated Initiating Events (PIEs) is acceptable as the basis for the safety analysis. AERB determines that the type of analytical considerations and assumptions are in conformance with applicable safety guides. AERB ensures that the input and assumptions made in the safety analysis are in line with the actual design and operating practices. 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 part borated heavy water addition to storage, cooling and moderator systems for flushing in specified limited quantity during which criticality is not possible.
	iii	Addition of heavy water to primary heat transport system: and
	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; and
	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 of 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 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 operating organization and training, qualification and 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.

(h) Establishment of personal protection system.

(i) Radiation protection program.

(j) Emergency Response Plans.

(k) Waste management.

(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 consenting for 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 and 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 operating organisation established at an Indian NPP is given in Annexure 19-2.

Some of the important aspects pertaining to the above are described in the following paragraphs.

19.3 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 operation of the NPP in the commissioning stage, this document is again reviewed and revised as necessary based on the commissioning results

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

The Technical specification document is reviewed at a periodicity of five years and based on the operating experience, the proposal for modifications are submitted to AERB for approval.

19.4 PROCEDURES

The Code of practice on safety in nuclear power plant operation", AERB/SC/O 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, 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 in co-operation with the designers and plant suppliers. The Plant Management ensures that the aspects of Quality assurance are duly considered in the preparation, review and approval of these procedures.

For dealing with anticipated operational occurrences and for the management of accident conditions, development of symptom-based procedure has been recommended by AERB. 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 also undertaken development of symptom-based procedures for accident management. These are undergoing validation on simulators.

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

All the NPPs presently operating in India are owned and operated by NPCIL, which is a fully owned company of the Central Government. NPCIL manages all 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. NPCIL has also entered into memoranda of understanding with several Research and Development and academic institutions so as to avail additional engineering and technical support as and when required.

A Corporate Level Safety Review Committee 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.

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.

19.6 EVENT REPORTING

AERB code of Practice on Regulation of Nuclear and Radiation Facilities, AERB/C/G specifies the reporting obligations of the Plant Management. This Code required that the event reports and significant event reports are prepared for events that have to be reported 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 indicating that all the investigations as required by AERB have been completed.

In addition, 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, reliability reports, minutes of Station Operation Review Committee (SORC) and other miscellaneous reports to AERB.

19.7 OPERATING SAFETY EXPERIENCE FEEDBACK (OSEF) SYSTEM

"Code of Practice on Safety in Nuclear Power Plant Operation", AERB/SC/O, 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 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 OSEF information amongst all senior management persons in NPPs and projects under construction.

The organisational structure at Plant Management level ensures that both national and international events are systematically analysed 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 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 finalisation 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 interact with each other at different levels. At these meetings the information on various modifications to equipment and procedures is exchanged. These exchange meetings are institutionalised and held periodically.

AERB is the national coordinator for all IAEA-IRS activities. AERB receives IRS reports from IAEA and disseminates these reports to all the NPPs, NPCIL, technical support organisations and research establishments as applicable. AERB receives feedback on the applicability of lessons learnt from the events. The effectiveness of the operating experience feedback system is formally reviewed at the time of reauthorisation of the operating NPPs. As part of the reauthorisation process, the NPP is required to submit review of the safety concerns arising from the events at NPPs in India and other countries. The remedial measures taken or proposed to be taken are also brought out.

19.8 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.

19.9 RADIOACTIVE WASTE MANAGEMENT

Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 specifies the requirement for obtaining authorisation 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 should demonstrate 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 limits on environmental releases of different radionuclides through various routes are specified in the Technical Specification for Operation, based on the apportionment of dose limit to public due to the operation of the NPP. AERB also specifies authorized limits for such discharges, which are lower than Technical Specification limits.

19.10 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. 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

SC/O	Code of Practice on Safety in NPP Operation
SG/O-1	Training & Qualification of Operating Personnel of NPPs
SG/O-2	ISI of NPPs
SG/O-3	Operational Limits and Conditions for NPPs
SG/O-4	Commissioning of NPPs
SG/O-5	Radiation Protection during Operation of NPP
SG/O-6	Preparedness of the Operating Organization for Emergencies at NPPs
SG/O-7	Maintenance and Modifications of NPPs
SG/O-8	Surveillance of Items Important to Safety in NPPs
SG/O-9	Management of NPPs for Safe Operation
SG/O-10A	Core Management and Fuel Handling for Heavy Water Reactor Based NPPs
SG/O-10B	Core Management and Fuel Handling for Boiling Water Reactor Based NPPs
SG/O-11	Operational Management of Radioactive Effluents and Wastes Arising in NPPs
SG/O-12	Renewal Of Authorisation for Operation of NPPs
SG/O-13	Operational Experience Feedback for NPPs
SG/O-14	Life Cycle Management of NPPs
SG/O-15	Proof and Leakage Rate Testing of Reactor Containments

Annexure 19-2: Typical Operating 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 is 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 strict 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 Station Operation Review Committee (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.

STATION HEALTH PHYSICIST 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)

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 license 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 Station Health Physicist 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 significant evets 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).

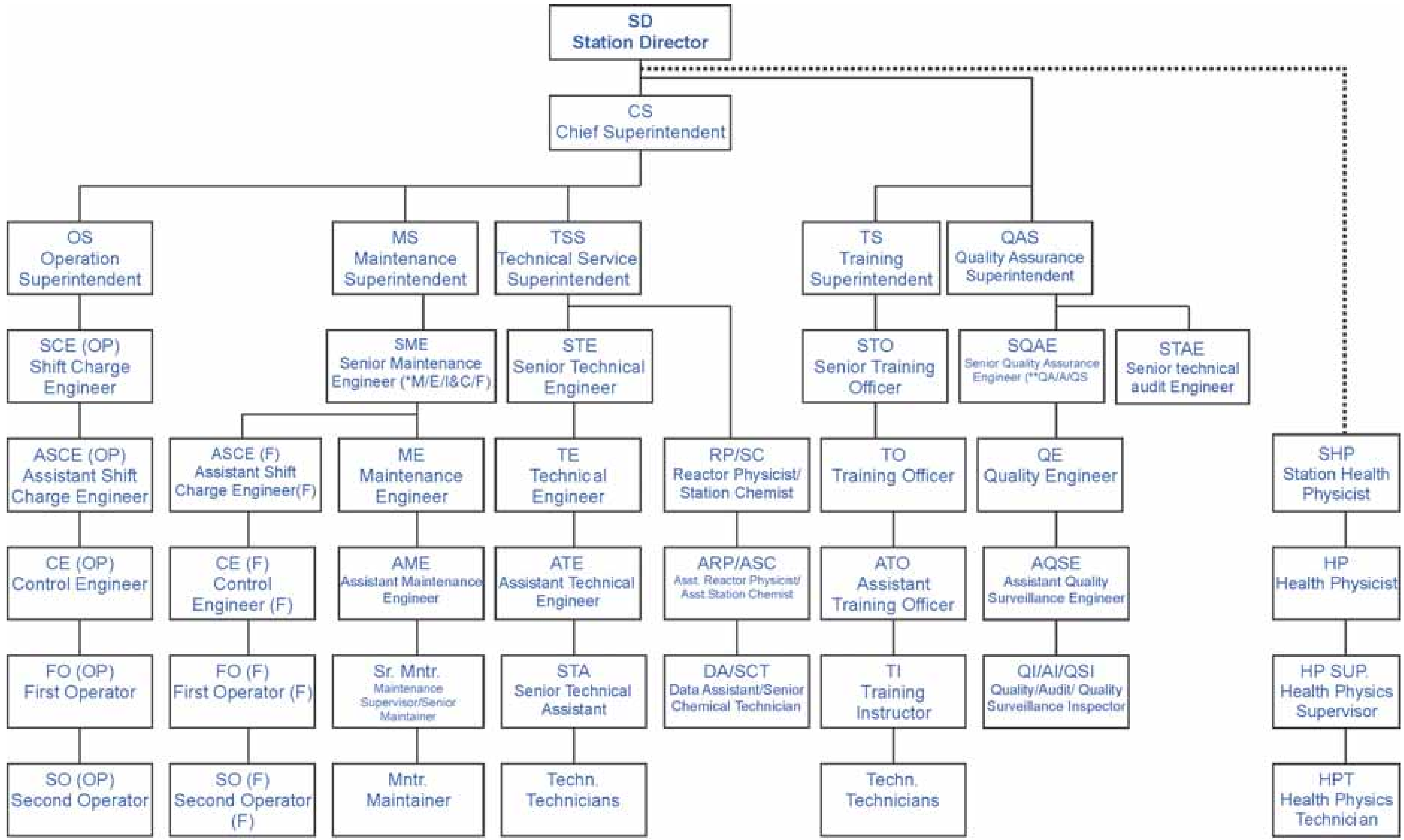
TECHNICAL AUDIT ENGINEER is responsible for auditing and monitoring the compliance with the operating procedures, administrative procedures, surveillance test schedules, SORC recommendations, in-service inspection and Engineering Change Notices of all safety related systems. He also monitors deviations 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 are carried out within specified tiMoEFrame 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 / SARCOP.



Organisation Chart of a Typical Indian Nuclear Power Station